Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant

Appendix SMP

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

Subsidence Monitoring Plan

CONTENTS

FIGURES

TABLES

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ACRONYMS

DOE	Department of Energy
GPS	Global Positioning System
NGS	National Geodetic Survey
QA	Quality Assurance
WID	Waste Isolation Division
WIPP	Waste Isolation Pilot Plant

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APPENDIX SMP

SMP.1 Introduction

Subsidence monitoring was chosen by the Department of Energy (DOE) as the basic long-term monitoring tool. Subsidence monitoring is a non-intrusive technique that can related to numerical predictions as a means of detecting substantial and detrimental deviations from expected repository performance by allowing a comparison of actual subsidence to that calculated numerically. Subsidence monitoring meets the regulatory requirements for long-term monitoring as stated in 40 CFR Part 191 (EPA 1993) as follows:

- It can be implemented without dependence on site utilities.

- It can provide useful data at reasonable cost over a long time period.

- It requires minimum maintenance.

This plan provides the following information with respect to subsidence monitoring:

- Subsidence Theory and Measurement

- Subsidence Baseline

- Monitoring Activities

- Equipment

- Quality Assurance

SMP.2 Subsidence Theory and Measurement

Subsidence is defined as vertical movement of the land surface anywhere in the subsidence basin. Subsidence monitoring is defined as the measurement of relative vertical movement of the land surface. This movement can be up (uplift) or down (subsidence) and is relative to an assumed fixed reference. This reference is assumed fixed, even though it may be subject to the same factors that cause the surface movement and may also be moving. The techniques used to monitor subsidence measure the vertical height difference between an array of markers on the surface and is typically done with a leveling survey. Usually, one reference benchmark (ideally outside the potential subsidence basin) is used as the standard and the relative movement of other stations or benchmarks are measured to detect vertical movement over time.

The error in subsidence measurements is determined by the equipment and distances between the stations. A first-order survey has an error of one part in 100,000 and a second-order survey has an error of one part in 20,000. With current technology, several thousandths of an inch vertical movement can be measured to this precision.

Subsidence can be caused by a variety of factors. Mining, hydrocarbon extraction, water injection and extraction, geological deformation, and dissolution are potential factors that may cause subsidence in the Waste Isolation Pilot Plant (WIPP) vicinity. Major subsidence features in the vicinity of the WIPP include Nash Draw, caused by dissolution of evaporites in the upper Salado and lower Rustler and localized mine-induced subsidence associated with areas in the potash mines in the vicinity of the WIPP where pillars have been removed as a portion of the mine is abandoned (second-mined areas).

Several documents related to subsidence in the vicinity of the WIPP have been completed. Several documents describing particular aspects of the WIPP include estimates of subsidence related directly to the excavations of the repository. These include the following:

1. *Final Environmental Impact Statement (FEIS), Waste Isolation Pilot Plant,* DOE/EIS-0026, DOE, 1980, (DOE 1980).

2. *Final Safety Analysis Report (FSAR), Waste Isolation Pilot Plant,* WP 02-09, WEC, 1990, (DOE 1990).

3. *Preliminary Comparison with 40 CFR §191, Part B for the Waste Isolation Pilot Plant, December 1991,* SAND91-0893, "Vol 1, Methodology and Results," SNL, 1991, (WIPP PA Division 1991).

4. *Backfill Engineering Analysis Report (BEAR),* (WEC 1994).

Those reports evaluate the potential for, and predict subsidence caused by the mining of the WIPP repository's shafts, drifts, and waste disposal rooms. These calculations account for a range of emplaced waste volumes, waste densities, and backfill types. Subsidence was also calculated for conditions where no backfill would be used. The calculated results from these reports are summarized in Table SMP-1.

The studies listed above predict the maximum subsidence expected. These studies were not specifically performed to estimate subsidence for long-term repository performance monitoring and do not account for other factors that may influence subsidence such as local hydrocarbon extraction and local potash mining.

The *Backfill Engineering Analysis Report (BEAR)* (WEC 1994) contains the most recent and detailed analysis of subsidence. Contour maps are included in this report that detail subsidence predictions using influence function and National Coal Board method for scenarios with and without backfill. The maximum subsidence was also calculated using the mass conservation method.

