

# WIPP

## Subsidence Monument Leveling Survey 2011

December 2011

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Processing and final preparation of this document was performed by Washington TRU Solutions LLC, the Waste Isolation Pilot Plant (WIPP) management and operating contractor under U.S. Department of Energy contract DE-AC29-01AL66444.

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### List of Acronyms

DOE	Department of Energy
DOY	Day of year
FGCS	Federal Geodetic Control Subcommittee
M&TE	Measurement and Test Equipment
NGS	National Geodetic Survey
WTS	Washington TRU Solutions
WIPP	Waste Isolation Pilot Plant

### References

*Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*, Federal Geodetic Control Committee (now Federal Geodetic Control Subcommittee), [1975] 1980, Reprint.

*FGCS Specifications and Procedures to Incorporate Electronic Digital / Bar-Code Leveling Systems*, Federal Geodetic Control Subcommittee, ver. 4.0, dated July 15, 1994.

WP 09-ES4001, *Subsidence Survey Data Acquisition and Report*, June 2002

*Subsidence Monitoring Software Quality Assurance Plan*, July 2002

*WIPP Subsidence Monument Leveling Surveys 1986-1997*, DOE / WIPP 98-2293, June 1998

*WIPP Subsidence Monument Leveling Survey 1998*, DOE / WIPP 99-2293, October 1998

*WIPP Subsidence Monument Leveling Survey 1999*, DOE / WIPP 00-2293, October 1999

*WIPP Subsidence Monument Leveling Survey 2000*, DOE / WIPP 01-2293, October 2000

*WIPP Subsidence Monument Leveling Survey 2001*, DOE / WIPP 02-2293, October 2001

*WIPP Subsidence Monument Leveling Survey 2002*, DOE / WIPP 03-2293, October 2002

*WIPP Subsidence Monument Leveling Survey 2003*, DOE / WIPP 04-2293, October 2003

*WIPP Subsidence Monument Leveling Survey 2004*, DOE / WIPP 05-2293, December 2004

*WIPP Subsidence Monument Leveling Survey 2005*, DOE / WIPP 06-2293,  
December 2005

*WIPP Subsidence Monument Leveling Survey 2006*, DOE / WIPP 07-2293,  
December 2006

*WIPP Subsidence Monument Leveling Survey 2007*, DOE / WIPP 08-2293,  
December 2007

*WIPP Subsidence Monument Leveling Survey 2008*, DOE / WIPP 09-2293,  
December 2008

*WIPP Subsidence Monument Leveling Survey 2009*, DOE / WIPP 10-2293,  
December 2009

*WIPP Subsidence Monument Leveling Survey 2010*, DOE / WIPP 11-2293,  
December 2010

## 1. Introduction

Sections 2 through 7 of this report define the result of the 2011 leveling survey through the subsidence monuments at the WIPP site. Approximately 15 miles of leveling was completed through nine vertical control loops. The 2011 survey includes the determination of elevation on each of the 48 existing subsidence monuments and the WIPP baseline survey, and 14 of the National Geodetic Survey's (NGS) vertical control points. The field observations were completed during September through November 2011 by the Washington TRU Solutions (WTS) Mine Engineering Surveyors.

Digital leveling techniques were utilized to achieve better than Second Order Class II loop closures as outlined by the Federal Geodetic Control Subcommittee (FGCS). Because it is important to perform the subsidence survey in exactly the same manner each year, WIPP procedure (WP 09-ES4001) details each step of the survey. Starting with the 2002 survey, this procedure has been used to perform the subsidence survey.

Starting with the survey of the year 2001, Loop 1 and redundant survey connections among the various loops were removed from the survey and report. This resulted in a reduction of fieldwork with no loss of accuracy or precision. The redundant connections caused multiple elevations for the same stations. The differences were so slight that they were not used in elevation adjustments for the loops. The redundancy was used to spot gross errors in the field. After several years of surveying these loops it is evident that no gross errors occur that are not also evident in the loop closures.

Finally, Section 8 contains Table F, which summarizes the elevations for all surveys from 1987 through 2011, inclusive. A detailed listing of the 1986 through 1997 surveys is contained in the report, *WIPP Subsidence Monument Leveling Surveys 1986-1997*, DOE/WIPP 98-2293. A reference to the summary reports for each year after 1997 is listed in the reference section of this document.

## 2. Equipment

The observations were taken with the WILD NA3003 Electronic Digital Level (WIPP M&TE ID# DM0999) manufactured by Leica, and bar coded leveling staffs. The calibration for the DM0999 is valid from April 29, 2011, through April 29, 2013. The data were recorded electronically on the Leica GRM10 REC-Module, which plugs directly into the instrument. In addition to the electronic record, a written field log was maintained to record information that is not stored in the electronic record.

## 3. Office Processing

The data were downloaded from the GRM10 REC-Module to the survey group computer. The original raw data files were maintained intact while further processing was performed on a copy of the original raw data file.

Listing of the data and the adjustment of the loops was completed with the DIGILEV software (version 10.94d) from Leica Canada. The results, as summarized below, were extracted from the output of the DIGILEV software. A Software Quality Assurance Plan was written for the computer programs used in reducing the subsidence survey field notes. DIGILEV was tested, verified, and validated. The program was deemed acceptable and is now in the WIPP controlled software list.

#### **4. Methodology**

The weather conditions during the observations of the 2011 survey were generally mild with moderate temperatures and light to moderate breezes.

