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TECHNICAL REPORT ON GEOLOGY, MINING, SUBSIDENCE AND SEISMICITY

Submitted to:

MANTI-LA SAL NATIONAL FOREST AND BUREAU OF LAND MANAGEMENT, UTAH STATE OFFICE

October 19, 2000

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1.0 INTRODUCTION

Canyon Fuel Company, LLC (CFC), submitted a Federal Lease Application to the Bureau of Land Management (BLM) for the Flat Canyon Tract (Tract) in March of 1998. A joint Manti-LaSal Forest Service (FS)/BLM Tract Delineation Team (TDT) ratified the Tract boundaries as submitted by CFC in August 1999.

The Tract is just west of the Wasatch Plateau Known Recoverable Coal Resource Area. The surface of the area is managed by the FS and the mineral estate by the BLM. The FS and BLM (Utah State Office) jointly determined that an Environment Impact Statement would be required as a basis for leasing decisions. The Office of Surface Mining (OSM) and Bureau of Reclamation (BOR) will participate as co-operating agencies.

The Tract encompasses some 2,692 acres immediately west of the existing CFC Skyline Mine as shown generally on Figure 1.1 and more particularly on Figure 1.2. Effects of mining the Tract may spill over into neighboring areas. The greater area of influence is termed the Reasonably Foreseeable Development Scenario Area (RFDS Area). While the terms Tract and RFDS Area define slightly different footprints, they are often used interchangeably in this Report.

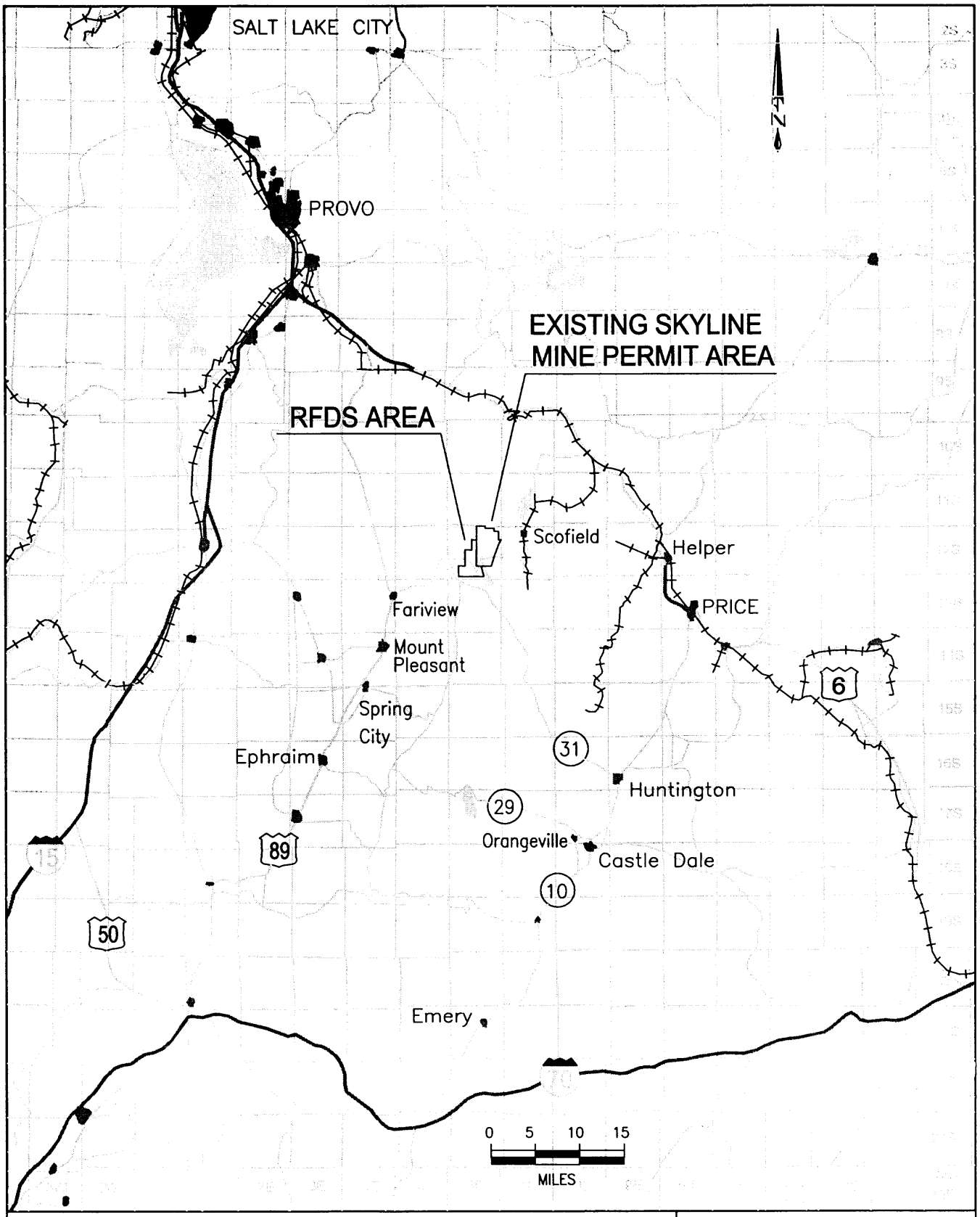
The EIS Summary is attached as Appendix A. The Table of Resource Element evaluation is attached as Appendix B.

1.1 AUTHORS

This Technical Report was prepared by NorWest Mine Services, Inc. (NorWest). Primary authors are, in alphabetical order:

- James (Jim) Alto – Co-Project Manager – NorWest;
- Conrad (Con) Houser – Co-Project Manager – NorWest;
- Dr. Alan Newman – President and Geotechnical Engineer – AME;
- Kelly Payne – Hydrogeologist – NorWest;
- Timothy (Tim) Peterson – Senior Geotechnical Engineer – NorWest; and
- Richard (Dick) Wright – Senior Mining Engineer – NorWest.

Resumes for each of these individuals are attached as Appendix C to this Report.



LEGEND

RAILROAD
HIGHWAY
ROAD
LAKE/RIVER
CITY

DETAIL AREA

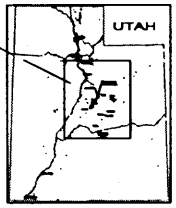


FIGURE 1.1
PROJECT LOCATION MAP

DATE: 10/18/2000
FILE: 2439LOCATION

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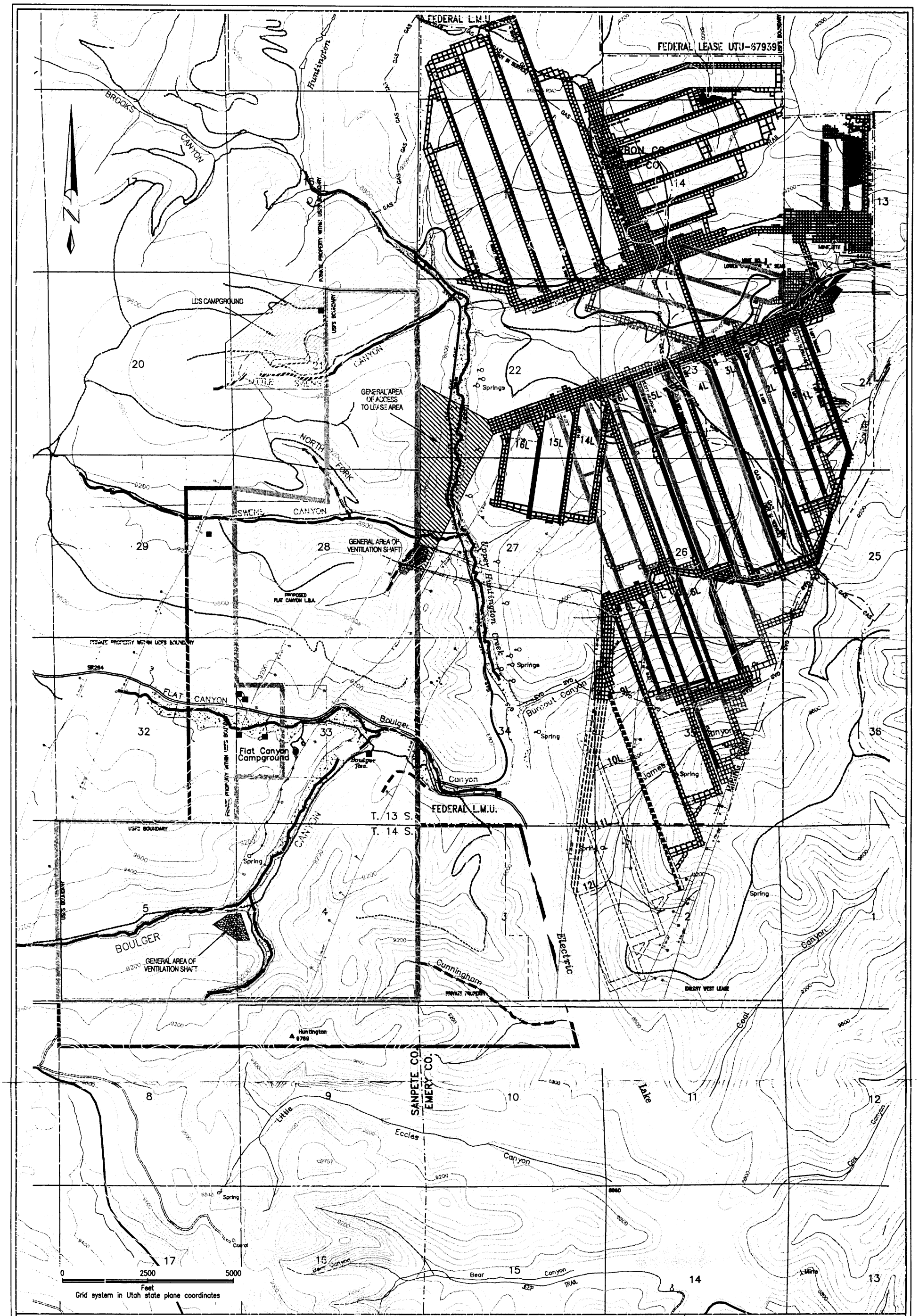

LEGEND

- LBA
- REASONABLY FORSEEABLE DEVELOPMENT AREA
- CABIN / BUILDING
- PAVED HIGHWAY
- UNPAVED HIGHWAY
- RIVER/CREEK,
- LAKE/RESERVOIR
- GAS PIPELINE (operational)
- GAS PIPELINE (not in service)
- WATER PIPELINE
- EXISTING MINE WORKINGS, MINE 1
- EXISTING MINE WORKINGS, MINE 2
- EXISTING MINE WORKINGS, MINE 3
- PROPOSED MINE WORKINGS, MINE 2 (existing lease)
- ESTIMATED PERIMETER of PERENNIAL STREAM ALLUVIUM
- MAJOR FAULTS
- PERENNIAL STREAM
- POSSIBLE PERENNIAL STREAM

FIGURE 1.2

DETAILED PROJECT LOCATION MAP

DATE: 10/18/2000

FILE: VW1-2.DWG

SCALE 1"=2640'

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1.2 PROPOSED ACTION

The FS and BLM propose to offer the Tract for competitive leasing based on CFC's application for lease as modified by the Interagency Tract Delineation Team. Only when or if it is determined that lease of this Tract, with special stipulations established by FS and BLM, can meet the primary objectives of all supervising agencies, will the Tract be offered.

1.3 PURPOSE AND NEED

The FS and BLM propose to offer the Tract for competitive leasing based on CFC's application for lease as modified by the Interagency Tract Delineation Team. The Tract would be accessed from the existing Skyline Mine. The TDT concluded that "no other independent access to the coal appears to be feasible." If a company other than CFC were to acquire the Tract, the most likely access to coal reserves would be through a 1200 foot shaft in the Boulger Canyon area between Boulger Reservoir and Electric Lake, as the coal does not outcrop. This is unlikely to be economically feasible (see the TDT's Reasonable Foreseeable Development Scenario discussed below).

Successful acquisition of the Tract by CFC would extend the life of the Skyline Mine by nine to twelve years, based on the reserves defined by the BLM Tract Delineation Report and an annual production rate from 3 to 4 million tons. However, if the BLM special stipulations are applied for resource protection then the reserves and mine life could be significantly reduced.

The Skyline Mine is a longwall operation. This technique for coal extraction would be extended into the Tract. Mine water discharge would be either from the existing permitted discharge point in Eccles Canyon or a proposed discharge into Electric Lake in the Huntington Creek drainage.

Surface disturbance associated with the development of facilities and exploration drilling on the Tract would be small: being limited to a number of exploratory drill holes and one or two passive ventilation shafts being the only newly constructed facilities. The location of the exploratory holes are preliminary and subject to change depending on geologic and environmental considerations.

Each drill hole would require a pad with an area of about one-half acre, approximately 100 ft by 200 ft and a temporary access road about 1,000 ft in length. If 10 additional holes are drilled, the area disturbed would be about 7.4 acres including drill pads and roads.

Ventilation shafts would not be constructed until underground mining progressed to each location and additional ventilation was required for safe operations. The general area proposed for location of these shafts is shown in Figure 1.2. The construction footprint for each ventilation shaft would be approximately one acre. Total disturbance for access roads to each ventilation shaft would be about 1,000 ft by 16 ft, or 0.36 acres for both shafts. The two shafts would be used for the life of the mine and would be abandoned and reclaimed thereafter. Disturbance and reclamation would be completed in accordance with permits issued by the FS and the State of Utah.

Total new surface disturbance for the Tract would be approximately 9.8 acres. This disturbance is related to predicted surface facilities only and does not include subsidence.

1.4 REASONABLE FORESEEABLE DEVELOPMENT SCENARIO (RFDS) - SUMMARY

The Tract covers an area of 2,692 acres and would be mined using longwall methods with multiple seam mining of two seams over the majority of the area and a total of 36 million tons of coal estimated to be recoverable. Continuous miners would be used for mine development. The reasonable range of longwall operational mining height would be from 7 to 12.5 ft and vary for each seam. Combined longwall extraction of two seams, based on reasonable operational constraints, could be as much as 22.5 ft of coal in some areas. These mining limits should not be regarded as rigid, as it may be possible to extract coal with a thickness down to 6 feet, or greater than 12.5 feet in some cases. Additional coal resources, not amenable to longwall mining, may be recovered by room and pillar methods with partial or full extraction.

The Tract would be accessed from the existing Skyline Mine (Federal Leases U-044076 and U-0147570) adjacent to the Huntington Creek drainage. The location of the general area where development is proposed to initially pass under Huntington Creek is shown on Figure 1.2. A development corridor, running parallel and under Huntington Creek, is the most likely mining scenario for main access to the Tract. This corridor is located mainly within the existing lease, but a small portion is within private land in the south. Development with full support room and pillar mining under the existing lease would be used to preclude subsidence of this creek.

1.5 REVIEWING AGENCY OBJECTIVES

The primary objectives of the BLM are to ensure:

- maximum economic recovery (MER) of the coal is achieved;
- the environment is protected; and
- all potential impacts resulting from mining are addressed and resolved.

To meet these objectives, the EIS must evaluate the Tract based on the following assumptions:

- assume full extraction mining to determine all potential surface impacts;
- surface areas determined to be not conducive to full extraction mining must be re-evaluated for impacts from partial extraction, first mining, or development mining;
- protective non-subsidence buffer zones must be considered (with appropriate angle-of-draw) for protection of sensitive resources, where these resources are protected by applicable laws, regulations, and management direction if the need is indicated or effects are relatively uncertain;
- geologic conditions that could limit coal extraction (other than coal thickness, interburden and depth) have only been considered where the data is thought to be sufficiently reliable;
- drilling of about 10 additional exploration holes would be necessary to delineate the reserves; and
- development of two passive vent holes.

The Forest Service has a wide range of Forest Management goals including the following:

- manage geologic resources to meet resource needs and minimize adverse effects;
- maintain satisfactory watershed conditions while providing favorable conditions for water flow;
- provide for production of mineral resources consistent with applicable laws, regulations, and Forest Plan management direction; and
- provide for public safety.

Where there is conflict between MER and the other objectives, the EIS must consider the effects of a reasonable range of alternatives, including no action, to allow for informed scientifically based decisions to be made.

1.6 ALTERNATIVES

Four alternatives were developed to address the significant issues associated with this proposed lease action and to meet the requirements of NEPA. This Technical Report will address Alternatives 2 and 3 and make recommendations to help FS and BLM compile special lease stipulations needed for inclusion in Alternative 4.

1.6.1 No Action (Alternative 1)

This alternative provides a baseline for estimating the effects of the action alternatives. Under this alternative, the lease Tract would not be offered for leasing and there would be no mining.

1.6.2 Offer The Tract For Leasing As Delineated With Special Lease Stipulations (Alternative 2)

Under this alternative the Tract would be offered for competitive leasing, as delineated, with standard terms and conditions and special stipulations to protect non-mineral resources and uses. Subsidence of perennial drainages, Boulger Dam and Reservoir, Flat Canyon Campground, State Highway SR 264 and Mainline #41 gas transmission pipeline would not be allowed.

1.6.3 Offer The Tract For Leasing As Delineated Without Special Lease Stipulations (Alternative 3)

Under this alternative the Tract would be offered for competitive leasing, as delineated by the TDT with standard lease terms and conditions. No special stipulations would be included. Longwall (full-extraction) mining would be allowed throughout the Tract resulting in subsidence of perennial drainages, Boulger Dam and Reservoir, and Flat Canyon Campground. It would be analyzed as the basis for comparison with other action alternatives that would include special stipulations needed to protect non-mineral resources and uses.

1.6.4 Offer The Tract With A Specific List Of Special Stipulations Needed To Protect Non-Mineral Resources (Alternative 4)

This alternative will be developed to address significant social, economic, or environmental issues or opportunities.

1.7 STATEMENT OF ISSUES AND EVALUATION CRITERIA

1.71 Geology, Subsidence, Seismicity

- Mining of the underground coal reserves can cause subsidence, seismicity, and cracking of the ground surface.

  Evaluation Criteria: Location and Amount of Subsidence Expected (measured in ft), Maximum Credible Mining-Induced Seismic Event By Range of Magnitude and Probability (Richter, % probability), Location and Severity of Cracks (primarily based on monitoring at Skyline Mine), Connection Between Surface and Underground Cracks Relative to Depth of Cover, Angle-of Draw, Tension and Compression Zones, Perception of Seismic Events by Campers and Dispersed Recreationists in the Area.

- Pillars in full-support mining areas intended to prevent subsidence could fail due to unforeseen geologic circumstances and oxidation/stress over many years. Planned full-support mining areas under Huntington Creek and other protected areas must be specifically analyzed.

  Evaluation Criteria: Support Capability of Pillars and Probability of Surface Subsidence in Planned Protected Areas for Long-Term (200 years).

1.72 Structures and Facilities

- Mining-induced subsidence and seismicity could damage the Boulger Dam (including the fish ladder) and Reservoir.

  Evaluation Criteria: Type and Risk of Damage (Damage Description, % probability), Cost of Repair, Public Safety Risk, Time Needed for Repairs/Duration of Lost Use, Cost of Lost Use.

- Mining-induced subsidence could damage State Hwy. 264.

  Evaluation Criteria: Description of Potential Damage and % Probability, Public Safety Risk, Cost of Repair, Cost of Lost Use

- Mining-induced subsidence could damage Mainline #41 gas transmission pipeline.

Evaluation Criteria: Description of Potential Damage and % Probability, Public Safety Risk, Cost of Repair, Cost of Lost Use

- Mining-induced subsidence and seismicity could damage facilities at the Flat Canyon Campground (including spring source, water storage tank, and associated pipeline).

  Evaluation Criteria: Description of Potential Damage, Cost of Repairs, Duration of Lost Use, Cost of Lost Use

- Mining-induced subsidence could damage recreation cabins and/or camp facilities and roads on adjacent private lands that are mined as a result of leasing the Flat Canyon Tract.

  Evaluation Criteria: Description of Potential Damage, Safety Risk, Cost of Repair, Duration of Lost Use, Cost of Lost Use.

1.8 CONTACTS MADE

A site visit was carried out by the Norwest project team to observe underground and surface conditions at the existing Skyline Mine and to observe the surface conditions over the Tract and adjacent areas.

FS and BLM specialists were consulted regarding current available information and knowledge of resource occurrence and conditions and to discuss standards and methodologies for data collection and analysis.

The CFC geologist, Mark Bunnell, assisted with providing data and information regarding the current mining operations and associated relevant geotechnical studies carried out by the company at Skyline, including projections for geology and geotechnical conditions for the Tract.

Additionally, verbal interactions with the University of Utah, Seismological Group, together with personnel at the Willow Creek mine, were made to assist with assessment of the seismicity parameters for the study.

1.9 DESCRIPTION OF DATA

The data used in this study is presented for public data in the bibliography in Section 9 and for confidential data in Appendix E. Data is listed below under general headings with the main sources given in parentheses:

- subsidence reports and information supplied by CFC for the impact of mining induced subsidence on State Highway SR 264, Burnout Creek and the Questar gas pipeline. (Consultants and the Skyline Mine);
- mine plans of the Skyline Mine workings include advance positions by month and associated extraction heights for all three mines. (Skyline Mine);
- mine maps showing existing topography and surface infrastructure for the existing lease and the Tract (Skyline Mine);
- geologic maps and associated digital files showing the existing geology, overburden thickness, coal thickness and seam elevations for the current mining area and projections for the Tract from exploration data (Skyline Mine);
- drill logs with both cuttings logs and geophysical logs for relevant boreholes on the existing mining lease and exploration of the Tract (Skyline Mine);
- aerial photographs flown in 1999 (Skyline Mine);
- geotechnical reports and technical papers on coal and rock strength testing, stress measurements, joint studies and seismicity related to the Skyline Mines (various consultants); and
- technical papers and reports relating to studies carried out at other locations regarding relevant aspects of mining, geology, subsidence and seismicity (various published documents).

1.10 METHODOLOGY

The methodology for this technical Report has been to address the requirements for defined issues related to general characterization of expected impacts for areas of the Tract with particular environmental concerns. No specific detailed mine plan has been provided by CFC. The RFDS has been developed considering the most reasonable access to the Tract and the application of longwall full extraction mining where this does not conflict with feasibility constraints. Room and pillar mining of remaining areas is then considered where feasible. The various mining scenarios for each seam and each alternative have then been considered, but no specific detailed mine plans have been developed.

While this approach is not comprehensive it is considered to be reasonable, given the level of information currently available from exploration. Exact geologic conditions can be difficult to reliably predict prior to underground development in any new mine area. Detailed future mine plans require regular revision to reflect conditions encountered underground and the final mine layout is seldom identical to the pre-mining layout. We have taken a reasonable approach when dealing with the possible range of scenarios and provided a range of impacts where more variability may be anticipated. Where doubt exists in the evaluation a conservative approach has been adopted or recommendations presented to address the issue.

The evaluation of subsidence from longwall mining has included nine locations for prediction that provide information used in a characterization process. Larger areas of concern, such as perennial drainages, have then been evaluated based upon the variation of impacts estimated from a number of subsidence prediction points within, or adjacent, to the area of concern. A numerical subsidence model, calibrated to measured subsidence on the adjacent Skyline Mine, was used to predict the subsidence expected. This was based on generic mining layouts for these longwall mining areas. The subsidence of room and pillar mining areas, with both partial and full extraction, has then been treated separately and varies with the different seams and alternatives evaluated.

This Report is restricted to evaluation of the degree of subsidence and seismicity expected in the Tract as a result of the four major mining alternatives discussed earlier. The impact of these factors on the structures and facilities is presented in Section 8 of this report. The impacts on surface and groundwater, and on wildlife and vegetation resources, have been evaluated separately in the relevant technical reports for these resources.

2.0 GEOLOGY

2.1 INTRODUCTION

The RFDS area is located in the Wasatch Plateau, a sub-province of the Colorado Plateau Physiographic Province. The geology of the Wasatch Plateau has been described by Spieker (1931) and Witkind and Weiss (1991). The geology of the Skyline Mine area and the RFDS area has been described by Knowles (1985), Oberhansley (1980), and by Canyon Fuel (1999). Larson (1996) described the glacial geomorphology of the RFDS area. Information on the geology of the area has also been gathered from field observations, discussions with the mine geologist, and drill hole logs.

2.2 AFFECTED ENVIRONMENT

In the Skyline Mine and RFDS areas five bedrock formations are exposed at the surface. In ascending stratigraphic order these are the Star Point Sandstone, Blackhawk Formation, Castlegate Sandstone, Price River Formation, and North Horn Formation. These formations are shown on a generalized columnar section (Figure 2.1) and on a geologic map (Figure 2.2). In the RFDS area bedrock formations are largely covered by thin, unconsolidated, Quaternary-age sediments including soil, alluvium, and glacial deposits.

2.2.1 Stratigraphy

Bedrock formations were deposited during the Late Cretaceous and Tertiary periods. Multiple transgressions and regressions of the Western Cretaceous Interior Seaway resulted in the deposition of a heterogeneous sequence of rock types that are both horizontally and vertically discontinuous. On the terrestrial side of the shoreline, sediment deposition occurred in lacustrine, fluvial, flood plain, and coal swamp environments. Along the shoreline beach sands accumulated. Offshore, sands swept from the beaches were laid down as bars and blankets of sand in the near-shore shallow marine water. The clay fraction of stream transported sediments reaching the shoreline were deposited as marine muds in deeper and more quiescent portions of the seaway (Mayo and Associates, 1997).

In Pleistocene time, the Wasatch Plateau was glaciated at least twice. The most recent glaciation ended at least 15,000 years before present (Larson, 1996). The geomorphology of many parts of the RFDS area is a result of glaciation.

Stratigraphic units are discussed below.

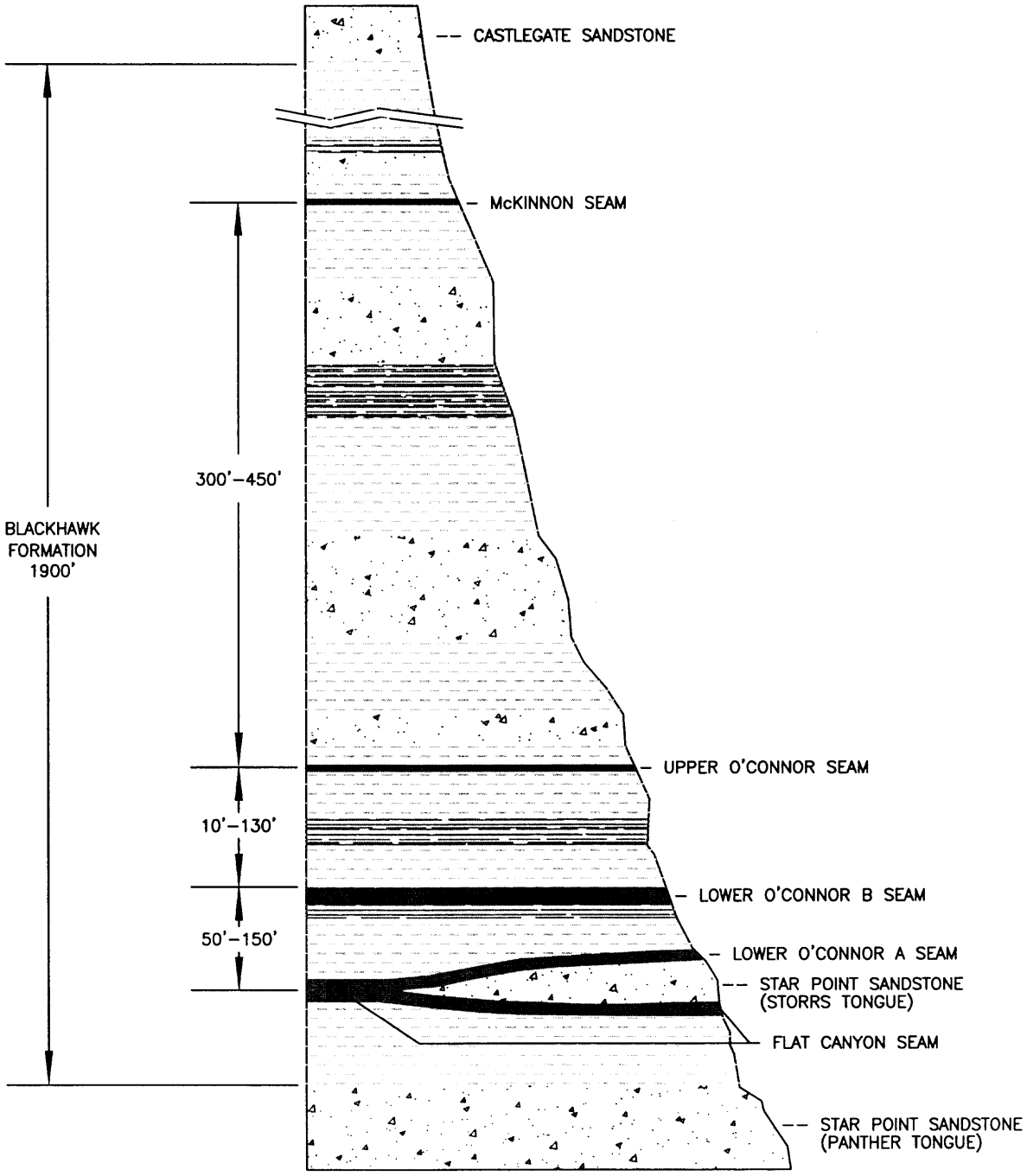
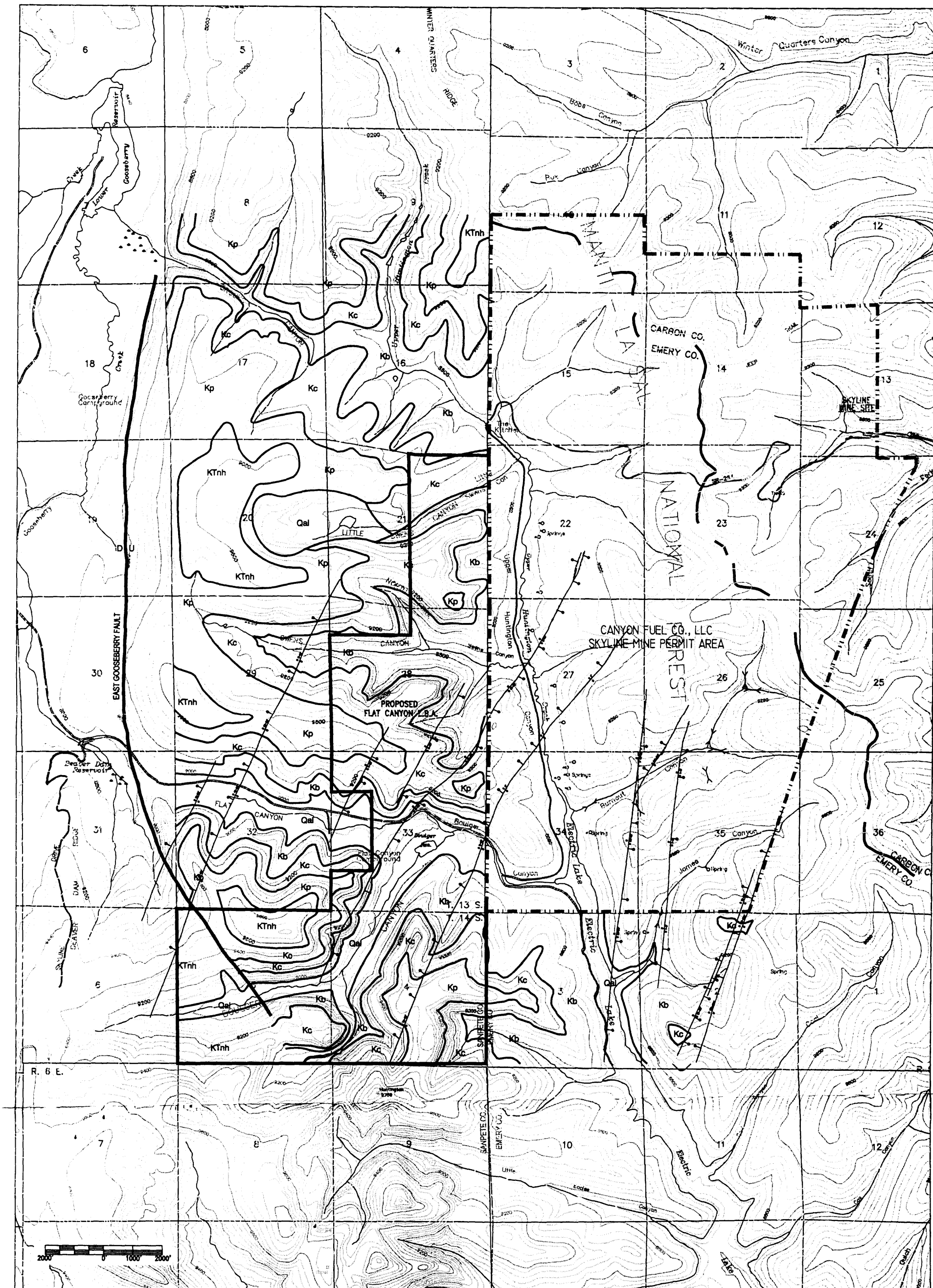


FIGURE 2.1
GENERALIZED COLUMNAR SECTION
FLAT CANYON TRACT AREA

DATE: 9/11/2000
DWG: 2439–COLUMN

NorWest



LEGEND

- FLAT CANYON COAL LEASE TRACT
- RFDS AREA
- SKYLINE MINE PERMIT AREA
- GEOLOGIC UNITS
- FAULTS

Qal	QUATERNARY ALLUVIUM
KTnh	NORTH HORN FORMATION
Kp	PRICE RIVER FORMATION
Kc	CASTLEGATE SANDSTONE
Kb	BLACKHAWK FORMATION

(After Knowles, 1996 and Oberhansley, 1980)

FIGURE 2.2

GEOLOGY MAP

FILE: HYDRO1-2.DWG	SCALE 1" = 3200'	NorWest
DATE: 9/11/2000		

2.2.1.1 Star Point Sandstone

The Star Point Sandstone is a marine shoreface deposit that is not exposed in the RFDS but is a prominent cliff former in canyons to the east. In this part of the Wasatch Plateau, the sandstone is comprised of two massive units, the Storrs Tongue and the underlying Panther Tongue, which intertongue with the lower Blackhawk Formation. The Storrs and Panther tongues both consist of fine- to medium-grained, sub-rounded to well-rounded light colored sandstone with a "salt and pepper" appearance. Measured thickness of the formation east of the Skyline Mine is 1,289 ft (Canyon Fuel, 1999).

The Storrs Tounge pinches out westward within the southern portion of the Flat Canyon Tract.

2.2.1.2 Blackhawk Formation

The Blackhawk Formation is 1,700 to 1,900 ft thick in the RFDS area (Canyon Fuel, 1999). However, only the uppermost 200 ft are exposed in outcrop within the RFDS area (Oberhansley, 1980). The Blackhawk Formation consists mainly of lenticular sandstone, siltstone, and claystone. The lower portion of the Blackhawk Formation is the coal-bearing section of mining interest.

Well drilling reports and laboratory analysis of samples indicate that claystone layers contain swelling clays that are expected to plastically deform and heal when fractured. Chempet Research Corporation (1989) found some claystone layers contained up to 58% montmorillonite, a swelling clay. Vaughn Hansen Associates (1982) report that holes drilled into the Blackhawk are very unstable, and when left open for a few days, slough badly. Shale and claystone horizons within the Blackhawk Formation provide barriers to vertical movement of water.

Coal to be mined in the RFDS area occurs in the lower portions of the Blackhawk Formation. Within the bottom 100 ft of the Blackhawk are several coal seams between the Storrs and Panther Sandstone tongues. Of these seams only the lowest-lying Flat Canyon seam is mineable.

The upper coal-bearing unit of the Blackhawk Formation, immediately above the Storrs tongue, contains three mineable seams, but only the Lower O'Connor B seam is mineable under the majority of the Tract. The Lower O'Connor A seam is not considered mineable until it merges with, and becomes part of, the Flat Canyon seam in the central and northern section of the RFDS area, although there may be areas with mineable thickness in the southern section of the RFDS.

Additional coal seams occur in the upper part of the formation, but these are typically discontinuous and only locally of mineable thicknesses. The coals are described as mid-lustrous, resinous and containing attrital materials. They are classified as high-volatile "B" bituminous in rank.

2.2.1.3 Castlegate Sandstone

The Castlegate Sandstone is a cliff-forming unit in much of the Wasatch Plateau. However, in the RFDS area, the Castlegate Sandstone does not form a prominent cliff but forms steep slopes with only occasional outcrops. The sandstone is light gray to light yellowish gray, medium- to coarse-grained, and occasionally conglomeratic. The reported thickness is 220-320 ft (Oberhansley, 1980).

2.2.1.4 Price River Formation

The Price River Formation is a slope-forming unit that is poorly exposed in the area because of vegetation and the thick soil mantle. Oberhansley (1980) reports that the formation consists of thin- to thick-bedded sandstone and mudstone. Mudstone beds are thicker and more common in the lower part of the formation while the top part of the formation contains thick massive channel sandstones. Sandstones thin laterally in both directions. The unit is 220 to 280 ft thick.

2.2.1.5 North Horn Formation

The North Horn Formation caps the uplands of the RFDS area. The formation consists of thick-to thin-bedded sandstone and mudstone in the lower 200 ft, a 430-foot thick middle unit that is comprised of interbedded lacustrine limestone, sandstone, and mudstone, and an upper unit that is similar to the lower unit. The complete formation is 1,350 ft thick (Oberhansley, 1980).

2.2.1.6 Alluvium

Minor alluvial deposits are found in the canyon bottoms. Soil and colluvium are relatively thick and cover most of the slopes in the area.

2.2.1.7 Glacial Deposits

Glacial deposits consist of terminal, recessional, and ground moraines. Morainal deposits are most notable in Boulger Canyon. Boulger Dam sits on terminal moraine and lateral and recessional moraines are visible along most of Boulger Canyon. End moraines are found near the head of Swens and Little Swens Canyons. The Boulger Canyon glacier and glacial moraine deposits created an impoundment in Flat Canyon that subsequently has filled with sediment. Exploration drill holes (CFC, 2000) show that these glacio-lacustrine deposits consist of 70 to 90 ft of primarily sand and gravel with only minor fine-grained materials.

2.2.2 Structure

The Tract is situated on the western limb of the Clear Creek Anticline and the dip of the sedimentary rocks is generally toward the west. Dips range from 3° to 6° within the lease area (Canyon Fuel, 1999).

Complex sets of north-south and northeast-southwest trending Cenozoic faults extend along the entire length of the Wasatch Plateau (Williams and Arabasz, 1989). The dip of the major faults is generally near vertical. The Connelville fault zone east of the RFDS has between 55 to greater than 250 ft of displacement and extends up to 1,000 ft in width. This fault zone forms the eastern mining limit of the current Skyline leasehold (Canyon Fuel, 1999). To the west of the RFDS area the bounding fault of the Goosberry Graben has a displacement ranging from 850 ft to 1,180 ft (Oberhansley, 1980). Geomorphology of the RFDS area suggests (Canyon Fuel, 1999) the probability of at least three northeast-southwest trending fault zones. These faults may be associated with the North Joes Valley fault zone as it dies out northward into the Tract area. Exploration to determine the location and throw of these potential faults is ongoing. Faults of this orientation have been encountered in Skyline mine workings with throws in the range of inches to over 20 ft.

Two other fault orientations have been encountered with trends of N. 80 W. and N. 60 W. Throws on the east-west trending faults are usually less than 10 ft. One N 60 W trending zone was encountered with displacements in excess of 40 ft. It is expected that these east-west trending faults occur in the Tract (Canyon Fuel, 1999).

Canyon Fuel (1999) has mapped four major joint and fracture orientations on the Skyline leasehold. The most common orientation observed within coal beds and immediate roof and floor strata are a set of joints spaced approximately 1 to 3 ft apart with a N 80 W orientation. This joint set is only occasionally observed in outcrop. A second joint orientation observed in the mines as well as in outcrop, are a set of N 5 W to N 20 E joints, spaced from 1 foot to over 10 ft apart at the surface. The remaining two orientations are a system of conjugate shear fractures and joints which are oriented at approximately N 60 W, and S 70 W, respectively.

Igneous dikes oriented in a nearly east-west direction occur within the RFDS area. Numerous dikes have been encountered during the mining activities located east of the RFDS area. The dikes are comprised of phlogopite mica-rich, quartz-poor material classified as lamprophyre. Where individual dike blades cut coal seams, a thin halo of coked coal is normally present. Dike width in coal varies from a few inches to tens of ft.

3.0 MINING

This section will discuss the overall mineability considerations used in this study and present them in the form of mineable zones for each seam and mining method. Further discussion of mining options and constraints will be discussed in Section 4 and the overall constraints incorporated into mining scenarios for each seam and each alternative.

3.1 PROPOSED MINING METHODS

A specific detailed mine plan has not been supplied by CFC, as further exploration data is required before sufficient confidence in the geology can be gained for commitment to a particular layout. However, there is sufficient exploration data to define mineable coal resources and to develop coal recovery mining scenarios for an EIS.

Longwall mining methods are expected to be economically feasible in the Tract area and have been assumed unless technical or resource protection constraints indicate otherwise. Where reserves are not amenable to longwall mining, additional recovery may utilize partial and full extraction room and pillar methods.

The mining scenarios presented have been developed to a level of detail that is sufficient for evaluation of the overall range of impacts necessary for this study. They are discussed in this section with regard to underground access development and production from both longwall and room and pillar mining methods.

3.1.1 Access Development

Main underground mining access to the Tract is planned in the Lower O'Connor B Seam by the westerly extension of the current main development entries in the Skyline Mine. The exact location where these mains would cross the lease boundary has not been finalized. A zone encompassing possible alternatives has been defined and is presented in Figure 1.2.

To provide sufficient capacity for ventilation, access, escape and haulage it is probable that all of the six entries in the existing mains would need to be developed into the new area. The exact number of entries has not been finalized and we have not carried out a detailed mine planning and engineering study that would be necessary for their confirmation. However, based on our experience it is reasonable at this stage to assume that all of the existing entries would need to be extended into the Tract.

For the MER there is merit in locating the mains below Upper Huntington Creek, as this would afford protection of this perennial drainage from subsidence, while allowing efficient recovery. This is the area where the thickest coal in the Lower O'Connor B Seam is located and will also allow development to progress from thick coal to the thinner coal in the west. CFC have confirmed that this is their preference and we have identified a development corridor that is 1600 ft wide based upon the assumption that longwall mining will not be allowed within the angle of draw from the edge of the creek alluvium, as defined by the estimated extent of the flood plain. The corridor is identical for each of the mineable areas presented in Figures 3.1 and 3.2 for the upper and lower seams, respectively. The corridor has sufficient width to allow for adequate barrier pillars on either side of the main development entries to protect the mains from any additional overburden load transfer that might result from longwall mining on either side of them.

In order to ensure adequate ventilation and mine dewatering at least one, and possibly two, return ventilation shafts would need to be constructed within the Tract area. The general areas for each of these proposed ventilation shafts are shown in Figure 1.2. They are proposed as vertical shafts for return ventilation that do not require the installation of power or fans for their operation. The requirement and location of the northerly vent shaft should be regarded as relatively definite at this stage and would likely be required early in the mine life. However, the requirement and location of the southerly vent shaft is less certain and is more likely to be subject to change in the future. It has been included as a contingency, as there is a reasonable likelihood that it may be necessary, especially with the limitations of passive vent shafts.

The main development system would be connected to these ventilation shaft(s) and sub-mains would also be required for access to production areas. Mining the majority of the Tract area would generally be at greater depths than the majority of the current lease, varying from 1000 ft to over 2000 ft.