Table SMP-1. Maximum Subsidence Predictions for the WIPP Site

CONDITION/AREA	PREDICTED SUBSIDENCE
FEIS	
70-percent backfill density	1-foot (0.3-meter) subsidence
50-percent backfill density	1.6-foot (0.5-meter) subsidence
No backfill	3.28-foot (1.0-meter) subsidence
FSAR	
Shaft pillar area (backfill type and amount not specified)	1- to 1.2-foot (0.3- to 0.38-meter) subsidence
SNL	
35° angle	0.3-foot (0.09-meter) subsidence
25° angle	0.4-foot (0.13-meter) subsidence
BEAR	
No backfill	1.3- to 2-foot (0.40- to 0.60-meter) subsidence
Highly compacted backfill	1- to 1.7-foot (0.30- to 0.52-meter) subsidence

SMP.3 Subsidence Baseline

During the initial site selection process, 195 miles (314 kilometers) of first order, Class 1 leveling survey was performed by the National Geodetic Survey (NGS) in 1977. Later, new survey lines were established that connected the previous first-order benchmarks through Carlsbad, to second-order survey lines through Eunice and Hobbs. Benchmarks were placed over the Nash Draw from the north end to the Remuda Basin, over potash mines, the WIPP site, and the San Simon Sink (Powers 1993). Independent of the National Geodetic Survey benchmarks, an additional 52 benchmarks were installed over the WIPP site and surrounding area.

The National Geodetic Survey network was resurveyed in 1981 and the relative movement between Carlsbad and the WIPP site was measured to be about 0.8 inches (2 centimeters). Relative motion across the network was down to the east and up to the west (Powers 1993).

The relationships between subsidence and potash mining in the WIPP vicinity are discussed in Powers (1993). From data in this report, potash mining was shown to have caused significant subsidence at mines close to the WIPP. Two benchmarks over the Mississippi Chemical

Corporation mine measured relative to Carlsbad show 10- and 40-inch (25.4- and 102.7-centimeter) movement downward from 1977 to 1981. Powers (1993) also discusses mining effects on surface subsidence at other mines and correlated a relationship between mining and the surface area effects. This work allows the possible effects of potash mining to be taken into account when evaluating WIPP-induced subsidence. Powers (1993) also includes an assessment of the effects resulting from the production of brine from WIPP 12.

SMP.4 Monitoring Activities

The WIPP Subsidence Monitoring Program is performed annually and then allows for a comparison of the data, development of a database, and analysis of subsidence characteristics at the WIPP Site. The program includes surface subsidence monitoring involving twenty (20) miles of leveling loops through approximately fifty (50) monuments (S-Caps). Subsidence monitoring surveys include the Global Positioning Satellite (GPS) and surveys of the S-Caps. Figure SMP-1 identifies approximately 50 benchmarks (those designated "S" and "PT") distributed throughout the area of influence of the repository. The annual survey is completed so as to achieve closures better than the minimum standard of Second Order Class II for verticle control surveys. State-of-the-art digital leveling technology is employed for all subsidence surveys.

A National Geodetic Survey was performed in 1996, however the final report has not yet been published. The current plan is to resurvey about every 10 years. The last National Geoditic Survey was performed in 1981.

Subsidence data are currently being compiled into a database that will be evaluated as part of this monitoring plan and will include a comparison with subsidence predictions such as those in the BEAR (WEC 1994). The subsidence monitoring study will also investigate factors that influence subsidence to the extent that these factors are identified in the failure scenarios considered in the performance assessment. The goal of the study is to document the most reliable subsidence predictions for the repository and to define the bounding limits of measurement that will indicate poor repository performance.

Additional benchmarks will be added, as necessary, to ensure adequate coverage of the subsidence basin.

SMP.5 Instrumentation

State-of-the-art leveling equipment is specified for subsidence measurement. The following is a list of technical specifications for typical leveling equipment used for subsidence monitoring:

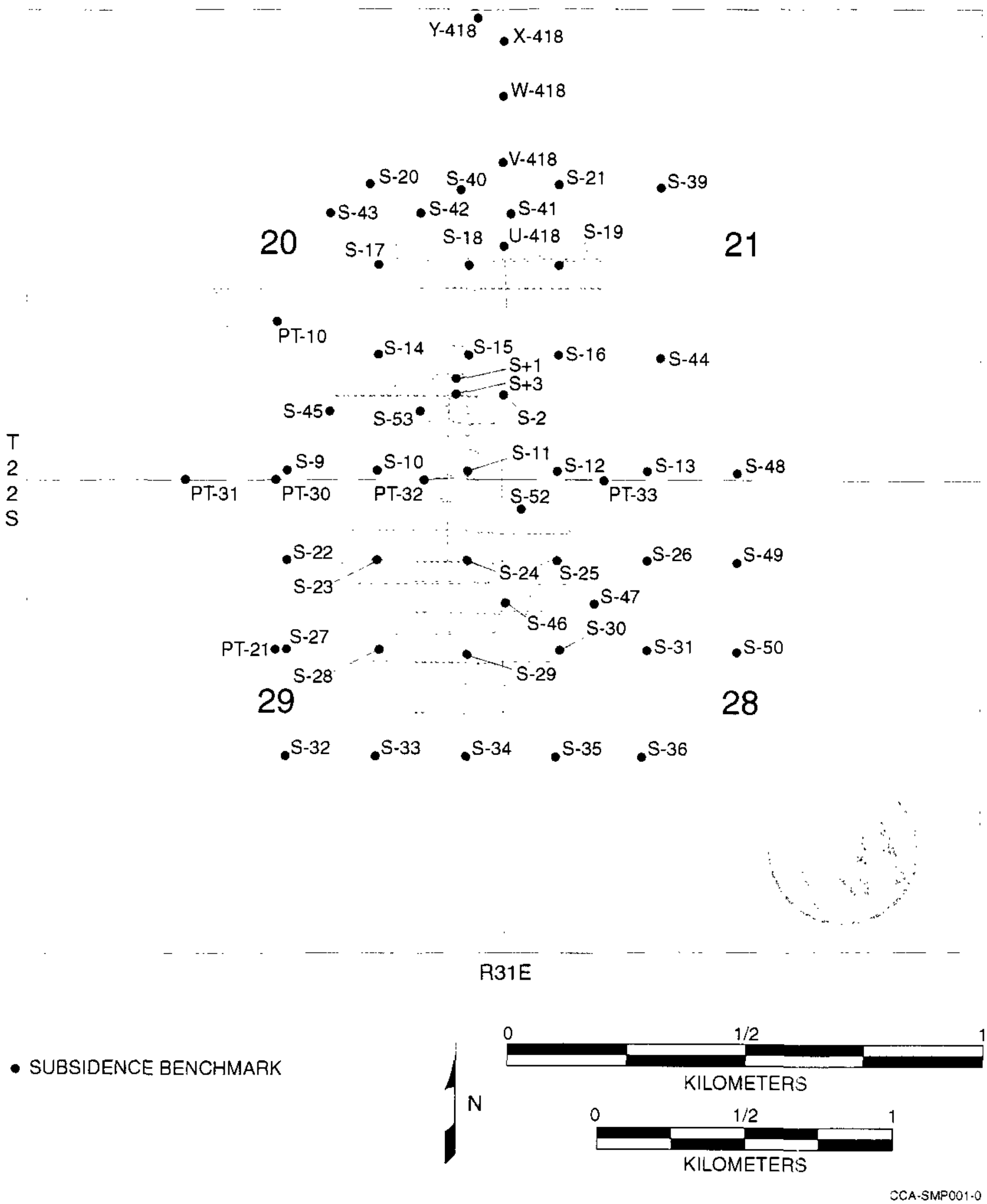

Figure SMP-1. Subsidence Monitoring Benchmarks

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Standard deviation	
(1kilometer double-run leveling)	
Electronically	1.5 millimeters
Optically	2.0 millimeters
Range	
Electronically	1.8 meters to 100 meters
Optically	0.6 meters upwards
Distance measurements	
Electronically	3 millimeters - 5 millimeters/10
Optically	0.2 meters - 0.5 meters
Temperature range	
Measurement	-20°C to + 50°C
Storage	-40°C to + 70°C
Compensator	Pendulum compensator with electronic range check.
Working range	±12 feet
Setting accuracy	±0.8 inches
Sensitivity of circular bubble	8feet/2 millimeters
Horizontal circle	rotable
Diameter	108 millimeters
Units	400 gon or 360°
Graduation interval	1 gon or 1°
Estimate to	~ 0.2 interval

SMP.6 Quality Assurance

Subsidence surveying is performed by a qualified contractor under the supervision of the Waste Isolation Division (WID) Site Survey Group. Vendors who perform surveying work must meet the following minimum standards:

- Five years experience in surveying field
- Proficient in using the precision leveling equipment specified for the program
- Proficient in using related surveying software
- Proficient in using global positioning satellite equipment and software

Quality Assurance (QA) requirements for Procurement of outside vendors to perform quality affecting work are in Section 2.3 of the CAO Quality Assurance Program Document (QAPD) (see Appendix QAPD).

Maintenance and calibration of equipment used for monitoring is addressed in Section 2.4.3 of the CAO QAPD (see Appendix QAPD). For subsidence measurements, maintenance and calibration are performed by the equipment vendor in accordance with national standards. Equipment is only procured from, maintained by, and calibrated by vendors on the WIPP approved Qualified Supplier's List.

Operational tests to verify that leveling instruments are in calibration are performed daily when equipment is in use.

Data, plots, graphics, and reports generated as a result of the subsidence surveys are reviewed by cognizant technical engineering personnel to ensure their adequacy and accuracy in accordance with DOE and DOE/WIPP Quality Assurance/Review procedures.

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