The elevations for the 2011 survey are computed from the adjusted observations based on the elevation of the subsidence monument, S-37 (3,423.874 feet). S-37, originally, was the WIPP monument furthest from the influence of the underground excavations. S-37 has been held fixed for all of the subsidence leveling surveys since 1993. The condition of the individual monuments was substantially the same as the previous subsidence survey.

In the 2004 survey, it was noted that the brass cap of monument PT-31 came loose making it unusable and monuments S-17 and S-18 no longer exist due to construction of the new salt storage/disposal pad.

As in previous years, the subsidence survey was divided into nine loops. Each loop generally takes one day to complete. This allows a loop to be completed in one surveying session and results in a lower probability of error.

For visual reference, Figure 1 is a graphic display of the individual loops, the total survey, and the relationship to the underground excavations.



## 5. General Summary of Results

Table A below describes the nine leveling loops that were measured to obtain the elevations of the subsidence monuments. The table contains the start date of the observations, a loop number, and the points that are contained within the loop.

**Table A. Description of 2011 Leveling Loops**

Start Date (DOY)	Loop	Points
September 9, 2011 (252)	2	D-419, S-37, C-419, S-38, S-51, D-419
September 20, 2011 (263)	3	C-419, B-419, A-419, Y-347, Z-418, Y-418, X-418, W-418, V-418, C-419
September 28, 2011 (271)	4	V-418, S-21, S-39, S-19, S-41, S-42, S-43, S-20, S-40, V-418
October 6, 2011 (279)	5	V-418, U-418, T-418, K-349, S-46, S-418, V-418
November 29, 2011 (333)	6	T-418, S-01, S-03, S-53, S-45, PT-10, S-14, S-15, S-16, S-44, T-418
October 25, 2011 (298)	7	K-349, S-24, S-23, S-22, PT-30, S-09, S-10, PT-32, K-349
October 18, 2011 (291)	8	K-349, S-52, S-25, S-26, S-49, S-48, S-13, PT-33, S-12, K-349
October 13, 2011 (286)	9	S-418, S-34, S-33, S-32, PT-21, S-27, S-28, S-29, S-418
November 18, 2011 (322)	10	S-418, S-35, S-36, S-50, S-31, S-47, S-30, S-418

Table B summarizes the results of the leveling loops in terms of vertical closure and accuracy. The requirement for Second Order Class II loop closure accuracy was achieved in all cases.

**Table B. Summary of Distance and Accuracy for 2011 Leveling Loops**

Loop	Cumulative Distance (ft.)	Vertical Closure (ft.)	Accuracy (ft./ $\sqrt{\text{mile}}$ )	Allowable Accuracy (ft./ $\sqrt{\text{mile}}$ )
2	7,911.74	-0.0026	0.002	0.040
3	12,635.82	0.0019	0.001	0.051
4	8,308.03	0.0059	0.005	0.041
5	13,610.28	0.0058	0.004	0.053
6	9,959.32	-0.0066	-0.007	0.045
7	6,758.91	0.0050	0.004	0.037
8	7,283.06	0.0004	0.000	0.039
9	7,489.72	0.0056	0.005	0.039
10	6,911.77	0.0021	0.002	0.038

### 5.1 Accuracy Summary by Loop

Table C displays a detailed summary of the observations in the leveling loops for the 2011 survey. All results are displayed in feet. The information in the table for each loop includes:

Between each benchmark in the loop:

- The distance leveled between benchmarks along the loop.
- The number of instrument setups between each of the benchmarks.
- The difference in adjusted elevation from each benchmark to the next.

For each loop as a whole:

- The cumulative, or total, distance of each loop.
- The vertical closure of the loop.
- The accuracy of leveling.
- Allowable accuracy for each loop.

The accuracy of the leveling is given in terms of feet times the square root of the length of the loop in miles. The actual accuracy of leveling is computed in the DIGILEV software, and is based on the actual vertical closure of the loop. The maximum allowable accuracy is based on the allowable accuracy of a loop as stated in the FGCS specification for digital leveling. The FGCS specification for Second Order Class II loop closure permits a maximum of  $8\text{mm}\sqrt{\text{Km}}$  (8mm times the square root of the length of the loop in Km). This converts to  $0.033\text{ ft}\sqrt{\text{mile}}$  (0.033 feet times the square root of the length of the loop in miles) when stated in the English System. All values indicated in this summary are expressed in feet.

Inspection of the following tables displays that in every case the actual accuracy is well below the maximum allowable accuracy for each loop. The column in each table that is labeled "Difference" is the vertical difference from one point to the next. It is important to note that the vertical difference figures are calculated from the adjusted point elevations and because of rounding, the algebraic sum of the column may not be zero.