Access to the Flat Canyon and Lower O'Connor 'A' Seams would be from underground by rock entries driven at a slope to mains in the lower seam. The lower main development entries and pillars would most likely be vertically aligned with those in the upper seam whenever possible to minimize the adverse effects that would result if these life of mine entries were misaligned. This becomes increasingly important where the interburden between seams is thin and weak. This would have the added benefit of higher coal recovery.

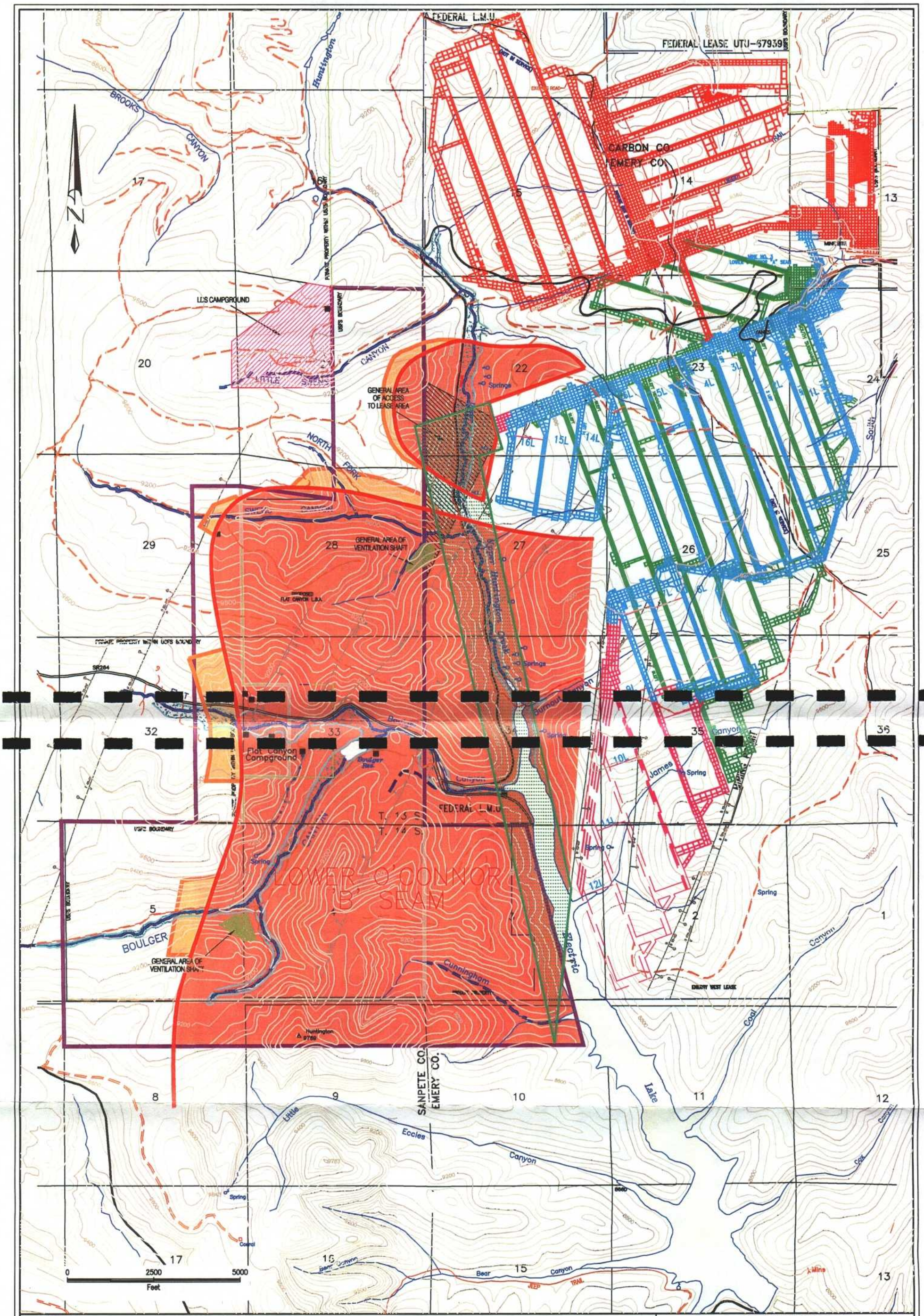
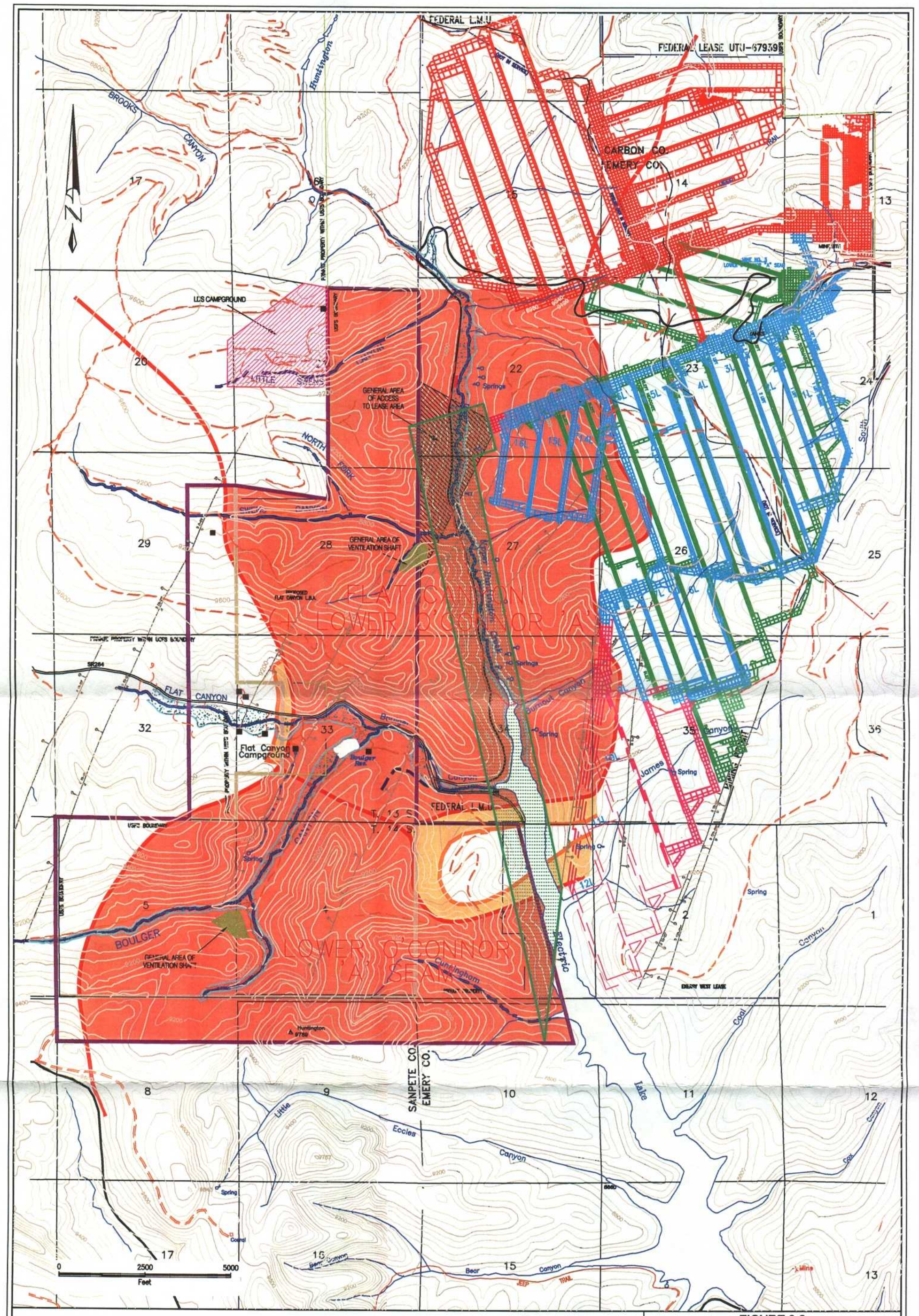


FIGURE 3.1
UPPER SEAM MINING ZONE



LBA
REASONABLY FORSEEABLE DEVELOPMENT AREA
CABIN / BUILDING
PAVED HIGHWAY
UNPAVED HIGHWAY
RIVER/CREEK,
LAKE/RESERVOIR
GAS PIPELINE (operational)
GAS PIPELINE (not in service)
WATER PIPELINE
EXISTING MINE WORKINGS, MINE 1
EXISTING MINE WORKINGS, MINE 2
EXISTING MINE WORKINGS, MINE 3
PROPOSED MINE WORKINGS, MINE 2 (existing lease)
ESTIMATED PERIMETER of PERENNIAL STREAM ALLUVIUM
MAJOR FAULTS
PERENNIAL STREAM
POSSIBLE PERENNIAL STREAM
LONGWALL MINEABLE ZONE (FLAT CANYON AND LOWER O'CONNOR 'A')
ROOM AND PILLAR MINEABLE ZONE (FLAT CANYON AND LOWER O'CONNOR 'A')
MAIN DEVELOPMENT CORRIDOR (MAINS AND BARRIER PILLARS)

FIGURE 3.2
LOWER SEAM MINING ZONES

FILE: MINING.DWG
DATE: 10/17/2000
SCALE 1" = 2640'
NorWest

3.1.2 Longwall Production

Coal production using longwall mining methods involves the development of longwall panels from the main or sub-main development entries. Development entries, known as gate roads, are driven on either side of each longwall panel. The gate roads are then connected at the limit of the panel for access and ventilation. Longwall mining is then carried out by fully extracting the seam between the two sets of gate roads by retreating the longwall face equipment from the panel limit back to the mains. A barrier pillar is left to protect the mains from damage due to mining induced stresses. It is expected that panels would be about 800 ft wide and their length would vary from about 3,000 to 15,000 ft, depending upon selected mine layout and geological / operational constraints.

It is not presently possible to define the orientation of longwall panels and their exact location. Based on rock mechanics considerations, the preferred orientation of longwall panels would likely be NNW to SSE, which is similar to the current workings. Previous mining experience has also shown that an orientation perpendicular to this direction would also be acceptable. Other geological constraints due to faults, dikes, channel washouts and coal thinning may influence the final choice of panel orientation. Protection of surface structures and resources may provide additional constraints on longwall location, orientation and sequence.

Mine production is planned from a single longwall section, in conjunction with production from continuous miners driving development entries. Additional production may come from room and pillar extraction.

Past experience at Skyline has reportedly shown that longwall mining at overburden depths beyond 2,100 ft would be difficult due to high stress concentrations, leading to instability and the increased potential for damaging bumps. This depth limitation has not been regarded as fixed for this study, but would require further evaluation if it had a significant impact. There are very few areas of longwall mineable reserves within the Tract that are deeper than 2100 ft. and hence it has been ignored as a significant constraint.

Reasonable equipment constraints have been used for the definition of the minimum and maximum extraction heights for full extraction longwall mining. These have been based on different criteria for the upper and lower seams.

The Lower O'Connor B Seam is the upper seam in the RFDS area and is generally thick with rapid thinning towards the western limit of the Tract. We have assumed that the current equipment being used in the existing Skyline Mine Lower O'Connor B workings would also be suitable for the new Tract.

The practical operational height range of this equipment is from 8.5 to 12.5 ft. Although the minimum height capability of longwall shields can be less, the maximum practical height is typically slightly less than 1.5 times the minimum height. There is normally limited ability to change equipment capability, especially during panel retreat. Consequently, if the minimum height is reduced by a given amount then the maximum height reduction will be reduced accordingly by a factor of 1.5. Approximately half of the Lower O'Connor B reserves in the Tract are over 12.5 ft in height and the coal thins rapidly to the west. We have not carried out an optimization study to assess whether this configuration is optimum from an MER perspective, but from our experience we believe that it is a reasonable choice. These limits should not be regarded as rigid, as it is possible that mining could be undertaken down to 6 feet, or greater than 12 feet high in some cases. The upper seam mining zone based on these criteria is shown in Figure 3.1.

The Flat Canyon and Lower O'Connor A Seams form the lower seam where the upper seam is mineable. The lower seam is thinner than the upper seam and only isolated areas are thicker than 10 ft. Longwall equipment with a reasonable operational height range capability from a minimum of 7 ft. to a maximum of 10 ft. has been assumed. The lower seam mining zone based on these criteria is shown in Figure 3.2.

The longwall mining zones for upper and lower seams, presented in Figures 3.1 and 3.2, do not incorporate any mining constraints due to depth, protection of structures and resources, or adverse geologic conditions. They are constrained only by seam thickness, previous mining, property control (where applicable), drill-hole coverage and the main development corridor below Huntington Creek.

3.1.3 Room and Pillar Production

Coal production using room and pillar mining methods involves use of the same equipment used for development of longwall mining areas and hence can normally be carried out concurrently with longwall mining. For the purposes of this report we have assumed that longwall mining will be the primary mining method where feasible.

Room and Pillar methods are more flexible, especially where irregular small areas are encountered. Partial extraction is carried out during development on advance and then the pillars can be recovered to the maximum extent possible during retreat, allowing the strata to cave in a similar manner to longwall mining. Coal recovery during retreat is not as complete as longwall recovery, but is referred to as 'full' recovery in this report. During advance the terms development mining or partial extraction are used. During retreat the terms retreat mining, full extraction or pillar recovery have been used interchangably in this report.

Room and pillar mining on retreat with full extraction is more difficult than longwall mining, as regular caving of the roof strata is difficult to initiate and control. The stability of coal pillars becomes increasingly important with depth due to the mining induced stresses. At depths greater than about 1600 ft problems and associated risk increase significantly, leading to increased costs and reduced safety. We have made a reasonable assumption, based on experience in other mines, that room and pillar retreat mining will not be carried out at depths greater than 1800 ft due to safety and economic issues. We have not carried out a detailed study to confirm this figure, as minor variation will not have a significant effect on the RFDS.

The BLM has undertaken studies showing that room and pillar mining with both partial and full extraction is economically feasible down to an extraction height of 6 ft. The economic feasibility of these mining methods and minimum thickness is likely to be contentious. However, for the purposes of this study we have taken a conservative approach from an impact standpoint and not imposed any further economic constraints. The additional areas where room and pillar mining can be used to mine beyond the longwall mineable reserves is shown in Figures 3.1 and 3.2 for the upper and lower seams, respectively.

Partial extraction can be used as a method of protecting the surface from subsidence and we have assumed that it is utilized for some of the alternatives discussed later in this report.

3.1.4 Multiple Seam Mining

The majority of the Tract contains mineable reserves in both the upper and lower seams. In these cases it is anticipated that the upper seam, the Lower O'Connor B, would be mined first, followed by the lower seam. This is standard practice for multiple seam mining, especially where there is potential for caving or subsidence resulting from mining of the lower seam to damage the upper seam.

Even if the upper seam is mined first, the potential for significant problems still remains, predominantly due to elevated stresses where pillars are left in the upper seam. Problems can also occur as a result of gas or water accumulations in the upper seam and a reduced ability of the strata above the upper seam to provide support. These problems are significantly increased as the interburden separating the two seams becomes thinner.

The interburden between the Lower O'Connor B and Flat Canyon Seams is generally between 100 and 140 ft, this is adequate to preclude major problems. Some adverse stress interactions may be experienced where major pillars are located in the upper seam.

The interburden between the Lower O'Connor B and Lower O'Connor A Seams is thinner than with the Flat Canyon Seam. In the area where the Lower O'Connor A Seam is potentially mineable the interburden varies from 30 to 60 ft. CFC have reported that they consider mining at an interburden thickness of less than 40 ft to be impractical based on their experience, although it is based on mining above the Lower O'Connor B Seam. The definition of a lower limit for interburden thickness will be very dependent on mining and geological conditions, which are not fully known for the new lease area at this point in time. We have assumed that mining down to a 40 ft thickness of interburden is feasible, but this should not be regarded as a recommendation for mine design. It should also be noted that mineable resources for the Lower O'Connor A seam are based on insufficient exploration data to confirm their technical and economic feasibility. Further exploration is planned that will clarify this issue and our approach has been adopted to be conservative from an impact perspective.

4.0 SUBSIDENCE AND SEISMICITY IMPACT ANALYSIS REQUIREMENTS

The main issues addressed in this Report are those relating to potential environmental and structural impact resulting from subsidence and seismicity. Subsidence above longwall mining areas would affect the integrity of the rock mass and create surface deformations with the potential to impact subsurface hydrogeology, surface hydrology and physical structures. Mining induced seismicity could result in the creation of vibrations that are transmitted through the rock to the ground surface and have the potential to damage structures and cause whole body vibrations to humans. The impact evaluation is restricted to surface vibrations only and does not include consideration of impact to the CFC underground facilities and operations.

This Report is limited to estimation of the location, magnitude and frequency of these mining related phenomena and their impact on man-made structures and facilities. Other technical reports will evaluate the extent to which these phenomena are expected to impact the environment and associated structures and resources.

4.1 METHODOLOGY

Our general approach is t~~o utilize~~ empirical data whenever possible from the adjacent Skyline mining operations. Mining conditions in the Tract area would be very similar to past mining and geologic conditions at Skyline. Empirically derived predictive techniques have been developed and then modified to account for the differences expected in the new area.

Confidence in the definition of reserves in the Tract area is limited by the limited exploration data and studies currently available. The data is sufficient for characterization of the general conditions to be expected and for the development of different mining scenarios, but is not sufficient for detailed analysis and detailed mine planning. Consequently, a characterization approach has been adopted to investigate the likely variation of mining scenarios and estimate their likely impacts. Where conditions or data are not fully known or understood a conservative approach has been adopted.

The evaluation has been carried out separately for a series of different mining alternatives which are defined in Section 4.5. The alternatives are based on different levels of mining restrictions that can be applied in the form of BLM lease stipulations to limit and control mining impacts.

4.2 MINING IMPACT FACTORS

No specific detailed mine plan has been supplied or confirmed for the new area. In the absence of a specific mine plan showing the location, orientation and dimensions of proposed development entries and longwall panels, we have made assumptions regarding the likely mining scenarios that might be reasonably expected. These mining scenarios have been based on the mining constraints discussed in Section 3 in relation to main development and longwall and room and pillar mining methods. Where there might be a significant variation in layout or orientation, we have evaluated the impact based upon a reasonable range of likely impacts that might result.

Where reasonable parameters can be allocated to the mining conditions anticipated then these have been assumed. For example, extraction thickness is based on limitations defined by reasonable equipment operational constraints. Due to limited data on the magnitude and extent of minor faulting we have generally assumed that these constraints do not significantly affect the mine layout. The accuracy of these assumptions can only be refined after further exploration has been carried out and confirmed by underground development.

The mining scenarios and their variation for each alternative are discussed further in Section 4.5, together with typical mining scenarios. These have subsequently been used in predicting impacts. A 'worst case' evaluation has not been carried out, except for specific areas with higher sensitivity to impact.

4.3 DESIGN BASIS FOR PREDICTIONS

The individual factors assumed for each area of evaluation are discussed in more detail in the relevant sections that follow. The major mining assumptions have been discussed in Section 3, but some of the more important specific mining assumptions are summarized below for clarification:

- The upper seam (Lower O'Connor B) would be extracted where amenable to longwall mining equipment having operational height limits from a minimum of 8.5 ft. to a maximum of 12.5 ft.
- The lower seams (Flat Canyon and Lower O'Connor A) are thinner and would be extracted with a different set of longwall equipment having operational height from a minimum of 7.0 ft. to a maximum of 10.0 ft.
- Dimensions of longwall panels would be similar to those currently being used at the Skyline Mine, having a face length of 800 ft. The generic layout would contain fire barriers, but these would not be stacked in the case of multiple seam mining. Gate roads would include a three-entry abutment/yield pillar system to be consistent with

current operations.

- The upper seam would be mined first and where the lower seam is also mined the fire barrier and gate road pillars would be offset so that they are located in the distressed zone below the gob of the upper panels. Mains and their barrier pillars would be vertically aligned where both seams are mined. This is for subsidence prediction purposes only, representing a moderate tensile strain impact, but should not be regarded as a recommended mine design option.
- It is possible to mine under abutment pillars left in the seam above at the limits of mining.
- In general, coal would not be extracted through faults with vertical displacements greater than about seam thickness.
- The extraction height and depth assumed for subsidence predictions at each surface location requiring evaluation would be the maximum estimated values expected from workings within the angle of draw from that location.
- Areas not amenable to longwall mining may be extracted using room and pillar methods.

It should be noted that these assumptions and criteria should not be regarded as mine design or operational recommendations. They represent a reasonable approach that has been used for evaluation of the range of impacts that might be expected. The longwall extraction height limits should not be regarded as rigid, as it may be possible to extract down to 6 feet, or greater than 12.5 feet in some cases.

4.4 STRUCTURES AND RESOURCES REQUIRING EVALUATION

The general areas and specific structures and resources requiring impact evaluation are discussed in the following sections with particular reference to subsidence impact and protection. Details for each structure will be presented later in this Report or in the relevant technical reports that addresses the impact. The structures and resources are listed in the following sections with their location defined in relation to the subsidence prediction points presented in Figure 4.1.

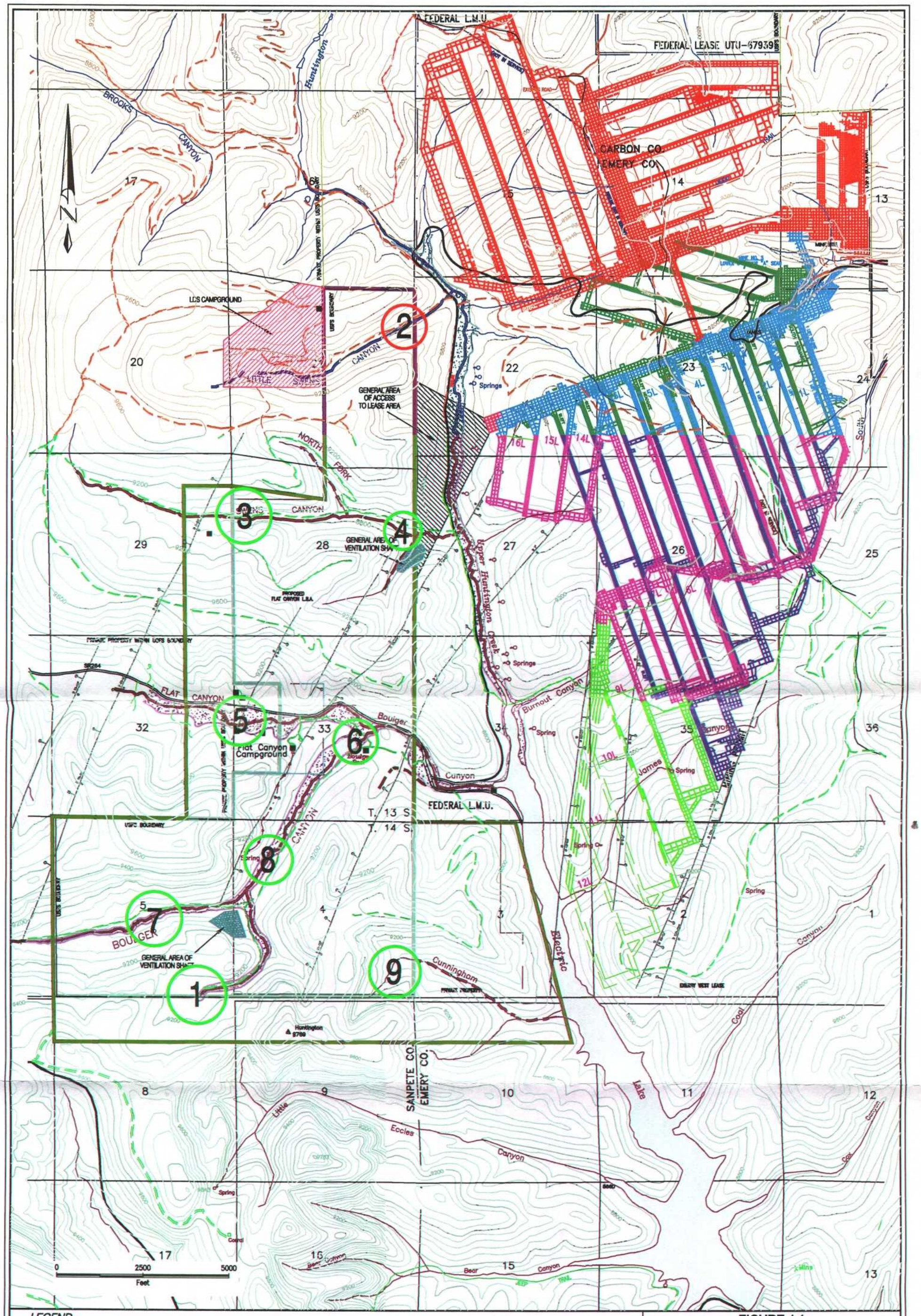


FIGURE 4.1
SUBSIDIENCE PREDICTION POINTS

4.4.1 Boulger Dam & Reservoir

This is an earthen dam and associated reservoir located at the mouth of Boulger Canyon near its confluence with Flat Canyon. The reservoir is below and adjoining the Flat Canyon Campground and provides recreational amenities. A fish ladder has been recently constructed to allow riparian access between the Boulger Canyon and Electric Lake. Characterization for this structure is covered by Subsidence Point No.6 in Figure 4.1.

4.4.2 State Highway 264

This is a paved, all-weather highway passing through the Tract following the valley floors of the Upper Huntington Creek, Boulger Canyon and Flat Canyon. Characterization of this structure in Flat Canyon is covered by Subsidence Point No.5 and in Boulger Canyon by Point No.6, as shown in Figure 4.1. No longwall mining that would affect the Upper Huntington Creek alluvium is planned; hence, there are no numerical model subsidence characterization requirements for this section of the highway. However, the worst case possibility of failure of the pillars in the mains has been addressed in Sections 7 and 8.

4.4.3 Mainline #41 Gas Transmission Pipeline

The Mainline #41 gas transmission pipeline in the Tract area runs alongside Highway SR 264 on the west side of the Upper Huntington Creek valley floor. No longwall mining is planned that would affect the Upper Huntington Creek alluvium; hence, there are no numerical model subsidence characterization requirements for this structure. However, the worst case possibility of failure of the pillars in the mains has been addressed in Sections 7 and 8.

4.4.4 Flat Canyon Campground & Facilities

The Flat Canyon Campground facility is operated by the Manti-LaSal National Forest Service and consists of camping areas with associated freshwater and toilet facilities. Freshwater is provided by a spring collection system located on the west side of Boulger Canyon with the water fed to the campground through a buried pipeline and storage tank near the campground. Characterization of these facilities is covered by Subsidence Point No.8 for the spring collection system and No.5 and No.6 for the Campground, as shown in Figure 4.1.

4.4.5 Private Cabins & Buildings

Within the area influenced by mining (RFDS) there are a number of privately owned cabins in Flat Canyon and Swens Canyon (Figure 1.2). Characterization of the four cabins in Flat Canyon is covered by Subsidence Point No.5 and the one cabin in Swens Canyon is covered by Point No. 3 (Figure 4.1).

4.4.6 Upper Huntington Creek Perennial Drainage

This drainage system is defined as the perimeter of the Upper Huntington Creek valley alluvium, which has been estimated from topographic contours of the flood plain and shown in Figure 1.2. No longwall mining that would subside this area is planned for the Tract area; however, there is likely to be development main entries running parallel and under the creek at considerable depth. The stability of these pillars will be addressed for a life in excess of 200 years and evaluation of the worst case scenario should they fail has been carried out. These aspects are discussed in Section 7.

4.4.7 Flat Canyon Perennial Drainage

This drainage system is defined as the perimeter of the Flat Canyon valley alluvium, the extent of which has been estimated from topographic contours defining the flood plain and is shown in Figure 1.2. Characterization of this canyon is covered by Subsidence Points No.5 and No.6, as shown in Figure 4.1.

4.4.8 Boulger Canyon Perennial Drainage

This drainage system is defined as the perimeter of the Boulger Canyon valley alluvium, the extent of which has been estimated from topographic contours defining the flood plain and shown in Figure 1.2. Characterization of this Canyon is covered by Subsidence Points Nos. 1, 6, 7 and 8, as shown in Figure 4.1. There is a potential wetlands area in the south at Subsidence Point No.1. A potential perennial creek tributary in the Lower Boulger Canyon drainage has been assumed to be proven for this study.

4.4.9 Swens Canyon Perennial Drainage

This drainage system is defined as the perimeter of the Swens Canyon Alluvium, but due to the limited extent of the valley floor the extent has been approximated by the Creek bed itself as shown in Figure 1.2. Characterization of subsidence in this canyon is addressed by subsidence Points 3 and 4, as shown in Figure 4.1. Potential perennial creek tributaries to the North and South of Swens Canyon have been assumed to be perennial for this study and this is addressed in more detail in the technical report on surface water and groundwater. If these tributaries are not designated as perennial, then the effect on the RFDS would not be major, as they are located in areas that already require a significant degree of protection due to their proximity to the vent shaft and a private campground with extensive facilities.

4.4.10 Little Swens Canyon Perennial Drainage

This drainage system is defined as the perimeter of the Little Swens Canyon alluvium. Due to the limited extent of the valley floor the extent has been approximated by the Creek bed itself as shown in Figure 1.2. Characterization of this Canyon is covered by a single Subsidence Point No. 2 due to the limited extent of the Creek within the RFDS, as shown in Figure 4.1.

4.4.11 Cunningham Possible Perennial Drainage

This drainage system is not projected as perennial within the Tract. It has been designated as possibly being perennial on adjacent private land and this is discussed further in the technical report on surface water and groundwater. The drainage is located in the Southeast corner of the Tract as shown in Figure 1.2. Characterization of this area is covered by a single Subsidence Point No.9 due to the limited extent of the drainage in the Tract, as shown in Figure 4.1.

4.5 MINING ALTERNATIVES

There are four main mining alternatives requiring evaluation that have different levels of mining restriction defined by BLM lease stipulations. Alternatives 2 and 3 require significant evaluation in this study and recommendations are included to assist the FS and BLM in developing Alternative 4.

4.5.1 Alternative 1

No mining would be allowed within the Tract and RFDS. This option is included for completeness, but does not require any evaluation in this report.

4.5.2 Alternative 2

This is a restrictive option that is intended to protect sensitive structures and resources from adverse impact due to subsidence by the imposition of additional special BLM lease stipulations. These stipulations are in addition to the standard stipulations and any other restrictions that are included in Alternative 3, such as the protection of Huntington Creek from subsidence. They are designed to prevent subsidence from impacting the following structures and resources:

- Perennial Drainages defined by their alluvial valley floors (estimated from the extent of their flood plain);
- Boulger Dam & Reservoir;
- Flat Canyon Campground including spring collection system;
- State Highway 264; and
- Mainline #41 Gas Transmission Pipeline.

Protection would be afforded by restricting mining to development entries or partial extraction room and pillar mining within an angle of draw of 23 degrees to the vertical from these structures and resources. No detailed evaluation has been carried out to define the amount of subsidence that could be tolerated by structures and resources, or the definition of a buffer zone to allow for local variation in subsidence.

The extent of perennial stream alluvial valley floors has not been defined in detail. In the case of wide valleys, such as Flat and Boulger Canyons, the extent of the flood plain from topographic contours has been used to estimate the extent of alluvium. Where valleys are narrow, such as Swens and Little Swens Canyons, the creek bed itself has been assumed to estimate the extent of the alluvium. The estimated perimeter of the perennial stream alluvium for the wide valleys is presented in Figure 1.2.

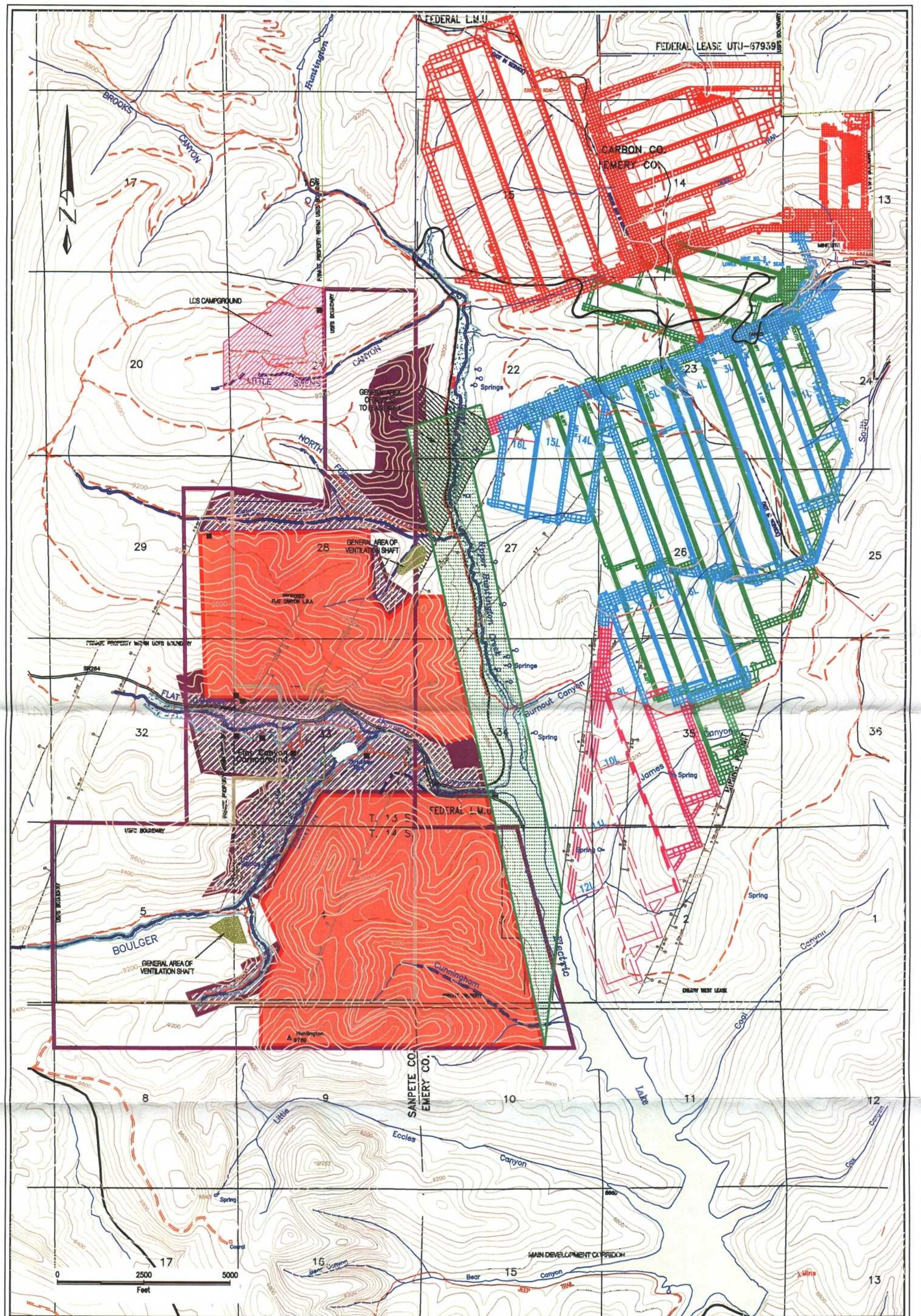
Subsidence of private cabins would be allowed and mining induced seismicity could have an impact on some of the structures.

The mining scenarios for this alternative were derived from the preferred mining scenarios developed under Alternative 3. The above restrictions were then applied to limit the areas where longwall mining could be used. Where longwall mining would not be possible it was assumed that room and pillar mining with partial extraction may be used. Mining scenarios for the upper and lower seams are presented in Figures 4.2 and 4.3, respectively. The effect of these restrictions would be to significantly reduce the recoverable reserves and shorten the associated mine life.

It should be noted that the technical and operational constraints on partial extraction room and pillar areas adjacent and between longwall mining areas may necessitate additional access to these areas and involve significant technical and scheduling constraints when carried out in conjunction with longwall mining. The economic feasibility of partial extraction room and pillar mining has also not been evaluated in this study and presentation of this option is not a recommendation that it be adopted. There are also two small room and pillar full extraction areas in the upper seam and four small areas in the lower seam that are likely to be too small to justify full extraction and they would most likely be restricted to partial extraction only.

4.5.3 Alternative 3

This would be the preferred mining scenario for MER. No additional protection would be afforded by the application of special lease stipulations, except that subsidence of the Upper Huntington Creek Alluvium would not be allowed. It has been assumed that all mineable coal areas amenable to



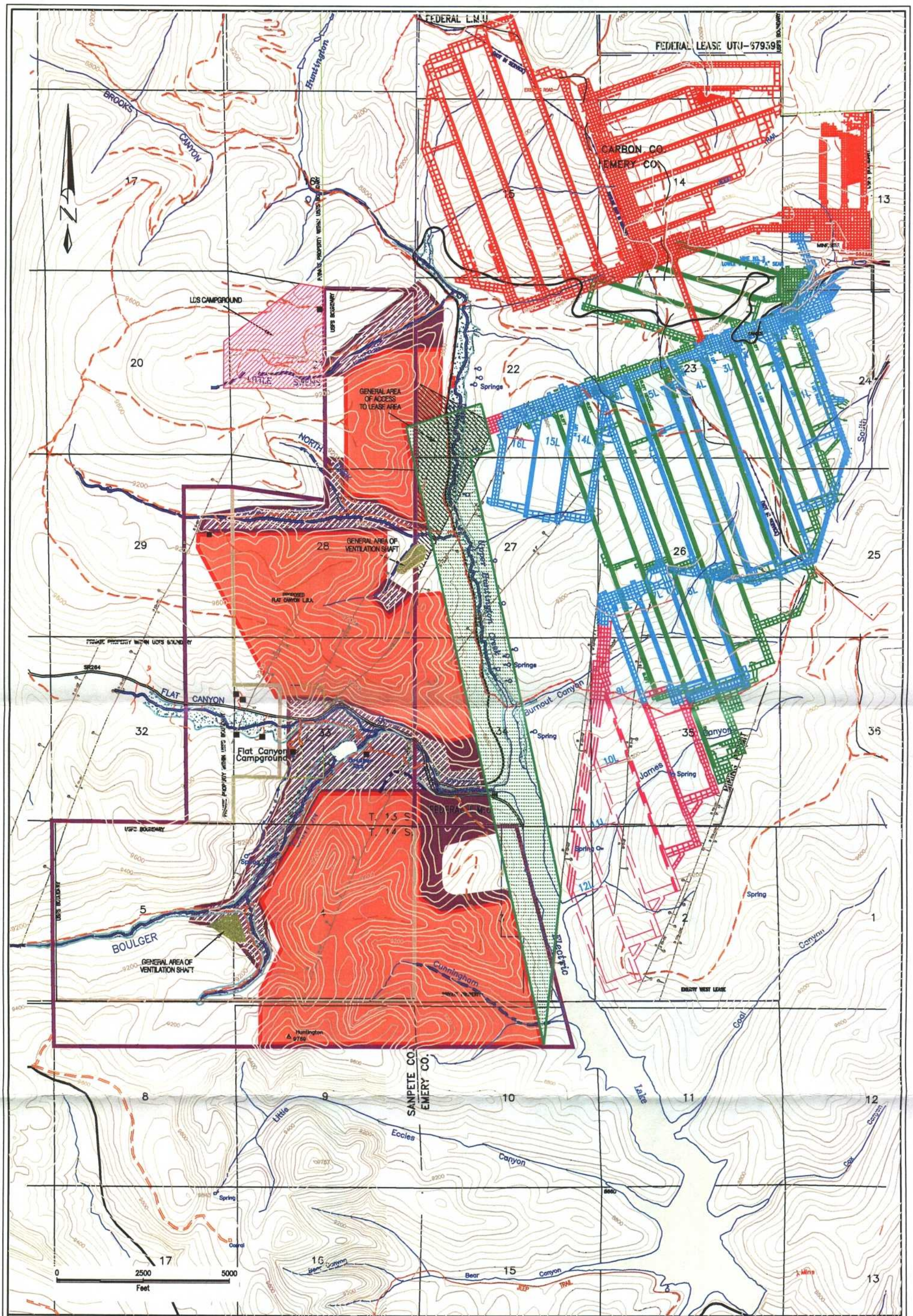
LEGEND

- LBA
- REASONABLY FORSEEABLE DEVELOPMENT AREA
- CABIN / BUILDING
- PAVED HIGHWAY
- UNPAVED HIGHWAY
- RIVER/CREEK,
- LAKE/RESERVOIR
- GAS PIPELINE (operational)
- GAS PIPELINE (not in service)
- WATER PIPELINE
- EXISTING MINE WORKINGS, MINE 1
- EXISTING MINE WORKINGS, MINE 2
- EXISTING MINE WORKINGS, MINE 3
- PROPOSED MINE WORKINGS, MINE 2 (existing lease)
- ESTIMATED PERIMETER of PERENNIAL STREAM ALLUVIUM
- MAJOR FAULTS
- PERENNIAL STREAM
- POSSIBLE PERENNIAL STREAM
- MAIN DEVELOPMENT CORRIDOR (MAINS AND BARRIER PILLARS)
- LONGWALL MINING (FULL EXTRACTION)
- POSSIBLE ROOM AND PILLAR MINING (PARTIAL EXTRACTION)
- POSSIBLE ROOM AND PILLAR MINING (FULL EXTRACTION)

FIGURE 4.2

UPPER SEAM MINING SCENARIO ALTERNATIVE 2

FILE: MINING.DWG	SCALE 1" = 2640'	NorWest
DATE: 10/17/2000		



LEGEND

- LBA
- REASONABLY FORSEEABLE DEVELOPMENT AREA
- CABIN / BUILDING
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- EXISTING MINE WORKINGS, MINE 1
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- PROPOSED MINE WORKINGS, MINE 2 (existing lease)
- ESTIMATED PERIMETER of PERENNIAL STREAM ALLUVIUM
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- LONGWALL MINING (FULL EXTRACTION)
- POSSIBLE ROOM AND PILLAR MINING (PARTIAL EXTRACTION)
- POSSIBLE ROOM AND PILLAR MINING (FULL EXTRACTION)

FIGURE 4.3

LOWER SEAM MINING SCENARIO ALTERNATIVE 2

FILE: MINING.DWG	SCALE 1" = 2640'	NorWest
DATE: 10/17/2000		

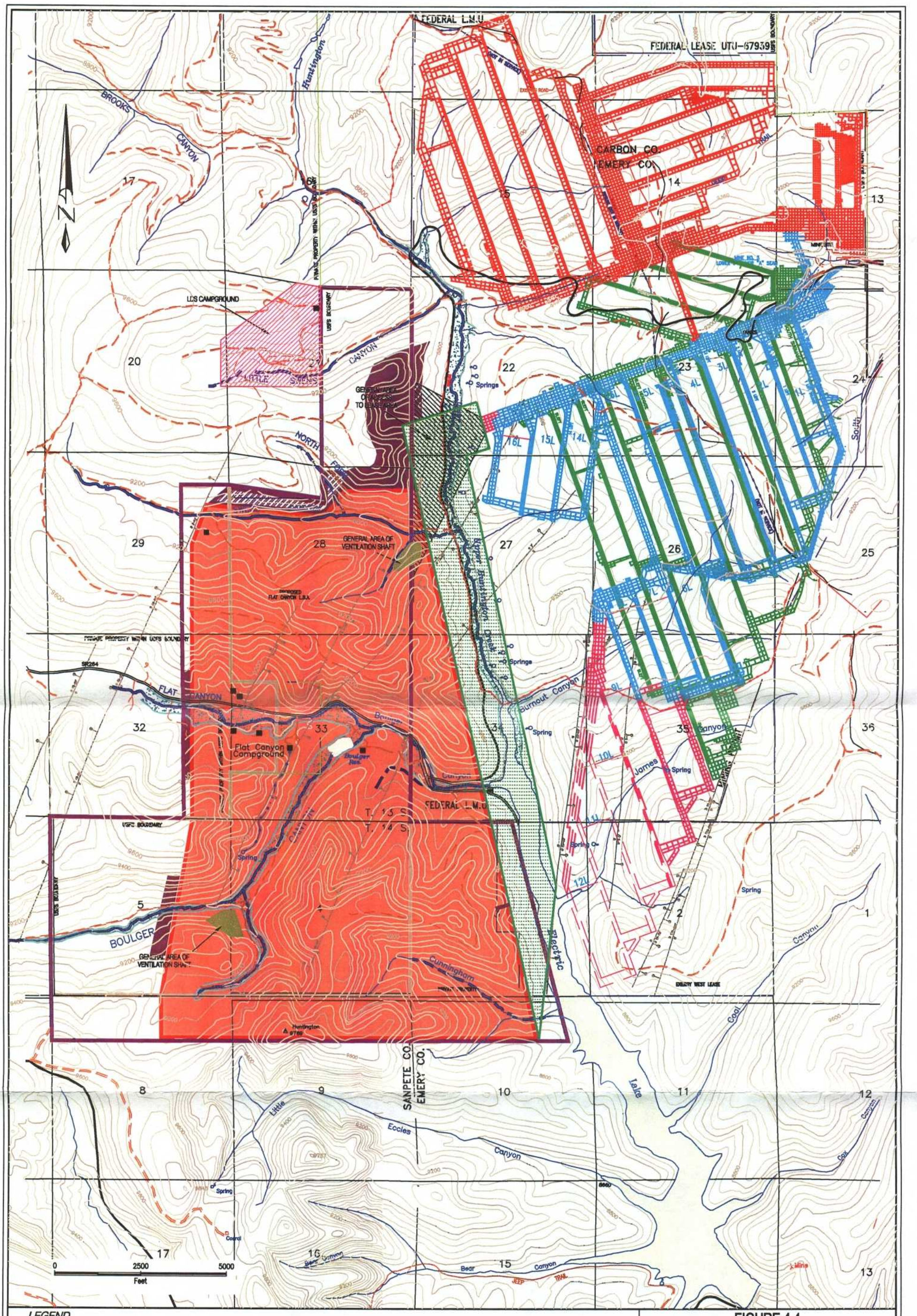
extraction by longwall mining would be exploited by this method in preference to room and pillar methods.