Table C. Detailed Loop Measurements

Loop 2					Loop 6				
From	To	Distance	Setups	Difference	From	To	Distance	Setups	Difference
D-419	S-37	575.45	4	0.621	T-418	S-01	741.29	6	-7.322
S-37	C419	1,174.01	8	13.808	S-01	S-03	183.89	2	-0.812
C-419	S-38	1,119.00	8	-7.922	S-03	S-53	520.56	4	-0.057
S-38	S-51	2,311.97	18	7.957	S-53	S-45	1,166.03	8	-8.237
S-51	D-419	2,731.31	22	-14.464	S-45	PT-10	1,149.11	8	7.265
<b>Cumulative Distance:</b>		7,911.74			PT-10	S-14	1,209.12	10	3.619
<b>Vertical Closure:</b>					S-14	S-15	1,002.53	8	1.791
<b>Accuracy of Leveling:</b>					S-15	S-16	1,067.54	10	8.192
<b>Allowable Accuracy:</b>					S-16	S-44	1,149.88	10	6.814
					S-44	T-418	1,769.37	14	-11.253
Loop 3					<b>Cumulative Distance:</b>		9,959.32		
From	To	Distance	Setups	Difference	<b>Vertical Closure:</b>		-0.007		
C-419	B-419	1,531.82	10	12.179	<b>Accuracy of Leveling:</b>		0.005		
B-419	A-419	953.34	6	4.896	<b>Allowable Accuracy:</b>		0.045		
A-419	Y-347	531.73	4	0.560					
Y-347	Z-418	408.17	4	5.805	Loop 7				
Z-418	Y-418	1,249.95	8	4.003	From	To	Distance	Setups	Difference
Y-418	X-418	667.32	6	-9.119	K-349	S-24	759.97	4	-2.205
X-418	W-418	572.46	4	-6.701	S-24	S-23	1024.17	6	-6.088
W-418	V-418	613.59	4	-12.819	S-23	S-22	1010.71	6	-8.025
V-418	C-419	6,107.44	46	1.195	S-22	PT-30	932.85	6	4.976
<b>Cumulative Distance:</b>		12,635.82			PT-30	S-09	302.91	2	1.305
<b>Vertical Closure:</b>					S-09	S-10	1,230.20	10	8.328
<b>Accuracy of Leveling:</b>					S-10	PT-32	556.97	4	1.763
<b>Allowable Accuracy:</b>					PT-32	K-349	941.13	8	-0.055
Loop 4					<b>Cumulative Distance:</b>		6,758.91		
From	To	Distance	Setups	Difference	<b>Vertical Closure:</b>		0.005		
V-418	S-21	720.40	6	5.457	<b>Accuracy of Leveling:</b>		0.004		
S-21	S-39	1,135.01	8	-3.799	<b>Allowable Accuracy:</b>		0.037		
S-39	S-19	1,443.81	10	-12.050					
S-19	S-41	790.46	6	4.777	Loop 8				
S-41	S-42	1,076.68	8	-2.637	From	To	Distance	Setups	Difference
S-42	S-43	1,002.25	8	-4.403	K-349	S-52	248.08	2	3.365
S-43	S-20	668.47	6	10.513	S-52	S-25	897.71	6	0.279
S-20	S-40	1,025.44	8	0.066	S-25	S-26	1,046.53	8	12.150
S-40	V-418	445.51	4	2.076	S-26	S-49	1,037.35	8	12.781
<b>Cumulative Distance:</b>		8,308.03			S-49	S-48	1,081.62	8	0.694
<b>Vertical Closure:</b>					S-48	S-13	963.13	8	-11.028
<b>Accuracy of Leveling:</b>					S-13	PT-33	530.87	4	-2.503
<b>Allowable Accuracy:</b>					PT-33	S-12	541.17	4	-8.192
Loop 5					S-12	K-349	936.60	8	-7.545
From	To	Distance	Setups	Difference	<b>Cumulative Distance:</b>		7,283.06		
V-418	U-418	809.14	6	-10.228	<b>Vertical Closure:</b>		0.000		
U-418	T-418	1,290.79	10	-9.418	<b>Accuracy of Leveling:</b>		0.000		
T-418	K-349	2,677.09	18	-12.799	<b>Allowable Accuracy:</b>		0.039		
K-349	S-46	1,264.59	10	-4.477					
S-46	S-418	960.15	8	1.950					
S-418	V-418	6,608.52	50	34.972					
<b>Cumulative Distance:</b>		13,610.28			<b>Vertical Closure:</b>		0.006		
<b>Accuracy of Leveling:</b>					<b>Accuracy of Leveling:</b>		0.004		
<b>Allowable Accuracy:</b>					<b>Allowable Accuracy:</b>		0.053		

Table C continued on next page...

Table C. Detailed Loop Measurements (continued)

Loop 9					Loop 10				
From	To	Distance	Setups	Difference	From	To	Distance	Setups	Difference
S-418	S-34	1,053.32	8	-9.534	S-418	S-35	1,101.87	8	-1.061
S-34	S-33	1,092.37	8	-13.019	S-35	S-36	985.42	6	9.086
S-33	S-32	1,098.04	8	-5.539	S-36	S-50	1,521.90	10	16.320
S-32	PT-21	1,257.66	10	10.416	S-50	S-31	952.93	6	-13.637
PT-21	S-27	88.10	2	3.362	S-31	S-47	849.06	6	-3.182
S-27	S-28	1,061.36	8	5.953	S-47	S-30	666.98	6	-5.246
S-28	S-29	1,055.73	8	6.666	S-30	S-418	833.61	6	-2.280
S-29	S-418	783.14	6	1.696	<b>Cumulative Distance:</b>		6,911.77		
<b>Cumulative Distance:</b>		7,489.72			<b>Vertical Closure:</b>				0.002
<b>Vertical Closure:</b>				0.006	<b>Accuracy of Leveling:</b>				0.002
<b>Accuracy of Leveling:</b>				0.005	<b>Allowable Accuracy:</b>				0.038
<b>Allowable Accuracy:</b>				0.039					

## 6. Adjusted Level Loops

Table D is a summary of the adjusted elevations for the nine loops measured in 2011. They have been extracted from the output of the DIGILEV software. These are adjusted elevations within each loop. These final adjusted elevations also appear in Table E.