The subsidence protection zone for Upper Huntington Creek was defined in the same manner as that for protection of perennial streams defined in Section 4.5.2.

The mining zones for the upper and lower seams are discussed in Section 3 and presented in Figures 3.1 and 3.2, respectively. These zones have been used, in conjunction with an evaluation of additional constraints and options, to develop the mining scenarios for the upper and lower seams that are presented in Figures 4.4 and 4.5, respectively. A discussion of the most significant parameters affecting the mine layout and orientation is given below.

It has been assumed that longwall mining within the angle of draw from the Upper Huntington Creek alluvium will not be allowed. Consequently, we have defined a Main Development Corridor that is predominantly within the existing lease and runs parallel and beneath Upper Huntington Creek. This would form the primary access to the new lease and enable efficient coal recovery combined with protection of this important perennial drainage. The location of this main access for the Tract should not be regarded as a mine design recommendation, but is a reasonable approach to development west of the creek. This is regarded as a conservative approach for the EIS, as location of the main development corridor farther to the west would result in a lower potential impact and reduced recovery of reserves.

It is reasonable to assume that the majority of longwall panels will be oriented in the same direction as those in the Skyline Mine. Past experience at Skyline with other orientations has reportedly led to major problems. The Main Development Corridor is oriented in the preferred direction and would allow for efficient longwall extraction in both the transverse (E-W) and longitudinal (N-S) directions. In the case of N-S longwall panels, one, or possibly two additional sub-mains would be required to access these panels. Exact definition of the location for any sub-mains that might be required cannot be reliably determined from the current exploration data. The mining zones defined in this mining scenario can be reasonably accessed from a number of different orientations for sub-mains and hence are considered to be reliable for the impact evaluation.



LEGEND

- LBA
- REASONABLY FORSEEABLE DEVELOPMENT AREA
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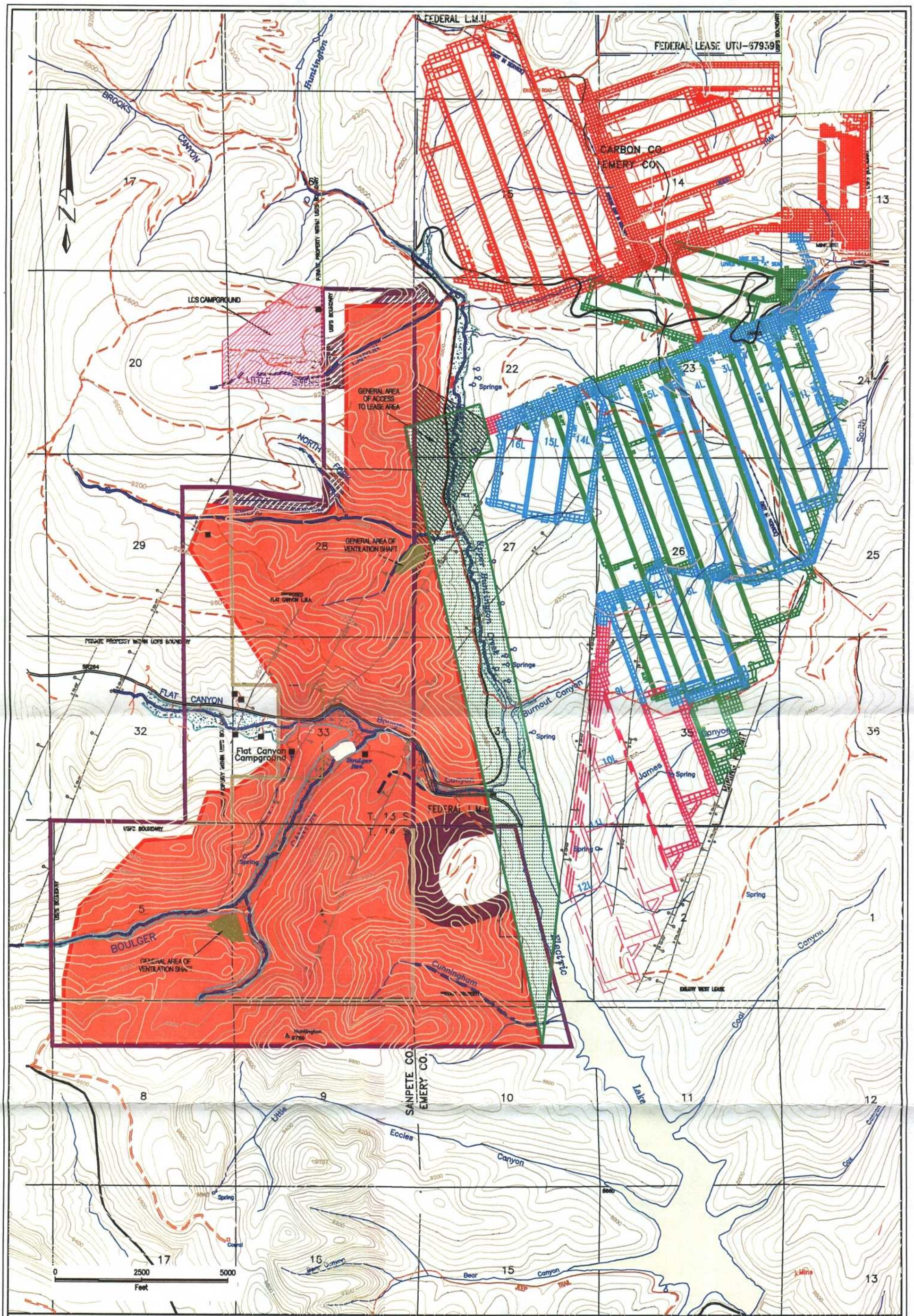
- LONGWALL MINING (FULL EXTRACTION)
- POSSIBLE ROOM AND PILLAR MINING (PARTIAL EXTRACTION)
- POSSIBLE ROOM AND PILLAR MINING (FULL EXTRACTION)

FIGURE 4.4

UPPER SEAM MINING SCENARIO ALTERNATIVE 3

FILE: MINING.DWG	SCALE 1" = 2640'	NorWest
DATE: 10/17/2000		



LEGEND

- LBA
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- CABIN / BUILDING
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- LONGWALL MINING (FULL EXTRACTION)
- POSSIBLE ROOM AND PILLAR MINING (PARTIAL EXTRACTION)
- POSSIBLE ROOM AND PILLAR MINING (FULL EXTRACTION)

FIGURE 4.5

LOWER SEAM MINING SCENARIO ALTERNATIVE 3

FILE: MINING.DWG	SCALE 1" = 2640'	NorWest
DATE: 10/17/2000		

There are further constraints where vent shafts are planned and it has been assumed that a protection pillar would be required to prevent subsidence from damaging the shaft or associated critical surface facilities. A buffer zone has also been left against the private property in the Northwest where a significant number of private campground structures have been assumed to require protection from subsidence. The application of an angle of draw of 23 degrees to the vertical has been assumed for protection of these structures and resources without any additional buffer.

Limits to the west have been assumed based on the CFC geologic model which predicts thinning of both the upper and lower seams, although this is based on extrapolated data and may be unreliable. The limits to the south are based on a reasonable extension of drill data beyond the southernmost data point.

The location and requirement for the vent shaft in the north is reasonable given the extension of the mine from the existing portals in Eccles Canyon. No engineering studies have been carried out to confirm this. The location and requirement for the vent shaft in the southwest should be regarded as a contingency, as it would be dependent upon the final mine layout, conditions and operational requirements. The requirement and location for these vent shafts has been supplied by CFC and should not be regarded as an engineering recommendation. However, it is reasonable to assume that they would be required for the purposes of this EIS study.

4.5.4 Alternative 4

This alternative will involve partial restrictions somewhere between Alternatives 2 and 3. It is expected that it will be developed by the FS and BLM based on the results from the impact analyses of Alternatives 2 and 3. The discussion regarding impacts and recommendations for addressing them under Alternative 4 will be presented in the relevant sections of this and other technical reports. The possible restrictions for consideration might include, but not be limited to, the following:

- a limited list of features requiring protection;
- limitations on the thickness of extraction;
- limitations on the number of seams that can be mined;
- limitations on the layout and location of mine workings to restrict conditions that are expected to result in particularly adverse subsidence or seismicity impacts;
- application of particular mitigation measures that reduce the anticipated impact at specific locations;
- limitations on mining layout and orientation;
- requirements for mitigation work necessary to limit or control impact;

- limitations on mining within specified proximity to particular structures sensitive to damage from mining induced seismicity; and
- requirements for further data, investigation and studies prior to mining within specified constraints.

5. SUBSIDENCE PREDICTION

During longwall extraction, coal supporting overburden is fully removed. The strata above then caves into the void. Rock strata failure is a complicated process and dependent upon rock strength, discontinuities, in-situ stress, orientation and area extracted. Failure of rock strata is transmitted to the surface, resulting in ground subsidence. Prediction of the extent and magnitude of surface subsidence is dependent on local geological variation and is more accurate where empirical data on mining parameters is combined with a surface subsidence monitoring program to derive the main subsidence parameters.

A number of previous studies have been carried out at Skyline relating to the effects of subsidence on perennial streams, springs, highways, ridges and a gas pipeline. These studies provide a valuable data set defining the local conditions and the degree of impact subsidence is likely to have on the surface and on sub-surface strata. Aspects relating to surface water and groundwater are discussed in more detail in the technical report on surface water and groundwater.

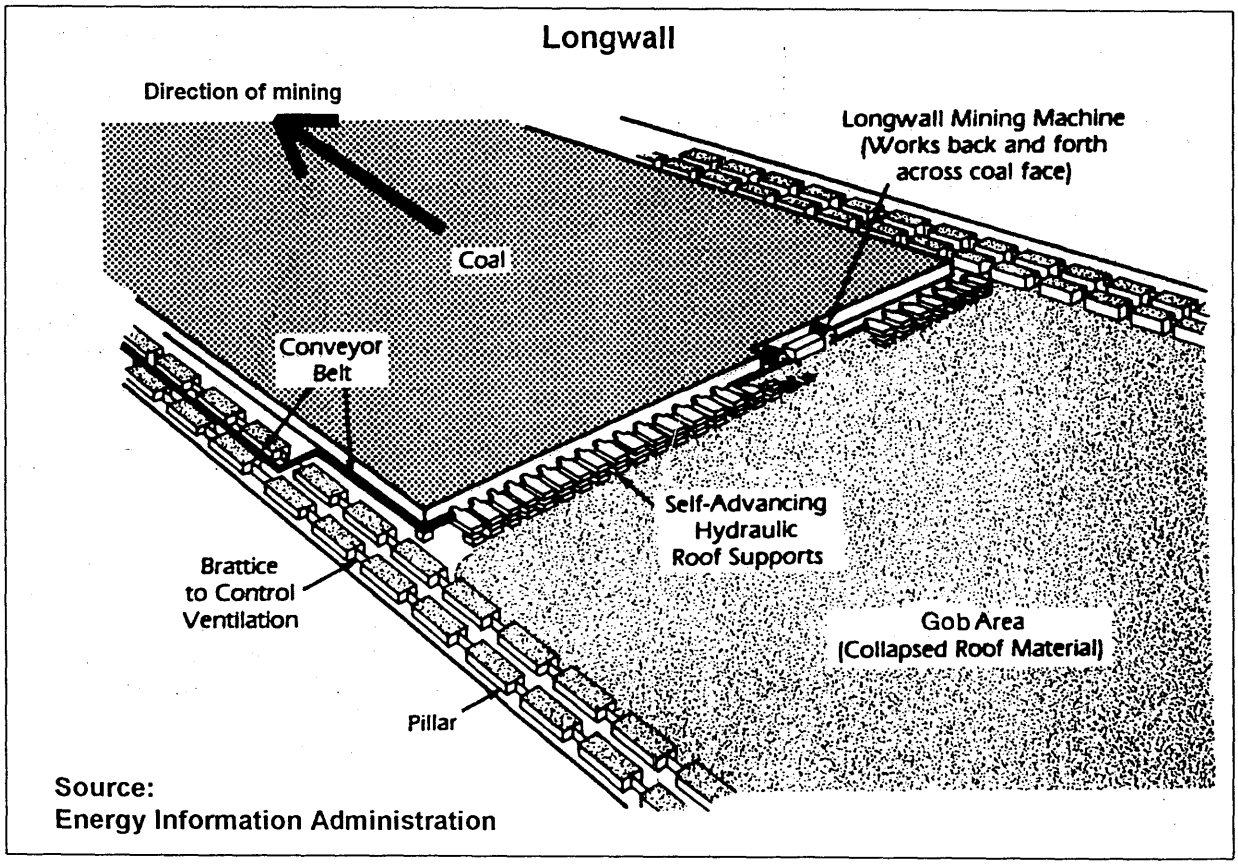
A numerical prediction method has been adopted for this study that enables the major parameters to be modified to simulate the behavior of a wide series of strata characteristics and mining conditions. The ability of this model to simulate more complex mining conditions and multiple seam mining enables the main parameters to be developed by back analyzing the response over previously mined panels. This process is referred to as calibration of the model to local mining and geologic conditions.

The areas that are outside of the longwall mineable zone, and recoverable by room and pillar mining with full extraction, are extremely limited (see Figures 4.2 and 4.3 for Alternative 2 and Figures 4.4 and 4.5 for Alternative 3). The only significant zone is for the upper seam in the northeast corner of the Tract. This area is relatively small and is in an area that may be influenced by a sandstone channel above the upper seam that could greatly restrict the mineable area. It is also located under an area of the surface that has no important structures or resources requiring special consideration. Consequently, if this area is mined by room and pillar extraction with full extraction and subsidence predictions are based on the assumption that it is longwall mined, then this represents a conservative approach with an insignificant error.

5.1 SUBSIDENCE CHARACTERISTICS

In order to understand the subsidence characteristics from longwall mining a description of the mining method is appropriate. Initially a rectangular panel of coal is developed by room and pillar methods and then completely extracted by the longwall equipment using an automated cutting head (shearer) that moves along a track parallel to the working coal face. The shearer contains two rotating drums that cuts a thin slice of coal on each successive pass. The cut coal falls onto a chain conveyor and is transported along the working face to the gate roads and eventually out of the mine. The coal within a longwall panel occupies a rectangular area which is about 800 ft in width and from 3,000 to 15,000 ft in length. Hydraulic roof supports are used to protect mine workers and equipment. As the shearing machine progresses through the panel, the roof supports are advanced. The unsupported mine roof and overlying rock then collapse into the void left behind the advancing roof supports. Once the panel is mined, the longwall machine is moved to an adjacent panel and the process is repeated resulting in near-complete extraction of the coal seam over large areas. (See Figure 5.1)

Figure 5.1
Schematic Diagram of a Longwall Mining Panel



The overburden caving and subsidence process can be divided into four main zones of strata movement above the mine where different subsidence behaviour is observed. These zones are not distinctly separate, but they transition into one another with some degree of variability dependent upon geologic conditions. These zones are presented in the schematic cross section in Figure 5.2 and described below, together with the approximate extent of the zone that might be expected.

The Cave Zone where the roof rock fail in discrete blocks and fall into the void behind the longwall supports. This is immediate and continues upwards until the bulking of these rocks provides support to the strata above. This height of this zone is dependent upon the bulking ratio and height of extraction and is typically in the range of 5 to 8 times seam height. It is expected to be in the range of 35 to 180 ft for the variation in conditions expected in the Tract. As the overburden fails above the vertical load will be transferred onto the cave zone and it will re-consolidate to support this load.

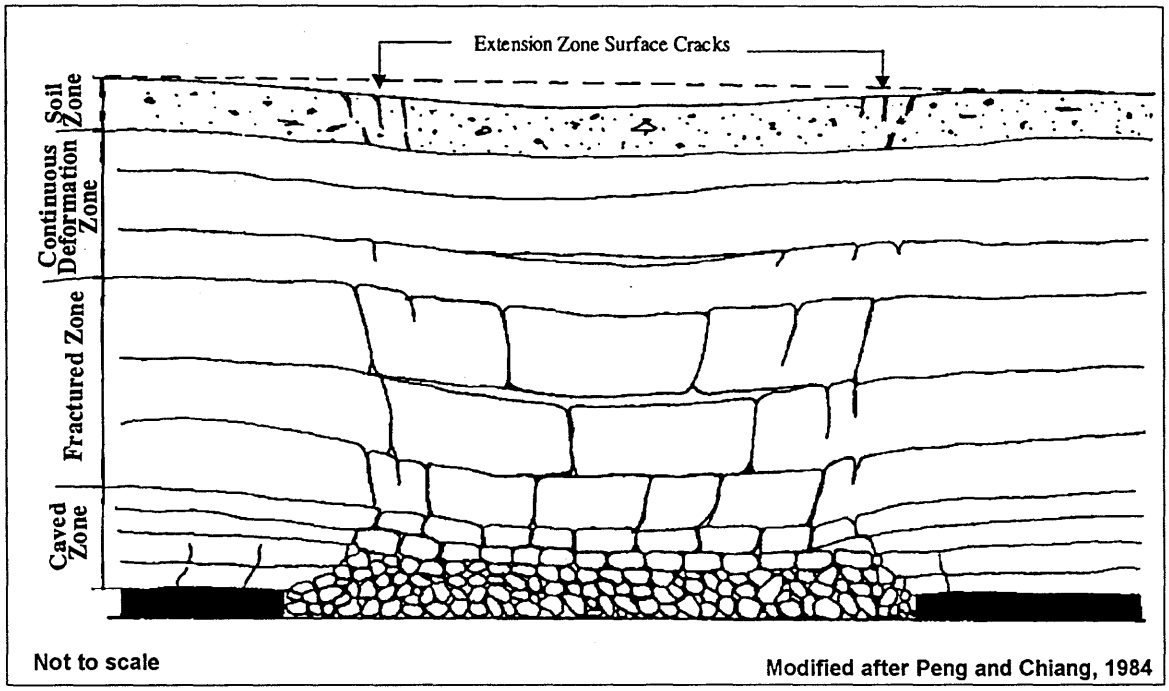
The Fractured Zone where the rocks are subjected to high stresses and fail along weakness planes and in some cases intact rock. It is a zone where the rock is fractured vertically and typically horizontally along bedding forming blocks. However, the discrete blocks remain in their relative position and no significant bulking occurs. This zone is dependent on the height of extraction and is expected to extend above the seam up to 30 times the extraction height. It is expected to extend above the seam for 210 to 675 ft for conditions expected in the RFDS area.

The Flexure Zone where the strata are not subjected to such high displacements and stresses to fail intact rock, being able to bend and flex. Movement is still expected on existing joints and bedding planes which can open up in zones of tension. Some shear movement along individual blocks may give rise to stepped vertical displacement of joints in strong beds or along fault planes. Vertical movement along fractures typically remains within individual beds and is not vertically extensive unless massive strong beds are in the zone. This zone extends to the soil interface and the effect diminishes with deeper workings and smaller extraction heights. In weaker rocks the upper part of this zone may flex without causing failure along joints or tension cracks to form. However, it should be noted that the upper end of this range is conservative, as it does not take into account multiple seam interactions that reduce the height.

The Soil Zone where the material is weak and does not generally fail in shear due to it's ability to flex with subsidence movement. However, it does fail in tension and this is observed as tension cracks that open up in the active tensile zone. It can also fail in compression and result in localized heave conditions. Fractures opened in tension will close again when the compression zone

reaches them, unless they are in a permanent tension zone where they will take longer to heal and close. This zone can vary in thickness from zero where the rock is exposed to 90 ft in Flat Canyon.

Figure 5.2
Overburden Subsidence Zones above a Longwall Panel



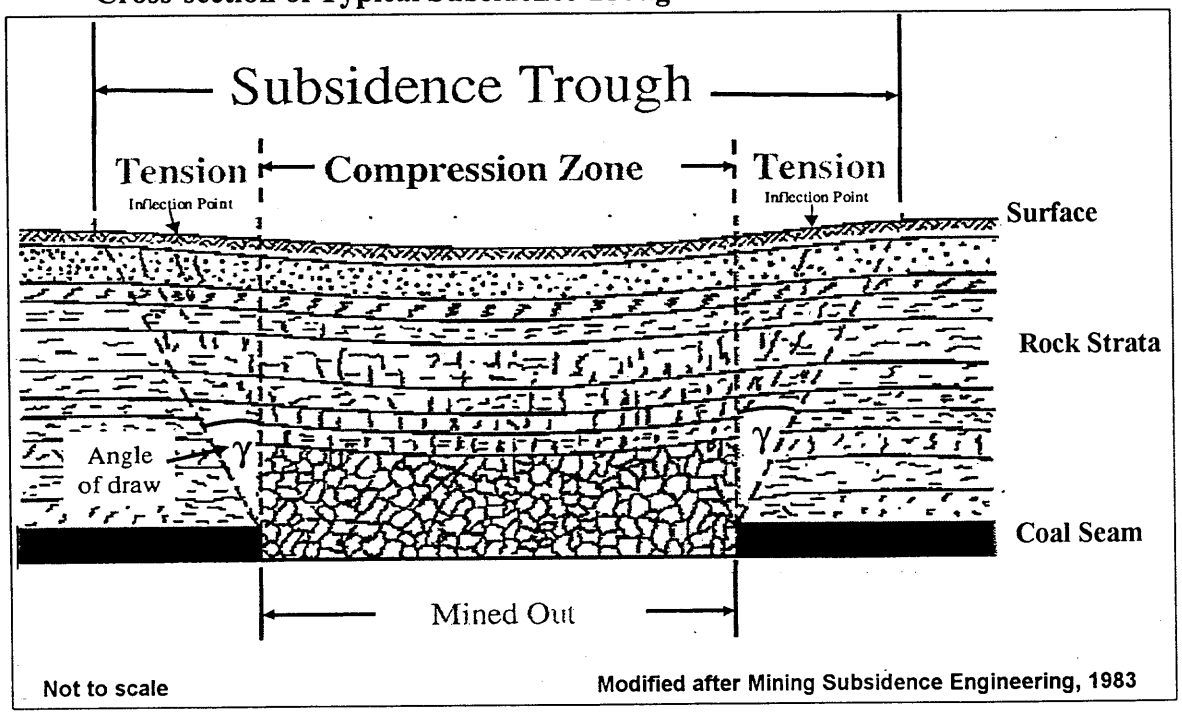
The extent of these zones for the RFDS area should be regarded as conservative, as they are based on a multiplication factor for the combined extraction from two seams. In the case of multiple seam mining, extraction of the second seam does not produce the same extent for the cave and fracture zones due to the previous subsidence that has already taken place (Peng, 1992). The extent of this reduction has not been empirically confirmed for Skyline and is not believed to be critical at the planned mining depths, hence we have taken a conservative approach and assumed no reduction for the lower seam. The range of extent for the cave and fracture zones is dependent upon the extraction height and is tabulated below for the Tract:

Table 5.1
Range of Cave and Fracture Zones Heights (ft)

Zone	Upper Seam		Lower Seam		Multiple Seam	
	From	To	From	To	From	To
Cave Zone	43	100	35	80	78	180
Fracture Zone	255	375	210	300	465	675

Surface subsidence above longwall panels forms in the shape of a trough. The surface area within a subsidence trough is normally larger than the area of the extracted coal seam due to the effect of the angle of draw. This is the angle that the line joining the limit of extraction to the limit of subsidence on the surface makes with the vertical. A cross section showing a typical subsidence profile is presented in Figure 5.3, which also shows the zones of surface tension that are located on the edge of the subsidence trough. The angle of draw (γ) shown in the schematic is estimated to be 22 degrees to the vertical for the Tract. The amount of vertical subsidence seen on surface is only a portion of the full extraction height. This is mainly due to bulking and reconsolidation of material in the cave zone, opening up of fractures in the fractured zone and to some extent dilation of rock in the flexure zone.

Figure 5.3
Cross-section of Typical Subsidence Trough



Ground movements within a subsidence trough have both vertical and horizontal components. Downward vertical movement usually occurs at all areas within the trough. The vertical movement is usually greatest at the center, and it progressively decreases at points along the trough profile until the limit of the affected surface area is reached.

Horizontal movement or displacement also occurs within the subsidence trough, as points on the surface tend to move horizontally toward the center. For adjacent points near the center, the horizontal distance between points is reduced resulting in compressive strains at the surface. The amount of compression decreases at points further from the center as the distance

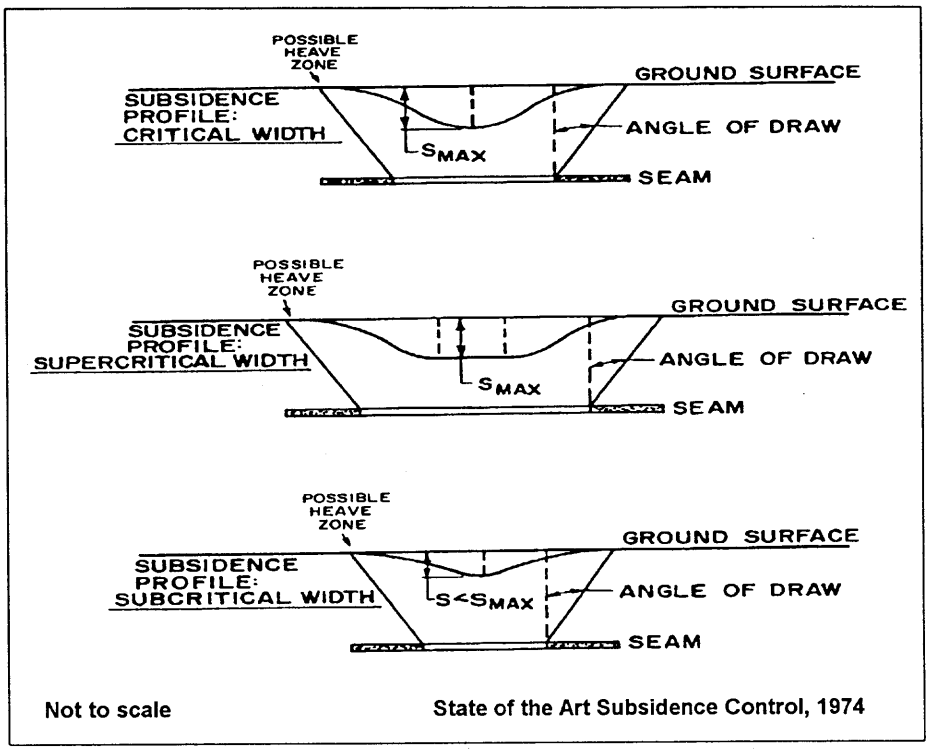
between neighboring points is reduced by lesser amounts, until a position is reached where the compression is zero. No horizontal movement will be experienced at this location. This position in the trough is referred to as the inflection point. Beyond this, the distance between neighboring points is increased, resulting in tensile strains on the surface. The inflection point also represents the location where the shape of the subsidence profile changes from concave to convex.

The areas of compressive and tensile strains within the subsidence trough are known as the *compression* and *tension* zones, respectively. The compression zone makes up the central portion of the subsidence trough, and develops above the center of the area of failure within the mine. The tension zone makes up the remainder of the subsidence trough, and usually extends beyond the extracted area. These zones can be seen in Figure 5.3.

The relationships between the width and length of the longwall panel, the thickness of the mined coal seam, and the type and thickness of the overburden play an important role in the development of a subsidence trough. When longwall subsidence occurs, the maximum vertical movement is at the center of the longwall panel. In theory, when the length and width of the panel reach a critical size, subsidence at the center of the trough will reach a maximum possible value. Once this panel size is exceeded it becomes 'supercritical' and the profile will subside the maximum amount forming a trough with a flat-bottomed central area, as shown in Figure 5.4. The maximum amount of subsidence will not increase regardless of how wide or long the panel becomes. Conversely, if the extraction area is less than this critical value, the maximum possible theoretical subsidence will not be achieved, and the resulting profile will be shallower and will not flatten out in the center.

Since the width of the panel is the shorter dimension, it plays the primary role in the determination of the maximum amount of subsidence. Critical width occurs when the width of the extracted area is typically in the range of 1 to 1.5 times the overburden thickness.

Figure 5.4
Critical, Supercritical, and Subcritical Widths

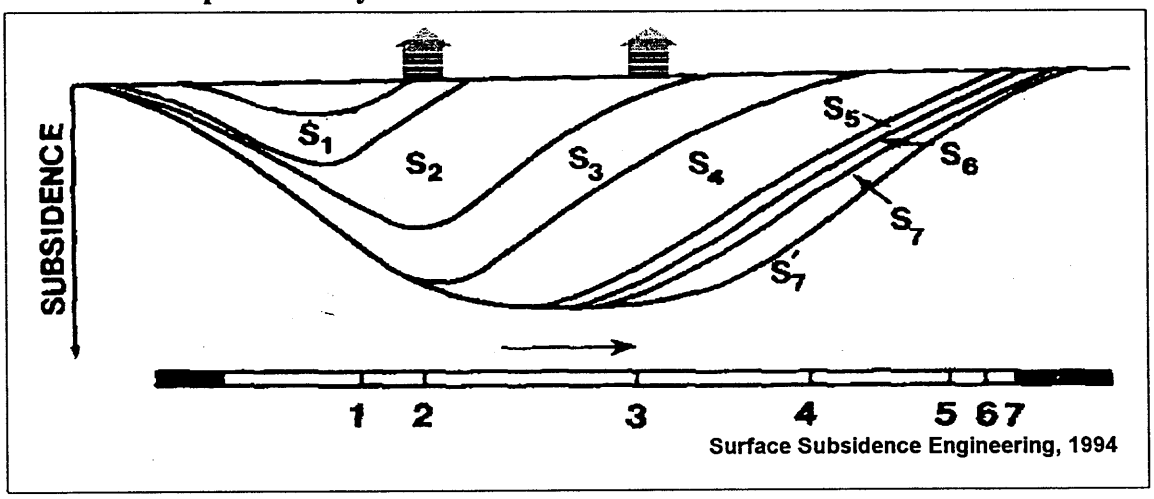


The development of a subsidence trough is a progressive event. When a longwall panel begins operation, initial surface subsidence will result in a subcritical trough. As the panel advances, the trough reaches critical dimensions, and ultimately flattens out as supercritical conditions are reached. A structure may initially be located in the tension zone of the basin as the panel approaches, causing a pulling of the structure towards the longwall face. Cracks and separations at structural interfaces may occur as a result of the dropping and extension of the ground surface. In addition, structures may tilt towards the approaching longwall face.

As the face advances below the ground surface the zone of tension now becomes a zone of compression, since it is now located near the center of the subsidence trough. Cracks which may have opened up in the tensile zone may now close. The induced slope of the ground surface may now return to it's original slope unless it is located on the margins of the panel.

The time dependent changes of the ground surface as the longwall passes below a given area is referred to as dynamic subsidence and is illustrated in Figure 5.5. Cracks in the surface land and structures may open and close as the subsidence 'wave' passes through.

Figure 5.5
Development of Dynamic Subsidence Profiles with Face Advance



A short discussion of the variation in subsidence factors related to the existing Skyline Mine experience and those expected in the Tract is given below. Reference is made to subsidence impact studies carried out by CFC at Burnout Creek, Trough Springs Ridge and State Highway SR 264. Discussion of relevant aspects of these impacts will be included with the technical reports relating to each area of impact.

5.1.1 Tension Fractures & Hydraulic Communication

Tension fractures can form at surface due to flexure of the strata as a result of differential subsidence. Where these cracks are observed they are often within 10 degrees from the vertical alignment of permanent coal pillars and their severity is dependent upon the degree of subsidence. The potential for surface cracking increases with the following factors:

- thicker or multi-seam extraction;
- shallower overburden depths;
- vertical alignment (stacking) of pillars in multi-seam mining;
- stacking of fire barrier pillars;
- reduced lateral constraint at escarpments and ridge crests;
- steeper slopes where gravitational components are greater;
- thicker and stronger beds that are shallow and jointed;
- thinner and more brittle soil cover; and
- surface features sensitive to cracking, such as roads;

Experience at the Skyline Mines where comparable overburden depths are greater than 600 ft. indicates that the formation of significant zones of surface tension fracture are relatively rare. They are seldom observed during mining of the upper seam and are generally associated with mining of the lower seam

where abutment or fire barrier pillars are vertically aligned in the vicinity of exposed ridges with low lateral constraint. Over the whole of the Skyline Mine area where depths are greater than 600 feet there are about 2,640 acres that have been influenced by subsidence. Regular subsidence inspections have identified less than 12 acres with significant fracture zones, representing less than 0.5 % of the deep mining areas.

Some minor tension cracks have been observed at State Highway SR264 above single seam extraction in the Skyline No.3 Mine at a depth greater than 600 feet. Generally these cracks were less than ¼" wide. In at least one case a vertical offset of about four inches was observed. No other significant tension cracks have been reported above single seam extraction areas, except where the depth is less than 300 feet.

A zone of significant tension cracks was observed at Skyline in the Trough Springs Ridge area, associated with an area of intensive tension above a stacked fire barrier pillar at a depth of about 900 ft. Extraction of the upper seam took place without incident, but extraction of the lower seam resulted in a very significant zone of tension fractures forming. Extraction totaled about 22 ft. of coal in this location and the fire barrier pillars in both seams were vertically aligned. Although the fire barrier extended for about 6,000 feet, less than 1,500 feet experienced cracking and this was at a ridge where a sandstone bed was located near the surface. A section of Burnout Creek passed through the same tension zone without any evidence of tension cracks or any significant hydraulic communication observed between surface water and groundwater systems.

A detailed study was not carried out by Skyline staff at the time, but the available data indicates that tension cracks at Trough Springs Ridge were over 5 ft wide in some places. It can be concluded that over 5 ft of total extension was experienced in this tensile zone, although the effect of possible slope movement on the ridge cannot be discounted. This is consistent with subsidence predictions that indicate the cumulative extension over the tensile zone would be expected to be in the region of 8 ft if the ground surface was flat.

Similar conditions to those observed at Trough Springs Ridge are unlikely to occur with the same degree of severity in the valley floors found within the Tract.

It should also be noted that the severity of tension crack formation that occurred above the Plateau Mine in the North Fork of the Right Fork of Miller Creek located on the steep eastern margin of the Wasatch Plateau (Slaughter et al., 1995) should not occur in the RFDS area. At the Plateau Mine, tension crack formation over multiple seam extraction under shallow cover (300 to

500 feet) caused the diversion of a perennial stream into mine workings. The greater depth of cover and the location of the RFDS area away from the plateau escarpment should preclude such catastrophic events as those observed at Miller Creek.

The potential for hydraulic communication between surface water, groundwater and the mine workings is generally restricted to the cave and fractured zones. Due to the expected overburden depths and strata, no significant vertical connection between surface water and groundwater is expected in the Tract. This topic is discussed in more detail in the technical report on surface water and ground water.

5.1.2 Dynamic Subsidence

The majority of areas will experience the temporary dynamic effects of subsidence as the longwall face retreats below them. These transient effects are likely to result in limited tension cracks opening up and then as the compression zone arrives they will self-heal and close up again. However, at the edge of workings the tension zone may remain for a longer time (months / years) until the adjacent panel is mined, or remain permanently where it is located at the edge of workings. This process may be repeated for mining of the lower seam where multiple seam mining is carried out.

The dynamic subsidence and impact as the longwall passes beneath a particular point on the surface in the center of a panel is less than above the gate roads and at the edge of panels and fire barriers. The effects generally reduce with the rate of longwall face retreat and at a rate of about 50 ft per day, as projected by CFC, the dynamic slope and horizontal strains may be reduced by up to 50% of the static value (Peng, 1992). Conversely, the maximum vertical subsidence velocity will increase in an approximately linear rate with the rate of face retreat. A value of about 0.2 vertical ft per day is projected for the overburden depths in the Tract (Peng, 1992).

5.1.3 Sinkhole Development

Where the thickness of bedrock above the coal seam is less than the potential cave zone there is the potential for sinkholes to develop due to void migration. The maximum height of the cave zone is conservatively estimated to be about 180 ft and the minimum depth of workings about 800 ft with no possibility that sinkholes could develop in the Tract. However, there is the potential for small holes to develop in tensile zones where shallow bedrock is fractured and soil migrates into the fractures at localized failure zones.

5.2 GEOTECHNICAL INFLUENCES

The main geotechnical influence on subsidence is the behavior observed with strong strata reducing the subsidence percentage and reducing the horizontal influence beyond the excavated area (angle of draw). The influence of strong beds has been estimated from the amount of sandstone in the overburden, as determined by exploration drilling and both cuttings and geophysical borehole logs. Each subsidence prediction point has been allocated a percentage of sandstone which is used in the numerical model as a key input parameter.

5.3 IMPACT OF TOPOGRAPHY AND SURFICIAL MATERIALS

Subsidence is often evaluated on the assumption that the coal seam and ground surface are both horizontal. In the proposed Tract. the dip of the seam is expected to be in the range from 2 to 6 degrees. For the evaluation of subsidence this is considered to be flat and hence no corrections have been applied for inclined workings.

The surface topography is generally undulating and cannot be considered to be flat, except in some of the valleys. Where steeper terrain is encountered; having ridges, cliffs and canyons, there are likely to be more significant topographic effects on subsidence. This can partly be explained by the lack of lateral confinement at steep slopes and cliffs. There is also the effect of the gravitational component of the slope weight that has the tendency of allowing material to move slightly down the slope or in extreme cases lead to slope failure.

Over the Tract there are only a few minor cliffs; and these are generally associated with the Castlegate Sandstone Formation that is typically thin and only found on some of the higher ridges. No prominent cliff escarpments were observed during the field visit. The canyon slopes are not generally steep, but in some cases may increase the effect of subsidence.

Previous experience at the Skyline Mine has encountered no major slope failures. Small localized movements have been observed. A detailed evaluation of slope impacts would require a specific detailed mine plan and sequence of extraction in order to estimate the location and extent of subsidence in relation to particular slopes. Without a specific mine plan this topic is discussed in general terms and the likely range of impact estimated. Slope stability aspects will be discussed further in Section 8.

The opening of tension fractures is possible where high tensile strains are imposed on brittle strata for significant periods of time. A series of tension fractures resulted on Trough Springs Ridge from prior mining. In this case, an

extensive zone of tension was created when fire barrier coal pillars were vertically aligned in two thick coal seams. The existence of a strong sandstone bed near to surface, on a ridge without lateral confinement on both sides, resulted in the very high tensile strains being focussed on particular joint sets within the sandstone bed. The combination of these factors resulted in significant short term impact due to the formation of fractures that opened in the bedrock.. Some of the fractures were over 5 ft wide and 25 ft deep, with longitudinal extent over 200 ft in places. They were mitigated by filling with soil and no long term adverse impact is expected for the area.

It is possible that similar conditions might exist in the vicinity of some ridges at higher elevations in the Tract, especially if stacked fire barriers are developed. However, it is likely that the magnitude would be less, as mining in the Tract is generally deeper over most of the area and extraction heights generally less than the Trough Springs Ridge area. If similar conditions of mining, topography and near surface sandstone exist, then similar fractures might occur, although the likelihood is believed to be low.

5.4 NUMERICAL PREDICTION METHOD

The Surface Deformation Prediction System (SDPS) numerical model was used to predict surface subsidence. This is discussed in more detail in Appendix F, together with a presentation of the results for the main subsidence parameters. The model was calibrated against actual subsidence monitoring data from the Skyline Mine.

Without a specific mine plan for the RFDS, a characterization process was used to estimate the likely range of subsidence for different mining scenarios based upon a generic longwall mining layout at each location. Single and multiple seam layouts, based on typical Skyline mine layouts, were developed for this purpose. These layouts are presented in Appendix F and are identical for each type of subsidence prediction point. They have not been placed at a particular location or assumed orientation. In order to evaluate the effect of mining at different orientations the layout can be rotated in order to simulate the orientation effects. The validity of rotating the generic layout to evaluate orientation effects is sufficient for the level of detail required to assess the general range of values likely to be encountered. It also enables a conservative approach to be adopted when evaluating location and orientation impacts.

5.5 NUMERICAL MODEL CALIBRATION

Calibration was based on subsidence data supplied by CFC from undermining of State Highway SR264 by longwall extraction of the Upper O'Connor Seam in the Skyline Mine. The model calibration is discussed in Appendix F. The percentage of hard rocks (sandstone) in the overburden for this area is estimated to be about 55 %. The calibration results indicate that an angle of draw of 18.4 degrees and a maximum vertical subsidence factor of 50 % of extraction height provide the best fit to the measured subsidence data. However, a conservative approach has been adopted for this study by assuming for the numerical model analysis that the angle of draw is 22 degrees, with a vertical subsidence factor of 55% for single seam extraction cases.

Further evidence at Skyline from Mining of the Upper O'Connor and Lower O'Connor B Seams indicates that there is a higher vertical subsidence factor for mining of the lower seam after the upper seam has already been extracted. This effect has been observed elsewhere (NCB, 1975 and USBM IC-9194). There is some limited evidence from subsidence monitoring data for the Questar Gas Transmission Pipeline, using photogrammetric survey techniques with a reported accuracy of ±1 ft., that suggests a vertical subsidence factor of 75% for mining of the second seam. However, this factor should be treated with caution, as it has not been confirmed by more reliable surveying techniques. In the absence of reliable subsidence monitoring data for multiple seam conditions, we believe that it is a reasonable basis for the evaluation at this point in time. The numerical model cannot accept different subsidence factors for each seam when multiple seam conditions are being modeled. In these cases we have assumed that a weighted average of the combined subsidence factors is applied to both seams at these locations.

The angle of draw used in the numerical model has been assumed to be constant at a value of 22 degrees. However, a slightly different angle of draw is recommended when defining mining restrictions to allow for the possibility that local variability may be observed due to operational and geologic variations. No rigorous evaluation has been carried out regarding the degree of local variability that might be expected. Previous work by Harding Lawson Associates (See Section 8 of this Report) indicated that the observed angle of draw was in the range of 18 to 23 degrees. We propose that the upper value of 23 degrees should be used as the basis for defining subsidence protection zones. In addition a buffer zone should be included to allow for the possibility of anomalous conditions due to variable geology and the possibility of pillar failure in the abutment area over time. The buffer against sensitive features can be incorporated into the Angle of Draw estimates by defining a conservative angle of draw. For sensitive resources and structures a

protection zones is recommended based on an Angle of Draw of 30 degrees from longwall extraction areas and is discussed later in the report.

5.6 PREDICTION RESULTS

The detailed results from the numerical model runs are presented in Appendix F. The three main subsidence factors likely to influence surface stability [vertical subsidence (ft), horizontal strain (millistrain), and induced slope change (%)] are presented for each subsidence prediction location as a series of contours overlain on the generic panel layout.

Vertical subsidence is the parameter most commonly quoted for impact evaluation, as the other main parameters are typically related to it. Subsidence predictions normally assume uniform flexure of the surface with subsidence occurring in small discrete steps. Flexure of the ground surface, due to differential subsidence, results in horizontal ground strains and induced slope changes that often occur soon after the longwall face passes underneath.

Horizontal strains are expressed in millistrain in this Report, with 1 millistrain being equivalent to a net change of 1 unit for each 1000 units of length. Tensile strains are positive and are equivalent to extension of the ground surface and compressive strains are negative. A measure of the degree of strain intensity is given by the maximum strain value and width of the zone of tension. The total extension possible over the tensile zone gives an indication of the degree to which tensile strains have the potential to result in tension cracks opening up at surface.

The seams, depths and sandstone percentages for each subsidence prediction point are summarized in Table 5.2, together with the maximum values estimated for each of the main subsidence parameters at the worst case position in relation to the mine layout. For the model results the worst case is generally represented by a fire barrier pillar in single seam extraction and a stacked abutment pillar in multi-seam extraction cases. Further details of the model runs and the generic mine layout used for the model are presented in Appendix F, together with the contour plots of subsidence parameters that were used to estimate the maximum parameter values presented in the table.

Table 5.2
Subsidence Point Characteristics and Maximum Predicted Values

Parameter	Subsidence Prediction Point								
	1 Boulger South	2 Little Swens	3 Swens West	4 Swens East	5 Flat West	6 Boulger Dam	7 Boulger West	8 Boulger Central	9 Cunn-ingham
Overburden Thickness above Lower Seam (ft)	1850	1600	1700	1100	1500	1200	1750	1500	1600
Number of Seams Mined	2	1	2	2	1	2	1	2	2
Amount of Hard Rocks in Overburden (% sst)	50	65	65	65	60	65	50	50	50
Estimated Thickness of Surficial Material (ft)	20	30	20	30	120	120	80	80	20
First Seam Maximum Vertical Subsidence (ft.)	5.5	5.5	4.7	5.5	4.7	6.9	5.0	6.6	6.9
Maximum Total Vertical Subsidence (ft)	11.5	5.5	10.7	13.0	4.7	14.4	5.0	14.1	12.9
Maximum Horizontal Tensile Strain (millistrain)	7	9	8	16	8	16	7	11	10
Average Tensile Strain in Tensile Zone (millistrain)	5	5.5	4.5	8.5	4.5	9	4	7	5.5
Width of Tensile Zone (ft)	500	500	600	450	500	500	600	600	600
Approximate Maximum Extension Possible in Tensile Zone (ft)	2.5	2.8	2.7	3.8	2.3	4.5	2.4	4.2	3.3
Maximum Horizontal Compressive Strain (millistrain)	-8	-5	-8	-16	-5	-16	-5	-12	-10
Maximum Slope Change (%)	1.5	0.9	1.5	2.8	0.7	3.0	0.7	2.2	1.9

The parameter values presented in Table 5.2 have been estimated for permanent locations with maximum impact such as; the edge of abutment pillars or above fire barriers, depending upon the parameter and single or multiple seam cases. These areas represent a relatively small proportion of the overall mining area and should not be regarded as representative. In reality, the subsidence parameters will vary over the mining area and with time. They can be sub-divided into permanent (at the edge of pillars), short term (between adjacent panels with durations measured in months) or dynamic (above the moving longwall face with durations measured in days). The range of subsidence parameter variation is dependent on the mining layout and geologic conditions. The numerical modeling results presented in Appendix F have been evaluated further in relation to the mining layout features listed below:

- panels (in the center of panels);
- single abutment (at the edge of solid coal pillars);
- stacked abutment (where both seams are next to solid coal pillars);
- single fire barriers (where a fire barrier is in one seam only);

- stacked fire barriers (where fire barriers in two seams are aligned);
- gate roads (where gate road pillars are left between panels); and
- longwall face (dynamic effects as the face retreats).

The significant parameter values for each of these areas is presented in Table 5.3 for each subsidence prediction point. It should be noted that these values are approximations that have been taken in most cases from the contour plots presented in Appendix F. In some multi-seam cases the parameter is not taken directly from the subsidence model output, but is estimated by applying a typical ratio derived from the single seam case. The figures relate to the cessation of mining, except for dynamic subsidence which applies to longwall face retreat or single abutments that exist for a short time between panels.

Table 5.3
Range of Predicted Subsidence Parameter Values at Different Mine Features

Parameter	Subsidence Prediction Point								
	1 Boulger South	2 Little Swens	3 Swens West	4 Swens East	5 Flat West	6 Boulger Dam	7 Boulger West	8 Boulger Central	9 Cunn-ingham
Overburden Thickness above Lower Seam (ft)	1850	1600	1700	1100	1500	1200	1750	1500	1600
Number of Seams Mined	2	1	2	2	1	2	1	2	2
Maximum Subsidence (ft)									
Panels	10	5	10	12	4	13	4	13	12
Single Fire Barrier	7	2	6.5	7	2	9	2	8	7
Stacked Fire Barriers	4.5	-	4.5	5.4	2	6	3.5	5.9	5.4
Gate Roads	9.5	4.5	9.5	11.5	3.5	12.5	3.5	12.5	11.5
Maximum Horizontal Tensile Strain (millistrain)									
Single Abutment	2	4	2	6	4	6	2	4	4
Stacked Abutment	6	-	8	16	-	14	-	10	10
Single Fire Barrier	4	8	4	12	8	12	6	8	8
Stacked Fire Barrier	12	-	16	32	-	28	-	20	20
Gate Roads	2	2	2	4	2	4	1	2	2
Longwall Face (Dynamic)	1	2	1	3	2	3	1	2	2
Maximum Slope Change (%)									
Single Abutment	0.6	0.8	0.6	1.4	0.6	1.2	0.6	1.0	0.8
Stacked Abutment	1.4	-	1.4	3.0	-	2.8	-	2.2	1.8
Single Fire Barrier	0.6	0.7	0.6	1.4	0.6	1.2	0.6	1.0	0.8
Stacked Fire Barrier	1.4	-	1.4	3.0	-	2.8	-	2.2	1.8
Gate Roads	0.2	0.1	0.2	0.4	0.2	0.4	0.1	0.2	0.2
Longwall Face (Dynamic)	0.3	0.4	0.3	0.7	0.3	0.6	0.3	0.5	0.4

From the table it can be seen that the different underground mine structures produce significantly different results for some parameters. It should also be noted that some of the values are slightly different from the figures presented in Table 5.2 due to the approximations used in reading contour intervals from the plots in Appendix F. Some of the most important observations are discussed below with the relative variation of parameter values.

Vertical Subsidence

For vertical subsidence the highest value is in the center of the panel and is only slightly reduced above gate roads. There is a significant reduction over fire barriers in a single seam which is further reduced to about half of the maximum value for stacked fire barriers in multiple seam cases. The highest value ranges from 10 to 13 feet for multi-seam cases and the lowest is 2 feet above single seam fire barriers.

Maximum Horizontal Tensile Strain (millistrain)

Low horizontal tensile strain (1 to 4 millistrain) is expected over gate roads and during dynamic subsidence. Low to Moderate values are expected over a single seam abutment or offset abutments in two seams (2 to 6 millistrain). Moderate to high values (4 to 16 millistrain) are expected over a stacked abutment in two seams and fire barrier in a single seam. A stacked fire barrier in two seams is expected to produce High to Very High values (12 to 32 millistrain).

Based on empirical observations at Skyline, the potential for significant tension fractures to develop is negligible at tensile strain values below about 6 millistrain, low for values between 6 and 16 millistrain and moderate for values over 16 millistrain. The potential increases significantly at ridges without lateral constraint and strong beds near surface, and decreases significantly at valley floors with increased lateral constraint and thicker soil layers. There is insufficient data to reliably estimate the dimensions of individual tension cracks characteristic of particular tensile strain values.

Maximum Slope Change (%)

The slope change is estimated to be very low (0.1 to 0.4 %) for gate roads and very low to low (0.3 to 0.7 %) for dynamic subsidence. It is estimated to be low to moderate (0.6 to 1.4 %) for a single abutment and single fire barrier, and moderate to high (1.4 to 3.0 %) for stacked abutments and stacked fire barriers in multi-seam mining.

These figures give an indication of the likely range of values in the vicinity of mine layout features. They do not represent exact figures, but should be treated as a reasonable approach to predicting the likely range of values for particular features and are useful in assessing the possible effect that these mine layout features would have at particular locations. Over the longwall

mineable zone in Alternative 3 it would be expected that about 10% of the area would be subjected to abutment effects (single and stacked), about 5% to fire barrier effects (single and stacked), about 20% to gate roads and the remaining 65% to dynamic subsidence.

Based upon qualitative definitions of relative degrees of subsidence from the Skyline Mine experience evaluated over the tract it is estimated that about 85 % of the mining area will be subjected to a low degree of subsidence, 10 % to a moderate degree of subsidence and 5% to a high degree of subsidence. It should be noted that these are approximations and do not represent the impact, but are intended to provide an indication of the relative value of subsidence parameters.

When a specific mine plan is available a more accurate estimation for subsidence parameters can be made, but in the meantime this approach is sufficient for characterization of the range of impact and evaluation of particularly sensitive areas. The numerical model has been calibrated on single seam mining only, as the available data was only suitable for this case. Further subsidence monitoring and evaluation for the Tract is recommended to confirm the parameters used in the model predictions.

It should be noted that without a specific detailed mine plan the values for some of the mining features listed in Table 5.3 may not in some cases be consistent with the layout presented in the applicable mining scenarios for either of the two main alternatives. The results are discussed in more detail in relation to each of the alternatives separately.

5.6.1 Alternative 1

No mining related impacts.

5.6.2 Alternative 2

In this alternative special stipulations restrict mining such that no subsidence would be allowed to impact perennial streams, Boulger Dam and Reservoir, Flat Canyon Campground, State Highway 264 and Mainline #41 gas transmission pipeline. This can only be achieved if no caving of strata is allowed within the angle of draw from these surface features.

The mining scenarios are presented as a series of mining zones for both the upper and lower seams in Figures 4.2 and 4.3, respectively and are discussed in more detail in Section 4.

It would be possible to extract coal within the angle of draw using partial extraction room and pillar production methods without subsidence. This is technically feasible, although it may have some operational limitations for

practical scheduling with longwall mining and a separate development access may be needed. It is likely that barrier pillars will need to be left against longwall mining areas in order to protect the partial extraction areas from interacting with the longwall areas while both are being extracted concurrently. Partial extraction room and pillar mining is normally a higher cost method when compared with longwall mining and we have not evaluated the economic feasibility of this mining method. In order to be conservative from an impact perspective we have assumed that it will be carried out. However, where partial extraction is carried out below protected areas the extraction ratio will need to be sufficiently low in order to ensure the long term stability of the pillars and ensure that no appreciable subsidence will occur. For this purpose the extraction ratio is likely to be less than 50% and could be lower than 40% in some areas, especially where pillar failure could lead to mining induced seismicity.

Entries for longwall panel development can be driven below these features without subsiding the surface. There should be no significant constraints on access that cannot be satisfactorily addressed when a detailed mine layout is prepared. The special case for mining under Upper Huntington Creek, where there is an increased sensitivity to impact, is addressed in Section 7.

The predicted angle of draw from longwall panels required to protect the surface was based on a value of 23 degrees, as previously discussed. This is the upper limit estimated in a previous study relating to subsidence experienced under Highway SR 264. It does not include any allowance for variable geology or mining conditions.

The zone in which longwall mining would be allowed under these restrictions was established. No attempt has been made to identify detailed technical or economic constraints that might prevent mining due to adverse geology or operational considerations. No detailed subsidence predictions have been evaluated for the small room and pillar full extraction areas at the margins of the longwall mining areas due to their small size in relation to the overall extraction area and the lack of significant surface features in their proximity. In all cases we have assumed the angle of draw is measured from the depth of the lowest coal seam to be mined.

In the case of Boulger Dam and Reservoir protection is gained by virtue of it's position within the alluvial valley floor of Boulger Canyon which effectively excludes full extraction within 1500 feet of this facility. Similar protection is also gained for much of State Highway SR264 and the gas transmission pipeline where they run along the Upper Huntington Creek alluvial valley floor. Many of the cabins in Flat Canyon are also protected in the same manner.

The subsidence zones for Alternative 2 are presented in Figure 5.6 and are based on the angle of draw of 23 degrees without any additional buffer.

Recommendations for Alternative 2

This alternative significantly reduces the subsidence related concerns for the Tract. The main concerns that remain are associated with the high differential subsidence zones defined by the stacked abutments expected at the perimeter of subsidence protection zones and shown in Figure 5.7. There are also concerns with subsidence of cabins in Swens Canyon and Flat Canyon on the north side of highway SR 264 which are discussed in Section 8.

The potential impact of the high differential subsidence zones can be reduced by offsetting the abutments in the lower seam and this will have the effect of reducing the horizontal strains and induced slope change by about 50%.

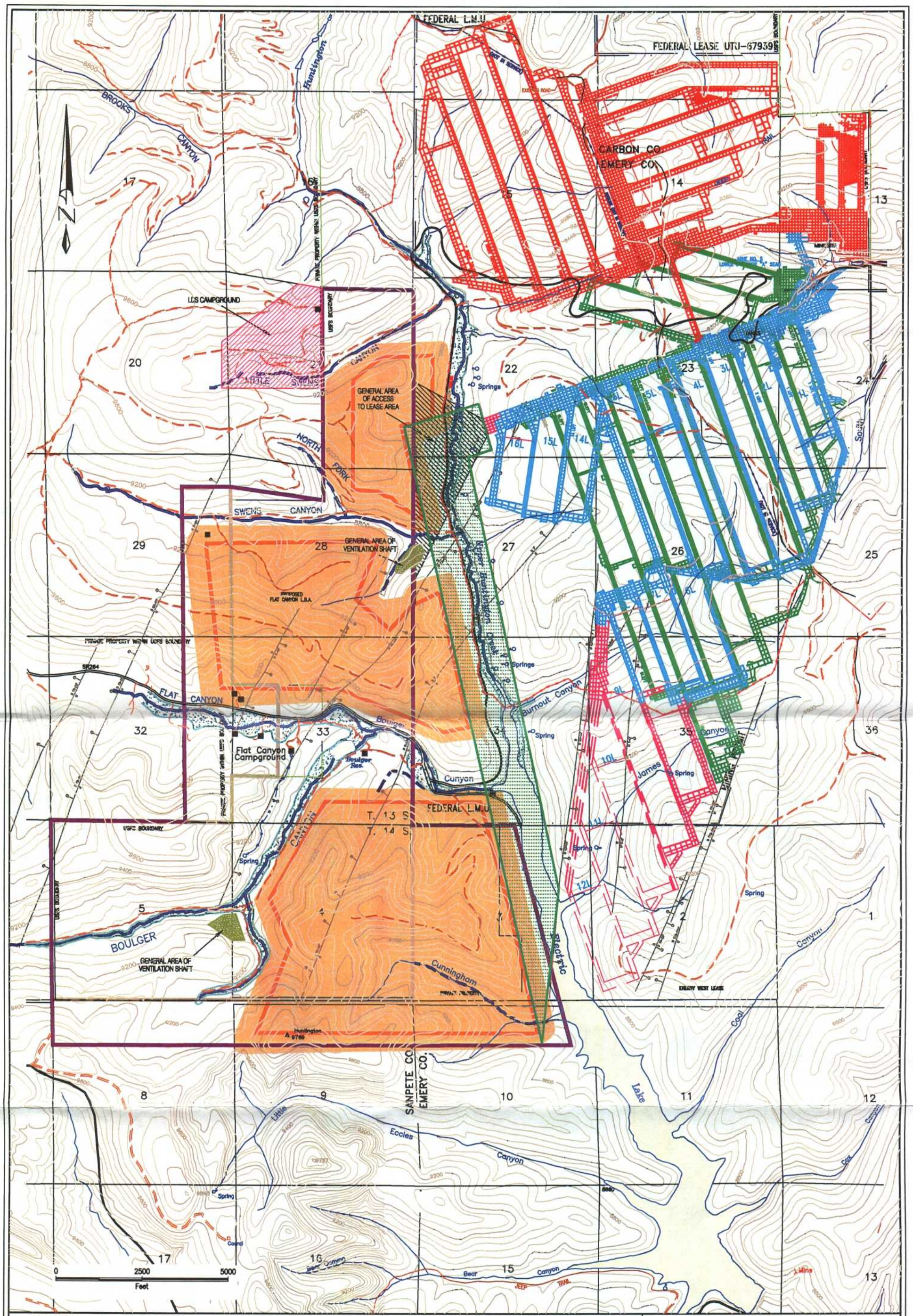
5.6.3 Alternative 3

In this alternative there are no significant restrictions imposed on mining, beyond those geologic and operational restrictions imposed by estimated coal thickness limitations. Over the Tract there are likely to be areas where faults, dikes, channel washouts, seam splits or other adverse geologic conditions restrict mining. With the current geologic information, it is difficult to have high confidence in the definition of these zones.

Projected fault vertical displacements are generally less than the limit of resolution possible with seismic geophysical techniques, expected to be in the order of about 10 ft. Longwall mining should be capable of mining through faults with vertical displacement of about 1 to 1.5 times seam thickness, depending upon a number of operational and geotechnical constraints. Without further exploration data there is insufficient evidence to conclude that the mine plan will have a great influence on the estimated impacts.

The area of longwall mining and subsidence zones is presented in Figure 5.8. Particular zones where permanent subsidence might lead to a significantly higher impact are related to the location of fire barriers, and both single and stacked abutment zones. The location of fire barriers cannot be reliably predicted without a specific mine plan, but the location of the major abutment zones can be reasonably estimated from the mining scenarios discussed previously. The location of the areas where higher differential subsidence is expected is presented in Figure 5.9, together with areas where the impact is expected to be higher.

The different zones of subsidence impact sensitivity presented in Figure 5.9 include single abutment zones where moderate differential subsidence is expected and stacked abutment zones where high differential subsidence is expected. Particular areas where the degree of subsidence might have a



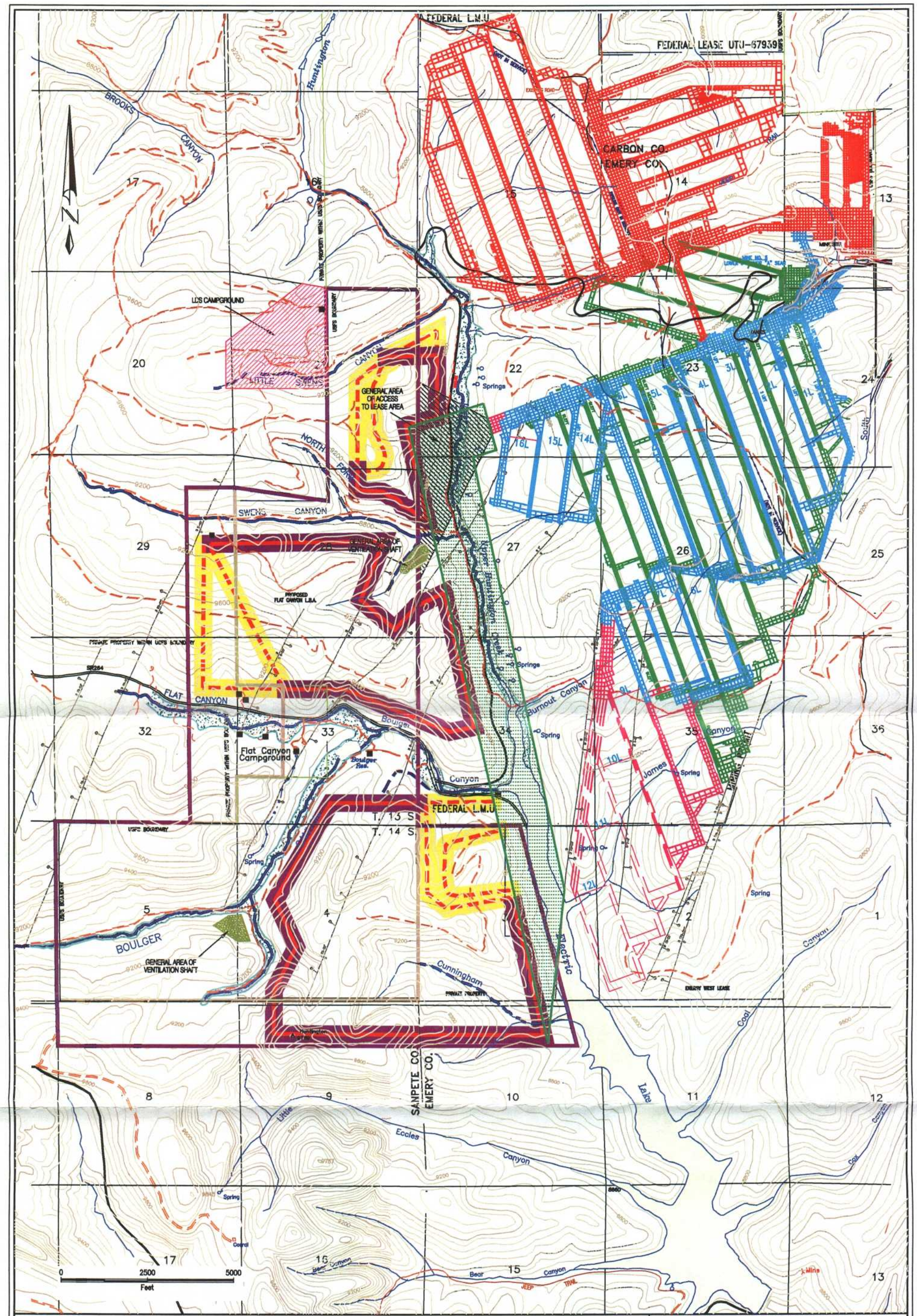
LEGEND

- LBA
- REASONABLY FORSEEABLE DEVELOPMENT AREA
- CABIN / BUILDING
- PAVED HIGHWAY
- UNPAVED HIGHWAY
- RIVER/CREEK,
- LAKE/RESERVOIR
- GAS PIPELINE (operational)
- GAS PIPELINE (not in service)
- WATER PIPELINE
- EXISTING MINE WORKINGS, MINE 1
- EXISTING MINE WORKINGS, MINE 2
- EXISTING MINE WORKINGS, MINE 3
- PROPOSED MINE WORKINGS, MINE 2 (existing lease)
- ESTIMATED PERIMETER of PERENNIAL STREAM ALLUVIUM
- MAJOR FAULTS
- PERENNIAL STREAM
- POSSIBLE PERENNIAL STREAM
- MAIN DEVELOPMENT CORRIDOR (MAINS AND BARRIER PILLARS)
- ZONE OF SUBSIDENCE
- LIMIT OF FULL EXTRACTION MINING

FIGURE 5.6

SUBSIDENCE ZONES ALTERNATIVE 2

FILE: MINING.DWG	SCALE 1" = 2640'	NorWest
DATE: 10/17/2000		



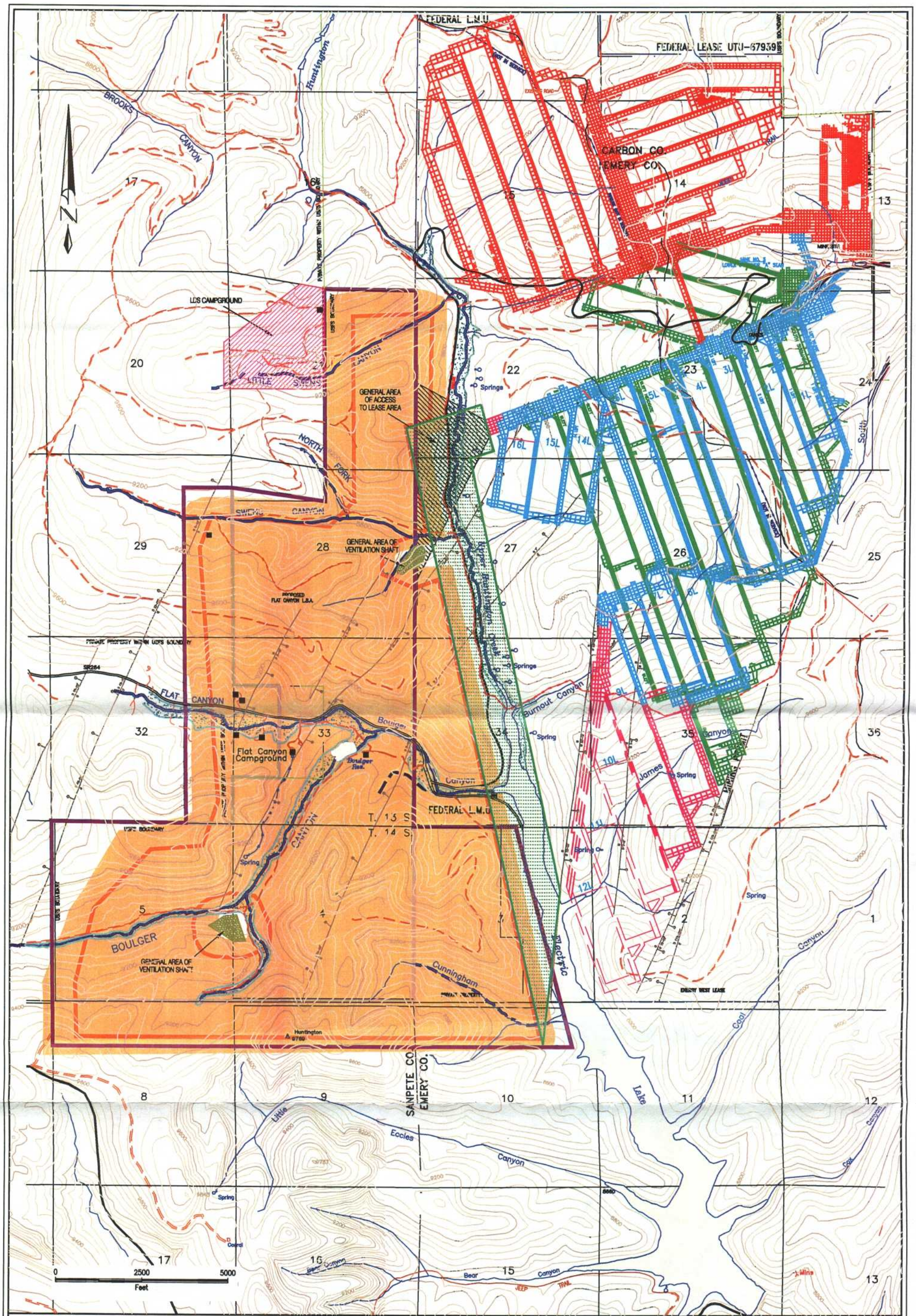
LEGEND

- LBA
- REASONABLY FORSEEABLE DEVELOPMENT AREA
- CABIN / BUILDING
- PAVED HIGHWAY
- UNPAVED HIGHWAY
- RIVER/CREEK,
- LAKE/RESERVOIR
- GAS PIPELINE (operational)
- GAS PIPELINE (not in service)
- WATER PIPELINE
- EXISTING MINE WORKINGS, MINE 1
- EXISTING MINE WORKINGS, MINE 2
- EXISTING MINE WORKINGS, MINE 3
- PROPOSED MINE WORKINGS, MINE 2 (existing lease)
- ESTIMATED PERIMETER of PERENNIAL STREAM ALLUVIUM
- MAJOR FAULTS
- PERENNIAL STREAM
- POSSIBLE PERENNIAL STREAM
- MAIN DEVELOPMENT CORRIDOR (MAINS AND BARRIER PILLARS)
- STACKED MULTIPLE ABUTMENT
- SINGLE ABUTMENT
- HIGH DIFFERENTIAL SUBSIDENCE ZONE
- MODERATE DIFFERENTIAL SUBSIDENCE ZONE

FIGURE 5.7

SUBSIDENCE IMPACT SENSITIVITY ALTERNATIVE 2

FILE: MINING.DWG	SCALE 1" = 2640'	NorWest
DATE: 9/17/2000		

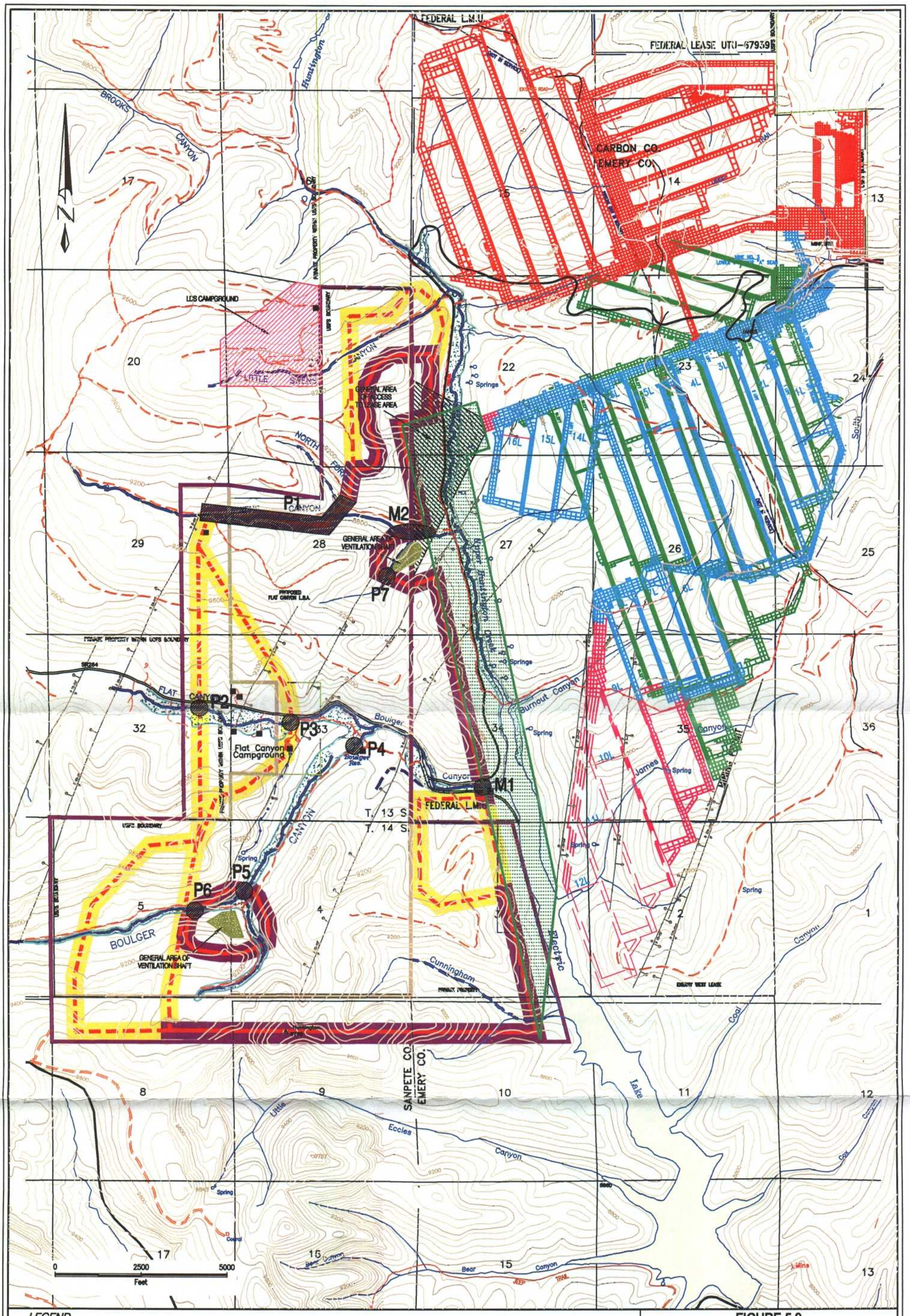


LEGEND

- LBA
- REASONABLY FORSEEABLE DEVELOPMENT AREA
- CABIN / BUILDING
- PAVED HIGHWAY
- UNPAVED HIGHWAY
- RIVER/CREEK,
- LAKE/RESERVOIR
- GAS PIPELINE (operational)
- GAS PIPELINE (not in service)
- WATER PIPELINE
- EXISTING MINE WORKINGS, MINE 1
- EXISTING MINE WORKINGS, MINE 2
- EXISTING MINE WORKINGS, MINE 3
- PROPOSED MINE WORKINGS, MINE 2 (existing lease)
- ESTIMATED PERIMETER of PERENNIAL STREAM ALLUVIUM
- MAJOR FAULTS
- PERENNIAL STREAM
- POSSIBLE PERENNIAL STREAM
- MAIN DEVELOPMENT CORRIDOR (MAINS AND BARRIER PILLARS)
- ZONE OF SUBSIDENCE
- LIMIT OF FULL EXTRACTION MINING

FIGURE 5.8
SUBSIDENCE ZONE
ALTERNATIVE 3

FILE: MINING.DWG	SCALE 1" = 2640'	NorWest
DATE: 10/17/2000		



LEGEND

- LBA
- REASONABLY FORSEEABLE DEVELOPMENT AREA
- CABIN / BUILDING
- PAVED HIGHWAY
- UNPAVED HIGHWAY
- RIVER/CREEK,
- LAKE/RESERVOIR
- GAS PIPELINE (operational)
- GAS PIPELINE (not in service)
- WATER PIPELINE
- EXISTING MINE WORKINGS, MINE 1
- EXISTING MINE WORKINGS, MINE 2
- EXISTING MINE WORKINGS, MINE 3
- PROPOSED MINE WORKINGS, MINE 2 (existing lease)
- ESTIMATED PERIMETER of PERENNIAL STREAM ALLUVIUM
- MAJOR FAULTS
- PERENNIAL STREAM
- POSSIBLE PERENNIAL STREAM
- POTENTIAL IMPACT AREA
- MAIN DEVELOPMENT CORRIDOR (MAINS AND BARRIER PILLARS)
- STACKED MULTIPLE ABUTMENT
- SINGLE ABUTMENT
- HIGH DIFFERENTIAL SUBSIDENCE ZONE
- MODERATE DIFFERENTIAL SUBSIDIENCE ZONE

FIGURE 5.9

SUBSIDENCE IMPACT SENSITIVITY ALTERNATIVE 3

FILE: MINING.DWG	SCALE 1" = 2640'	NorWest
DATE: 9/17/2000		

higher potential for impact to structures, facilities or resources are highlighted as potential impact areas and individually numbered on the figure. These locations relate to areas where significant mitigation might be required and are discussed in the text that follows for each structure and resource evaluated.

The locations for nine prediction points used in the numerical subsidence model are shown in Figure 4.1 and the results are presented in Tables 5.2 and 5.3.

The subsidence predictions will be discussed separately in relation to each of the main surface areas that would be impacted.

5.6.3.1 Boulger Dam and Reservoir

Longwall mining of both the Lower O'Connor B and Flat Canyon seams is expected under Subsidence Point No.6. This point is located between two projected faults. Without any definite mine plan it is possible that the dam and reservoir might be located at the edge of mine workings with the potential for them to be exposed to permanent tensile strains.

There are significant superficial deposits in the Flat Canyon area and boreholes have shown them to have a thickness of up to 90 ft. They are thought to predominantly consist of relatively unconsolidated sands and gravels of glacial origin. No detailed soil sampling or geotechnical testing has been carried out to define the nature of these deposits.

Model results show that there is a potential for total surface subsidence of about 14 ft after mining both seams, with about 7 ft occurring initially after the upper seam is mined. If a stacked abutment is located below the dam, the maximum tensile strain is estimated to be 16 millistrain with an overall tensile zone about 500 ft wide. The maximum compressive strain is estimated to be about -16 millistrain and the maximum induced slope change is estimated tobe about 3.0 %. Generally, the values will be significantly less than these values and the approximate range is given in Table 5.3 for different mine layout features.

The topography is relatively flat in this area. No slope adjustments for existing topography are considered necessary. Without a conceptual mine plan the horizontal strains and slope change could conceivably have any orientation. With the thick superficial deposits it is not expected that large tensile cracks would open up and remain open. However, it is possible that minor cracks would open and close again as the longwall passes underneath.

The dam has a high potential for impact and has been designated as Potential Imapct Area P4 on Figure 5.9.

5.6.3.2 State Highway SR 264

The highway runs along the canyon floor of Upper Huntington Creek, Boulger Canyon and Flat Canyon. Protection of the Upper Huntington Creek Alluvium would also protect the highway in this area and hence it would not be impacted by subsidence. Where the road turns E-W it would be subjected to subsidence in Boulger and Flat Canyons. Characterization of this zone is covered by Subsidence Prediction Points 5 and 6 with the range of parameter values given in Tables 5.2 and 5.3.

Model results show that there is a potential for total surface subsidence ranging from about 5 ft with single seam mining to 14 ft after mining both seams. If a stacked abutment is located below the road, the maximum tensile strain is estimated to be 16 millistrain with an overall tensile zone about 500 ft wide. The maximum compressive strain is estimated to be about -16 millistrain and the maximum induced slope change is estimated to be about 3.0 %. Generally, the values will be significantly less than these values and the approximate range is given in Table 5.3 for different mine layout features.

For the majority of the highway in Flat and Boulger Canyons the degree of subsidence is expected to be low. However, there are two locations where single abutments are expected and the degree of subsidence is expected to be moderate at Potential Impact Areas P2 and P3. At the stacked abutment of the Main Development Corridor the degree of subsidence is expected to be high and this has been designated Potential Impact Area M1 in Figure 5.9. It should be noted that these Potential Impact Areas have been designated predominantly for their potential for impacting flat sections of perennial drainages where induced slope changes may change the nature of these watercourses.

5.6.3.3 Mainline #41 Transmission Gas Pipeline

The gas pipeline runs alongside State Highway SR 264 on the west side of Upper Huntington Creek adjacent to the alluvial floodplain. This zone is subject to protection from subsidence and is, therefore, not expected to be influenced by subsidence. Consequently, no specific subsidence predictions are necessary for this facility. The potential impact in the worst case scenario of failure of pillars in the Main Development Zone is discussed in Section 7.

5.6.3.4 Flat Canyon Campground and Facilities

Longwall mining of both the Lower O'Connor B and Flat Canyon seams is expected east of the campground, defined by Subsidence Point No.6. However, the Flat Canyon Seam thins to the west and only the Lower O'Connor B Seam is expected to be mined at Subsidence Point No.5. It is possible that these facilities will be at the single abutment zone for the upper seam. The spring collection system is located close to Subsidence Point No.8 where the Lower O'Connor B, and possibly the Lower O'Connor A Seams are expected to be mined.

The campground, spring and pipeline are also located close to a projected fault which may be subject to increased differential subsidence. If a pillar needs to be left against the fault, then this may require a stacked abutment and result in increased permanent tensile zones.

There are significant superficial deposits in the Flat Canyon and Boulger Canyon areas and boreholes have shown them to have a thickness of up to 90 ft. They predominantly consist of relatively unconsolidated sands and gravels, possibly of glacial origins. No detailed soil sampling or geotechnical testing has been carried out to define the nature of these deposits.

The numerical model results show a potential for total surface subsidence ranging from about 5 ft where the upper seam is mined to about 14 ft where both seams are mined. In this case, about 7 ft of subsidence is expected after mining the upper seam. If stacked abutments are developed, the maximum tensile strain is estimated to be about 16 millistrain in a zone that is about 500 ft wide, with the maximum compressive strain estimated to be about -16 millistrain and the maximum induced slope change estimated to be about 3.0 %. The expected range of parameter values with mine layout factors is presented in Table 5.3.

The topography in this area varies from relatively flat to moderately steep. No slope adjustments for existing topography are considered to be necessary. In the absence of a specific mine plan, the horizontal strains and slope change could conceivably have any orientation, although the preferred orientation from the Skyline Mine is the most probable one. With the thick superficial deposits, it is not expected that large tensile cracks would open up and remain open. However, with the total amount of subsidence it is possible that minor cracks would dynamically open and close again as the longwall passes below. There may be some potential for tensile cracks in bedrock to remain open if active tension zones are left.

No specific Potential Impact Area has been designated for this facility, although the buildings are located above a projected single abutment zone that is expected to have a moderate degree of subsidence. It is expected that mitigation options for mine layout changes or facility protection will be available to control the potential impact.

5.6.3.5 Private Cabins and Buildings

Two main groups of private cabins exist on the Tract. There is one group of four cabins on the western zone of Flat Canyon, with two cabins north of the valley and the other two on the south side. Another cabin is located on the south side of Swens Canyon on the western edge of the Tract.

Four Cabins in Flat Canyon. Longwall mining of the Lower O'Connor B Seam only is expected below the private cabins in Flat Canyon. This is covered by Subsidence Point No.5. There is a minor fault projected in this location and some differential subsidence is possible if the fault extends to bedrock. The possibility of thick superficial deposits in the Flat Canyon area, up to 90 ft thick, may distribute horizontal strains relatively uniformly.

The numerical model results show that there is a potential for total surface subsidence of about 5 ft after mining the Lower O'Connor B Seam. There is a possibility that some of the cabins may lie within the angle of draw of mining the lower seam. The worst case condition might be for a single abutment with single seam mining, with the maximum tensile strain estimated to be 8 millistrain in a zone that is about 500 ft wide, the maximum compressive strain estimated to be about -5 millistrain and the maximum induced slope change estimated to be 0.7 %. The range of parameter values for various mine layout factors are presented in Table 5.3.

The topography is relatively flat in this area. No slope adjustments for existing topography are considered to be necessary. Without a specific mine plan the horizontal strains and slope change could conceivably have any orientation. With the thick superficial deposits, it is not expected that large tensile cracks would open up and remain open. However, it is possible that minor cracks would open and close again as the longwall passes underneath.

One Cabin in Swens Canyon. Longwall mining of both the Lower O'Connor B and Flat Canyon Seams is expected below the private cabin in Swens Canyon. This is covered by Subsidence Point No.3.

The numerical model results show that there is a potential for total surface subsidence of about 10.7 ft after mining both seams. If stacked abutments are located below the cabin, the maximum tensile strain is estimated to be 8 millistrain in a zone that is about 600 ft wide, with the maximum compressive strain estimated to be about -8 millistrain and the maximum induced slope change estimated to be 1.5 %.

The topography is moderately steep in this area; and some slope adjustment for existing topography may be necessary, but would depend upon a specific mine plan and sequence of extraction. Without a specific mine plan the horizontal strains and slope change could conceivably have any orientation.

With the depth of mining and the limited maximum horizontal strains it is not expected that large tensile cracks would open up and remain open, unless the cabin were in a permanent abutment zone. Where thick sandstone beds exist close to surface and long term tension zones are left, there is the potential for minor vertical fractures to open up. However, it is possible that these minor cracks would open and close again in the dynamic subsidence zone when the longwall passes underneath.