**Table D. Adjusted Elevations by Loop**

<b>Loop 2</b>		<b>Loop 5</b>		<b>Loop 8</b>	
D-419	3,423.253	V-418	3,436.487	K-349	3,404.042
S-37	3,423.874	U-418	3,426.259	S-52	3,407.407
C-419	3,437.682	T-418	3,416.841	S-25	3,407.685
S-38	3,429.760	K-349	3,404.042	S-26	3,419.835
S-51	3,437.717	S-46	3,399.565	S-49	3,432.616
D-419	3,423.253	S-418	3,401.515	S-48	3,433.310
<b>Loop 3</b>		V-418	3,436.487	S-13	3,422.282
C-419	3,437.682	<b>Loop 6</b>		PT-33	3,419.778
B-419	3,449.861	T-418	3,416.841	S-12	3,411.586
A-419	3,454.757	S-01	3,409.519	K-349	3,404.042
Y-347	3,455.317	S-03	3,408.707	<b>Loop 9</b>	
Z-418	3,461.122	S-53	3,408.650	S-418	3,401.515
Y-418	3,465.125	S-45	3,400.412	S-34	3,391.981
X-418	3,456.006	PT-10	3,407.678	S-33	3,378.962
W-418	3,449.306	S-14	3,411.297	S-32	3,373.423
V-418	3,436.487	S-15	3,413.088	PT-21	3,383.838
C-419	3,437.682	S-16	3,421.280	S-27	3,387.200
<b>Loop 4</b>		S-44	3,428.094	S-28	3,393.153
V-418	3,436.487	T-418	3,416.841	S-29	3,399.819
S-21	3,441.944	<b>Loop 7</b>		S-418	3,401.515
S-39	3,438.145	K-349	3404.042	S-35	3,400.454
S-19	3,426.095	S-24	3401.836	S-36	3,409.540
S-41	3,430.872	S-23	3395.748	S-50	3,425.860
S-42	3,428.236	S-22	3387.724	S-31	3,412.223
S-43	3,423.832	S-09	3394.005	S-47	3,409.041
S-20	3,434.345	S-10	3402.333	S-30	3,403.795
S-40	3,434.411	PT-32	3404.097	S-418	3,401.515
V-418	3,436.487	K-349	3404.042		

## 7. Adjusted Elevations (2011)

Table E displays the adjusted elevations for the subsidence monuments and the NGS points contained within the 2011 survey. These elevations are normalized to the monument, S-37. All elevations are displayed in feet and are within the WIPP local coordinate system.

**Table E. 2011 Adjusted Elevations**

Point	Elevation (ft.)	Point	Elevation (ft.)
S-01	3,409.519	S-42	3,428.236
S-03	3,408.707	S-43	3,423.832
S-09	3,394.005	S-44	3,428.094
S-10	3,402.333	S-45	3,400.412
S-12	3,411.586	S-46	3,399.565
S-13	3,422.282	S-47	3,409.041
S-14	3,411.297	S-48	3,433.310
S-15	3,413.088	S-49	3,432.616
S-16	3,421.280	S-50	3,425.860
S-19	3,426.095	S-51	3,437.717
S-20	3,434.345	S-52	3,407.407
S-21	3,441.944	S-53	3,408.650
S-22	3,387.724		
S-23	3,395.748	PT-10	3,407.678
S-24	3,401.836	PT-21	3,383.838
S-25	3,407.685		
S-26	3,419.835		
S-27	3,387.200	PT-32	3,404.097
S-28	3,393.153	PT-33	3,419.778
S-29	3,399.819	S-418	3,401.515
S-30	3,403.795	T-418	3,416.841
S-31	3,412.223	U-418	3,426.259
S-32	3,373.423	V-418	3,436.487
S-33	3,378.962	W-418	3,449.306
S-34	3,391.981	X-418	3,456.006
S-35	3,400.454	Y-347	3,455.317
S-36	3,409.540	Y-418	3,465.125
S-37	3,423.874	Z-418	3,461.122
S-38	3,429.760	A-419	3,454.757
S-39	3,438.145	B-419	3,449.861
S-40	3,434.411	C-419	3,437.682
S-41	3,430.872	D-419	3,423.253
		K-349	3,404.042

## 8. Comparison of Elevations\*

Table F compares the elevations from all of the subsidence leveling surveys from 1987 through 2011. All elevations are displayed in feet.