5.6.3.6 Huntington Canyon Perennial Drainage

No longwall mining is planned within the angle of draw from the Huntington Creek alluvial flood plain, therefore, no subsidence of this resource will be allowed. However, limited development entries would be allowed under the Creek in the Main Development Zone for access to mining areas in the Tract and evaluation of the stability of these workings is presented in Section 7, together with a worst case scenario for subsidence should the pillars fail.

5.6.3.7 Flat Canyon Perennial Drainage

This canyon has been characterized by two subsidence prediction points 5 and 6. The Flat Canyon Seam thins in a westerly direction and hence is not expected to be mineable at Point 5. Approximately half of Flat Canyon in the Tract area is expected to be undermined by both seams. The numerical model predictions indicate that the total vertical subsidence would vary from about 14.4 ft in the east to 4.7 ft in the west. If a stacked abutment is located below the drainage then the maximum horizontal tensile strain is estimated to be in the range of 8 to 16 millistrain from west to east, with maximum horizontal compressive strain estimated to range from -5 to -16 millistrain from west to east and maximum induced slope change estimated to be in the range of 0.7 to 3.0 % from west to east. The range of parameter values for different mine layout factors are presented in Table 5.3.

The Flat Canyon valley bottom has a significant thickness of superficial deposits, with poorly consolidated sands and gravels identified in boreholes with depths of up to 90 ft. The upper seam is separated from the bedrock at the base of the alluvium by about 1000 ft of Blackhawk Formation interbedded sandstone, siltstones and claystones with the expectation that no significant vertical connection between the alluvium and mine would be observed as a result of subsidence.

Relevant experience from the Skyline Mine, where areas were extracted in two seams below the upper reaches of Burnout Creek, experienced comparable vertical subsidence of about 14 ft. Significant tensile zones near a fire barrier pillar observed where there was about 900 ft of overburden above the upper seam. Results from the Burnout Creek Study indicated that there was no significant hydraulic connection with the mine workings or major aquifers.

There are two areas of Flat Canyon that may be subjected to moderate differential subsidence as a result of single abutment pillars. Due to the flat section of this perennial drainage there is the potential for some degree of impact and these points have been designated Potential Impact Areas P2 and P3 in Figure 5.9.

5.6.3.8 Boulger Canyon Perennial Drainage

This Canyon has been characterized by four subsidence prediction points, numbered 1, 6, 7 and 8. The Flat Canyon Seam thins in a southwesterly direction; hence, it is not expected to be mineable over the majority of this area. However, the Lower O'Connor A Seam thickens and may be sufficiently extensive to be mineable. It is assumed that the Lower O'Connor A seam is mineable. This would need to be confirmed with further exploration drilling. Two seams are assumed to be mined over the majority of the area, except for the westerly extent characterized by Point No.7.

The numerical model predictions indicate that total vertical subsidence would vary from about 14.4 ft in the east to 5.0 ft in the west. If stacked abutments were located in this area, the maximum horizontal tensile strain in a narrow 500 ft zone above them is estimated to be in the range of 7 to 16 millistrain with the maximum horizontal compressive strain estimated to range from -5 to -16 millistrain and the maximum induced slope change estimated to be in the range of 0.7 to 3.0 %. The range of variation with different mine layout features is presented in Table 5.3.

Thick surficial deposits are expected in the lower sections of Boulger Canyon, with up to 90 ft of poorly consolidated sands and gravels, reported to be of glacial origins.

There are three areas of Boulger Canyon that may be subjected to high differential subsidence as a result of stacked abutment pillars. Due to flat sections of this perennial drainage there is the potential for some degree of impact and these points have been designated Potential Impact Areas M1, P5 and P6 in Figure 5.9.

5.6.3.9 Swens Canyon Perennial Drainage

This Canyon has been characterized by two subsidence prediction points 3 and 4. Both the Lower O'Connor B and Flat Canyon Seams thin in a westerly direction, although they are both expected to be mineable at each location. Numerical model predictions indicate that total vertical subsidence would vary from about 13.0 ft in the east to 10.7 ft in the west. If stacked abutments are located in the vicinity the maximum horizontal tensile strain is estimated to be in the range of 8 to 16 millistrain from west to east, with maximum horizontal compressive strain estimated to range from -8 to -16 millistrain from west to east and maximum induced slope change estimated to be in the

range of 1.5 to 2.8 % from west to east. The range of parameter values estimated for different mining layout features is presented in Table 5.3.

The Swens Canyon valley bottom is estimated to have a limited thickness of superficial deposits. The upper seam is separated from the bedrock at the base of the alluvium by about 1000 to 1600 ft of Blackhawk Formation interbedded sandstone, siltstones and claystones with the expectation that no significant vertical connection between the alluvium and mine would be observed as a result of subsidence.

There are three areas of Swens Canyon that may be subjected to high differential subsidence as a result of stacked abutment pillars. Due to the length of these sections and the flat gradient of this perennial drainage in places there is the potential for some degree of impact and these points have been designated Potential Impact Areas M2, P1 and P7 in Figure 5.9.

5.6.3.10 Little Swens Canyon Perennial Drainage

This Canyon has been characterized by a single subsidence prediction point No. 2 due to it's limited extend within the Tract. Only the Flat Canyon Seam is expected to be mined. The numerical model predictions indicate that total vertical subsidence would be about 5.5 ft. If a fire barrier is located in the vicinity, the maximum horizontal tensile strain is estimated to be 9 millistrain, the maximum horizontal compressive strain is estimated to be -5 millistrain and the maximum induced slope change is estimated to be 0.9 %. The variation of parameter values for different mining layout features is presented in Table 5.2.

The Little Swens Canyon valley bottom is estimated to have a limited thickness of superficial deposits. The upper seam is separated from the bedrock at the base of the alluvium by about 1200 to 1500 ft of Blackhawk Formation interbedded sandstone, siltstones and claystones with the expectation that no significant vertical connection between the alluvium and mine would be observed as a result of subsidence.

There are two areas of Little Swens Canyon that may be subjected to moderate differential subsidence as a result of a single abutment pillars. However, due to the steeper gradient of this perennial drainage the potential for impact is low and no Potential Impact Areas have been designated in Figure 5.9.

5.6.3.11 Cunningham Possible Perennial Drainage

This area has been characterized by a single subsidence point No.9 due to it's limited extent within the Tract. Both the Lower O'Connor B and the Lower O'Connor A Seams are expected to be mineable in this area. Model

predictions indicate that total vertical subsidence would be about 12.9 ft. If a stacked abutment is located in the vicinity the maximum horizontal tensile strain is estimated to be about 10 millistrain, the maximum horizontal compressive strain is estimated to be about -10 millistrain and the maximum induced slope change is estimated to be about 1.9 %. The variation of parameter values for different mining layout features is presented in Table 5.2.

The area is estimated to have a limited thickness of superficial deposits. The upper seam is separated from the bedrock at the base of the soil by about 1400 ft of Blackhawk Formation interbedded sandstone, siltstones and claystones with the expectation that no significant vertical connection between the surface and mine would be observed as a result of subsidence.

5.6.4 Alternative 4

No specific mining scenarios have been evaluated in detail for Alternative 4. However, there are a number of specific options for reducing impact that should be considered. The options listed below are intended for further evaluation and should not be regarded as recommendations:

- The location of stacked fire barriers and stacked abutment zones should be avoided where important perennial drainages are relatively flat. Consideration could be given towards offsetting these mining features to avoid concentrating the impact in one location, although this will result in some loss of reserves.
- The location of permanent tensile zones should be avoided where sensitive structures are concerned. This would include both single and stacked abutments and fire barriers. Some of the sensitive zones are shown in Figure 5.9 for Alternative 3.
- It may be possible to incorporate some protection of the majority of sensitive perennial drainage zones with protection of structures in the mine planning process. For example, if N-S longwall panels are selected then it may be possible to locate the sub-mains below Flat Canyon and provide protection for portions of the drainage, dam, campground, cabins and road with only a limited loss of reserves. However, this could have significant mine design and associated cost implications for mining in the Tract.

Further discussion of options for Alternative 4 are given in Sections 6, 7 and 8.

6. MINING INDUCED SEISMICITY

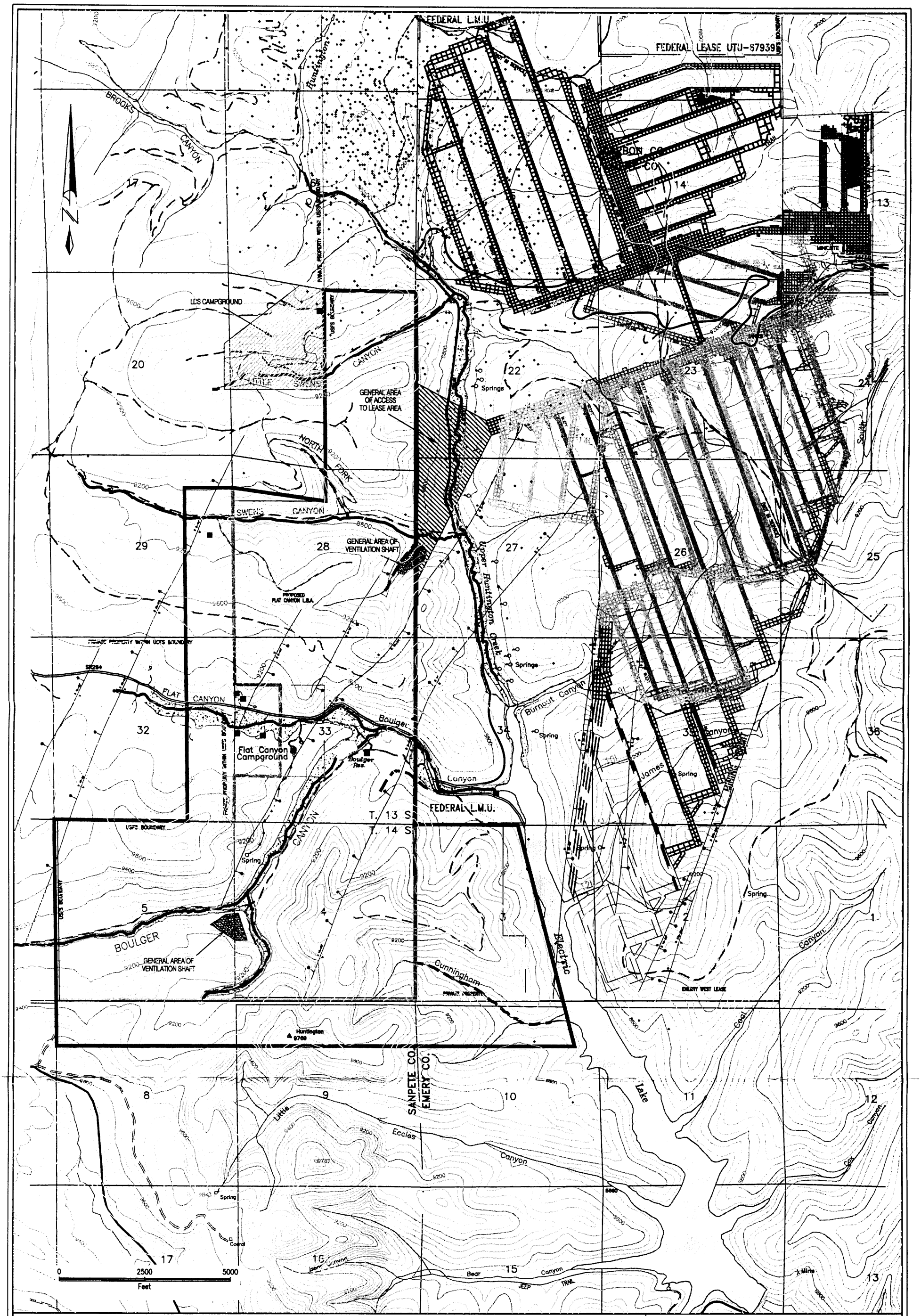
The Wasatch Plateau area of Utah is in a tectonically active zone with a history of significant earthquake activity. Seismicity associated with mining induced seismic events is the major focus of this study. Natural earthquakes have only been considered in relation to the effect that vibrations from them in the past may have had on sensitive structures and provide confirmation of their ability to withstand the particular vibration levels discussed in Section 8.

6.1 HISTORIC MINING INDUCED SEISMICITY

The subject of mining induced seismicity in the Wasatch Plateau and Book Cliffs areas of Utah has been the source of much prior study. The most relevant study was carried out on the Skyline Mine with data from 1986 to 1996, while the Skyline Mine was operating in the northern section of the current mining lease (Arabasz et. al., 1996).

At the time of the study one longwall unit was operating at depths ranging from 1200 ft to 2000 ft while a second longwall unit was operating at depths ranging from 400 to 1300 ft. Results of the study indicated a very strong correlation between mining induced seismicity and production rate at depths greater than 1500 ft; however, there was very little correlation with mining at the relatively shallow depths. During this time the Mine was experiencing stress-related problems caused by coal bumps when mining at depths greater than about 1500 ft.

The University of Utah earthquake catalog has been used to evaluate the seismic activity in the area, with emphasis on mining induced seismicity. A total of 1013 events were recorded with magnitudes greater than Richter 2 within a range of several miles from the Skyline Mine workings. These have been plotted for the majority of events in relation to the mine workings on the base map which is presented in Figure 6.1. It should be noted that the events are skewed several km northwest of the mine workings and this represents an inherent location error due to the predominance of recording stations to the west (Arabasz et. al., 1996). A high correlation was also observed linking the majority of events with the Skyline No.3 Mine workings in the Lower O'Connor A Seam at depths greater than about 1400 ft.



LEGEND

- LBA
- REASONABLY FORSEEABLE DEVELOPMENT AREA
- CABIN / BUILDING
- PAVED HIGHWAY
- UNPAVED HIGHWAY
- RIVER/CREEK,
- LAKE/RESERVOIR
- GAS PIPELINE (operational)
- GAS PIPELINE (not in service)
- WATER PIPELINE
- EXISTING MINE WORKINGS, MINE 1
- EXISTING MINE WORKINGS, MINE 2
- EXISTING MINE WORKINGS, MINE 3
- PROPOSED MINE WORKINGS, MINE 2 (existing lease)
- ESTIMATED PERIMETER of PERENNIAL STREAM ALLUVIUM
- MAJOR FAULTS
- PERENNIAL STREAM
- POSSIBLE PERENNIAL STREAM
- SEISMIC EVENT LOCATION

FIGURE 6.1

SEISMIC EVENTS

FILE: MINING.DWG	SCALE 1" = 2640'	NorWest
DATE: 9/17/2000		

The fifty events with the highest magnitudes have been plotted in the cumulative frequency plot against magnitude presented in Figure 6.2. All of these fifty events were recorded from 1993 to 1996 when Skyline was extracting coal from the deeper sections of the No.3 Mine. This shows that the maximum seismic event in the vicinity of the Mine was a magnitude 3.45 event, followed by three events with magnitudes of about 3.3 and a total of eight events with a magnitude of 3.1 or greater.

The event magnitude was then plotted against focal depth and presented in Figure 6.3, where it can be seen that the highest 3.45 magnitude was estimated to have a focal depth of about 18,000 ft. The majority of events are estimated to originate from depths that are shallower than about 2 km and probably represent sources close to mine workings. It should be noted that the depth estimation is subject to significant error and cannot be regarded as reliable. The three events with an estimated magnitude of 3.3 were all estimated at shallower depths of less than 5,000 ft. A magnitude 3.3 event has been chosen as a reasonable figure for the MCE based upon this information.

need to finish

The mine has also reported that the intensity of mining induced seismicity significantly decreases during mining of a lower seam, providing further evidence that the events are

It should be noted that the mine workings and many of the events have been within 10,000 ft of the small dam located at the campground in Little Swens Canyon without any reported damage to the dam.

Mining-induced seismic events of a greater magnitude have been produced by other Wasatch mines. The largest documented event in the Gentry Mountain area was estimated at a local magnitude of 3.8 (Arabasz, 1996), although this was related to room and pillar workings and is not considered to be directly applicable to longwall mining.

A recent event at the Willow Creek Mine in March 2000 had a reported magnitude of 4.2 but this has not been officially documented. The source for this event appears to have been located above mine workings at a depth in the region of 2,000 ft and may be associated with shear movement on a reverse fault plane, but this has not been confirmed. The mine was operating at a depth of about 2,500 ft at the time. No major problems were reported in the Mine or at surface as a result of the stress redistribution or seismic vibrations. The Willow Creek Mine is a longwall mine extracting coal at depths of about 2,500 ft below the Castlegate Sandstone which is very thick and strong in this area, forming prominent cliffs. Mining in the Tract is at significantly shallower depth and the Castlegate sandstone is less prominent when compared to the Willow Creek Mine area. These two areas are sufficiently different to reject this event for use as the MCE in impact evaluations.

Figure 6.2
Plot of Cummulative Number of Events Versus Event Magnitude for Skyline Mine

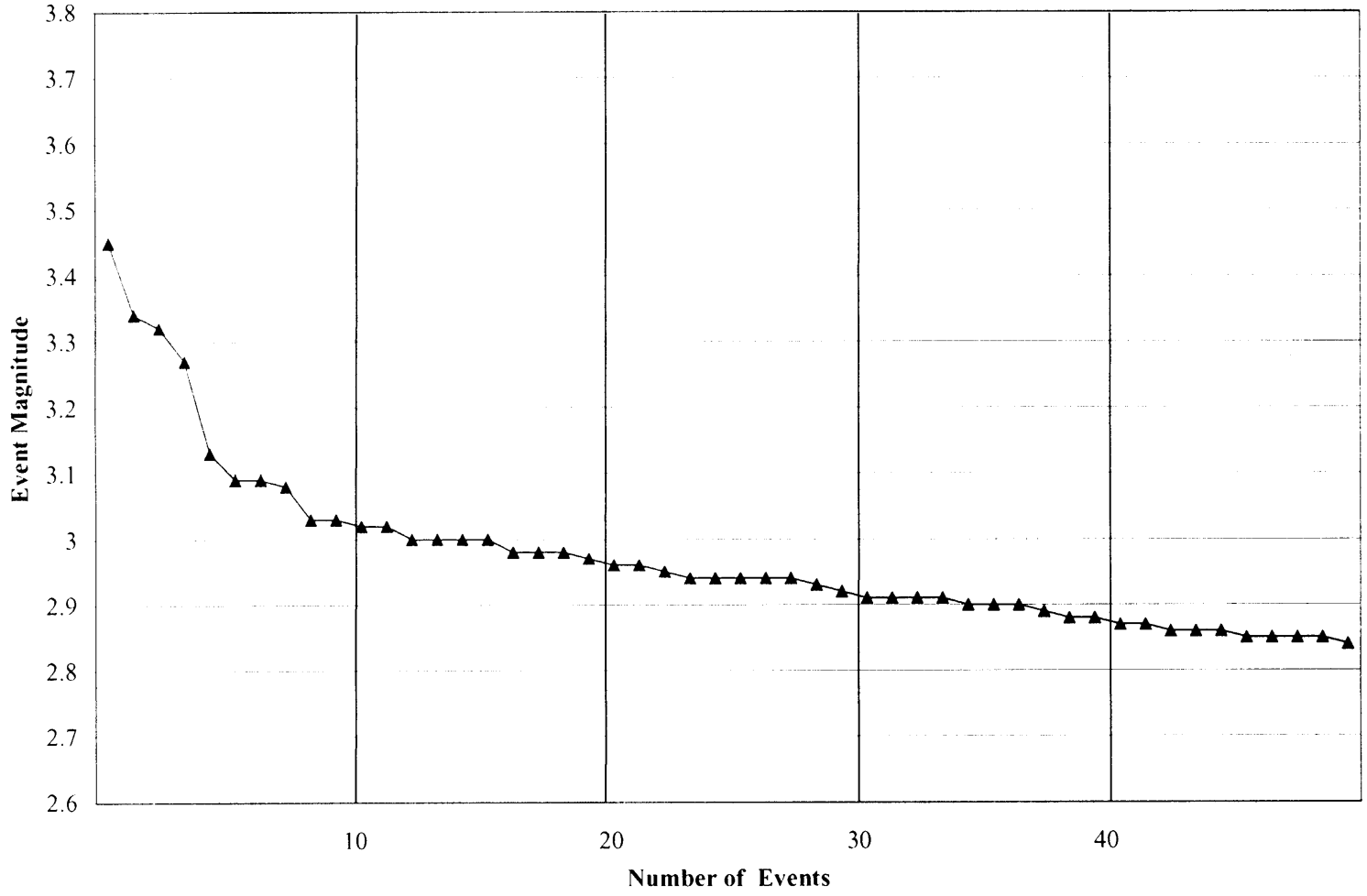
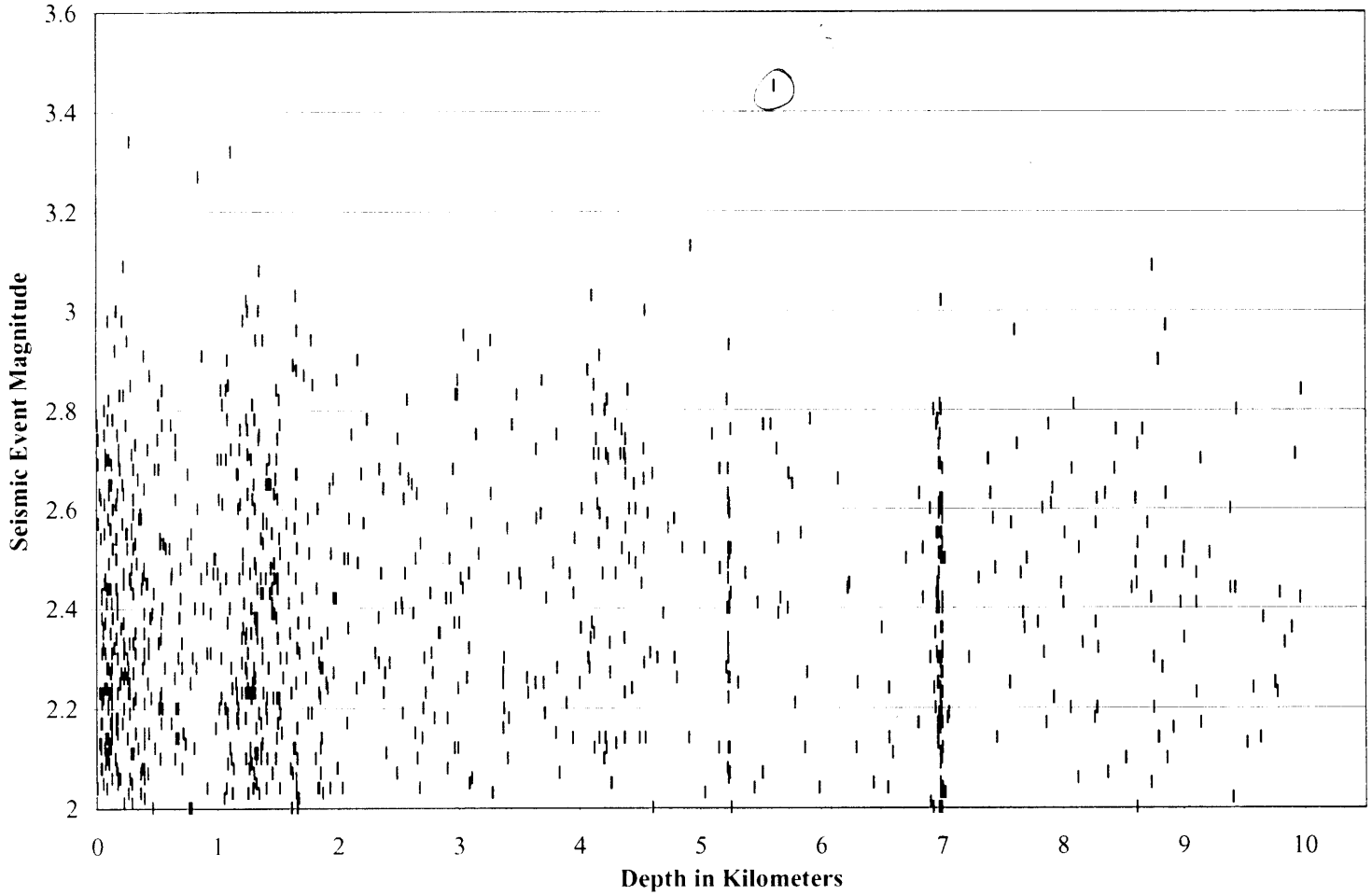


Figure 6.3
Plot of Event Magnitude Versus Focal Depth for Skyline Mine



The areas of Tract that are considered for room and pillar mining with full extraction are very small and hence adoption of an MCE based upon this method is not considered to be appropriate. The collapse in 1995 of pillars over a large area of about 2 square kilometers in a trona mine near Green River, Wyoming is not considered relevant to longwall coal mining where large areas of unstable pillars do not remain after mining. However, if large areas of partial extraction are being considered, as in Alternative 2, then this assumption may need to be reviewed in relation to the potential for large scale pillar failures.

6.2 METHODS OF PREDICTION

The predictions in this study are primarily directed towards estimating the ground vibrations likely to be experienced at the dam structures located on or near the Tract. They do not include those that might be applicable to the Electric Lake Dam which is over 10,000 ft away from projected mining. Electric Lake Dam has a significantly greater potential safety hazard than the recreational dams on the Tract, although it can withstand much greater vibration levels. The Beaver Dam and Reservoir is another recreational facility located over 8,000 ft west of projected mine workings. It has not been evaluated in this study.

Prediction of seismic events, natural or induced by mining, is not an exact science. Many variables are unknown or cannot be reliably predicted for all possible combinations. In order to predict ground vibrations at a given point from mining induced seismicity the following aspects need to be considered:

- Magnitude of Credible Event (MCE) which is historically reported as local magnitude on the Richter scale based on monitoring typically located a significant distance from the epicenter. This is based on recording vibrations within a frequency range that is important for typical structures.
- Source location, type and period of vibrations generated.
- The mechanism involved in transmitting the vibrations through the rock and soil to the ground surface that affects their attenuation with distance from the source.
- The site specific reaction of the surficial materials with the bedrock interface and the degree to which particular structures respond to ground vibrations. This may involve separate evaluation of the different vibration parameters for displacement, velocity and acceleration in three orthogonal planes and their variation with frequency.

These aspects involve very complicated interactions and reliable prediction is very difficult without many assumptions being made. The major aspects are discussed in the following sections. The nature of the frequency of vibrations, obtained from full spectral analysis, is important to defining the likely impact on structures with different natural vibration frequencies.

6.2.1 Magnitude of Event

Experience at the Skyline Mine is the most applicable empirically derived source of data. There are some indications that the source of mining induced seismicity is related to depth (Arabasz, 1997) and stress conditions. The vast majority of events have been associated with mining at Skyline, with emphasis on production from the Skyline No.3 Mine.

Proposed mining in the Tract would use methods and layouts similar to past mining at Skyline. There is a strong correlation between seismic events and depth which is indicative that mining in the Tract would not be significantly different from the Skyline Mine; however, geologic and associated mining conditions are difficult to reliably extrapolate over long distances.

Based on experience in the area, we have selected a local magnitude of 3.3 for the MCE as the most appropriate choice. The basis for this selection has been discussed in Section 6.1. Selection of higher magnitude events for use in predictions would provide a greater degree of security, but we cannot justify their use for evaluation of the relatively small structures being evaluated. However, comparison of a larger 3.8 magnitude event has been included for evaluation of the potential for mining to impact the Electric Lake Dam in order to be more conservative for this larger structure with a significantly greater risk should it fail. Application of a magnitude 3.8 event for evaluation of this dam has been made for comparison purposes only in order to provide more confidence in the finding that the Electric Lake Dam is not considered to be at any risk from mining induced seismicity from mining in the RFDS.

6.2.2 Event Location

Previous studies have indicated that the source for the magnitude of events is significantly influenced by local tectonic stresses, with larger events often associated with shear displacement along fault planes located at depths below the mine workings. The recent Willow Creek event was reportedly located above the mine workings at a depth of about 2,000 ft.

In order to be conservative we have assumed that any event is located at the shallowest depth of workings that might possibly induce seismic events. We have chosen 1,000 ft based on the previous mine experience that significant events may not occur until the depth reaches 1500 ft and the source is located 500 ft above the mine, as was indicated by the Willow Creek event. We believe that this is a reasonable approach, although the resolution of depth for events may be relatively unreliable in the majority of cases.

6.2.3 Attenuation Equation

The identification of a reliable attenuation equation for the near source vibrations expected at the dam structures within the Tract is subject to significant uncertainty. The use of attenuation equations developed for strong motion earthquakes over large distances are not considered to be directly applicable for mining induced seismicity. The expected vibrations are likely to be shallower, contain different vibration frequencies, have different periods, contain stronger vertical components and pass through different rock strata for shorter distances.

These conditions are similar to the evaluation of rock bursts in hard rock mines, or the evaluation of blast induced vibrations from surface or underground mine blasting. One of the most widely used attenuation formulae is that developed for deep South African gold mines (McGarr, 1981). Different attenuation relationships were developed by McGarr for the estimation of peak particle acceleration and peak particle velocity based on the magnitude and distance from the event. Equations developed by McGarr include an inverse linear relationship with distance:

$$\text{Log}\,(\rho\, a\, R) = 1.4 + 0.38\, M_L$$

Where :

ρ	=	density of rock strata (2.7)
a	=	peak acceleration (resultant)
R	=	distance from epicenter
M_L	=	Local magnitude

The equation for peak particle velocity will not be presented here, as peak particle acceleration is the parameter most widely used for dam stability evaluation.

Other studies have indicated that the inverse linear relationship with distance for vibrations in rock does not fully take attenuation into account (Joyner & Boore, 1988). Attenuation with an inverse relationship with distance to the power of -1.6 has been applied to blasting induced vibrations (Dowding,

1985) and hard rock mining in Idaho (Laverdure). This gives a greater attenuation with distance and lower estimate of vibration magnitudes.

In reality there are many unknown site specific variables regarding the magnitude, location and attenuation. Some of them can be estimated based on current data and some can be more reliably estimated with site specific measurements. The remaining uncertainty is more reasonably addressed by taking a conservative approach and applying suitable safety factors during analysis of structures.

Although the validity of the McGarr equation is questionable, experience with monitoring at the Joes Valley Dam has confirmed that it appears to overestimate the vibration levels for comparable mining and geologic conditions, hence this approach is considered to be conservative. The variation of peak particle acceleration with distance from an event of magnitude 3.3 is presented in Table 6.1.

Table 6.1
Attenuation of Mining Induced Seismic Vibration with Distance for a magnitude 3.3 Event (after McGarr, 1981)

Distance (Ft)	Peak Particle Acceleration (g)
1000	0.4
1600	0.3
2600	0.2
5500	0.1
6900	0.08

These acceleration zones from 0.1 to 0.3 g are plotted in Figure 6.4 for the two dams that may be impacted by mining in the Tract. It should be noted that these circles represent the location for an MCE that has the potential to produce the stated acceleration at the dam structure. Vibrations of this magnitude would only be expected for a single event during mining of the RFDS, although it may be located outside of the zone of influence.

It should be noted that this evaluation has assumed that the source of vibration is located near the longwall area. No allowance is taken for the possibility that mining could induce an event that is located adjacent to mine workings and closer to any particular structure of interest.

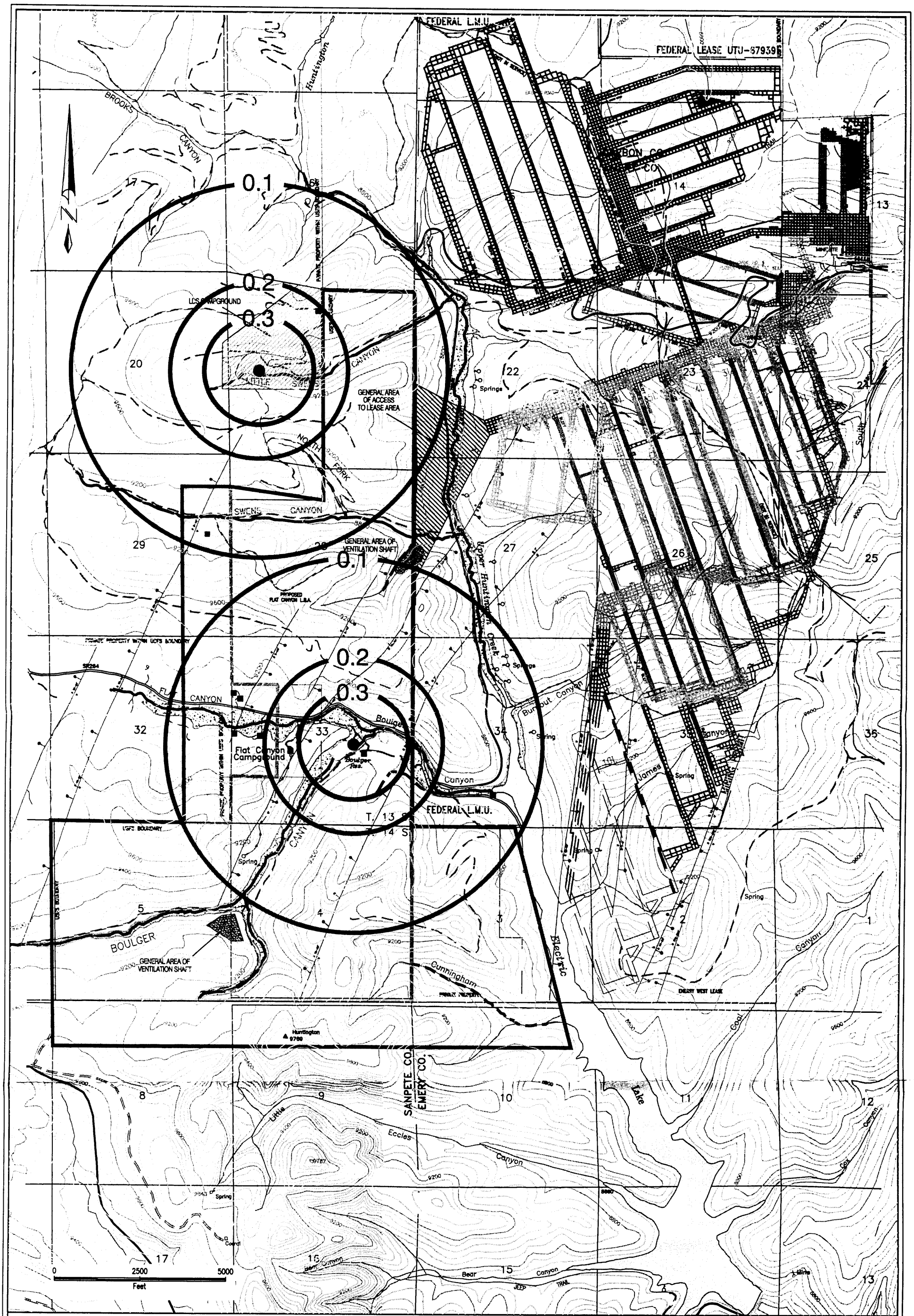
It is likely that mining-induced seismicity is primarily related to the re-distribution of horizontal stresses and failure of the overburden strata as a result of mining. This would most likely be prominent during mining of the upper seam and less likely with mining of lower seams in multiple seam mining scenarios. The cave and fracture zones of subsidence from mining of

the upper seam may also have some impact on the site specific attenuation factor that could increase attenuation of vibrations and result in lower ground vibrations at the structure of interest during mining of the lower seam.

It is recommended that prior to production mining inside of the 0.1 g circular acceleration zones around sensitive structures (Boulger and Hunt Dams) a study is carried out to evaluate the site specific parameters likely to affect the magnitude of mining induced ground vibrations, combined with a site investigation of the strength of the structure and the hazards posed by failure of the dam. The mitigation options and their associated hazards will dictate the level of monitoring and investigation required. If a monitoring program is necessary, then it would gain most benefit if carried out in conjunction with the study currently being undertaken by CFC on the effect of their current mine workings on the Electric Lake Dam.

The full impact of mining on these structures cannot be reliably assessed without further evaluation, however it is likely that mitigation options would be cost effective. We believe that the conservative approach presented, in conjunction with the alternatives for mitigation discussed further in Section 8, will not preclude longwall mining from being carried out in near vicinity to these small dams.

Mining induced seismic loading on the Electric Lake Dam structure has been estimated to be less than 0.1 g, from similar assessments described for the Boulger Dam. This evaluation indicates that, using an MCE of 3.3, as used for assessing the two smaller dams, the ground vibrations will be less than 0.1g at a horizontal distance greater than about 5500 ft from the mine workings. However, for evaluation of Electric Lake Dam, we have also evaluated a higher MCE due to the higher risks associated with the potential for failure of this structure. If a more conservative approach is adopted by assuming a higher MCE of 3.8, the same magnitude as the maximum event experienced at Gentry Mountain for room and pillar workings, then the ground vibrations are estimated to be less than 0.1g at a horizontal distance of about 8600 ft from mine workings.



LEGEND

- LBA
- REASONABLY FORSEEABLE DEVELOPMENT AREA
- CABIN / BUILDING
- PAVED HIGHWAY
- UNPAVED HIGHWAY
- RIVER/CREEK
- LAKE/RESERVOIR
- GAS PIPELINE (operational)
- GAS PIPELINE (not in service)
- WATER PIPELINE
- EXISTING MINE WORKINGS, MINE 1
- EXISTING MINE WORKINGS, MINE 2
- EXISTING MINE WORKINGS, MINE 3
- PROPOSED MINE WORKINGS, MINE 2 (existing lease)
- ESTIMATED PERIMETER of PERENNIAL STREAM ALLUVIUM
- MAJOR FAULTS
- PERENNIAL STREAM
- POSSIBLE PERENNIAL STREAM
- 0.1 MINING LIMITS FROM DAMS FOR DIFFERENT PEAK ACCELERATIONS (g) ALLOWED

FIGURE 6.4

DAM SEISMIC ZONES

FILE: MINING.DWG

DATE: 9/17/2000

SCALE 1" = 2640'

NorWest

6.3 HUMAN RESPONSE TO MINING INDUCED SEISMICITY

There will be a variety of people using the surface lands, including forest visitors, campers and occupants of cabins. They will be exposed to ground vibrations resulting from mining induced seismicity. The impact is considered in this section.

Mining induced seismic ground vibrations would be similar to those experienced in relation to surface blasting, except that there will be no airblast component in the audible range. The parameter commonly used for evaluation of blasting impacts is the Peak Particle Velocity. Seismic event evaluation normally considers peak acceleration as the descriptor for evaluating the response to seismic events. We have evaluated the results of the seismic events in Section 6 in relation to peak acceleration. Conversion from Peak Particle Acceleration (PPA) in gravitational units to peak particle velocity for sinusoidal vibrations can be carried out using the following formula (Dowding, 1985):

$$PPV = (PPA \times 386.4) / (2 \times \pi \times \text{Frequency in Hz})$$

Mining induced seismic vibrations with an assumed dominant frequency of 3 Hz would produce an equivalent PPV of about 20 times the PPA in gravitational units. The equivalent PPV for an acceleration of 0.1 g is 2 in/sec.

The human body is very sensitive to whole body vibrations resulting from ground vibrations. Vibrations are barely perceptible for PPV magnitudes as low as 0.05 in/sec for single events with a duration of less than 10 seconds (Dowding, 1985). For events of several seconds duration they are distinctly perceptible at levels of 0.4 in/sec. However, these aspects relate to single events that are infrequent, as would be expected of mining induced seismicity. The level associated with reduced comfort is at about 1 in/sec with exposure times of over one minute duration, which is much greater than mining induced seismic event durations. At levels of over 1 in/sec seismic events would be strongly perceptible and the degree of perception may vary with human activity and position.

Much of the nuisance factor with human response to surface blasting is associated with the public perception of the impact. If persons are worried about their health, safety or damage to property their sensitivity to airblast and ground vibration is greatly increased. The startle factor will be much higher where personnel are not aware of the increased potential for seismicity, especially in a region that is subject to earthquakes. If people perceive that the vibration may be associated with major earthquake activity then fear may enhance their perception and response to these vibrations. If cabin owners

believe that the vibrations will damage their property then their perception will be enhanced, especially if they feel that they will not be compensated adequately for any inconvenience and damage that might be caused. The aspect of damage to structures and facilities is discussed in Section 8.

The frequency of events can be reasonably assumed to be similar to those experienced during mining at Skyline from 1986 to 1999, having a similar range of depths that might be expected in the majority of the Tract. About 1000 events with magnitudes greater than 2 were recorded during 13 years of mining. Based upon a distinctly perceptible limit for short duration events of 1 in/sec PPV an event of magnitude 2 can be distinctly felt for radius of about 3400 ft from the location of mining. This is equivalent to an average of about one event every five days being distinctly felt for a radius of about 3500 ft from longwall mining. However, it is probable that they are more likely to be unevenly distributed with a higher frequency of events in the vicinity of deeper mining areas and particular geological conditions.

Health related problems are not expected as a direct response to the magnitude and frequency of mining induced events. Education, warning and a good public relations program is the key to reducing adverse human response to ground vibrations. Warning notices can be posted at the campgrounds and home owners informed of the likelihood and effect of the vibrations that might be expected. The campground in Little Swens Canyon and other private cabins are located in near vicinity to the Skyline No.3 Mine workings that have been the source of mining induced seismicity in the past. We are not aware of any problems being reported regarding the human response to the mining induced ground vibrations during this time. We would not anticipate that adverse human response to ground vibrations would be excessive.

7. PILLAR DESIGN FOR ACCESS UNDER UPPER HUNTINGTON CREEK

7.1 DESCRIPTION OF MINING DEVELOPMENT

The new Tract would be accessed by extending the existing mains of the Skyline Mine. Six entries would likely be driven in the general vicinity of the area shown on Figure 1.2. No longwall mining is planned under Upper Huntington Creek; hence, no coal extraction would take place near the entries. In the absence of a specific mine plan, it has been assumed that for the proposed development the pillars would be identical to those in the existing mains which has a similar range of overburden depth. These pillars dimensions are 70 ft wide and 80 ft long with a height of 9 ft.

Development for the Tract is discussed in Section 4. We have assumed that a main development corridor will be required to access the Tract with higher overall coal recoveries possible if the main entries are located below Upper Huntington Creek. The location of a Main Development Corridor is shown in Figures 4.2 and 4.3 for the upper and lower seams, respectively and are identical for the main alternatives. These mains are vertically aligned in both the upper and lower seams in order to optimize coal recovery and minimize adverse stress interactions between the two sets of main entries. This would allow access to reserves both east and west of the creek in both the upper and lower seams.

Overburden thickness in the development corridor would be in the range of 700 ft for the upper seam in the south to 1000 ft for the lower seam in the north. Boreholes in the area indicate the thickness of alluvial surficial materials is up to 65 ft in some places.

7.2 PILLAR DESIGN METHODOLOGY

Pillar design involves the following stages:

- estimate the vertical load on pillars as a result of supporting overburden and the additional load induced by driving the entries;
- estimate the induced load from extracting coal in adjacent areas;
- estimate the strength of coal pillars between and adjacent to the main entries; and
- apply a stability factor incorporating an acceptable factor of safety against collapse.

For the design of main development entries and associated coal pillars the tributary area method has been traditionally used for estimating vertical loads. This assumes that each pillar is loaded by the overburden that is tributary to it and that no loads are transferred from adjacent mined out areas. This would be true where there is solid coal or wide barrier pillars adjacent to the mains. This is a conservative approach that does not take into account the ability of the roof strata to form a compression arch above the mains. The formation of a compression arch enables the entry pillars to partially fail while some of the overburden load is transferred onto the rigid barrier pillars which support an increased proportion of the tributary load that would otherwise have been applied to the entry pillars.

The estimation of vertical stresses and pillar loads is a reliable method, as it is generally found that the weight of the overburden is a good estimation of vertical stresses found at a particular depth. This is especially true in the case of the Tract where the strata has not been significantly distorted by folding or faulting.