**Table F. Comparison of Elevations 1987-2011**

	S-01	S-02	S-03	S-09	S-10	S-11	S-12	S-13	S-14
1987	3,409.738	3,408.219	3,408.914	3,394.056	3,402.466	3,406.437	3,411.790	3,422.428	3,411.500
1989	3,409.719	3,411.907	3,408.900	3,394.046	3,402.459	3,406.408	3,411.739	3,422.413	3,411.483
1992	3,409.695	3,411.904	3,408.875	3,394.053	3,402.440	3,406.372	3,411.727	3,422.412	3,411.439
1993	3,409.616	(1) (2)	3,408.797	3,393.969	3,402.365	(3)	3,411.630	3,422.324	3,411.382
1994	3,409.626		3,408.806	3,393.988	3,402.374		3,411.653	3,422.348	3,411.372
1995	3,409.613		3,408.795	3,393.986	3,402.373		3,411.650	3,422.345	3,411.376
1996	3,409.615		3,408.795	3,393.994	3,402.373		3,411.645	3,422.340	3,411.369
1997	3,409.610		3,408.793	3,394.002	3,402.379		3,411.656	3,422.349	3,411.368
1998	3,409.617		3,408.802	3,394.011	3,402.388		3,411.653	3,422.352	3,411.374
1999	3,409.613		3,408.798	3,394.004	3,402.385		3,411.650	3,422.358	3,411.365
2000	3,409.607		3,408.792	3,394.003	3,402.381		3,411.644	3,422.352	3,411.364
2001	3,409.599		3,408.786	3,394.006	3,402.378		3,411.636	3,422.350	3,411.361
2002	3,409.595		3,408.783	3,394.012	3,402.381		3,411.637	3,422.354	3,411.357
2003	3,409.583		3,408.771	3,394.007	3,402.372		3,411.629	3,422.307	3,411.351
2004	3,409.575		3,408.762	3,394.006	3,402.373		3,411.630	3,422.310	3,411.329
2005	3,409.551		3,408.739	3,393.997	3,402.357		3,411.611	3,422.274	3,411.307
2006	3,409.539		3,408.727	3,393.992	3,402.349		3,411.603	3,422.274	3,411.301
2007	3,409.546		3,408.734	3,394.012	3,402.356		3,411.609	3,422.281	3,411.301
2008	3,409.533		3,408.722	3,394.006	3,402.350		3,411.606	3,422.284	3,411.297
2009	3,409.531		3,408.721	3,394.008	3,402.344		3,411.596	3,422.279	3,411.294
2010	3,409.513		3,408.701	3,393.999	3,402.329		3,411.586	3,422.268	3,411.287
2011	3,409.519		3,408.707	3,394.005	3,402.333		3,411.586	3,422.282	3,411.297

**Note:** (1) The subsidence monument, S-02 was relocated in 1989.  
(2) The subsidence monument, S-02, no longer exists after the 1992 survey.  
(3) The subsidence monument, S-11, no longer exists after the 1992 survey.

	S-15	S-16	S-17	S-18	S-19	S-20	S-21	S-22	S-23
1987	3,413.291	3,421.378	3,422.519	3,425.010	3,426.235	3,434.464	3,442.030	3,387.786	3,395.914
1989	3,413.291	3,421.341	3,422.482	3,424.974	3,426.217	3,434.452	3,442.005	3,387.795	3,395.970
1992	3,413.263	3,421.331	3,422.469	3,424.964	3,426.223	3,434.364	3,441.956	3,387.788	3,396.028
1993	3,413.185	3,421.256	3,422.404	3,424.859	3,426.136	3,434.332	3,441.919	3,387.701	3,395.853
1994	3,413.188	3,421.261	3,422.402	3,424.852	3,426.134	3,434.339	3,441.932	3,387.732	3,395.886
1995	3,413.189	3,421.261	3,422.418	3,424.864	3,426.143	3,434.342	3,441.936	3,387.727	3,395.877
1996	3,413.182	3,421.263	3,422.419	3,424.860	3,426.138	3,434.345	3,441.935	3,387.727	3,395.885
1997	3,413.178	3,421.268	3,422.431	3,424.864	3,426.141	3,434.346	3,441.937	3,387.738	3,395.889
1998	3,413.184	3,421.271	3,422.436	3,424.869	3,426.150	3,434.355	3,441.946	3,387.744	3,395.887
1999	3,413.177	3,421.275	3,422.435	3,424.865	3,426.152	3,434.362	3,441.959	3,387.729	3,395.873
2000	3,413.172	3,421.278	3,422.440	3,424.864	3,426.140	3,434.362	3,441.956	3,387.727	3,395.861
2001	3,413.167	3,421.277	3,422.434	3,424.858	3,426.138	3,434.363	3,441.956	3,387.728	3,395.857
2002	3,413.159	3,421.275	3,422.434	3,424.855	3,426.132	3,434.361	3,441.950	3,387.731	3,395.857
2003	3,413.152	3,421.279	3,422.430	3,424.849	3,426.117	3,434.350	3,441.939	3,387.728	3,395.850
2004	3,413.142	3,421.281	(4)	(5)	3,426.128	3,434.359	3,441.955	3,387.727	3,395.841
2005	3,413.118	3,421.268			3,426.107	3,434.343	3,441.941	3,387.720	3,395.826
2006	3,413.109	3,421.269			3,426.101	3,434.338	3,441.937	3,387.711	3,395.815
2007	3,413.113	3,421.280			3,426.105	3,434.346	3,441.947	3,387.730	3,395.823
2008	3,413.099	3,421.274			3,426.104	3,434.344	3,441.945	3,387.721	3,395.810
2009	3,413.093	3,421.283			3,426.107	3,434.347	3,441.950	3,387.726	3,395.802
2010	3,413.083	3,421.271			3,426.088	3,434.331	3,441.936	3,387.716	3,395.768
2011	3,413.088	3,421.280			3,426.095	3,434.345	3,441.944	3,387.724	3,395.748

**Note:** (4) The subsidence monument, S-17, no longer exists after the 2003 survey.  
(5) The subsidence monument, S-18, no longer exists after the 2003 survey.

**Table F continued on next page...**

Table F. Comparison of Elevations 1987-2011 (continued)

	S-24	S-25	S-26	S-27	S-28	S-29	S-30	S-31	S-32
1987	3,402.201	3,408.036	3,420.010	3,387.280	3,393.414	3,400.111	3,404.082	3,412.315	3,373.513
1989	3,402.167	3,408.005	3,419.978	3,387.287	3,393.400	3,400.098	3,404.064	3,412.302	3,373.498
1992	3,402.159	3,407.974	3,419.948	3,387.310	3,393.421	3,400.113	3,404.073	3,412.303	3,373.533
1993	3,402.042	3,407.870	3,419.854	3,387.181	3,393.287	3,400.008	3,403.958	3,412.206	3,373.396
1994	3,402.072	3,407.907	3,419.883	3,387.225	3,393.312	3,400.038	3,403.984	3,412.234	3,373.427
1995	3,402.062	3,407.895	3,419.871	3,387.216	3,393.309	3,400.031	3,403.978	3,412.230	3,373.425
1996	3,402.074	3,407.897	3,419.875	3,387.213	3,393.316	3,400.037	3,403.979	3,412.221	3,373.411
1997	3,402.077	3,407.897	3,419.883	3,387.229	3,393.330	3,400.050	3,403.994	3,412.248	3,373.438
1998	3,402.076	3,407.902	3,419.883	3,387.248	3,393.338	3,400.059	3,403.998	3,412.248	3,373.452
1999	3,402.067	3,407.898	3,419.886	3,387.229	3,393.322	3,400.053	3,403.990	3,412.252	3,373.429
2000	3,402.051	3,407.876	3,419.871	3,387.226	3,393.316	3,400.045	3,403.980	3,412.252	3,373.428
2001	3,402.035	3,407.862	3,419.872	3,387.231	3,393.318	3,400.040	3,403.972	3,412.255	3,373.431
2002	3,402.029	3,407.858	3,419.877	3,387.231	3,393.316	3,400.034	3,403.968	3,412.258	3,373.433
2003	3,402.012	3,407.840	3,419.871	3,387.233	3,393.311	3,400.016	3,403.951	3,412.252	3,373.433
2004	3,401.995	3,407.822	3,419.870	3,387.231	3,393.310	3,399.996	3,403.932	3,412.254	3,373.439
2005	3,401.976	3,407.786	3,419.853	3,387.221	3,393.294	3,399.961	3,403.902	3,412.235	3,373.426
2006	3,401.956	3,407.762	3,419.857	3,387.207	3,393.278	3,399.930	3,403.870	3,412.221	3,373.413
2007	3,401.958	3,407.764	3,419.850	3,387.226	3,393.280	3,399.928	3,403.872	3,412.237	3,373.431
2008	3,401.929	3,407.739	3,419.850	3,387.217	3,393.260	3,399.910	3,403.848	3,412.222	3,373.421
2009	3,401.910	3,407.725	3,419.840	3,387.218	3,393.235	3,399.888	3,403.834	3,412.225	3,373.423
2010	3,401.868	3,407.700	3,419.832	3,387.202	3,393.190	3,399.846	3,403.811	3,412.218	3,373.413
2011	3,401.836	3,407.685	3,419.835	3,387.200	3,393.153	3,399.819	3,403.795	3,412.223	3,373.423

	S-33	S-34	S-35	S-36	S-37	S-38	S-39	S-40	S-41
1987	3,379.093	3,392.128	3,400.597	3,409.583					
1989	3,379.073	3,392.137	3,400.583	3,409.584	3,423.888	3,429.736			
1992	3,379.090	3,392.138	3,400.591	3,409.605	3,423.874		3,438.146	3,434.469	3,430.931
1993	3,378.975	3,392.026	3,400.478	3,409.504	3,423.874	3,429.736	3,438.110	3,434.430	3,430.888
1994	3,379.006	3,392.042	3,400.490	3,409.518	3,423.874	3,429.740	3,438.115	3,434.425	3,430.888
1995	3,379.009	3,392.042	3,400.495	3,409.520	3,423.874	3,429.739	3,438.124	3,434.437	3,430.899
1996	3,378.992	3,392.028	3,400.483	3,409.501	3,423.874	3,429.744	3,438.118	3,434.436	3,430.891
1997	3,379.019	3,392.057	3,400.516	3,409.533	3,423.874	3,429.745	3,438.127	3,434.444	3,430.894
1998	3,379.028	3,392.066	3,400.516	3,409.539	3,423.874	3,429.750	3,438.134	3,434.442	3,430.901
1999	3,379.011	3,392.056	3,400.507	3,409.539	3,423.874	3,429.751	3,438.149	3,434.445	3,430.900
2000	3,379.012	3,392.053	3,400.505	3,409.541	3,423.874	3,429.754	3,438.145	3,434.445	3,430.902
2001	3,379.014	3,392.057	3,400.509	3,409.546	3,423.874	3,429.756	3,438.145	3,434.436	3,430.898
2002	3,379.017	3,392.060	3,400.513	3,409.550	3,423.874	3,429.757	3,438.142	3,434.437	3,430.897
2003	3,379.016	3,392.057	3,400.511	3,409.546	3,423.874	3,429.760	3,438.130	3,434.425	3,430.892
2004	3,379.020	3,392.055	3,400.514	3,409.549	3,423.874	3,429.761	3,428.152	3,434.449	3,430.900
2005	3,379.011	3,392.035	3,400.505	3,409.536	3,423.874	3,429.757	3,438.144	3,434.449	3,430.882
2006	3,378.994	3,392.017	3,400.484	3,409.524	3,423.874	3,429.757	3,438.145	3,434.448	3,430.881
2007	3,379.001	3,392.022	3,400.492	3,409.536	3,423.874	3,429.763	3,438.143	3,434.450	3,430.882
2008	3,378.988	3,392.006	3,400.476	3,409.530	3,423.874	3,429.759	3,438.145	3,434.442	3,430.878
2009	3,378.979	3,391.999	3,400.469	3,409.535	3,423.874	3,429.758	3,438.150	3,434.439	3,430.884
2010	3,378.961	3,391.982	3,400.464	3,409.532	3,423.874	3,429.751	3,438.135	3,434.426	3,430.864
2011	3,378.962	3,391.981	3,400.454	3,409.540	3,423.874	3,429.760	3,438.145	3,434.411	3,430.872

Table F continued on next page...