The estimation of coal pillar strengths has been the subject of much debate, with many differing formulas applied. Recent work over the last two decades has refined this process, with much of this work being carried out by the USBM (1992, 1999) based on empirical studies. These studies indicate that for longwall mine design pillar strength does not depend on the results of laboratory coal sample strength testing but remains constant at 900 psi.

Further USBM work (Mark, 1999) indicates that squat pillars with width to height ratios greater than 8-10 have a significantly greater load carrying capacity. The resulting strength formula is presented below:

$$S_p = S_1 (0.64 + 0.54 w / h - 0.18 (w^2 / L h)$$

Where:

S_p = Pillar Strength
S_1 = in-situ coal strength
W = width of pillar
L = length of pillar
H = height of pillar

The standard design methodology described above is based on stability requirements for the maintenance of operational capability of the entries, although some degree of maintenance and support can be assumed. For evaluation of the long term stability over a period of time in excess of 200 years the Mine would be closed and there would be no need for entries to

remain open. Operational conditions are, therefore, more stringent than long term stability requirements. Additionally, long term effects on pillar stability from strata deterioration are to be expected.

Long term stability of coal pillars is an area that has not been studied in detail and there is little empirical data that can be relied upon for periods of time beyond about 70 years. Recent work carried out to estimate deterioration of pillar strength with time (Biswas, Mark & Peng, 1999) is based on the deterioration of the coal rib over time resulting in a gradual deterioration of pillar strength and associated increase in pillar load over the remaining stable core. Unfortunately, this method does not take stress or flooding into account and cannot be reliably extrapolated to the Skyline Mine, as it requires knowledge of the time dependent behavior of the coal and other parting materials in the seam. There are a number of limitations listed for this method that would need further investigation in order to be more confident in applying them to long term mine design.

Empirical evidence is available from the Castlegate Mine near Helper, Utah. Room and Pillar workings with partial and full extraction of both the Kenilworth and A Seams was carried out from 1912 to 1973 when the mine was closed down. The mine was inspected in 1981 and the condition of roadways and pillars were evaluated, together with the collection of photographic evidence. This inspection identified little evidence of long term time-dependent deterioration of the pillars, even for those that were 69 years old at the time of inspection and had been driven by conventional drill and blast methods. These included pillars that were adjacent to caved areas with barrier pillars only 50 ft wide at depths of up to 1000 ft for the older pillars and up to 2500 ft for pillars that were about 20 years old. There is no evidence in this mine that ongoing deterioration would prevent these pillars from remaining stable for a time period considerably in excess of 200 years. However, the inspected areas of the mine were dry and this empirical evidence does not take into account the potential effect that flooding could have on stability.

It is unlikely that any empirical confirmation of pillar stability for identical conditions and covering time periods in excess of 200 years can be identified. Due to the very high sensitivity of the Upper Huntington Creek to impact, a worst case scenario has been carried out on the assumption that the pillars in these mains would fail and may then lead to progressive failure of the overburden that ultimately results in surface subsidence. Barrier pillars should be designed to withstand the tributary area loading and any load transfer from the adjacent longwall areas and mains. This failure process can be likened to longwall mining of a panel with the same width as the mains and a reduced height that accounts for the partial extraction of coal.

7.3 PILLAR DESIGN EVALUATION

Based on the tributary area theory, an analysis has been carried out on a six entry system at a depth of 1000 ft with coal pillars 70 ft by 80 ft and entries 20 ft wide by 9 ft high. Based on empirically derived evaluations (Mark, 1999) an in-situ strength for coal is assumed at 900 psi. This has been modified to take into account the additional strength expected for squat pillars which increases the pillar strength to about 3,250 psi and gives an overall safety factor (tributary area basis) of 1.74.

These results indicate acceptable safety factors for these pillar dimensions. The effective extraction ratio is about 40% for the proposed configuration and it is likely that small variations in these pillar dimensions, without reducing the effective extraction ratio, would also produce similar safety factors.

A higher safety factor would result if larger pillars were used. For example, if the pillars were 75 ft wide by 90 ft long the safety factor would be increased to 1.95 at an extraction ratio of 38%. For pillars 80 ft wide by 100 ft long the safety factor would be further increased to 2.16 at an extraction ratio of 36%. There are some practical limitations for increasing pillar sizes that will result in operational difficulties, reduced development rates and the potential for equipment limitations. Increasing pillar widths will also result in increasing the overall width of mains and the increased potential that the strata will not be able to arch and re-distribute the overburden loads onto barrier pillars.

During the underground field visit the Lower O'Connor B workings closest to the Tract were inspected to assess pillar stability. Roof spans were very stable in all areas and pillars were observed to be generally stable with minor spalling of ribs. In stressed areas adjacent to longwall panels rib spalling was more pronounced and some floor heave was observed. No indications were observed that there are any significant near seam weak claystone partings that might reduce long term pillar stability in the Lower O'Connor B Seam.

The Flat Canyon Seam pillars are likely to behave in a similar manner to the pillars in the Skyline No.3 Mine which extracted the combined Lower O'Connor A and Flat Canyon Seams. We are not aware of any significant near seam weak claystone layers that might give cause for concern regarding the long term pillar stability of pillars in this seam. However, no geotechnical testing has been carried out on core from exploration holes in the tract and our evaluation is based on knowledge of the general lithology and rock types expected in the RFDS.

Pillar strength could be further increased by reinforcing the external rib with cables or bolts, but their long term resistance to corrosion, especially in

flooded conditions, might preclude their realistic ability to enhance pillar stability over the long term. Entries could also be stabilized by installing cribs or backfilling with rock or coal following abandonment, but this option is likely to have a very high cost. We do not believe that the reinforcement of pillars or backfilling of entries is justifiable from a long term stability perspective or cost effective for additional subsidence protection.

7.4 SUBSIDENCE IMPACT

The pillar design evaluation indicates that there is sufficient width in the proposed Main Development Corridor to incorporate pillar dimensions that are stable over the long term. However, it is prudent to evaluate a worst case scenario to assess the possible impact in the unlikely event of a pillar failure.

Consequently, the worst case scenario assumes that the development pillars in both seams fail over the long term, defined as over 200 years for this study. In this case it is possible that the strata would gradually fail and this might conceivably progress upwards to ultimately produce surface subsidence. The shallowest overburden thickness is expected to vary from 700 ft in the south to 900 ft in the north.

In a worst case scenario we have assumed that the total length of mains is significantly greater than critical width and that full subsidence will be seen on surface. In this case the total width of all pillars that might fail has been evaluated on the basis that the overall span behaves like a longwall panel with a total width of 560 ft. spanning six entries if existing (70 x 80 ft) pillar dimensions are retained. The pillars might fail due to punching into the roof or floor, spalling of ribs, floor heave or squeezing.

If the coal pillars were to fail then the adjacent rock strata might also fail, ultimately filling up the entries with broken material that will reconsolidate and stabilize the overburden in the long term. In this case the strata will not be lowered for the full height of the seam, but a proportion defined by the extraction ratio, assumed to be 40%, if no further material bulking takes place.

At an assumed entry height of 9 ft this is equivalent to 3.6 ft of extraction without bulking. If it is assumed that this takes place in both seams, then the equivalent total extraction height would be 7.2 ft. Furthermore, if this is assumed to behave in a similar manner to longwall mining subsidence with subsidence factors of 55% for the upper seam and 75% for the lower seam, it would produce a total subsidence at surface estimated to be about 4.7 ft.

If pillars were to fail, it is likely that the process would take place gradually as they deteriorate over time. Barrier pillars would need to be sized to ensure that no load from adjacent longwall mining was transferred onto the pillars in the mains. Gradual failure of the pillars would then transfer load onto these rigid barrier pillars and prevent any rapid pillar collapse due to a domino effect.

Gradual failure, if it occurs, would most likely be relatively uniform over the mains, although it might also be restricted to particular areas that have weaker coal or overburden, resulting in differential subsidence troughs. In this worst case scenario it might produce subsidence with parameters values similar to the numerical model results for the single abutment values for point No.5 presented in Table 5.2. This worst case might lead to maximum horizontal tensile strains in the region of 4 millistrain and a maximum slope of 0.6 %.

This is unlikely to cause any significant impact on the Upper Huntington Creek and it's alluvium. The potential impact is discussed in the Technical Report on Surface Water and Groundwater.

In the unlikely event that pillars were to fail, then the predicted impact of subsidence is expected to be minor, although some inspection and repair work for Highway SR264 may be required over a time period that might extend over centuries. There could be some impact on the Gas Transmission Pipeline #41 that requires a mitigation plan to be developed at the time of mine abandonment if the pipeline is still operational.

8. STRUCTURES AND SURFACE FACILITIES

The RFDS area includes a number of structures and surface facilities that could be affected by mine subsidence and mining induced seismicity. A complete catalogue of these facilities has been developed, from on-site inspections, study of recent (1999) aerial photography and searches of Forest Service records. Pertinent details of the nature of the structures and facilities have been documented to permit an assessment of the potential impact of undermining and, where appropriate, to develop conceptual mitigation design measures.

From an underground mining perspective the RFDS area to be considered has been presented in Section 4 as the basis for this evaluation. One of the major constraints imposed on the study was that no mining would be permitted that would cause subsidence under any part of Huntington Creek.

8.1 CATALOG OF STRUCTURES AND SURFACE FACILITIES

All the structures and surface facilities addressed in this assessment are shown on Figure 1.2 and are described in the following sections. The list includes small dams and reservoirs, paved and unpaved highways, several private cabins, the Flat Canyon Campground, gas and water pipelines and natural canyon slopes.

The discussion of potential impacts generally relates to mining under Alternative 3 with limited discussion regarding how this would differ under the restricted mining defined in Alternative 2. Where protection of structures and resources is included under Alternative 2 this will enable significant areas to be mined by room and pillar methods with partial extraction. In this case pillars will need to be of sufficient dimensions to remain stable over the long term and this is likely to result in extraction ratios in the range of 40 to 50%. A detailed evaluation of exact pillar dimensions can be carried out during development of a detailed mine plan if this alternative is being considered.

The estimates of subsidence and seismicity are presented in Sections 5 and 6, respectively. The duration of active subsidence for any particular structure will depend on a detailed mine plan and sequence of mining in both seams. In general, dynamic subsidence may take place over a period of days and subsidence between panels may take place over a period of months. Where both seams are mined there could be a pause of several years between mining of each seam. It is generally observed for longwall mining that about 95% of subsidence will take place within two years of mining and the residual 5% of subsidence may occur gradually over an extended period of time.

8.2 DESCRIPTION AND ASSESSMENT OF STRUCTURES AND FACILITIES

8.2.1 Boulger Dam and Reservoir

Descriptive details of the construction of the Boulger Dam were supplied by the Forestry Service. The Dam was constructed in 1938 to create a fish pond at the junction of Boulger Canyon and Flat Canyon. A cross-section through the Dam shows homogeneous earth-fill constructed on the original stream bed with a nominal key trench into the foundation materials. As originally constructed, the Dam was approximately 220 ft long, a maximum of 16 ft high, with a crest width of 10 ft. The slope of the upstream face was 3H:1V with 3 ft of rip rap protection, and the downstream face was 2H:1V. A note on the original drawing indicates organic soils were removed prior to fill placement in 6" layers compacted by roller, with coarser material in the downstream half of the Dam. An overflow masonry chute spillway was constructed on the right abutment at a grade of approximately 8-10%. The chute was provided with 3 ft deep cut-offs at the top, Dam centerline and bottom of the chute. The Utah Division of Water Rights listing indicates a drainage area of 3.1 sq. miles and a maximum storage of 45 acre-ft.

In 1994, the chute spillway was replaced with a reinforced concrete fish ladder, a toe drain was installed to control seepage and the rip-rap was upgraded on the upstream face. The fish ladder was constructed in 10 ft sections and was provided with strip foundations at the top and bottom of the chute constructed at a 10% grade. The 1994 modifications were designed by the US Department of Agriculture.

No descriptive information on the foundation or sub-surface conditions is available from drill holes or test pits, and no qualitative data has been located on the Dam fill or foundation materials. Other than the toe seepage that indicates a phreatic surface at ground level at the downstream toe, there is no recorded information on the phreatic surface through the dam.

Construction of the fish ladder effectively resulted in lowering of the water level in the reservoir. Over the past 62 years of operation there has likely been significant siltation of the reservoir. The combination of these two factors has likely reduced the maximum storage to significantly less than the original capacity of 45 acre-ft., but no measurements have been carried out to confirm a more definitive figure.

8.2.1.1 Stability of the Dam

A typical cross section through the highest part of the Dam was prepared based on the available information. Consistent with the descriptive data, a homogeneous fill section placed on stream bed material has been assumed, with a phreatic surface profile typical of a non-zoned construction.

Reasonably conservative shear strength parameters were assigned to the various materials, although it should be noted that the nature of the foundation remains highly speculative and has been based on inspection of near surface materials in the vicinity of the Dam.

Limit equilibrium analyses of the structure under normal and extreme loading conditions was carried out to investigate the potential for both circular and composite (part circular/part linear) failure surfaces to develop through the upstream and down stream slopes. The results of the analyses show that under normal conditions the structure is stable with factors of safety of 2.5 and 1.3 for the upstream and downstream slopes respectively. An acceptable factor of safety for normal conditions is generally 1.5, thus the downstream face with a 2H:1V slope and high phreatic surface is likely already below normal standards.

Subsidence of the Dam structure has been modeled by assuming that as the subsidence wave passes under the structure, the shear strength of the foundation materials drops to near zero ie. subsidence causes continuous lateral cracks to open up in the foundation that, combined with lateral strains, impart little or no shear resistance to potential slope movement. This dynamic condition is considered to be the most critical, as the structure would experience this condition under any configuration of undermining being considered. Maximum static subsidence, lateral strains and slope associated the mining limits, gateroads and fire barriers, can be kept away from the structure with appropriate panel design. This would be necessary as the predicted maximum subsidence under the Dam over such features in two seam mining is 14.4 ft with a maximum strain of 4.5 ft over 500 ft and a maximum differential of 3.0% or 3 ft over the width of the Dam footprint.

Assuming this dynamic condition under the Dam structure indicates that the downstream slope would fail in a deep part rotational/part linear movement that would cause a breach and subsequent outflow. However, the upstream slope would likely remain stable until the downstream movement progresses through the structure. This mode of failure would likely occur at normal reservoir levels or even when fully drained. The rate of movement will be governed by the rate of longwall face retreat. At a high rate of about 60 ft per day, the rate of failure of the dam could be relatively quick and preclude the potential for monitoring and repair prior to a catastrophic breach.

There is some potential benefit to be gained by subsiding the Dam in a direction parallel to the Dam axis rather than from an upstream or downstream direction as there would be less differential settlement and lateral strain under the slopes in the upstream/downstream direction and therefore higher foundation strength. However, subsiding in this direction could induce upstream/downstream cracks through the structure that could lead to piping

failure. The impact of these cracks would be offset by the natural tendency for the cracks to heal under compression in the valley profile as the subsidence passes, although full draw down of the reservoir would be necessary during the subsidence event.

Seismic loading on the Dam that could be induced by underground mining activity in the vicinity, has been modeled in the traditional manner by applying equivalent horizontal ground accelerations in stability analyses. Under these conditions, and with the foregoing assumptions with regard to material strengths, a Parametric Stability Analysis was carried out on the dam. The results are presented in Appendix G and indicate that the Dam would likely withstand a seismic event with an equivalent horizontal ground acceleration of up to 0.1g. Any acceleration greater than this could induce failure of the downstream slope and a potential breach. A review of historical events included in the USGS and University of Utah databases, confirms that to date the structure has probably not experienced any seismic events, either natural or mining induced, with an equivalent ground acceleration greater than about 0.08g.

The stability analyses carried out, albeit based on certain assumptions with regard to foundation stratigraphy, material strengths and piezometric levels, indicates that unrestricted longwall mining of the Flat Canyon Tract under the Dam would cause significant subsidence and failure of the dam. Furthermore, longwall mining adjacent to, but not necessarily under the structure could induce a seismic event of sufficient magnitude with the potential to fail the dam.

8.2.1.2 Integrity of the Fish Ladder

The reinforced concrete fish ladder is constructed on a natural 10% grade at the right Dam abutment. At this slope there is very low potential for the structure to suffer any form of displacement due to slope movement during a subsidence or seismic event of the magnitude expected, other than any movement induced by failure of the adjacent Dam.

If a dynamic subsidence event progresses in the upstream/downstream direction, there would be a tendency for the construction joints between 10 ft panels to open up and water stops could become overstressed. As the subsidence passes, the joints would close again but there may be some permanent damage to the seals between panels. This would need to be corrected to prevent long term seepage and potential erosion under the structure. If the dynamic subsidence event progresses along the Dam centerline, the differential ground movements at the fish ladder would be minimized and potential damage is expected to be minimal.

There is no indication of any key wall between the concrete wall of the fish ladder and the Dam fill to control seepage along the fill/concrete interface. Subsidence of the structure would induce differential movement along this interface that could result in increased seepage.

8.2.1.3 Potential Mitigation Measures

Any mitigation measures considered should be designed in accordance with applicable codes and regulations. Designs should be preceded by detailed investigation of the structure and foundation materials, and a program of monitoring should be formulated. The restrictive mining under Alternative 2 will afford protection to the dam by limiting full extraction mining to outside of the angle of draw from the structure.

No Dam Enhancement and Limit Mining - if the Dam structure remains the same and no damage or interruption to use can be tolerated, further evaluation and investigation would be required prior to longwall mining in the Flat Canyon Tract within 5,500 ft. of the dam. If longwall mining occurs within this distance, mining induced seismicity could affect dam stability. This is a worst case option and we believe that acceptable mitigation options can be found to address this limitation.

If the structure is to be protected from subsidence then no full extraction mining should take place within the angle of draw from the structure. In this case it is possible that partial extraction room and pillar mining could be allowed providing coal pillar dimensions are sufficient to ensure long term stability.

Drain the Reservoir, Unrestricted Mining and Rebuild Dam - provided the reservoir is drawn down, the adverse consequences of failure of the Dam structure are restricted to the cost of loss of use for an extended period of time and reconstruction of the Dam and repair of the fish ladder. The estimated costs are included in Section 8.3 and indicate a total reconstruction cost in the order of $320,000 plus loss of use costs roughly estimated to be $70,000 based on a figure of $5,000 per month for the summer months only.

Buttress added to the Downstream Face - the stability of the structure can be significantly enhanced by adding a buttress and under drain to the downstream face and flattening the downstream slope. The grade of the fish ladder would permit a slope as flat as 5H:1V without alteration to the concrete structure. Such a buttress would upgrade the stability of the downstream face to be comparable with that of the upstream face. The enhanced structure could be capable of withstanding seismic events of up to 0.25g and subsidence from two seam longwall mining progressing from a north east direction. During the dynamic subsidence phase it would still be prudent to draw down the reservoir for a short period. Estimated costs are shown in Section 8.3 and

indicate that enhancing the stability of the dam with a downstream berm, together with repairs to the fish ladder, would cost in the region of $125,000.

Alternatively a secondary permeable (eg. rockfill) dyke could be constructed at some point downstream to control flows into Huntington Creek should a breach occur. Longwall mining progressing from the north west could be carried out, although this would have a greater potential for inducing preferential seepage paths through the Dam structure. The reservoir should be drawn down for this configuration of mining and additional maintenance to fill cracks or place an upstream impervious blanket may be necessary. Estimated costs for this alternative would be approximately in the range of $125,000 to $200,000.

It is possible that various options could be considered that combine limited mitigation with mine layout or extraction restrictions. During the development of a detailed mine plan these options can be considered in finding an acceptable solution.

8.2.2 Highway SR 264

This paved two lane highway runs east-west through the center of the Tract along Flat Canyon as shown on Figure 1.2. The road runs along the base of the Canyon over terminal moraine-type deposits at the lower east end and over alluvial sand deposits further west. The maximum subsidence predicted near the east boundary of the Lease is about 14 ft with a maximum strain of 4.5 ft over 500 ft and a maximum differential slope of 3.0%. Corresponding values at the west boundary are 4.7 ft, 2.3 ft over 500 ft and 0.7%. No mining would be allowed under Huntington Creek that would result in subsidence to the alluvium. Due to the close vicinity of the highway to the flood plain for the majority of length on the eastern side of the RFDS, then this also affords protection to the highway.

The road construction comprises flexible asphalt surfacing over granular roadbase material, which would readily conform to the surface subsidence profiles generated by longwall mining. As the dynamic subsidence occurs the road is unlikely to shows signs of any significant distress. However, the static subsidence at the limits of mining would result in cracking of the surface that would degrade unless remedial work is carried out. It is anticipated that resurfacing of the road would be required over a length of approximately 100 ft at the west limit of mining and both roadbase reconstruction and resurfacing would be necessary over a length of approximately 200 ft at the east limit. Drainage ditches alongside the road at the east limit would also require regrading to prevent ponding and saturation of the roadbase and the concrete culvert near the east boundary of the RFDS may need to be replaced.

As the estimated thickness of the surficial materials is up to 90 ft, there is a low probability that the lateral strains or vertical subsidence would be sufficiently concentrated to create wide cracks or vertical offsets that might present extremely hazardous conditions for road traffic. However, during the period when dynamic subsidence is most active, warning signs and regular inspections of the road surface may be necessary for additional safety. The total estimated costs for mitigating the effects of undermining on Highway SR 264 are in the order of $52,000.

The greatest potential impact area is at the east end of Boulger Canyon where a stacked abutment is expected at the Main Development Corridor, defined as Potential Impact Area M1 in Figure 5.9. It is possible that this impact could be significantly reduced if the barrier pillar width in the lower seam is increased to allow the two abutments to be staggered, thereby spreading the differential subsidence over a larger area.

The possibility of pillar failure below Upper Huntington Creek, and resulting subsidence if this were to occur, has been evaluated in Section 7. This is not expected to occur with the provision of adequate pillar dimensions, consequently no evaluation or estimation of associated costs has been carried out. The potential for significant impact to the road and associated ditches and culverts is remote, even if the pillars were to gradually fail over the long term.

The protection of perennial drainages in Alternative 2 would provide a major degree of protection of the highway for the majority of it's length through the Tract.

8.2.3 Unpaved Access Roads

There are several unpaved roads that cross the RFDS Area, most notably the roads up Boulger Canyon, Swens Canyon and Little Swens Canyon. Dynamic subsidence is unlikely to result in any significant noticeable distress to these roads; however, some regrading work on the roads and side ditches would be required near the mining limits, particularly at the east end of Swens Canyon and Boulger Canyon at an estimated cost of $12,000. In this case it may be necessary to control speeds, restrict access or carry out regular inspections to ensure the safety of road users where there is a potential for large tension cracks to create safety hazards during active subsidence in these zones.

It should be noted that experience at the Skyline Mines indicates that less than 1% of the mining area is likely to be influenced by tension cracks and the majority of these areas are associated with stacked barrier and fire barrier pillars. The potential impact of these areas can be reduced by modifying the

mine layout to stagger abutment and fire barrier pillars so that they are not vertically aligned in the two seams. This would result in some limited loss of reserves in the lower seam, but the potential benefits may outweigh this disadvantage.

Protection of perennial drainages under Alternative 2 may provide a major degree of protection for access roads to private cabins in Little Swens, Swens and Flat Canyons.

8.2.4 Flat Canyon and Swens Canyon Cabins

The four private cabins within the RFDS Area in Flat Canyon and the one in Swens Canyon are relatively modest log or timber frame structures supported on concrete strip or pad foundations. There are some other properties further along Flat Canyon and up Little Swens Canyon, but these are outside the area under consideration.

Total subsidence predicted in the area of the cabins in Flat Canyon resulting from single seam mining is 4.7 ft, with a lateral strain of 2.3 ft over 500 ft and a maximum differential of 0.7%. Total subsidence in the area of the Swens Canyon cabin due to two seam mining is 10.7 ft, with a lateral strain of 2.7 ft over 600 ft and a maximum differential of 1.5%. From a structural perspective, the critical displacement criteria are the maximum differential settlement and maximum lateral strain that would occur beneath the cabin foundations, both dynamic as the subsidence progresses through an area and static at the limits of mining.

Dynamic subsidence under the cabins would be felt and would likely cause minor distress in the structures, particularly in any finished surfaces. Doors and windows may fail to operate normally and non-flexible underground service connections may rupture. Four of the five cabins are likely to be close to the limit of mining and as such would experience static subsidence. This would amplify the adverse dynamic effects on the structures and may result in permanent differential settlement of the cabins. Leveling, structural repair and re-finishing would likely be necessary in the cabins close to the limit of single seam mining in Flat Canyon and significant reconstruction may be necessary where the cabin is near the limit of two seam mining in Swens Canyon. The rate of dynamic subsidence will be governed by the longwall face retreat rate and may take a number of days for the major active zone to pass each cabin site. Occupancy during this phase should not be permitted, particularly during second seam mining. The estimated costs of mitigating the effects of undermining is shown in Section 8.3 and are approximately $380,000 for Flat Canyon and $360,000 for Swens Canyon cabins.

Mitigation by applying surface control measures or modification of mining layouts may reduce the level of impact to these structures. Some of the mitigation options that might be considered are listed below:

- trenching around structures to isolate the foundations from the sub-soil tensile zone;
- provide flexible joints for utilities;
- jacking the structure in order to minimize structural distortion;
- reinforcing structural elements that are weak in tension;
- avoiding full extraction mining within the angle of draw from the structure or limiting extraction heights;
- restricting stacked abutments, fire barrier pillars or other pillars that would result in significant permanent tensile forces applied to the structure; and
- rapid extraction below the structure to minimize dynamic subsidence.

During development of a detailed mine plan further consideration can be given to providing acceptable mitigation with a combination of modifications to the mine layout and carrying out protective measures at surface where this is expected to be beneficial.

The protection of perennial drainages under Alternative 2 will provide some degree of protection for cabins at the edge of the alluvium, but may result in others being subjected to increased impact as a result of abutment pillars being required below them. This is especially true for the cabins north of the highway in Flat Canyon and the cabin in Swens Canyon. The degree of this impact might be reduced by modifying the mine layout to stagger abutment pillars or widening the protection zone at these locations.

8.2.5 Flat Canyon Campground

The Campground is located at the junction of Flat Canyon and Boulger Canyon overlooking the Boulger Dam and reservoir. There are several prepared camp sites located within a treed area on a gentle slope, together with centrally located restrooms. Water supply to the campground is from a spring located approximately 3000 ft south west along Boulger Canyon. Access roads to the camp sites and the sites themselves are all of flexible construction. Details of the restroom facilities, indicate a wood frame superstructure supported on a 6.5" reinforced concrete pad integral with a below grade storage vault approximately 12 ft long, 7 ft wide and 4 ft deep.

A small aluminum tied-back retaining wall impounds a small headpond at the spring location which feeds into a short length of 4" cast iron pipe to a valve and vent, and then into a 2" galvanized steel pipe to the campground. At the campground, the galvanized steel pipe feeds into a buried 3000 gallon fiberglass tank that in turn feeds 5 hydrants and the restrooms. The system is

gravity fed and contours shown on the plans supplied by the Forest Service indicate a head differential of approximately 5 ft.

Two seam mining is expected in the area of the campground and the spring with a maximum predicted subsidence of 14.4 ft, a lateral strain of 4.5 ft over 500 ft and a maximum differential settlement of 3.0%. Dynamic subsidence that progresses through the site would be felt and may cause minor distress in the restroom structure but nothing that would affect usage. The campsite may be close to the limit of Lower O'Conner 'A' Seam mining, which would result in static subsidence. This would amplify the adverse dynamic effects on the structures and may result in permanent differential settlement of the restroom structure; however, the integrity of this relatively small structure should not be affected and no structural enhancement is expected to be required. Cosmetic repair will likely be required, such as the re-adjustment of door openings to ensure correct operation.

As dynamic subsidence progresses through the alignment of the water supply pipeline, spring, storage tank and hydrant locations, pipe connections could become overstressed and fracture. This would require a program of regular monitoring and maintenance.

Of more concern is the potential for the head differential between the spring and the storage tank being reduced by differential subsidence at the two sites. The storage tank is located close to the limit of two seam mining whereas the spring is located well within the area of two seam mining. Should the static subsidence at the storage tank be closer to that expected for single seam extraction, the driving head would be eliminated and the gravity fed water supply would be shut down. This would require either raising of the headpond at the spring or the installation of a pumped system. Total estimated costs for mitigation are approximately $53,000.

During development of a detailed mine plan further consideration can be given to providing acceptable mitigation with a combination of modifications to the mine layout and carrying out protective measures at surface where this is expected to be beneficial.

The protection of this facility is covered under Alternative 2 and no full extraction mining would be allowed within the angle of draw in this case. Partial extraction room and pillar mining would be allowed and providing adequate pillar dimensions defined there is not expected to be any significant impact for this alternative.

8.2.6 Gas Transmission Pipeline #41

The #41 gas transmission pipeline runs down Burnout Creek over the existing Skyline Mine and then follows Huntington Creek running north outside the east boundary of the Tract. The pipeline does not cross any part of the Lease area and as no subsidence under Huntington Creek is to be permitted, the line would not be affected by any longwall mining subsidence at Flat Canyon. Similarly, the magnitude of any mining induced seismicity in the area of Huntington Creek is not expected to adversely affect the integrity of the gas pipeline.

The possibility of pillar failure below Upper Huntington Creek, and resulting subsidence if this were to occur, has been evaluated in Section 7. This is not expected to occur with the provision of adequate pillar dimensions, consequently no evaluation or estimation of associated costs has been carried out. If the gas transmission pipeline is still operational at the time of mine abandonment, then any potential impacts and associated mitigation options can be addressed at that point in time.

8.2.7 Natural Canyon Slopes and Road Cuts

Most of the major natural canyon slopes in the Lease area were inspected during the site visit in June and all others were studied on aerial photography. In addition, the natural slopes that have already been subsided over the Skyline Mine at Burnout Canyon were inspected. All slopes in the area were found to be stable with no signs of any significant movement. No significant natural escarpments or erosional features are present in the RFDS Area. Most of the natural slopes are in the range of 10 to 20 degrees with a few locally steeper on the east and west flanks of Boulger Canyon where slopes up to 25 to 35 degrees are present. There is one road cut in stable weathered rock on the north side of Highway SR 264 just downstream of Boulger Dam.

Natural slopes in the area of the Flat Canyon Lease Tract are expected to perform in a similar manner to those over the existing Skyline Mine and no significant instability in the natural slopes is expected to result from longwall mining over the area north of Boulger Canyon. It is unlikely that any instability would occur in the steeper slopes either side of Boulger Canyon or in the road cut, however a program of monitoring of these areas should be established. In particular, a possible fault has been interpreted along the west slope of Boulger Canyon in the vicinity of the water supply pipeline to the campground and subsidence in this area could concentrate along the fault and cause slope movement that may affect the water supply.

Mitigation of the potential impacts may be considered where the mine layout includes stacked abutment and fire barrier pillars. In these cases consideration might be given to staggering the alignment of these pillars by increasing their size in the lower seam with only a limited impact on recovery of reserves.

The potential for impact will be increased with Alternative 2 due to the stacked pillars resulting in significant permanent tension zones along the slopes adjacent to perennial drainages. In this case the staggering of abutment pillars may be more important.

8.2.8 Electric Lake Dam

Mining within the RFDS area will not cause any surface subsidence in the area of Electric Lake Dam. Furthermore, location of the main development corridor and the gentle slopes in the vicinity of Electric Lake preclude the potential for subsidence induced slope failures in near vicinity to the lake shore creating a surge in the lake level that might threaten the dam. Due to the very low potential for subsidence to impact this structure, either directly or indirectly, no subsidence prediction point has been used to estimate subsidence.

Mining induced seismic loading on the structure has been estimated to be less than 0.1 g, from similar assessments described for the Boulger Dam. This evaluation indicates that, using an MCE of 3.3, as used for assessing the two smaller dams, the ground vibrations will be less than 0.1g at a horizontal distance greater than about 5500 ft from the mine workings.

If a more conservative approach is taken by assuming that the higher MCE of 3.8, experienced at Gentry Mountain for room and pillar workings, is used then the ground vibrations are estimated to be less than 0.1g at a horizontal distance of about 8600 ft from the mine workings. Seismic analysis of the Electric Lake Dam has confirmed (Harding Lawson & Associates, March 2000) that the structure can withstand bedrock ground vibrations of 0.1g for an Operating Basis Earthquake (OBE) and 0.53 g for an MCE. The dam is over 9400 ft from the closest mine workings defined by the RFDS and hence any impact from mining induced seismicity is very remote.

8.3 ESTIMATED COSTS ASSOCIATED WITH LOSS OF USE AND REMEDIAL WORKS

Estimated costs associated with loss of use and remedial works are shown in Table 8.1. The relevant costs, also quoted in Section 8.2, are not detailed and should be treated as order of magnitude estimates.

Table 8.1
Flat Canyon Cost Estimates

Item	Description	Calculation	Quantity	Units	Rate	Cost
1	**BOULGER DAM**					
1.1	*Reconstruction*					
	Pumping/diversion					10,000
	Excavation	(90*(15*16+16/2*(48+32))+130*(15*8+8/2*(24+16))/27	4281	yd^3	15	64,222
	Foundation preparation	220*70/9	1711	yd^2	5	8,556
	Place and compact earthfill	(90*(15*16+16/2*(48+32))+130*(15*8+8/2*(24+16))/27	4281	yd^3	25	107,037
	Riprap replacement					15,000
	Engineering/approvals etc.					40,963
	Contingency		15%			36,867
	Total					282,644
1.2	*Downstream berm*					
	Stripping	220*50/9	1222	yd^2	3	3,667
	Foundation preparation	220*50/9	1222	yd^2	5	6,111
	Place drain	220*35/9	856	yd^2	20	17,111
	Place and compact earthfill	20*10*220/27	1630	yd^3	25	40,741
	Engineering/approvals etc.					10,144
	Contingency		15%			11,666
	Total					89,440
1.3	*Repair cracks*					
	Excavate	25*2*20*1	37	yd^3	30	1,111
	Fill and compact	25*2*20*1	37	yd^3	35	1,296
	Engineering/inspections etc.					5,000
	Contingency		15%			1,111
	Total					8,519
1.4	*Place upstream blanket*					
	Pumping/diversion					7,000
	Remove riprap					10,000
	Surface preparation	220*60/9	1467	yd^2	5	7,333
	Place and compact blanket	1.5*220*60/27	733	yd^3	25	18,333
	Riprap replacement					15,000
	Engineering/approvals etc.					11,533
	Contingency		15%			10,380
	Total					79,580
1.5	*Loss of use*					
	Reconstruction		4	month	10000	40,000
	First seam undermining		12	month	10000	120,000
	Second seam undermining		12	month	10000	120,000
1.6	*Fish Ladder repairs*					
	Clean out joints	10*20	200	ft	50	10,000
	Replace and re-cast	10*20	200	ft	100	20,000
	Contingency		15%			4,500
	Total					34,500
1.7	*Pervious control dyke*					
	Stripping	250*80/9	2222	yd^2	3	6,667
	Place coarse fill		4000	yd^3	25	100,000
	Culverts		200	ft	50	10,000
	Engineering/approvals etc.					23,333
	Contingency		15%			17,500
	Total					157,500

Table 8.1
Flat Canyon Cost Estimates

2	**LDS CAMP DAM**					
2.1	*Reconstruction*					
	Pumping/diversion					2,000
	Excavation	(90*(15*14+14/2*(35+28))+250*(15*7+7/2*(18+14)))/27	4179	yd^3	15	62,689
	Foundation preparation	400*70/9	3111	yd^2	5	15,556
	Place and compact earthfill	(90*(15*14+14/2*(35+28))+250*(15*7+7/2*(18+14)))/27	4179	yd^3	25	104,481
	Riprap placement					15,000
	Engineering/approvals etc.					39,945
	Contingency		15%			35,951
	Total					275,622
2.2	*Downstream berm*					
	Stripping	400*50/9	2222	yd^2	3	6,667
	Foundation preparation	400*50/9	2222	yd^2	5	11,111
	Place drain	400*40/9	1778	yd^2	20	35,556
	Place and compact earthfill	20*10*400/27	2963	yd^3	25	74,074
	Engineering/approvals etc.					19,111
	Contingency		15%			21,978
	Total					168,496
2.3	*Loss of use*					
	Reconstruction		4	month	10000	40,000
3	**HIGHWAY SR 264**					
	Resurfacing		500	ft	45	22,500
	Restore roadbase		300	ft	35	10,500
	Regrade ditches		500	ft	25	12,500
	Contingency		15%			6,825
	Total					52,325
4	**UNPAVED ROADS**					
	Additional grading		1200	ft	10	12,000
5	**FLAT CANYON CABINS**					
	Restore levels		20000	unit	3	60,000
	Structural repair		30000	unit	3	90,000
	Restore finishes		15000	unit	4	60,000
	Inconvenience to owners		20000	unit	4	80,000
	Engineering/approvals etc.					43,500
	Contingency		15%			50,025
	Total					383,525
6	**SWENS CANYON CABIN**					
	Significant Reconstruction		220000	unit	1	220,000
	Inconvenience to owners		50000	unit	1	50,000
	Engineering/approvals etc.					40,500
	Contingency		15%			46,575
	Total					357,075
7	**FLAT CANYON CAMPGROUND**					
	Cosmetic repairs to restrooms					5,000
	Repair fractured hydrant supply					5,000
	Repair supply pipe from spring					10,000
	Raise and re-build headpond OR					
	Install pumped supply					20,000
	Engineering/approvals etc.					6,000
	Contingency		15%			6,900
	Total					52,900

SECTION 9

NorWest Mine Services

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APPENDIX A

EIS SUMMARY

EIS SUMMARY

GEOLOGY, MINING, SUBSIDENCE & SEISMICITY

1. AFFECTED ENVIRONMENT

Geology

The RFDS area is located in the Wasatch Plateau, a sub-province of the Colorado Plateau Physiographic Province. The geology of the Wasatch Plateau has been described by Spieker (1931) and Witkind and Weiss (1991). The geology of the Skyline Mine area and the RFDS area has been described by Knowles (1985), Oberhansley (1980), and by Canyon Fuel (1999). Larson (1996) described the glacial geomorphology of the RFDS area. Information on the geology of the area has also been gathered from field observations, discussions with the mine geologist, and drill hole logs.

In the Skyline Mine and RFDS areas five bedrock formations are exposed at the surface. In ascending stratigraphic order these are the Star Point Sandstone, Blackhawk Formation, Castlegate Sandstone, Price River Formation, and North Horn Formation. These formations are shown on a generalized columnar section (Figure A.1) and on a geologic map (Figure A.2). In the RFDS area bedrock formations are largely covered by thin, unconsolidated, Quaternary-age sediments including soil, alluvium, and glacial deposits.

Bedrock formations were deposited during the Late Cretaceous and Tertiary periods. Multiple transgressions and regressions of the Western Cretaceous Interior Seaway resulted in the deposition of a heterogeneous sequence of rock types that are both horizontally and vertically discontinuous. On the terrestrial side of the shoreline, sediment deposition occurred in lacustrine, fluvial, flood plain, and coal swamp environments. Along the shoreline beach sands accumulated. Offshore, sands swept from the beaches were laid down as bars and blankets of sand in the near-shore shallow marine water. The clay fraction of stream transported sediments reaching the shoreline were deposited as marine muds in deeper and more quiescent portions of the seaway (Mayo and Associates, 1997).

In Pleistocene time, the Wasatch Plateau was glaciated at least twice. The most recent glaciation ended at least 15,000 years before present (Larson, 1996). The geomorphology of many parts of the RFDS area is a result of glaciation.

Individual stratigraphic units are discussed below.

Star Point Sandstone

The Star Point Sandstone is a marine shoreface deposit that is not exposed in the RFDS area but is a prominent cliff former in canyons to the east. In this part of the Wasatch Plateau, the sandstone is comprised of two massive units, the Storrs Tongue and the underlying Panther Tongue, which intertongue with the lower Blackhawk Formation. The Storrs and Panther tongues both consist of fine- to medium-grained, sub-rounded to well-rounded light colored sandstone with a "salt and pepper" appearance. Measured thickness of the formation east of the Skyline Mine is 1,289 feet (Canyon Fuel, 1999).

The Storrs Tounge pinches out westward within the southern portion of the Flat Canyon Tract.

Blackhawk Formation

The Blackhawk Formation is 1,700 to 1,900 feet thick in the RFDS area (Canyon Fuel, 1999). However, only the uppermost 200 feet are exposed in outcrop within the RFDS area (Oberhansley, 1980). The Blackhawk Formation consists mainly of lenticular sandstone, siltstone, and claystone. The lower portion of the Blackhawk Formation is the coal-bearing section of mining interest.

Well drilling reports and laboratory analysis of samples indicate that claystone layers contain swelling clays that are expected to plastically deform and heal when fractured. Chempet Research Corporation (1989) found some claystone layers contained up to 58% montmorillonite, a swelling clay. Vaughn Hansen Associates (1982) report that holes drilled into the Blackhawk are very unstable, and when left open for a few days, slough badly. Shale and claystone horizons within the Blackhawk Formation provide barriers to vertical movement of water.

Coal to be mined in the RFDS area occurs in the lower portions of the Blackhawk Formation. Within the bottom 100 feet of the Blackhawk are several coal seams between the Storrs and Panther Sandstone tongues. Of these seams only the lowest-lying Flat Canyon seam is mineable.

The upper coal-bearing unit of the Blackhawk Formation, immediately above the Storrs tongue, contains three mineable seams, but only the Lower O'Connor B seam is mineable under the majority of the Tract. The Lower O'Connor A seam is not considered mineable until it merges with, and becomes part of, the Flat Canyon seam in the central and northern section of the RFDS area, although there may be areas with mineable thickness in the southern section of the RFDS.

Additional coal seams occur in the upper part of the formation, but these are typically discontinuous and only locally of mineable thicknesses. The coals are described as mid-lustrous, resinous and containing attrital materials. They are classified as high-volatile "B" bituminous in rank.

Castlegate Sandstone

The Castlegate Sandstone is a cliff-forming unit in much of the Wasatch Plateau. However, in the RFDS area, the Castlegate Sandstone does not form a prominent cliff but forms steep slopes with only occasional outcrops. The sandstone is light gray to light yellowish gray, medium- to coarse-grained, and occasionally conglomeratic. The reported thickness is 220-320 feet (Oberhansley, 1980).

Price River Formation

The Price River Formation is a slope-forming unit that is poorly exposed in the area because of vegetation and the thick soil mantle. Oberhansley (1980) reports that the formation consists of thin- to thick-bedded sandstone and mudstone. Mudstone beds are thicker and more common in the lower part of the formation while the top part of the formation contains thick massive channel sandstones. Sandstones thin laterally in both directions. The unit is 220 to 280 feet thick.

North Horn Formation

The North Horn Formation caps the uplands of the RFDS area. The formation consists of thick-to thin-bedded sandstone and mudstone in the lower 200 feet, a 430-foot thick middle unit that is comprised of interbedded lacustrine limestone, sandstone, and mudstone, and an upper unit that is similar to the lower unit. The complete formation is 1,350 feet thick (Oberhansley, 1980).

Alluvium

Minor alluvial deposits are found in the canyon bottoms. Soil and colluvium are relatively thick and cover most of the slopes in the area.

Glacial Deposits

Glacial deposits consist of terminal, recessional, and ground moraines. Morainal deposits are most notable in Boulger Canyon. Boulger Dam sits on terminal moraine and lateral and recessional moraines are visible along most of Boulger Canyon. End moraines are found near the head of Swens and Little Swens Canyons. The Boulger Canyon glacier and glacial moraine deposits created an impoundment in Flat Canyon that subsequently has filled with sediment. Exploration drill holes (CFC, 2000) show that these glacio-lacustrine deposits consist of 70 to 90 feet of primarily sand and gravel with only minor fine-grained materials.