Table F. Comparison of Elevations 1987-2011 (continued)

	S-42	S-43	S-44	S-45	S-46	S-47	S-48	S-49	S-50
1987									
1989									
1992	3,428.279	3,423.849	3,428.146	3,400.501	3,399.946	3,409.236	3,433.308	3,432.635	3,425.868
1993	3,428.230	3,423.813	3,428.070	3,400.406	3,399.837	3,409.133	3,433.238	3,432.572	3,425.809
1994	3,428.228	3,423.820	3,428.066	3,400.419	3,399.865	3,409.163	3,433.264	3,432.596	3,425.830
1995	3,428.238	3,423.826	3,428.071	3,400.424	3,399.856	3,409.158	3,433.258	3,432.588	3,425.830
1996	3,428.238	3,423.823	3,428.078	3,400.423	3,399.856	3,409.157	3,433.256	3,432.585	3,425.816
1997	3,428.249	3,423.815	3,428.084	3,400.428	3,399.877	3,409.181	3,433.274	3,432.600	3,425.846
1998	3,428.252	3,423.822	3,428.086	3,400.440	3,399.876	3,409.178	3,433.276	3,432.598	3,425.838
1999	3,428.255	3,423.825	3,428.091	3,400.435	3,399.866	3,409.176	3,433.289	3,432.611	3,425.851
2000	3,428.254	3,423.820	3,428.095	3,400.434	3,399.842	3,409.168	3,433.288	3,432.606	3,425.854
2001	3,428.247	3,423.818	3,428.094	3,400.433	3,399.824	3,409.163	3,433.290	3,432.606	3,425.858
2002	3,428.246	3,423.815	3,428.097	3,400.435	3,399.818	3,409.160	3,433.297	3,432.613	3,425.863
2003	3,428.236	3,423.805	3,428.090	3,400.430	3,399.790	3,409.147	3,433.294	3,432.610	3,425.857
2004	3,428.254	3,423.814	3,428.105	3,400.440	3,399.770	3,409.149	3,433.311	3,432.620	3,425.876
2005	3,428.243	3,423.798	3,428.093	3,400.421	3,399.745	3,409.114	3,433.297	3,432.603	3,425.855
2006	3,428.242	3,423.795	3,428.097	3,400.415	3,399.718	3,409.096	3,433.310	3,432.617	3,425.854
2007	3,428.244	3,423.802	3,428.099	3,400.417	3,399.705	3,409.095	3,433.306	3,432.612	3,425.866
2008	3,428.242	3,423.802	3,428.100	3,400.415	3,399.675	3,409.079	3,433.321	3,432.623	3,425.859
2009	3,428.245	3,423.818	3,428.099	3,400.414	3,399.643	3,409.064	3,433.306	3,432.611	3,425.856
2010	3,428.227	3,423.819	3,428.087	3,400.399	3,399.605	3,409.048	3,433.301	3,432.608	3,425.852
2011	3,428.236	3,423.832	3,428.094	3,400.412	3,399.565	3,409.041	3,433.310	3,432.616	3,425.860

	S-51	S-52	S-53	S-54	PT-10	PT-21	PT-30	PT-31	PT-32
1987									
1989									
1992	3,437.765	3,407.611	3,408.775	3,411.085	3,407.722		3,392.914	3,385.117	3,404.370
1993	3,437.746	3,407.523	3,408.670	(6)	3,407.664	3,383.821	3,392.823	3,385.027	3,404.296
1994	3,437.749	3,407.542	3,408.709		3,407.672	3,383.868	3,392.843	3,385.051	3,404.311
1995	3,437.746	3,407.542	3,408.702		3,407.671	3,383.862	3,392.844	3,385.050	3,404.322
1996	3,437.729	3,407.536	3,408.704		3,407.669	3,383.858	3,392.852	3,385.053	3,404.312
1997	3,437.725	3,407.544	3,408.702		3,407.675	3,383.874	3,392.857	3,385.063	3,404.321
1998	3,437.724	3,407.549	3,408.714		3,407.687	3,383.887	(7)	3,385.067	3,404.322
1999	3,437.729	3,407.544	3,408.709		3,407.689	3,383.868		3,385.053	3,404.315
2000	3,437.729	3,407.531	3,408.704		3,407.685	3,383.868		3,385.053	3,404.306
2001	3,437.731	3,407.522	3,408.701		3,407.687	3,383.874		3,385.053	3,404.259
2002	3,437.733	3,407.521	3,408.700		3,407.688	3,383.871		3,385.057	3,404.250
2003	3,437.731	3,407.507	3,408.690		3,407.685	3,383.874		3,385.054	3,404.234
2004	3,437.730	3,407.501	3,408.686		3,407.685	3,383.874		(8)	3,404.172
2005	3,437.720	3,407.473	3,408.667		3,407.669	3,383.862			3,404.152
2006	3,437.720	3,407.461	3,408.659		3,407.667	3,383.848			3,404.138
2007	3,437.720	3,407.458	3,408.666		3,407.670	3,383.866			3,404.146
2008	3,437.720	3,407.445	3,408.659		3,407.669	3,383.857			3,404.132
2009	3,437.721	3,407.432	3,408.656		3,407.673	3,383.858			3,404.124
2010	3,437.705	3,407.408	3,408.640		3,407.665	3,383.841			3,404.101
2011	3,437.717	3,407.407	3,408.650		3,407.678	3,383.838			3,404.097