Structure

The Tract is situated on the western limb of the Clear Creek Anticline and the dip of the sedimentary rocks is generally toward the west. Dips range from 3° to 6° within the lease area (Canyon Fuel, 1999).

Complex sets of north-south and northeast-southwest trending Cenozoic faults extend along the entire length of the Wasatch Plateau (Williams and Arabasz, 1989). The dip of the major faults is generally near vertical. The Connelville fault zone east of the RFDS has between 55 to greater than 250 feet of displacement and extends up to 1,000 feet in width. This fault zone forms the eastern mining limit of the current Skyline leasehold (Canyon Fuel, 1999). To the west of the RFDS area the bounding fault of the Goosberry Graben has a displacement ranging from 850 feet to 1,180 feet (Oberhansley, 1980). Geomorphology of the RFDS area suggests (Canyon Fuel, 1999) the probability of at least three northeast-southwest trending fault zones. These faults may be associated with the North Joes Valley fault zone as it dies out northward into the Tract area. Exploration to determine the location and throw of these potential faults is ongoing. Faults of this orientation have been encountered in Skyline mine workings with throws in the range of inches to over 20 feet.

Two other fault orientations have been encountered with trends of N. 80 W. and N. 60 W. Throws on the east-west trending faults are usually less than 10 feet. One N 60 W trending zone was encountered with displacements in excess of 40 feet. It is expected that these east-west trending faults occur in the Tract (Canyon Fuel, 1999).

Canyon Fuel (1999) has mapped four major joint and fracture orientations on the Skyline leasehold. The most common orientation observed within coal beds and immediate roof and floor strata are a set of joints spaced approximately 1 to 3 feet apart with a N 80 W orientation. This joint set is only occasionally observed in outcrop. A second joint orientation observed in the mines as well as in outcrop, are a set of N 5 W to N 20 E joints, spaced from 1 foot to over 10 feet apart at the surface. The remaining two orientations are a system of conjugate shear fractures and joints which are oriented at approximately N 60 W, and S 70 W, respectively.

Igneous dikes oriented in a nearly east-west direction occur within the RFDS area. Numerous dikes have been encountered during the mining activities located east of the RFDS area. The dikes are comprised of phlogopite mica-rich, quartz-poor material classified as lamprophyre. Where individual dike blades cut coal seams, a thin halo of coked coal is normally present. Dike width in coal varies from a few inches to tens of feet.

Mining

Previous Mining

Previous mining in near vicinity to the Tract has been at the Skyline Mining Complex with surface facilities located east of the Tract in Eccles Canyon. The complex is made up of the Skyline No.1, No.2 and No.3 Mines that have extracted coal underground using the longwall mining method. They utilize common infrastructure and are located in three separate coal seams which partially overlap each other in the current mine permit area. Historically, production has utilized two sets of longwall mining equipment operating concurrently in separate mines. However, current production is from a single longwall face operating in the Lower O'Connor B Seam of the Skyline No.2 Mine. The relation of the existing mine workings to the Tract is shown on the Location Map presented in Figure M.1 (Figure 1.2 in technical report).

The longwall mining method requires continuous miners to create development entries used for access to longwall mining areas. The coal is then fully extracted using longwall face equipment from panels about 800 ft. wide and up to 15,000 ft. long. The continuous miners can also be used to extract coal by room and pillar methods using partial or full extraction where feasible. Previous mining at Skyline has included little production from room and pillar mining areas.

The Skyline No.3 Mine has been restricted to extraction of the Lower O'Connor A Seam in the northern section of the current lease. In the central and southern sections of the current lease the No.1 Mine workings in the Upper O'Connor Seam have been mined and production is now from the Lower O'Connor B Seam below. In this area extraction of multiple seams has been carried out, with the seams extracted sequentially from the top down with extraction heights of up to 14 feet in a single seam and up to 25 feet where both seams have been mined.

Full extraction longwall mining results in failure of the immediate roof strata, leading to fracture and flexure of the overburden rocks progressing upwards and resulting in surface subsidence. The degree of subsidence varies with mining layout and thickness of extraction. With the overburden depths at Skyline, flexure of the rock strata occurs near the surface due to differential subsidence, generally without fracture. However, in some isolated areas tension fractures can open up where the degree of tension is more pronounced and the strain is not uniformly distributed, such as where strong rock beds are located near the surface.

The dynamic subsidence resulting from a longwall face passing beneath the surface produces a zone of flexure where tension can sometimes result

in minor cracking of the surface that is soon followed by a zone of compression where the fractures close and rapidly heal.

Permanent tensile zones are observed above coal pillars left underground at the edge of longwall extraction areas and if fractures open up in these areas they may take longer to heal. The experience of longwall mining at Skyline is that very few tensile fractures are observed following extraction of a single seam at depths greater than 600 feet. The majority of cracks are associated with mining of the lower seam and are located where differential subsidence is concentrated at pillars which are vertically aligned in both seams. These conditions give rise to the highest degree of flexure with associated tensile zones near surface.

Although the vertically aligned or stacked pillars produce the greatest zones of tension the formation of fractures does not generally occur unless the surface has little lateral constraint, as in the case of ridges. Of the total area mined at Skyline, less than 0.5% has produced tensile fractures. The majority of this area was associated with an area known as Trough Springs Ridge.

Sometimes it is necessary to leave pillars between two adjacent longwall areas. This can result in increased tension, such as that experienced at Trough Springs Ridge above a fire barrier pillar left in both seams. In this case major fractures were observed after mining of the lower seam in an area where strong sandstone beds were located near the surface on a ridge where lateral constraint was absent. Tension fractures opened up in a zone that was 1500 feet long with fractures that were from several inches to 5 feet wide and up to 200 feet long. The fractures created a short term safety hazard, but were mitigated by filling with soil. No long term adverse impact is expected. In this area up to 23 feet of coal was extracted in two seams with depths from 650 to 1100 feet.

An expanded zone of fracturing can increase the potential for vertical groundwater permeability. Experience at Skyline with longwall mining of two seams below Burnout Canyon has shown that no long term adverse effects have been observed with surface waters and near surface aquifers. This has included a section above the same fire barrier that led to the Trough Springs Ridge tension cracks opening up. Overburden in the Burnout Canyon area has been as low as 600 feet with extraction of up to 23 feet and subsidence of up to 14 feet observed.

Subsidence can also have adverse effects on slope stability, but no major slope failures have been observed at Skyline. Undermining of State Highway SR 264 has also taken place with minor damage observed that required repair without long term impact.

Mining induced seismicity has also been experienced as a direct result of longwall mining at Skyline. A study of this phenomenon was carried out from 1986 to 1996 while the Skyline Mine was operating in the northern section of the current mining lease (Arabasz et. al., 1996). During this time one longwall unit was operating at depths ranging from 1200 feet to 2000 feet while a second longwall unit was operating at depths ranging from 400 to 1300 feet.

Results of the study indicated a very strong correlation between mining induced seismicity and longwall production at depths greater than 1500 feet. During this time the Mine was experiencing stress-related problems caused by coal bumps at depth in the Skyline No.3 Mine. No surface damage associated with this mining was reported, although mining was not carried out in close vicinity to sensitive structures. A large campground, small dam and private cabins were location within 7,000 feet of these mine workings. The mining was also in the vicinity of Highway SR264 and a gas transmission pipeline. There was no reported damage due to seismicity. The natural slopes in the area are similar to those in the Tract and no evidence was reported of slope instability as a result of seismicity.

Current mining is projected to continue with extraction of the Lower O'Connor B Seam in a limited area at the southern end of the current lease and a new lease is required if the mine life is to be extended.

Reasonably Foreseeable Development Scenario

The geologic conditions predicted in the Tract indicate that mining conditions would be relatively similar to those that have been experienced in the Skyline Mines, except that the reserves become progressively deeper towards the West. The Reasonably Foreseeable Development Scenario (RFDS) for future mining in the Tract has been developed on the assumption that longwall mining would be carried out on a similar basis to that successfully employed at Skyline.

Main underground mining access to the Tract is planned in the Lower O'Connor B Seam by the westerly extension of the current main development entries in the Skyline Mine. To provide sufficient capacity for ventilation, access, escape and haulage it is probable that all of the six entries in the existing mains would need to be developed into the new area.

For Maximum Economic Recovery (MER) it has been assumed that a Main Development Corridor would be located below Upper Huntington Creek, as this would afford protection of this perennial drainage from subsidence, while allowing efficient recovery. The proposed corridor is about 1600 feet wide and

is sufficient to allow for a sufficient number of entries and pillars with adequate dimensions to ensure long-term stability.

In order to ensure adequate ventilation and mine dewatering at least one, and possibly two, return ventilation shafts would need to be constructed within the Tract area. The general areas for the proposed ventilation shafts are shown in Figure M.1. They would be vertical shafts that do not require the installation of power or fans. The northerly vent shaft would be needed early in the mine life, but the southerly vent shaft is less certain and has been included as a contingency.

The main development system would be connected to these ventilation shaft(s) and sub-mains might also be required for access to production areas. Mining the majority of the Tract area would generally be at greater depths than the majority of the current lease, varying from about 1000 feet to over 2000 feet.

Access to the Flat Canyon and Lower O'Connor 'A' Seams would be from underground, by developing rock entries at a slope to access mains in the lower seam. The lower main development entries and pillars would be driven underneath those in the upper seam and pillars would be vertically aligned to minimize adverse stress interactions and optimize coal recovery.

Production is planned by longwall methods similar to those currently being used in the Skyline Mine. It is expected that panels would be about 800 feet wide and their length would vary from about 3,000 to 15,000 feet, depending upon selected mine layout and both geological and operational constraints.

The most likely orientation of longwall panels would be approximately N-S, which has been shown to be successful at Skyline. Previous mining experience has also shown that an orientation approximately E-W would also be acceptable. Other geological and operational constraints may influence the final choice of panel orientation. Protection of surface structures and resources may also provide additional constraints on the location, orientation and sequence of longwall extraction.

Mine production is planned from a single longwall section, in conjunction with production from continuous miners driving development entries. Additional production may come from room and pillar extraction, although a depth limitation of 1800 feet for this method has been assumed. There are two mineable seams over the majority of the area and the upper Lower O'Connor B Seam would be mined first, followed by the lower Flat Canyon Seam.

The BLM have identified in the Tract Delineation Report longwall mining reserves of about 36 million tons. At an estimated annual production rate of three to four million tons this would extend the life of the Skyline Mine from nine to twelve years.

Reasonable equipment constraints for the definition of the minimum and maximum extraction heights for full extraction longwall mining have been assumed for evaluation of impacts due to subsidence. For the upper seam an operational height range from 8.5 to 12.5 feet is reasonable. The lower seam is thinner and longwall equipment with a height range from 7 ft. to 10 ft. is more reasonable. These are not definitive height restrictions and it is possible that longwall mining down to 6 feet, or higher than 12.5 feet, could be undertaken in some areas where conditions and equipment allow.

For the prediction of subsidence it has been assumed that a three entry gate road system would be used between longwall panels with a combination of yield and rigid pillars. This is considered to be a conservative assumption, as other options might include two or three entry gate roads with yield pillars that would be expected to produce lower differential subsidence.

Areas not amenable to longwall mining, due to their shape, size, coal thickness or surface protection requirements, have been evaluated on the assumption that they would be mined by room and pillar using full or partial extraction methods.

2. POTENTIAL ENVIRONMENTAL CONSEQUENCES

This section is restricted to the prediction of surface disturbance and mining induced subsidence and seismicity, with the environmental consequences limited to those that affect structures and facilities. The impact on Surface Water and Groundwater Resources, and Vegetation and Wildlife, are discussed in other sections.

Surface Disturbance

Surface disturbance associated with development of facilities and exploration drilling on the Tract would be small; being limited to a number of exploratory drill holes and one or two passive ventilation shafts being the only newly constructed facilities.

It is estimated that about ten additional holes will be required and the area disturbed by temporary access roads would be about 3.4 acres and that for drill pads about 4 acres. The total disturbance would be about 7.4 acres.

Ventilation shafts would not be constructed until underground mining progressed to each location and additional ventilation was required for safe operations. The general area proposed for location of these shafts is shown in Figure M.1. The construction footprint for each ventilation shaft would be approximately one acre and about 1000 feet of access road would be required, giving a total of about 2.4 acres. These areas would be disturbed for the majority of the mine life and then they would be abandoned and reclaimed thereafter.

The total new surface disturbance for the Tract would be about 10 acres with this divided into about 4.5 acres for access roads and 5.5 acres for drill pads and ventilation shafts. This disturbance is related to predicted surface facilities only and does not include subsidence resulting from underground mining.

Subsidence and Seismicity

The evaluation of effects due to subsidence and seismicity has been carried out based on the following criteria:

- Mining of the underground coal reserves can cause subsidence, seismicity, and cracking of the ground surface.

  Evaluation Criteria: Location and Amount of Subsidence Expected (measured in feet), Maximum Credible Mining-Induced Seismic Event By Range of Magnitude and Probability (Richter, % probability), Location and Severity of Cracks (primarily based on monitoring at Skyline Mine), Connection Between Surface and Underground Cracks Relative to Depth of Cover, Angle-of Draw, Tension and Compression Zones, Perception of Seismic Events by Campers and Dispersed Recreationists in the Area.

- Pillars in full-support mining areas intended to prevent subsidence could fail due to unforeseen geologic circumstances and oxidation/stress over many years. Planned full-support mining areas under Huntington Creek and other protected areas must be specifically analyzed.

  Evaluation Criteria: Support Capability of Pillars and Probability of Surface Subsidence in Planned Protected Areas for Long-Term (200 years).

Structures and Facilities

The following structures and facilities require evaluation:

- Mining-induced subsidence and seismicity could damage the Boulger Dam (including the fish ladder) and Reservoir.

Evaluation Criteria: Type and Risk of Damage (Damage Description, % probability), Cost of Repair, Public Safety Risk, Time Needed for Repairs/Duration of Lost Use, Cost of Lost Use.

- Mining-induced subsidence could damage State Hwy. 264.

  Evaluation Criteria: Description of Potential Damage and % Probability, Public Safety Risk, Cost of Repair, Cost of Lost Use

- Mining-induced subsidence could damage Mainline #41 gas transmission pipeline.

  Evaluation Criteria: Description of Potential Damage and % Probability, Public Safety Risk, Cost of Repair, Cost of Lost Use

- Mining-induced subsidence and seismicity could damage facilities at the Flat Canyon Campground (including spring source, water storage tank, and associated pipeline).

  Evaluation Criteria: Description of Potential Damage, Cost of Repairs, Duration of Lost Use, Cost of Lost Use

- Mining-induced subsidence could damage recreation cabins and/or camp facilities and roads on adjacent private lands that are mined as a result of leasing the Flat Canyon Tract.

  Evaluation Criteria: Description of Potential Damage, Safety Risk, Cost of Repair, Duration of Lost Use, Cost of Lost Use

Subsidence

A total of nine subsidence prediction points have been used for the evaluation of impact to structures, facilities and resources and their locations are presented in Figure M.2 (Figure 4.1 in technical report). The main resources, structures and facilities that have been evaluated for impact from mining induced subsidence are listed below together with their description and reference to the numbered prediction points used to characterize the degree of subsidence:

Boulger Dam & Reservoir
This is an earthen dam and associated reservoir located at the mouth of Boulger Canyon near its confluence with Flat Canyon. The reservoir is below and adjoining the Flat Canyon Campground and provides recreational amenities. A fish ladder has been recently constructed to allow riparian access between the Boulger Canyon and Electric Lake. Characterization for this structure is covered by Subsidence Point No.6.

State Highway 264
This is a paved, all-weather highway passing through the Tract following the valley floors of the Upper Huntington Creek, Boulger Canyon and Flat Canyon. Characterization of this structure in Flat Canyon is covered by Subsidence Point No.5 and in Boulger Canyon by Point No.6. Where it runs alongside the west side of the Upper Huntington Creek valley floor it is protected from subsidence by restrictions on longwall mining below this important drainage.

Mainline #41 Gas Transmission Pipeline
The Mainline #41 gas transmission pipeline in the Tract area runs in Burnout Canyon and then alongside Highway SR 264 on the west side of the Upper Huntington Creek valley floor where it is protected from subsidence by restrictions on longwall mining below this important drainage.

Flat Canyon Campground & Facilities
The Flat Canyon Campground facility is operated by the Manti-LaSal National Forest Service and consists of camping areas with associated freshwater and toilet facilities. Freshwater is provided by a spring collection system located on the west side of Boulger Canyon with the water fed to the campground through a buried pipeline and storage tank near the campground. Characterization of these facilities is covered by Subsidence Point No.8 for the spring collection system and No.5 and No.6 for the Campground.

Private Cabins & Buildings
Within the area influenced by mining (RFDS) there are a number of privately owned cabins in Flat Canyon and Swens Canyon. Characterization of the four cabins in Flat Canyon is covered by Subsidence Point No.5 and the one cabin in Swens Canyon is covered by Point No. 3.

Upper Huntington Creek Perennial Drainage
This drainage system is defined as the perimeter of the Upper Huntington Creek valley alluvium. No longwall mining that would subside this area is planned for the Tract area, but it is likely that a main development corridor would be required running parallel and under the creek at depths from 700 to 1000 feet.

Flat Canyon Perennial Drainage
This drainage system is defined as the perimeter of the Flat Canyon valley alluvium. Characterization of this canyon is covered by Subsidence Points No.5 and No.6.

Boulger Canyon Perennial Drainage
This drainage system is defined as the perimeter of the Boulger Canyon valley alluvium. Characterization of this Canyon is covered by Subsidence Points Nos. 1, 6, 7 and 8.

Swens Canyon Perennial Drainage
This drainage system is defined as the perimeter of the Swens Canyon alluvium. Characterization of subsidence in this canyon is addressed by Subsidence Points 3 and 4.

Little Swens Canyon Perennial Drainage
This drainage system is defined as the perimeter of the Little Swens Canyon alluvium. Characterization of this Canyon is covered by Subsidence Point No. 2.

Cunningham Possible Perennial Drainage
This drainage system is not projected as perennial within the Tract, but has been designated as possibly perennial on adjacent private land. Characterization of this area is covered by a single Subsidence Point No.9.

Electric Lake Dam
This is an earth and rock dam located about 2 miles south of the Tract. No mining is planned in near vicinity of this dam, but it may be subjected to mining induced seismicity.

Hunt Dam
This is a small earthen dam located outside of the RFDS, but may be subjected to mining induced seismicity.

Subsidence predictions have been based on a numerical model that has been calibrated to actual subsidence monitoring data from the existing Skyline Mine operations. The model predictions for each subsidence point were based on projected exploration data for seam thickness that was corrected for mining height where necessary. A series of different mining scenarios were evaluated to assess the most likely range of mine layouts and their effect on the range of subsidence values that might be reasonably expected.

The predictions have been primarily based on Alternative 3 with standard BLM stipulations applied to the Tract and subsidence impacts expected at all of the prediction points. The degree to which these predictions apply to Alternative 2 has then been evaluated due to the increased protection afforded in this option. An angle of draw of 23 degrees to the vertical has been assumed for estimating the surface area that is likely to be impacted by subsidence, although this does not include a buffer to allow for potential variability.

Alternative 3

In this alternative, defined by the application of standard BLM lease stipulations, the majority of the Tract would be impacted by subsidence from longwall mining with a high proportion of the area subjected to multiple seam mining. The exact subsidence impact at any particular location would be dependent on a specific detailed mine plan and extraction sequence. However, the degree of subsidence expected from different aspects of the mine layout is discussed below in relation to the major features of importance:

- panels (above the center of panels);
- single abutment pillar (above the edge of solid coal pillars);
- stacked abutment pillars (above the edge of coal pillars aligned in two seams);
- single fire barrier pillar (a fire barrier pillar is in one seam only);
- stacked fire barrier pillars (fire barrier pillars are aligned in two seams);
- gate roads (where gate road pillars are left between panels); and
- longwall face (dynamic effect at center of panels during retreat).

The manner in which subsidence occurs and the location of pillars left underground defines the range of temporary and permanent subsidence impacts to be expected. Particular zones where permanent subsidence might lead to a higher impact are related to areas of higher differential subsidence above fire barrier pillars and abutment pillar zones. Where these pillars are stacked above each other in multiple seam cases the degree of differential subsidence is much greater. The location of fire barriers cannot be reliably predicted without a specific mine plan, but the location of the major abutment zones can be reasonably estimated from the mining scenarios evaluated. The variation of subsidence and the relative degree of effect in relation to the Skyline subsidence is presented for different mining layout features in Table A.1.

Table A.1
Predicted Subsidence and Relative Degree of Effect in Comparison to Skyline

Parameter	Subsidence Prediction Point								
	1 Boulger South	2 Little Swens	3 Swens West	4 Swens East	5 Flat West	6 Boulger Dam	7 Boulger West	8 Boulger Central	9 Cunningham
Overburden Thickness above Lower Seam (feet)	1850	1600	1700	1100	1500	1200	1750	1500	1600
Number of Seams Mined	2	1	2	2	1	2	1	2	2
Maximum Subsidence (feet)									
Panels	10	5	10	12	4	13	4	13	12
Single Fire Barrier Pillar	7	2	6.5	7	2	9	2	8	7
Stacked Fire Barrier Pillars	4.5	-	4.5	5.4	2	6	3.5	5.9	5.4
Gate Roads	9.5	4.5	9.5	11.5	3.5	12.5	3.5	12.5	11.5
Degree of Differential Subsidence (Relative to Skyline)									
Single Abutment Pillar	VL	L	VL	M	L	M	VL	L	L
Stacked Abutment Pillars	M	-	M	H	-	H	-	H	H
Single Fire Barrier Pillar	L	M	L	H	M	M	L	M	M
Stacked Fire Barrier Pillars	H	-	H	VH	-	VH	-	H	H
Gate Roads	VL	VL	VL	L	VL	L	VL	VL	VL
Longwall Face (Dynamic)	VL	VL	VL	L	VL	L	VL	L	VL

VL = Very Low, L = Low, M = Moderate, H = High, VH = Very High
(relative to experience at Skyline)

The qualitative descriptors used to define the degree of differential subsidence are defined below in relation to typical conditions experienced at Skyline. They should not be regarded as quantitative and have been developed based upon relating observations at Skyline to expected subsidence from the mine layout.

Very Low: This generally applies to most of the areas between panels (above gate roads) and dynamic subsidence as the longwall face retreats at greater depth. A gentle flexure of the strata is expected with no major tension cracking and induced surface gradient changes less than about 0.4 %.

Low: This generally applies to some single abutment and fire barrier pillars at greater depth and above some gate roads and dynamic subsidence areas at shallower depth. Flexure of the strata is expected with a low potential for tension fractures to occur and induced surface gradient changes of about 0.4 to 0.8 %.

Moderate: This generally applies to single abutment pillars at shallower depth, single fire barrier pillars at depth and stacked abutment

pillars at depth. Generally flexure of the strata is expected with a low to moderate potential for some minor tension fractures to occur at ridges with low lateral constraint. Induced surface gradient changes of about 0.8 to 1.5 % are expected.

High: This generally applies to stacked abutment pillars at shallower depths and stacked fire barriers at depth. Flexure of the strata has a moderate potential for tension fractures to form at ridges or steeper slopes with reduced lateral constraint. Induced surface gradient changes of about 1.5 to 2.5 % are expected.

Very High: This only applies to stacked fire barrier pillars at shallow depths. Major flexure of the strata has a high potential to create major zones of tension fractures in areas with reduced lateral constraint. Induced surface gradient changes of over 2.5 % would be expected.

The range of subsidence predictions in Table A.1 are discussed below in relation to their effects on important resources and structures.

Potential Subsidence Effects to Boulger Dam & Reservoir
The results for subsidence Prediction Point 6 indicate that cumulative vertical subsidence of up to about 13 feet could be expected from mining two seams below the dam. The dam is already estimated to be marginally stable and will not withstand major subsidence without failure. The rate and extent of failure will depend upon the degree of differential subsidence imposed on the structure and whether or not the reservoir is drained. Due to the sensitivity of this structure it is prudent to assume that stacked abutment or fire barrier pillars will not be located within the angle of draw from the dam, as they would result in High to Very High differential subsidence. Hence, the degree of differential subsidence is expected to vary from Low to Moderate and require that mitigative measures be carried out.

The main options for mitigation are listed below:

- Drain the reservoir during subsidence and repair the dam afterwards. This is estimated to cost about $390,000, including about 2 – 3 years of lost use.
- Reinforce the structure by adding a buttress to the downstream face with the reservoir drawn down for short periods of active subsidence. This is estimated to cost about $150,000 including loss of use.

The public safety risks will need to be addressed and other mitigative measures taken to limit the potential safety hazards if the dam were to fail. This is a relatively small dam, with a limited ability to damage

infrastructure or injure personnel downstream should it fail. With the ability to carry out full or partial draining of the dam and minimize downstream damage, it is likely that acceptable mitigation safety measures can be identified.

Potential Subsidence Effects to State Highway 264

The section of the highway that passes alongside Upper Huntington Creek is protected by the requirement for protection of this perennial drainage. The results for Subsidence Prediction Points 5 and 6 in Flat and Boulger Canyons indicate that cumulative vertical subsidence from about 5 ft. in the west up to about 13 feet in the central and eastern section could be expected. The degree of differential subsidence is expected to range from Very Low to Moderate over the majority of the length of the road, with the possibility that it will be High at the east end where stacked barrier pillars will be located.

Skyline has undermined SR 264 in the past without major problems. The road follows the valley floor with thick surficial soils, predominantly of glacial origin, and lateral constraint. The effect of subsidence is expected to result in flexure of the surface with induced gradient changes up to 3% for the majority of the area and some minor surficial cracking at the east end. Resurfacing of the road at the east end with re-grading of drainage ditches and the possibility of replacement of one culvert may be required. The total costs for this work are estimated to be in the order of $52,000.

There are not expected to be any major safety concerns, although warning signs and regular inspections of the road surface are likely to be required during the periods of active subsidence.

Potential Subsidence Effects to Mainline #41 Gas Transmission Pipeline

The gas transmission pipeline runs along the Upper Huntington Creek valley floor alongside State Highway SR264. This structure will be protected due to the pillars left in the Main Development Corridor to protect this perennial drainage. Consequently, no subsidence is expected for this structure.

Potential Subsidence Effects to Flat Canyon Campground & Facilities

The results for subsidence prediction points 5, 6 and six show that from 5 to 13 feet of subsidence may be observed at the main facilities and up to 13 feet may be observed at the spring collection system. The degree of differential subsidence is likely to range from Very Low to Moderate.

Some minor damage to the restroom structure may be observed with repair of cosmetic damage to the structure expected. There is a minor potential for damage to the water supply pipeline, tank and hydrant system that

might require a program of regular monitoring and maintenance during periods of active subsidence. The spring collection system and pipeline has a very low driving head which might be eliminated under some subsidence conditions and necessitate repair work to be carried out. The total estimated cost for mitigation are in the order of $53,000. No major public safety concerns are expected for this facility.

Potential Subsidence Effects to Private Cabins & Buildings
The results for subsidence prediction points 5 for Flat Canyon and 3 for Swens Canyon indicate that subsidence will range from 4 to 10 feet in these areas. The degree of differential subsidence in both areas is expected to be from Very Low to Low.

Subsidence is likely to result in minor distress and cosmetic damage to structures and the rupture of underground service connections. Where the cabins in Flat Canyon are located close to the limit of single seam mining there is the possibility that they may be exposed to permanent subsidence requiring major reconstruction. Occupancy during active subsidence should not be permitted. The estimated costs for mitigation are estimated to be $360,000 for Flat Canyon and $360,000 for Swens Canyon. While there are safety concerns, these can be mitigated to acceptable levels.

Potential Subsidence Effects to Upper Huntington Creek Perennial Drainage
These will be addressed in the technical report on Surface Water and Groundwater.

Potential Subsidence Effects to Flat Canyon Perennial Drainage
These will be addressed in the technical report on Surface Water and Groundwater..

Potential Subsidence Effects to Boulger Canyon Perennial Drainage
These will be addressed in the technical report on Surface Water and Groundwater..

Potential Subsidence Effects to Swens Canyon Perennial Drainage
These will be addressed in the technical report on Surface Water and Groundwater..

Potential Subsidence Effects to Little Swens Canyon Perennial Drainage
These will be addressed in the technical report on Surface Water and Groundwater..

Potential Subsidence Effects to Cunningham Possible Perennial Drainage
These will be addressed in the technical report on Surface Water and Groundwater..

Potential Subsidence Effects to Electric Lake Dam
No mining will take place within 2 miles of this structure, consequently no subsidence is expected.

Potential Subsidence Effects to Hunt Dam
No mining will take place in near vicinity to this structure, consequently no subsidence is expected.

A summary of effects is presented in Table A.2 for Alternatives 2 and 3.

Alternative 2
Protection of resources, structures and facilities from subsidence impacts requires that only partial extraction is allowed within the angle of draw from full extraction mining areas. This would also result in no impact to the majority of structures that have not been included in the list requiring protection. Many of the excluded structures are located within perennial drainage alluvial deposits which provide them with protection.

The only structures not covered are two private cabins on the north side of Flat Canyon and one private cabin in Swens Canyon. These would be impacted, as the cabins in Flat Canyon are located in a single seam abutment zone and the cabin in Swens Canyon is located in a double abutment zone. The extent of potential impact would depend on the specific detailed mine layout and extraction sequence.

The partial extraction below protected surface features would need to have a sufficiently low extraction ratio, possibly in the region of 40%, to ensure that pillar failure would not result in unacceptable surface subsidence. It would be expected that a conservative pillar design would result in no subsidence at surface.

This alternative results in a potential increase in stacked abutments required to protect features. These may result in higher impact due to the increased differential subsidence values expected in these zones. However, the impact of an increased potential for cracks to remain open where strong rocks are located near surface in permanent tensile zones is discussed in other technical report sections.

Seismicity

Prediction of seismic events and the resulting ground vibrations at a given point from mining activity requires evaluation of the following parameters:

- Magnitude of Credible Event (MCE) which is historically reported as local magnitude on the Richter scale. This is based on recording vibrations within a frequency range that is important for evaluation of the impact on typical structures.
- Source location, type and period of vibrations generated.
- The mechanism involved in transmitting the vibrations through rock and soil to the ground surface, typically defined by an attenuation equation based on the distance from the source.
- The site specific reaction of the surficial materials with the bedrock interface and the degree to which particular structures respond to ground vibrations. This may involve separate evaluation of the different vibration parameters for displacement, velocity and acceleration in three orthogonal planes and their variation with frequency.

Evaluation of historic mining induced seismicity at the Skyline Mine has been used to predict the MCE level to be used in calculations. A magnitude of 3.3 was selected for the MCE based on evaluation of the results from monitoring 1013 events with magnitudes greater than 2. A source location about 500 feet above mine workings was selected to be conservative. A conservative attenuation relationship, known as the McGarr Equation, was selected for estimation of ground vibrations variation with distance from the MCE. No site specific data was available concerning the effect of vibrational coupling between bedrock, superficial materials and structures, consequently it was assumed that there was no attenuation or magnification.

Alternative 2

This alternative requires that longwall mining is not carried out directly below Boulger Dam. The recommendations for Alternative 3 are equally applicable to this alternative. However, it is possible that a different value for MCE may be applicable to this case due to the increased possibility of large scale pillar failures in zones of partial extraction.

Alternative 3

Longwall mining would be carried out directly below Boulger Dam if mitigation of subsidence impacts were adequately addressed. There is insufficient knowledge of the Boulger and Hunt Dams to adequately address the stability and safety concerns associated with mining induced seismicity.

We believe that these dams are sufficiently small, and there is sufficient flexibility regarding possible mitigation options available, that they would

not ultimately have a major impact on the degree to which reserves can be recovered from the Tract. However, safety issues recommend further investigation and evaluation be undertaken concerning these dams to identify acceptable mitigation programs prior to longwall mining within 5500 ft. of them.

Human response to mining induced seismicity has the potential to be noticeable by campers, forest visitors and cabin residents within a range of about 3500 feet from longwall mining areas. With a possible frequency of one event that can be distinctly felt every 5 days on average, this is not considered to result in adverse impact. It should be possible to minimize any adverse impact by adequate warning, education and the implementation of a suitable public relations program.

The range of seismicity predictions have been summarized in relation to their effects on the resources and structures and presented in Table A.2 for each of the main two mining alternatives.

Recommendations for Monitoring and Mitigation

The following monitoring and investigations are recommended:

1. A comprehensive subsidence monitoring and evaluation program should be carried out in the new lease area to confirm subsidence predictions prior to undermining sensitive structures. This should include monitoring of multiple seam mining in order to improve confidence in the estimation of subsidence parameters following extraction of the lower seam.

2. Prior to full extraction mining below sensitive structures and flat sections of perennial drainages a specific mine layout and extraction sequence, together with specific subsidence predictions should be carried out and mitigation options proposed to minimize adverse impact.

3. Where stacked fire barriers or abutment pillars are contemplated below sensitive structures or flat sections of perennial drainages a detailed investigation, evaluation and mitigation program should be undertaken. This should include the possibility that revision of the mine layout may be required to address the potential for adverse impacts that cannot be adequately mitigated on surface.

4. Prior to full extraction mining within 5500 feet of the Boulger and Hunt Dams, further site investigation should be carried out, including evaluation of safety and associated mitigation measures. This should address the potential damage and associated safety hazard posed by these structures

should they fail. This would ideally be carried out in conjunction with the current monitoring program for Electric Lake Dam.

The following mitigation options might be considered:

1. Consideration for restricting full extraction mining to outside of the angle of draw from Boulger Dam if mitigation options prove to be costly or cannot be agreed.

2. If E-W Sub-Mains are required in the centre of the Tract, consideration should be given during detailed mine planning for their location below Boulger and Flat Canyons in order to provide some degreee of protection for the perennial drainages, dam and other structures that are concentrated in this area.

3. Care should be taken when locating stacked abutments or fire barriers and consideration should be given towards offsetting them in the two seams in order to reduce zones of permanent tensile strain and maximum slope.

4. Consideration should be given towards the use of yield pillar systems for longwall gate roads in order to reduce differential subsidence.

5. Consideration for the location of the main development corridor further to the west would enable a larger unmined pillar to be left under Huntington Creek to reduce the possibility of mains pillar failure resulting in surface subsidence over the long term. However, this would impact the MER and the real benefit is debatable.

6. Consideration for an additional buffer for conservative protection against subsidence by defining an angle of draw of 30 degrees allowing for variable geology, strata response and possibility of abutment pillar failures.

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RESOURCE/ISSUE	COMPARISON OF ALTERNATIVES BY ISSUE / RESOURCE*	
	Alternative 2	Alternative 3
	Standard BLM Lease Terms and Conditions with special stipulations to protect resources. (No subsidence of sensitive resource areas or facilities.)	Standard BLM Lease Terms and Conditions only.
MINING		
General	Two seams over majority of area mined with mainly longwall and some partial extraction Room-and Pillar mining below perennial drainages and other protected structures. Less than 36 million Tons recoverable, extending mine life for a shorter period compared with Alternative 3.	Two seams over majority of area mined mainly by longwall with some very limited room-and-pillar mining. About 36 million tons recoverable, extending mine life by 9 to 12 years at an annual production rate from 3 to 4 million tons.
Mine Discharge Water	Possibility of pumping mine discharge water to Upper Huntington Creek.	Possibility of pumping mine discharge water to Upper Huntington Creek.
Vent Shafts	Two passive vent shafts with limited surface facilities and access roads, as required for Alternative 3.	Two passive vent shafts with limited surface facilities and access roads. Possibility of pumping mine discharge water to Upper Huntington Creek. Temporary period of disturbance during construction. Surface operational disturbance of about 2 acres for vent shafts and 0.5 acres for access roads for the life of the mine, with abandonment and reclamation after mine closure.
Exploration Boreholes	About 10 additional boreholes, as required for Alternative 3.	About 10 additional boreholes required with a temporary surface disturbance of about 4 acres for drill pads and 3.5 acres for access roads which will be reclaimed directly afterwards

* minor effect – inferior in importance; comparatively unimportant; moderate effect – limited in effect; observing reasonable limits; major effect – greater in extent or importance.

RESOURCE/ISSUE	COMPARISON OF ALTERNATIVES BY ISSUE / RESOURCE	
	Alternative 2	Alternative 3
SUBSIDENCE		
General	**Minor Potential Effect** - Same as Alternative 3 in areas where longwall extraction is allowed and no impact in areas with partial extraction.	**Minor Potential Effect** – Longwall subsidence of 2 to 14 ft, generally with flexure of ground surface producing localized slope changes and tension fractures in zones of high differential subsidence expected to be less than 1% of the mined area. Mitigation requirements: cracks may need to be filled in some locations where permanent tensile zones are permanent. No long term adverse effects anticipated.
Boulger Dam and Reservoir (Subsidence Pt. 6)	**Minor Potential Effect** – No longwall mining allowed to protect perennial drainages and full-support pillars would not cause subsidence, effectively limiting full extraction mining within1500 feet from the dam. No cracks or subsidence damage to dam provided pillar dimensions are adequate.	**Major Potential Effect** - Longwall mining with the potential to cause failure of the dam. Damage may be limited by mining restrictions and mitigation of structure in combination with temporary lowering of the reservoir during undermining. No mining within angle of draw without site investigation and mitigation may be required. Tensile zones at edges of longwall mining areas should be avoided. Can be undermined, but suitable precautions required and some loss of use anticipated.
Hunt Dam and Reservoir	**No Effect** - (outside angle of draw)	**No Effect** - (outside angle of draw)
Highway SR 264 (Subsidence Pts. 5 and 6)	**No Effect** – No longwall mining within angle of draw. Projected full support pillars would result in no subsidence with no possibility of cracks.	**Minor Potential Effect** - Longwall mining subsidence of 2 to 14 ft., with the possibility of minor cracking of surface in some isolated areas. Repair of some sections may be necessary where tensile zones are permanent, but without long term impact. Mitigation requirements: repair of cracks and regrading in some areas with resurfacing of road and replacement of culverts, but without long term effects. Special precautions may be required for two major culverts and temporary safety measures.

RESOURCE/ISSUE	COMPARISON OF ALTERNATIVES BY ISSUE / RESOURCE	
	Alternative 2	Alternative 3
Unpaved Roads (Forest Service roads and access roads to cabins).	**Minor Potential Effect** – Similar to Alternative 3 in longwall mining areas. No effect where pillars left to protect surface resources.	**Minor Potential Effect** – see General Subsidence. Some repair work required in tensile zones to fill cracks and maintain slopes and drainage with temporary safety measures required.
#41 Gas Transmission Pipeline	**No Effect** – Similar to Alternative 3.	**No Effect** – No longwall extraction allowed within angle of draw to Huntington Creek, with secondary effect of protecting gas pipeline from subsidence.
Flat Canyon Campground (subsidence pts. 5, 6 and 8)	**No Effect** – Protected with no subsidence of the structures allowed. No possibility of cracks or subsidence damage to facilities provided pillar dimensions are adequate.	**Moderate Potential Effect** - Longwall mining subsidence of 2 to 14 ft. Minor cracking of surface expected in some areas with no long term impact. Mitigation may be required to protect and repair campground buildings and water system. Tensile zones at edges of longwall mining areas should be avoided.
Flat Canyon Cabins (subsidence pt. 5)	**Minor Potential Effect** – Most cabins protected due to no longwall mining allowed for protection of perennial drainage. Two cabins north of canyon may be subject to tensile strains at edge of stacked pillars with some mitigation required.	**Minor Potential Effect** - Longwall mining subsidence of 2 to 4 ft., with potential for tensile strain and induced slope changes with the possibility of cracks. Some mitigation required to protect and repair cabins, especially if abutment pillars result in permanent differential subsidence. Loss of use for short time while dynamic subsidence occurs.
Swens Canyon Cabins (subsidence pt. 3)	**Minor Potential Effect** – Similar to Alternative 3, but could be located above pillars giving rise to greater tensile zone and associated subsidence impact.	**Minor Potential Effect** - Longwall mining subsidence of 4 to 10 ft. Pillars at edge of longwall area could result in higher tensile strains with the possibility of damage. Some mitigation required to protect and repair cabins, especially if pillars result in permanent differential subsidence. Loss of use for short time while dynamic subsidence occurs.
Upper Huntington Perennial Drainage	**No Subsidence** – Same as Alternative 3.	**No Subsidence** - No longwall mining allowed within angle of draw. No effect of main development corridor below creek due to adequate pillar dimensions with minor possibility of failure. Worst case of long term pillar failure presented in Technical Report on Surface Water and Groundwater.

RESOURCE/ISSUE	COMPARISON OF ALTERNATIVES BY ISSUE / RESOURCE	
	Alternative 2	Alternative 3
Flat Canyon Perennial Drainage (subsidence pts. 5 and 6)	**No Subsidence** - No longwall mining allowed within angle of draw. No effect of partial extraction due to adequate pillar dimensions with minor possibility of failure.	**Minor to Moderate Subsidence** - Longwall mining subsidence of 2 to 14 ft with no major cracking of surface expected. Some mitigation required in places to correct adverse gradients if pillars are aligned in both seams. Impacts discussed in Technical Report on Surface Water and Groundwater.
Boulger Canyon Perennial Drainage (subsidence pts. 1, 6, 7 & 8)	**No Subsidence** - No longwall mining allowed within angle of draw. No effect of partial extraction due to adequate pillar dimensions with minor possibility of failure.	**Minor to Moderate Subsidence** - Longwall mining subsidence of 4 to 14 ft. with no major cracking of surface expected. Some mitigation required in places to correct adverse gradients if pillars are aligned in both seams. Impacts discussed in Technical Report on Surface Water and Groundwater.
Swens Canyon Perennial Drainage (subsidence pts. 3 and 4)	**No Subsidence** - No longwall mining allowed within angle of draw. No effect of partial extraction due to adequate pillar dimensions with minor possibility of failure.	**Minor to Moderate Subsidence** - Longwall mining subsidence of 4 to 12 ft with no major cracking of surface expected. Some mitigation required in places to correct adverse gradients if pillars are aligned in both seams. Impacts discussed in Technical Report on Surface Water and Groundwater.
Little Swens Canyon Perennial Drainage (subsidence pt. 2)	**No Subsidence** - No longwall mining allowed within angle of draw. No effect of partial extraction due to adequate pillar dimensions with minor possibility of failure.	**Minor to Moderate Subsidence** - Longwall mining subsidence of 2 to 5 ft. with no major cracking of surface expected. Some mitigation required in places to correct adverse gradients where pillars are aligned in both seams. Impacts discussed in Technical Report on Surface Water and Groundwater.

RESOURCE/ISSUE	COMPARISON OF ALTERNATIVES BY ISSUE / RESOURCE	
	Alternative 2	**Alternative 3**
Cunningham Possible Perennial Drainage (subsidence pt. 9)	**Minor to Moderate Subsidence** – Similar to Alternative 3, as no protection of this drainage is expected. Some mitigation required in places to correct adverse gradients where pillars are aligned in both seams. Impacts discussed in Technical Report on Surface Water and Groundwater.	**Minor to Moderate Subsidence** - Longwall mining subsidence of 5 to 12 ft with no major cracking of surface expected. Some mitigation required in places to correct adverse gradients where pillars are aligned in both seams. Impacts discussed in Technical Report on Surface Water and Groundwater.
Natural Slopes	**Minor Potential Effect** - Similar to Alternative 3, but increased requirements for pillars adjacent to perennial drainages may increase tensile zones parallel to slopes with an increased potential for slope failures.	**Minor Potential Effect** - Minor instability, with increased potential above pillar zones at edge of longwall areas. No major slope failures expected.
SEISMICITY		
General	**Minor Potential Effect** – Similar to Alternative 3.	**Minor Potential Effect** - Longwall mining induced seismicity expected with increased potential at depths below 1500 ft. Maximum Credible Event (MCE) of Richter 3.3 recommended for impact evaluation. Frequency of events over extended mine life expected to be about one event with magnitude greater than 2 every 5 days. No effect on roads, slopes or perennial drainages expected. Human response to ground vibrations from seismicity is expected to result in events being distinctly felt by campers, forest visitors and cabin dwellers about once every 5 days within 3500 ft. of longwall mining areas.
Boulger Dam and Reservoir	**Major Potential Effect** – Similar to Alternative 3.	**Moderate Potential Effect** - Longwall mining induced seismicity with potential to damage dam within range of about 5500 ft. based on MCE of 3.3 using conservative relationship and dam ability to withstand acceleration of 0.1g.
Hunt Dam and Reservoir	**Major Potential Effect** – Similar to Alternative 3.	**Moderate Potential Effect** – Similar to Boulger Dam, but effect may be less due to longwall mining not predicted within 2500 ft. of dam.