Note: (6) The subsidence monument, S-54, no longer exists after the 1992 survey.  
(7) The monument, PT-30, has been physically disturbed and was removed from the 1998 survey.  
(8) The monument, PT-31, has been physically disturbed and was removed from the 2004 survey.

*Table F continued on next page...*

Table F. Comparison of Elevations 1987-2011 (continued)

	PT-33	S-418	T-418	U-418	V-418	W-418	X-418	Y-347	Y-418
1987									
1989									
1992	3,419.939								
1993	3,419.853								
1994	3,419.884								
1995	3,419.869								
1996	3,419.865	3,401.696	3,416.902	3,426.267	3,436.481	3,449.276	3,455.969	3,455.274	3,465.080
1997	3,419.873	3,401.708	3,416.906	3,426.272	3,436.487	3,449.282	3,455.976	3,455.281	3,465.091
1998	3,419.879	3,401.715	3,416.915	3,426.279	3,436.497	3,449.292	3,455.987	3,455.291	3,465.101
1999	3,419.880	3,401.707	3,416.913	3,426.275	3,436.500	3,449.304	3,456.000	3,455.304	3,465.117
2000	3,419.872	3,401.702	3,416.911	3,426.273	3,436.502	3,449.307	3,456.005	3,455.309	3,465.123
2001	3,419.866	3,401.702	3,416.905	3,426.270	3,436.502	3,449.310	3,456.007	3,455.312	3,465.125
2002	3,419.868	3,401.701	3,416.901	3,426.269	3,436.502	3,449.311	3,456.009	3,455.314	3,465.126
2003	3,419.866	3,401.685	3,416.892	3,426.264	3,436.500	3,449.308	3,456.007	3,455.312	3,465.125
2004	3,419.855	3,401.670	3,416.887	3,426.265	3,436.499	3,449.310	3,456.009	3,455.315	3,465.126
2005	3,419.789	3,401.634	3,416.868	3,426.252	3,436.485	3,449.295	3,455.993	3,455.301	3,465.113
2006	3,419.784	3,401.605	3,416.860	3,426.247	3,436.481	3,449.290	3,455.991	3,455.300	3,465.111
2007	3,419.788	3,401.604	3,416.865	3,426.258	3,436.491	3,449.302	3,456.003	3,455.311	3,465.122
2008	3,419.785	3,401.580	3,416.857	3,426.259	3,436.490	3,449.301	3,456.000	3,455.307	3,465.120
2009	3,419.783	3,401.562	3,416.853	3,426.261	3,436.493	3,449.307	3,456.006	3,455.312	3,465.125
2010	3,419.771	3,401.531	3,416.840	3,426.246	3,436.477	3,449.293	3,455.994	3,455.301	3,465.113
2011	3,419.778	3,401.515	3,416.841	3,426.259	3,436.487	3,449.306	3,456.006	3,455.317	3,465.125

	Z-418	A-419	B-419	C-419	D-419	K-349			
1987									
1989									
1992									
1993									
1994									
1995									
1996	3,461.073	3,454.714	3,449.825	3,437.633	3,423.234	3,404.152			
1997	3,461.082	3,454.720	3,449.829	3,437.642	3,423.238	3,404.162			
1998	3,461.091	3,454.730	3,449.835	3,437.648	3,423.242	3,404.173			
1999	3,461.105	3,454.744	3,449.848	3,437.657	3,423.247	3,404.169			
2000	3,461.109	3,454.749	3,449.853	3,437.660	3,423.250	3,404.157			
2001	3,461.111	3,454.752	3,449.856	3,437.663	3,423.254	3,404.152			
2002	3,461.113	3,454.754	3,449.857	3,437.665	3,423.256	3,404.150			
2003	3,461.112	3,454.752	3,449.856	3,437.665	3,423.256	3,404.137			
2004	3,461.117	3,454.754	3,449.858	3,437.668	3,423.257	3,404.127			
2005	3,461.108	3,454.742	3,449.848	3,437.663	3,423.243	3,404.105			
2006	3,461.108	3,454.739	3,449.846	3,437.664	3,423.243	3,404.091			
2007	3,461.117	3,454.749	3,449.855	3,437.673	3,423.248	3,404.096			
2008	3,461.112	3,454.747	3,449.854	3,437.673	3,423.250	3,404.081			
2009	3,461.117	3,454.752	3,449.857	3,437.675	3,423.251	3,404.073			
2010	3,461.109	3,454.741	3,449.846	3,437.666	3,423.240	3,404.047			
2011	3,461.122	3,454.757	3,449.861	3,437.682	3,423.253	3,404.042			

\* The 1986 elevations that appear in all reports prior to the 2001 report are from a report filed by Jerry Williams (3/89), Geoscience Department. Those elevations were, in turn, taken from the 1987 data, rounded to two decimal places and referenced as 1986. When this was discovered it was decided to remove the 1986 information from all subsequent reports.