RESOURCE/ISSUE	COMPARISON OF ALTERNATIVES BY ISSUE / RESOURCE	
	Alternative 2	**Alternative 3**
Electric Lake Dam	**No Effect** – Similar to Alternative 3.	**No Effect** – Longwall mining induced seismicity has no potential to impact this dam. A conservatively high MCE of 3.8 would result in vibrations below the Operating Basis Earthquake (OBE) of 0.1g for this dam.
Highway SR 264 and unpaved roads	**No Effect** – Similar to Alternative 3.	**No Effect** – Longwall mining induced seismicity has no potential to damage highways.
#41 Gas Transmission Pipeline	**No Effect** – Similar to Alternative 3.	**No Effect** – Longwall mining induced seismicity has no potential to damage gas pipeline. Previous mining has been in close vicinity to the pipeline without impact.
Flat Canyon Campground	**Minor Effect** – Similar to Alternative 3. The full support pillars may require the use of a higher MCE for evaluations.	**Minor Potential Effect** - Longwall mining induced seismicity has the potential to vibrate structures once every 5 days at a Peak Particle Velocity (PPV) of over 1 in/sec within a range of 3500 ft. from mining areas. Some minor cosmetic damage may result with a minor possibility of structural damage to buildings for infrequent larger events. No damage to the water system is expected.
Private Cabins in Flat Canyon and Swens Canyon	**Minor Effect** – Similar to Alternative 3. The full support pillars may require the use of a higher MCE for evaluations.	**Minor Potential Effect** - Similar effect to Flat Canyon Campground.
Perennial Drainages	**No Effect** – Similar to Alternative 3.	**No Effect** – Vibration levels are too low for damage.
Natural Slopes	**No Effect** – Similar to Alternative 3.	**No Effect** – Vibration levels are too low for potential impact to slope stability. Confirmed by lack of evidence for slope failure due to past mining at Skyline.

APPENDIX B

TECHNICAL REPORT SUMMARY TABLE

RESOURCE/ISSUE	TECHNICAL REPORT SUMMARY TABLE	
	Alternative 2	**Alternative 3**
	Standard BLM Lease Terms and Conditions with Special Stipulations to Protect Resources. (No Subsidence of Sensitive Resource Areas or Facilities)	Standard BLM Lease Terms and Conditions Only.
MINING		
General	Two seams over majority of area mined with mainly longwall and partial extraction Room-and Pillar mining below perennial drainages. Significantly less than 36 million tons recoverable, with an associated reduction in extension of the mine life compared with Alternative 3.	Two seams over majority of area mined mainly by longwall with some very limited Room-and-Pillar. About 36 million tons recoverable, extending mine life by 9 to 12 years at an annual production rate of 3 to 4 million tons.
Vent Shafts	Two passive vent shafts with limited surface facilities and access roads.	Two passive vent shafts with limited surface facilities and access roads.
Mine Water Discharge	Possibility of pumping mine discharge water to Upper Huntington Creek.	Possibility of pumping mine discharge water to Upper Huntington Creek.
Exploration Boreholes	About 10 additional boreholes required.	About 10 additional boreholes required.
SUBSIDENCE		
General	**Minor Effect** - Same as Alternative 3 in areas where longwall extraction is allowed and negligible impact in areas with partial extraction.	**Minor Effect** – Longwall subsidence of 2 to 14 ft, generally with induced slope change of 0.1 to 1.4% and tensile strains from 1 to 16 millistrain. Stacked pillars at edge of longwall areas could result in 3.0 % induced slope change and tensile strain of 32 millistrain with major cracks. Mitigation requirements: cracks may need to be filled where stacked pillars remain at the edge of longwall areas with strong rock beds near surface. No long term adverse effects anticipated.

RESOURCE/ISSUE	TECHNICAL REPORT SUMMARY TABLE	
	Alternative 2	Alternative 3
Boulger Dam and Reservoir (Subsidence Pt. 6)	**No perceptible Effect** – No longwall mining allowed within 1500 ft to protect perennial drainages and full-support pillars would not cause subsidence. Negligible possibility of cracks or subsidence damage to dam provided pillar dimensions are adequate.	**Major Effect** – Longwall mining with potential subsidence from 6 to 14 ft, generally with induced slope change of 0.4 to 1.2% and tensile strains from 3 to 14 millistrain. Minor cracking of surface expected in some areas with major impact on dam stability. Stacked pillars at edge of longwall areas could result in 2.8% induced slope change and tensile strain of 28 millistrain with major cracks and damage to dam. No mining within angle of draw without site investigation. Mitigation may be required. Tensile zones at edges of longwall mining areas should be avoided. Can be undermined, but suitable precautions required and loss of use anticipated.
Hunt Dam and Reservoir	**No Effect** - (outside angle of draw)	**No Effect** - (outside angle of draw)
Highway SR 264 (Subsidence Pts. 5 and 6)	**No perceptible Effect** – No longwall mining within angle of draw. Projected full support pillars would result in negligible subsidence with no possibility of cracks.	**Minor Effect** – Longwall mining subsidence of 2 to 14 ft., generally with induced slope change of 0.2 to 1.2% and tensile strains from 2 to 14 millistrain. Minor cracking of surface expected in some areas with no long term impact. Stacked pillars at edge of longwall areas could result in 2.8% induced slope change and tensile strain of 28 millistrain with major cracks. Mitigation requirements: repair of cracks and re-grading with resurfacing of road, but no long term effects. Special precautions required for two major culverts.
Unpaved Roads (Forest Service roads and access roads to cabins).	**Minor Effect** – Similar to Alternative 3 in longwall mining areas. No effect where pillars left to protect surface resources.	**Minor Effect** – see General Subsidence estimates. Some repair work required in tensile zones to fill cracks and maintain slopes and drainage.
#41 Gas Transmission Pipeline	**No perceptible Effect** – Similar to Alternative 3.	**No perceptible Effect** – No longwall mining allowed within angle of draw to Huntington Creek also protects gas pipeline from subsidence.

RESOURCE/ISSUE	TECHNICAL REPORT SUMMARY TABLE	
	Alternative 2	Alternative 3
Flat Canyon Campground (subsidence pts. 5, 6 and 8)	**No perceptible Effect** – Protected with no subsidence allowed of perennial drainages. Negligible possibility of cracks or subsidence damage to facilities provided pillar dimensions are adequate.	**Moderate Effect** - Longwall mining subsidence of 2 to 14 ft., generally with induced slope change of 0.2 to 1.2 % and tensile strains from 2 to 14 millistrain. Minor cracking of surface expected in some areas with no long term impact. Stacked pillars at edge of longwall areas could result in 2.8 % induced slope change and tensile strain of 28 millistrain with major cracks. Tensile zones at edges of longwall mining areas should be avoided. Can be undermined, but suitable precautions required. Mitigation may be required to protect and repair campground buildings and water system.
Flat Canyon Cabins (subsidence pt. 5)	**No perceptible Effect** – Most cabins protected due to no longwall mining allowed for protection of perennial drainage. Two cabins north of canyon may be subject to tensile strains at edge of stacked pillars with some mitigation required.	**Minor Effect** - Longwall mining subsidence of 2 to 4 ft., generally with induced slope change of 0.2 to 0.6 % and tensile strains from 2 to 4 millistrain. Stacked pillars at edge of longwall areas could result in 0.6 % induced slope change and tensile strain of 8 millistrain with possibility of cracks. Some mitigation required to protect and repair cabins, especially if abutment pillars result in permanent differential subsidence. Loss of use for short time while dynamic subsidence occurs.
Swens Canyon Cabins (subsidence pt. 3)	**Minor Effect** – Similar to Alternative 3, but could be located above stacked pillars giving rise to greater effect.	**Minor Effect** - Longwall mining subsidence of 4 to 10 ft., generally with induced slope change of 0.2 to 0.6 % and tensile strains from 1 to 4 millistrain. Stacked pillars at edge of longwall areas could result in 1.4% induced slope change and tensile strain of 16 millistrain with possibility of cracks. Some mitigation required to protect and repair cabins, especially if stacked pillars result in permanent differential subsidence. Loss of use for short time while dynamic subsidence occurs.
Upper Huntington Perennial Drainage	**No perceptible Effect** – Similar to Alternative 3.	**No perceptible Effect** - No longwall mining allowed within angle of draw. Negligible effect of main development corridor below creek due to adequate pillar dimensions with remote possibility of failure.

RESOURCE/ISSUE	TECHNICAL REPORT SUMMARY TABLE	
	Alternative 2	Alternative 3
Flat Canyon Perennial Drainage (subsidence pts. 5 and 6)	**No perceptible Effect** - No longwall mining allowed within angle of draw. Negligible effect of partial extraction due to adequate pillar dimensions with remote possibility of failure.	**Minor Effect** - Longwall mining subsidence of 2 to 14 ft., generally with induced slope change of 0.2 to 1.2% and tensile strains from 2 to 14 millistrain. Minor cracking of surface expected in some areas with no long term impact. Stacked pillars at edge of longwall areas could result in 2.8% induced slope change and tensile strain of 28 millistrain with major cracks. No major long term effect of increased vertical fracture permeability expected. Some mitigation required in places to correct gradients. Stacked pillars could result in problematic gradients where creek has low gradient and may require minor mitigation or mine planning modifications.
Boulger Canyon Perennial Drainage (subsidence pts. 1, 6, 7 & 8)	**No perceptible Effect** - No longwall mining allowed within angle of draw. Negligible effect of partial extraction due to adequate pillar dimensions with remote possibility of failure.	**Minor Effect** - Longwall mining subsidence of 4 to 14 ft., generally with induced slope change of 0.1 to 1.2% and tensile strains from 1 to 14 millistrain. Minor cracking of surface expected in some areas with no long term impact. Stacked pillars at edge of longwall areas could result in 2.8% induced slope change and tensile strain of 28 millistrain with major cracks. No major long term effect of increased vertical fracture permeability expected. Some mitigation required in places to correct gradients. Stacked pillars could result in problematic gradients where creek has low gradient and may require minor mitigation or mine planning modifications.
Swens Canyon Perennial Drainage (subsidence pts. 3 and 4)	**No perceptible Effect** - No longwall mining allowed within angle of draw. Negligible effect of partial extraction due to adequate pillar dimensions with remote possibility of failure.	**Minor Effect** - Longwall mining subsidence of 4 to 12 ft., generally with induced slope change of 0.2 to 1.4 % and tensile strains from 1 to 6 millistrain. Minor cracking of surface expected in some areas with no long term impact. Stacked pillars at edge of longwall areas could result in 3.0 % induced slope change and tensile strain of 32 millistrain with major cracks. No major long term effect of increased vertical fracture permeability expected. Some mitigation required in places to correct gradients. Stacked pillars could result in high gradient zones requiring some mitigation.

RESOURCE/ISSUE	TECHNICAL REPORT SUMMARY TABLE	
	Alternative 2	Alternative 3
Little Swens Canyon Perennial Drainage (subsidence pt. 2)	**No perceptible Effect** - No longwall mining allowed within angle of draw. Negligible effect of partial extraction due to adequate pillar dimensions with remote possibility of failure.	**Minor Effect** - Longwall mining subsidence of 2 to 5 ft., generally with induced slope change of 0.1 to 0.8 % and tensile strains from 2 to 4 millistrain. Minor cracking of surface expected in some areas with no long term impact. Fire barrier pillar could result in tensile strain of 8 millistrain with minor cracks. No major long term effect of increased vertical fracture permeability expected. No major mitigation expected to be required.
Cunningham Possible Perennial Drainage (subsidence pt. 9)	**Minor Effect** – Similar to Alternative 3, as no protection of this drainage is expected.	**Minor Effect** - Longwall mining subsidence of 5 to 12 ft., generally with induced slope change of 0.2 to 0.8 % and tensile strains from 2 to 4 millistrain. Minor cracking of surface expected in some areas with no long term impact. Stacked pillars at edge of longwall areas could result in 1.8 % induced slope change and tensile strain of 20 millistrain with possibility of cracks. No major long term effect of increased vertical fracture permeability expected. No major mitigation expected to be required.
Natural Slopes	**No perceptible Effect** - Similar to Alternative 3, but increased requirements for stacked pillars may increase tensile zones and potential for slope failures.	**No perceptible Effect** - Minor instability, with increased potential above pillar zones at edge of longwall areas. No major slope failures expected.

RESOURCE/ISSUE	TECHNICAL REPORT SUMMARY TABLE	
	Alternative 2	Alternative 3
SEISMICITY		
General	**Minor Effect** – Similar to Alternative 3.	**Minor Effect** - Longwall mining induced seismicity expected with increased potential at depths below 1500 ft. Maximum Credible Event (MCE) of Richter 3.3 recommended for impact evaluation. Frequency of events over extended mine life expected to be about one event with magnitude greater than 2 every 5 days. No effect on roads, slopes or perennial drainages expected. Human response to ground vibrations from seismicity is expected to result in events being distinctly felt by campers, forest visitors and cabin dwellers about once every 5 days within 3500 ft. of longwall mining areas. Some nuisance may be caused that can be minimized with a good education, warning and public relations program.
Boulger Dam and Reservoir	**Major Effect** – Similar to Alternative 3.	**Major Effect** - Longwall mining induced seismicity with potential to damage dam within range of about 5500 ft. based on MCE of 3.3 using conservative relationship and dam ability to withstand 0.1g. Recommendation for further site investigation of dam structure, monitoring of vibrations and stability analysis. Final results are likely to have minor impact on undermining potential for dam, but would probably require mitigation of dam and several years loss of use.
Hunt Dam and Reservoir	**Major Effect** – Similar to Alternative 3.	**Major Effect** – Similar to Boulger Dam, but effect may be less due to longwall mining over 2500 ft. away.
Electric Lake Dam	**No perceptible Effect** – Similar to Alternative 3.	**No perceptible Effect** – Longwall mining induced seismicity has negligible potential to impact this dam. A conservatively high MCE of 3.8 would result in vibrations below the Operating Basis Earthquake (OBE) of 0.1g for the dam.
Highway SR 264 and unpaved roads	**No perceptible Effect** – Similar to Alternative 3.	**No perceptible Effect** – Longwall mining induced seismicity has negligible potential to damage highways.
#41 Gas Transmission Pipeline	**No perceptible Effect** – Similar to Alternative 3.	**No perceptible Effect** – Longwall mining induced seismicity has negligible potential to damage gas pipeline. Previous mining has been in close vicinity to the pipeline without impact.

RESOURCE/ISSUE	TECHNICAL REPORT SUMMARY TABLE	
	Alternative 2	Alternative 3
Flat Canyon Campground	**Minor Effect** – Similar to Alternative 3. The full support pillars may require the use of a higher MCE for evaluations.	**Minor Effect** - Longwall mining induced seismicity has the potential to vibrate structures once every 5 days at a Peak Particle Velocity (PPV) of over 1 in/sec within a range of 3500 ft. from mining areas. Some minor cosmetic damage may result with a remote possibility of structural damage to buildings for infrequent larger events. No damage to the water system is expected. The predictions for vibration levels can be improved if the recommended evaluation is carried out for the dam structures. Some mitigation may be required and nuisance resulting from adverse human response can be minimized by implementation of a good education, warning and public relations program.
Private Cabins in Flat Canyon and Swens Canyon	**Minor Effect** – Similar to Alternative 3. The full support pillars may require the use of a higher MCE for evaluations.	**Minor Effect** - Longwall mining induced seismicity has the potential to vibrate structures once every 5 days at a Peak Particle Velocity (PPV) of over 1 in/sec within a range of 3500 ft. from mining areas. Some minor cosmetic damage may result with a remote possibility of structural damage to buildings for infrequent larger events. No damage to the water system is expected. The predictions for vibration levels can be improved if the recommended evaluation is carried out for the dam structures. Some mitigation may be required and nuisance resulting from adverse human response can be minimized by implementation of a good education, warning and public relations program.
Perennial Drainages	**No perceptible Effect** – Similar to Alternative 3.	**No perceptible Effect** – Vibration levels are too low for damage.
Natural Slopes	**No perceptible Effect** – Similar to Alternative 3.	**No perceptible Effect** – Vibration levels are too low for potential impact to slope stability. Confirmed by lack of evidence for slope failure due to past mining at Skyline.

APPENDIX C

RESUMES

NAME	James D. Alto, P. E.
TITLE	Manager, Environmental Services
SUMMARY OF EXPERIENCE	Over 17 years experience in a variety of engineering roles in the mining and environmental fields. Licensed professional engineer and registered environmental manager with more than seven years management experience in environmental and engineering consulting. Extensive background in environmental compliance auditing, preparation of Plans and Operations, site reclamation design and bond calculations, financial analysis, project feasibility justification, project management, proposal development, NEPA, RCRA, and CERCLA. Proven leadership abilities with commitment toward the quality process and team management principles.

PROFESSIONAL HISTORY

1997-Present
NorWest Mine Services, Inc., Salt Lake City, UT
MANAGER, ENVIRONMENTAL SERVICES

1990 - 1997
JBR Environmental Consultants, Salt Lake City, Utah
MANAGER, ENGINEERING & INVESTIGATION TEAM

1990 - 1991
Plexus Resources Corporation, Salt Lake City, Utah
MANAGER, PERMITTING AND ENVIRONMENTAL AFFAIRS

1988 - 1990
Plexus Resources Corporation, Salt Lake City, Utah
MINING ENGINEER

1981 - 1988
Arentz Mining Engineers, Salt Lake City, Utah
MINING ENGINEER

1980
Ranchers Exploration & Development Corp., Escalante Silver Mine
JUNIOR MINING ENGINEER

1979 Black Butte Coal Company, Black Butte Mine
JUNIOR MINING ENGINEER

NAME	Dr. C.B. (Conrad) Houser
TITLE	Vice President
SUMMARY OF EXPERIENCE	Internationally experienced mining engineer and manager with broad engineering, environmental, legal, marketing, planning, and financial experience as well as focussed skills in surface and underground mining of coal, oil shale and trona.
ACADEMIC AND PROFESSIONAL QUALIFICATIONS	M.S. (civil engineering - Tuition Scholarship - Rice University, Houston, Texas, 1969 B.C. (top civil engineering graduate), U.S. Air Force Academy, Colorado Springs, Colorado, 1967 MBA course work, University of Utah, Salt Lake City, Utah, 1977 J.D. (Cum Laude), J. Reuben Clark Law School at BYU, Provo, Utah, 1975 U.S. Patent License Member of Utah State Bar Registered Professional Engineer in Colorado and Wyoming Certificated in Total Quality Management, Financial Analysis of Investments, Project Management, International Finance, Industrial Relations, Safety Supervision, Negotiation Techniques
PROFESSIONAL HISTORY	**1996 - Present** **NorWest Mine Services, Inc., Salt Lake City, Utah** VICE PRESIDENT: Provides mining, financial services, and project management. Recent assignments include preparing final EPC and contract mining documents for an Indian coal project; due diligences studies and appraisals; and project manager on Brazilian underground mining project. **1995 - 1996** **Rocky Mountain Leadership Institute, Casper, Wyoming** PRESIDENT: Consulting and training for businesses and governmental entities. Acquisition analysis and due diligence. Asset maximization. Marketing realignment. Strategic planning. **1993 - 1995** **Wold Trona Company, Inc., Casper, Wyoming** VICE PRESIDENT, CHIEF OPERATING OFFICER: Overall responsibility for integration of $200 million new mineral process technology development, design, financing, and permitting.

- MARKETING: Pre-sold 80% of initial 10 year's production via letters of intent; established strategy, introduced new product to market, initiated revision of industry specifications, established customer relations all leading to project revenue base loading.

- ADMINISTRATION: Organized all office functions from ground zero to produce synergistic MIS, planning, accounting, budgeting, and associated functions.

- PERMITTING: Orchestrated all aspects of permit preparation, review, and approval at minimal cost and record speed to clear the way for project construction.

- ENGINEERING: Participated in process development, capital and operating cost reduction, process and mine design and engineering, construction of demonstration plant, preparation of bid packages, leading to successful posturing of Engineering Procurement - Construction contract.

- LEGAL: Developed in-house and through outside counsel partnership agreements (Limited Liability companies and Limited Partnerships) sales, contracts, Interior Board of Land Appeals defence, patent applications, engineering contracts, and the project financial prospectus.

1992
Drummond, Gillette, Wyoming
ENGINEERING & ENVIRONMENTAL MANAGER: After purchase of Mobil operations by Drummond, responsibilities included development of plans and permits to transition the Caballo Rojo Mine from truck and shovel to dragline operations.

1977 - 1991
Mobil Corporation
VICE PRESIDENT - ENGINEERING MANAGER, DENVER, COLORADO (1988 - 1991): Operations in Wyoming's Powder River Basin and Indonesia. Complete engineering, environmental, strategic planning and financial responsibility. Key participant in Booz, Allen, Hamilton strategic posturing project in New York City to determine whether Mobil should remain in the coal business. Recommended Mobil discontinue its coal focus unless it was willing to become a major player. Played a major role in the solicitation of buyers and the sale of Mobil's coal interests, netting $80 million in asset recovery. Quarterbacked lawsuit defending

Mobil's integrity against claims of tortuous contract interference by a competitor.
ENGINEERING & ENVIRONMENTAL MANAGER, GILLETTE, WYOMING (1985 - 1987): Created $3 million unanticipated profit enhancement by changing mining location to better optimize returns from the operation - required complete revision of both short and long term mining plans as well as major permit revisions in record time. Made major operating changes to match coal quality to customer needs - necessitated changing both vertical and horizontal mining orientations. Development drilling techniques were significantly enhanced. Developed special software for selection of coal to yield increased profits through proper shipment scheduling. Truck and shovel operations were optimized.

Negotiated a win-win agreement out of deadlocked conflict saving over $1.3 million. Actively participated in marketing of coal. Led an environmental team to the only perfect record (zero notices of violation) in U.S. fossil fuelled mining history (over 280 inspections). Revitalized and empowered a stagnant engineering and environmental staff.

1982 - 1985
Mobil Synfuels, Denver, Colorado
VENTURE SERVICES ADVISOR: Led matrix organization including all reserve definition and underground mine planning supporting $6 billion project. Complete infrastructure alignment with mining and processing operations.

1980 - 1981
Mobil Corporation, Ndola, Zambia
MANAGING DIRECTOR/GENERAL MANAGER: Originated program for converting wasted flare-gas into replacement fuel for transportation with national hard currency savings estimated at $4 million per year. Pioneered transfer of wholesale metered distribution system into developing country, saving over $180,000 in annual operating costs. Coordinated legal, financial, and engineering activities for EPC blending and packaging plant in Zambia with revenue contribution projected at $8 million per year.

1977 - 1980
Australia Marketing Operations; Manager, Queensland, Brisbane
TERMINAL MANAGER: Dramatically improved customer and marketing support services and responsiveness. Resolved hot union conflicts and sustained peaceful and productive relationships, avoiding work stoppages and their attendant loss

of revenue and market share. Reorganized production practices to dramatically reduce losses and costs.

1975 - 1977
Spafford, Nixon & Houser; Salt Lake City, Utah
LAW FIRM PARTNER

1971 - 1973
Nelson, Haley, Patterson & Quirk; Greeley, Colorado
ENGINEERING COORDINATOR

1968 - 1971
Captain, US Air Force; Tokyo, Japan
Headquarters Fifth Air Force
BASE ENGINEER

David Alan Newman

Education:

Doctor of Philosophy - Mining Engineering
The Pennsylvania State University, 1985
Master of Science - Mining Engineering
The Pennsylvania State University, 1980
Bachelor of Arts - Geology
Vassar College, 1977

Employment Background:

Present- 1985	President, **Appalachian Mining and Engineering, Inc./Geolab** Lexington, Kentucky
Present- 1989	President, **Newman Engineering, PSC.** Lexington, Kentucky
1988- 1984	Assistant Professor of Mining Engineering, Director of Weekend/Evening Graduate Program **University of Kentucky** Lexington, Kentucky
1984- 1978	Graduate Research Assistant **The Pennsylvania State University** University Park, Pennsylvania
1978- 1977	Assistant Drill Manager, **American Testing and Engineering Company** Indianapolis, Indiana

Professional Registration:

Commonwealth of Kentucky, Registered Professional Engineer, No. 14,891
Commonwealth of Kentucky, Registered Professional Geologist, No. 2,601
State of West Virginia, Registered Professional Engineer, No. 11,656
Commonwealth of Virginia, Licensed Professional Engineer, No. 023660
State of Indiana, Registered Professional Engineer, No. PE19300222

Professional Experience:

Present- 1985	**Appalachian Mining and Engineering, Inc./Geolab,** *President* Engineering consulting firm specializing in rock and soil mechanics investigations, geotechnical engineering, subsidence prediction and abatement, blast design and evaluation, mine design and ground control, slope stability, mine property valuation and reserve analysis, coal refuse impoundment design and stability assessment, rock and soil property testing through **Geolab** a state-of-the-art materials testing laboratory using a computer controlled 200,000 pound capacity SATEC load frame.

Professional Experience (continued):

Present- 1988 **Newman Engineering, PSC.,** *President*
Municipal engineering projects involving urban hydrologic analysis and design, storm sewer design and evaluation, detention pond design, review of subdivision construction plans, highway design, and blasting projects.

1988- 1984 **University of Kentucky**, *Assistant Professor - Mining Engineering*
Dr. Newman directed five externally funded research projects, conducted internally funded research while overseeing M.S. theses. He developed and directed the weekend/evening graduate program with Friday evening/Saturday morning courses at the Southeast Community College campus in Cumberland, Ky. Teaching responsibilities included undergraduate and graduate courses in rock mechanics, slope stability, and mine valuation. Dr. Newman developed and taught, the "Elements of Coal Mining" and "SUBSIDE" short courses.

1984- 1978 **The Pennsylvania State University**, *Graduate Research Assistant*
Dr. Newman carried out research on four major research grants involving; development of a rock mass classification system for assessing mine roof stability,

- yield pillar design,
- longwall gateroad stability,
- coal pillar design for room-and-pillar mining,
- in-situ stress measurements,
- in-mine seismic refraction, and
- numerical simulation of roof behavior

1978- 1977 Assistant drill manager, **ATEC Drilling**
Responsibilities included scheduling drilling crews, the maintenance of repair shop inventory, and geotechnical core logging. Projects included geotechnical drilling and conducting a seismic surveys

Professional Societies:

Society for Mining, Metallurgy, and Exploration, Inc. (SMME)
- Rock Mechanics Award Committee, Chairman 2001
- Professional Engineering Examination Committee
- Student Activities Committee

Central Appalachian Section, SMME
American Society for Testing and Materials
Order of the Engineer
National Coal Association - Acid Mine Drainage Committee

Listings and Recognitions:

Who's Who in the South and Southwest
Phi Kappa Phi Honor Society
Mineral Research Institute Fellowship
U.S. Office of Education Mining, Mineral, Mineral Fuel Conservation Fellowship

Patents and Inventions:

"A Flexible Wire Rope Roof Bolt for Use in Thin Seam Coal Mines," Patent disclosure document No. 246721

"An In-situ Coal Face Sampling Device," Patent disclosure document No. 177846

"A Method of Increasing the Bulk Density of Coal in Underground Haulage Equipment," Patent disclosure document No. 180682

Grants and Contracts:

1988-1986 **U.S. Bureau of Mines**, Generic Research Program Mine Systems Design and Ground Control Virginia Polytechnic Institute, Blacksburg, Va. Principal Investigator "Field Investigation of the Post-Failure Behavior of Coal Pillars"

1988-1986 **Arch of Kentucky**, Lynch, Kentucky Principal Investigator "Rock and Coal Property Testing for Proposed Multiple Seam Mining Operation"

1986 **Arch of Kentucky**, Lynch, Kentucky Principal Investigator "In-situ Stress Measurements at Mine 37"

1986 **U.S. Bureau of Mines**, Mining and Mineral Resources Research Institute Seed Grant Program Principal Investigator "Laboratory Investigation of the Post-Failure Behavior of Coal"

1984 **University of Kentucky** - Graduate School Major Research Equipment Fund Strain extensometers for post-failure research

1984-1982 **SOHIO Center For Scientific Excellence in Mining Technology**, Researcher "Longwall Pillar Design and Gateroad Stability Assessment"

1984-1982 **U.S. Bureau of Mines**, Mining and Mineral Resources Institute Grant, Contract No. G5105083, Researcher "Design Procedures for Coal Mine Tunnels"

1983 G.A.I. Consultants, Inc., Monroeville, Pennsylvania **U.S. Dept. of Energy**, Contract No. DE-AC22-80PC30120 Contract Researcher "Characterization of Subsidence Over Pillar Extraction Panels"

Grants and Contracts (continued):

1983-1981 **U.S. Dept. of Energy**, Contract No. ET-78-G-01-3427 Researcher "Improved Design of Room-and-Pillar Coal Mining"

1980-1978 **U.S. Dept. of Energy**, Contract No. ET-77-C-01-9144 Researcher "Geotechnical Investigation of Roof Conditions in the Area Mined by the Automated Extraction System"

Publications:

Newman, D.A., "The Role of Engineering and Geology in Analyzing Ground Control Conditions," 18th Int. Conf. on Ground Control in Mining, 1999, pp. 64 - 71.

Newman, D.A., "Landslide Occurrence in Steep Slope Areas of Appalachia," 17th Int. Conf. on Ground Control in Mining, 1998, pp. 309-316.

Newman, D.A., "Surface Subsidence and Structural Damage," Chapter 5 in: An Investigation of High Extraction Mining and Related Valley Fill Practices in Southwestern Pennsylvania, Audubon Society of Western Pennsylvania, 1998, pp. B-85 - B-120.

Newman, D.A., "Subsidence Prediction Techniques," Chapter 6 in: An Investigation of High Extraction Mining and Related Valley Fill Practices in Southwestern Pennsylvania, Audubon Society of Western Pennsylvania, 1998, pp. B-121 - B-131.

Newman, D.A., "Integration of Geology and Engineering Design in Mining: Multiple Seam Mining in the Southern Appalachian Coal Field," Milestones in Rock Engineering: A Jubilee Collection, Bieniawski, ed. A.A. Balkema, 1996.

Newman, D.A., "Planning and Design for Barrier Pillar Recovery - Three Case Histories," 14th Int. Conf. on Ground Control in Mining, West Virginia Univ., 1995, pp. 72-79.

Newman, D.A. and Hoelle, J.L., "The Impact and Variability in Coal Strength on Mine Planning and Design - A Case History," West Virginia Univ., 12th Int. Conf. on Ground Control in Mining, 1993, pp. 237-243.

Artrip. P.S., Nelson, J.S., and Newman, D.A., "Modern Geotechnical Exploration and Mine Design,"West Virginia Univ., 12th Int. Conf. on Ground Control in Mining, 1993, pp. 249-260.

Newman, D.A. and Bennett, D.G., "The Effect of Specimen Size and Stress Rate for the Brazilian Test - A Statistical Analysis," Rock Mechanics and Rock Engineering, Vol. 23, 1990, pp. 123-134.

Newman, D.A., "In-Situ Yield Behavior of a Coal Pillar," International Journal of Mining and Geological Engineering, No. 2, Vol. 7, May, 1989, pp. 163-170.

Leonard, J.W. and Newman, D.A., "Volumetric Efficiency and the Potential for Increased Productivity in Underground Haulage Units" AIME-Society of Mining Engineers Annual Transactions, 1989, pp. 1202-1203.

Newman, D.A., "Yield Pillar Behavior in Deep Coal Mines," Proc. Sixth Annual Technical Workshop of the Generic Mineral Technology Center, Univ. of Alaska, 1988, pp. .

Newman, D.A., "Automated Data Acquisition System for Remote Monitoring of Pillar and Roof Deformation on a Longwall Panel," AIME-Society of Mining Engineers Annual Meeting, Preprint 88-64, Phoenix, Arizona, January, 1988.

Newman, D.A. and Bennett, D.B., "A Microcomputer Based System for the Prediction of Mining Costs and Mine Property Valuation," AIME-Society of Mining Engineers Annual Meeting, Preprint 88-63, Phoenix, Arizona, January, 1988.

Publications (continued):

Martin, J.S. and Newman, D.A., "The Characterization and Redesign of a Failing Highwall in Eastern Kentucky," AIME-Society of Mining Engineers Annual Meeting, Phoenix, Preprint 88-80, Arizona, January, 1988.

Newman, D.A., "Evaluation of Stability in Longwall Chain Pillars - A Technical Note," AIME-SME Transactions, Vol. 281, 1987.

Newman, D.A., "Automated Monitoring of the Stress-Strain Behavior of a Yield Pillar," Proc. Fifth Annual Technical Workshop of the Generic Mineral Technology Center, Univ. of Alabama, 1987, pp. 94-100.

Newman, D.A., "A Laboratory Investigation of the Post-Failure Behavior of Coal," IMMR Highlights, University of Kentucky Institute for Mining and Minerals Research, Vol. 6, No. 5, 1987, pp. 1-2.

Newman, D.A. and Bieniawski, Z.T., "A Modified Version of the Geomechanics Classification for Roofspan Design in Underground Coal Mines," AIME-SME Transactions, Vol. 280, 1986, pp. 2134-2138.

Newman, D.A. and Bieniawski, Z.T., "A Modified Version of the Geomechanics Classification for Roofspan Design in Underground Coal Mines," Preprint No. 85-313, AIME-SME Fall Meeting, Albuquerque, 1985.

Newman, D.A., "Mine Drainage and Pumping," in: **Kentucky Coal Mine Reference Book**, Cameron ed., Dept. of Mines and Minerals and Kentucky Mining Institute, 1985, pp. 89-99.

Snodgrass, J.J. and Newman, D.A., "An In-Situ Technique for the Assessment of Failure in Coal Pillars," Proc. 26th U.S. Symp. on Rock Mech., Ashworth ed., Univ. of S. Dakota, Rapid City, 1985, pp. 1181-1188.

Newman, D.A., "A Modified Version of the Geomechanics Classification for Use in Coal Mines," Proc. 2nd Conf. on Ground Control in the Illinois Basin, Chugh, ed., S. Ill. Univ., Carbondale, 1985, pp. 64-72.

Newman, D.A., "Coal Mine Ground Control - The Effect of Geology," Proc. 12th Ann. Meeting Eastern Sec. Amer. Assoc. Petrol. Geol., S. Ill. Univ., Carbondale, 1983, pp. 68-74.

Bieniawski, Z.T., Rafia, F., and Newman, D.A., "Ground Control Investigations for Assessment of Roof Conditions in Coal Mines," Proc. 21st U.S. Symp. on Rock Mech., Missouri-Rolla, 1980, pp. 693-700.

Bieniawski, Z.T., Rafia, F., and Newman, D.A., "Performance Evaluation of Automated Extraction System, Vol. 5, Geotechnical Investigations of the Roof Conditions in the Area Mined by the AES Machine," Final Technical Report, DOE Contract ET-77-C-01-9144, 1980, 73 p.

NAME	Kelly L. Payne
TITLE	Hydrogeologist
EDUCATION	M.S. Hydrogeology, Expected Graduation Date December 2000 Brigham Young University, Provo, Utah, Usa Thesis Title: *Occurrence and Geochemical Evolution of Shallow Groundwater in the Northern Altiplano, Bolivia: Implications for Groundwater Resource Development* B.S. Geology, 1994 Brigham Young University, Provo, Utah, USA
WORK EXPERIENCE	NorWest Mine Services, Inc, Salt Lake City, Utah, June 2000 to present. Mayo and Associates, LC, Lindon, Utah, April 1994 to June 2000, hydrogeologist, project manager, office manager
PROJECT EXPERIENCE	**Coal Mine Permitting** Supervised the preparation of Chapter 6 (Geology) and Chapter 7 (Hydrology) of the Mining and Reclamation Plan (MRP) for the new West Ridge Mine. Work was performed for WEST RIDGE Resources, Price, Utah. Supervised the investigation of groundwater systems, preparation of a statement of Probable Hydrologic Consequences (PHC), and a surface water and groundwater monitoring plan for existing coal leases and new properties acquired by the C.W. Mining Company, Huntington, Utah. Made a presentation at an Informal Conference before the director of UDOGM when the permit was protested. Characterized groundwater systems and evaluated the impacts of underground coal mining on surface water and groundwater at a number of mines in the Wasatch Plateau and Book Cliffs Coal Fields. Prepared a statement of the Probable Hydrologic Consequences (PHC) and a surface water and groundwater monitoring program, as required for a Mining and Reclamation Permit (MRP) by the Utah Division of Oil, Gas and Mining. These mines include:

Soldier Canyon Mine, Soldier Creek Coal Company, Wellington, Utah.
Skyline Mines, Canyon Fuel Company, Scofield, Utah
SUFCO Mine, Canyon Fuel Company, Salina, Utah
PacifiCorp Mines (Deer Creek, Cottonwood, and Trail Mountains), Huntington, Utah
Crandall Canyon Mine, GENWAL Resources, Inc, Huntington, Utah
Willow Creek Mine, Plateau Mining Corp., Helper, Utah

Supervised the investigation of potential impacts of longwall mining at the SUFCO Mine to the hydrologic balance of Box Canyon Creek, a perennial stream. Prepared a report summarizing impacts to cultural resources, riparian ecosystems, and hydrologic balance. The purpose of the investigation was to gain U.S. Forest Service consent to use longwall extraction to undermine the perennial stream. Evaluation performed for Canyon Fuel Company, Salina, Utah.

Investigated the source of large volume groundwater in-flows from faults in the West Elk Mine in order to predict future encounters and assess the hydrologic impacts of intercepting fault waters. This investigation was undertaken for Mountain Coal Company, Somerset, Colorado.

NEPA
Managed the preparation of technical reports and groundwater resource sections of Environmental Impact Statements for both The Pines and the Cottonwood Coal Lease Tracts. Work was performed for the Manti-La Sal National Forest as a third-party NEPA contractor.

Water Supply, Water Resources, and Water Rights
Performed a preliminary evaluation of the shallow groundwater resources and assessed the potential for contamination of shallow water wells in the northern Altiplano, Bolivia for the Benson Institute, a non-governmental organization based in Provo, Utah.

Managed the evaluation of background water quality and infiltration potential for a new sewage treatment facility in Cedar Valley, Utah. The project included the installation and sampling of monitoring wells and soil borings and in situ permeability tests. Prepared Delineation Reports for the Drinking Water Source Protection Plan, required by the State of Utah for all public

culinary water supplies. Work was completed for Skyline Mines and SUFCO Mine.

Preparing the Delineation Report and Drinking Water Source Protection Plan for Alpine Cove Water Company's culinary wells.

Characterized groundwater conditions in the New Harmony, Utah Area in order to help defend water rights held by the LDS Church. Gave oral testimony in deposition and at trial.

Hazardous Materials Investigations
Conducted geophysical investigations at several UST sites in Provo, Utah. The research evaluated the response of electrical resistivity (ER), very low frequency electromagnetic (VLF), and ground-penetrating radar (GPR) geophysical methods to shallow gasoline contamination.

Performed a characterization of groundwater flow regimes and the fate of hydrocarbon contamination in the Big Piney Oil and Natural Gas Field, Wyoming for Mobil Exploration and Producing, U.S.

Characterized the hydrogeology and extent of natural gas condensate contamination and prepared a groundwater monitoring plan for a natural gas production well site near Big Piney, Wyoming. Work was completed for Mobil Exploration and Producing, U.S. and Williams Field Services.

Provided technical and logistical support to the investigation of heavy metal contamination caused by irrigation with raw sewage in the Mezquital Valley north of Mexico City. This investigation was conducted by Brigham Young University and the University of Hidalgo in Pachuca, Hidalgo, Mexico. Performed initial project reconnaissance and provided verbal translation for BYU faculty.

Prepared a site characterization and groundwater monitoring plan for a hydrocarbon contaminated site at a natural gas compressor station in Wyoming. The project included the installation of monitoring wells, water quality sampling, and the review and analysis of historical data.

Managed the hydrogeologic characterization and hydrocarbon contamination evaluation at the Foundation Creek Natural Gas Compressor Station, Rangely, Colorado. This project involved the installation of monitoring wells and soil borings, chemical

sampling, and preparation of final report. Work was completed for Williams Field Services.

Forensic Hydrogeology and Litigation
Participated in the hydrogeologic characterization and evaluation of the extent of Cr^{6+} contamination of an alluvial aquifer at Hinkley, California. The work was performed in support of the lawsuit Anderson v. PG&E and Aguyo v. PG&E. Complied a database from more than 80,000 pages of documents produced by the defendant. Produced maps, graphs, and interpretations that were used in the presentation of expert testimony.

Currently participating in the hydrologeologic characterization of evaluation of the extent of TCE and perchlorate contamination of aquifers supplying domestic water to the City of Redlands, California. Work is being performed in support of a class-action and direct-action lawsuit brought against Lockheed-Martin Corporation.

PUBLICATIONS

Benson, A.K., Payne, K.L., and Stubben, M.A., 1995, Detecting organic groundwater contamination using electrical resistivity and VLF surveys *in* Hinchee, R.E., Douglas, G.S., and Ong, S.K., eds., Monitoring and verification of bioremediation: Battelle Press, Columbus, p. 105-113.

Benson, A.K., Payne, K.L., and Stubben, M.A., 1997, Mapping groundwater contamination using dc resistivity and VLF geophysical methods—A case study: Geophysics, v. 62, n. 1, p. 80-86.

Mayo, A.L., Morris, T.H., Petersen, E.C., and Payne, K.L., 1997, Groundwater flow systems in the Utah Coal District: Proceedings Rocky Mountain Ground Water Conference, Boise, Idaho.

NAME T.W.P. (Tim) Peterson

TITLE Senior Geotechnical Engineer

SUMMARY OF EXPERIENCE

Tim Peterson has over 25 years of engineering experience in geotechnical and civil engineering. He has been responsible for numerous geotechnical site investigations for thermal and hydroelectric power plants, dams, open cast mines, light to heavy industrial complexes, gas plants, low and high rise residential, hospital, educational, and commercial buildings, roads, bridges, port facilities, off-shore platforms, small and large diameter water, sulphur and gas pipelines and transmission lines. His experience includes the design of pad, raft and most types of piled foundations including foundation analyses for offshore platforms in the North Sea and Indian Ocean; the design of earth, tailings and water retaining structures; detailed settlement analyses; seismic analyses; and stability analyses of open pit mines, road and rail cuttings and embankments, earth and rockfill dams, and excavated marine slopes. He has specialized experience in the field of geotechnical engineering in permafrost regions, and has been responsible for conducting numerous geotechnical failure investigations for insurers. He has worked on several projects worldwide including major hydroelectric studies in Pakistan and Bolivia; open pit mines in Indonesia, Thailand, the Philippines, Colombia and Australia; industrial and commercial projects in the Middle East and the U.K. and spent most of 1994 managing field investigations for four high head hydroelectric schemes in Bolivia. He provides ongoing mining assistance to a major Canadian Utility, including design and monitoring of highwalls, waste dumps and tailings impoundments and geotechnical input to mine planning.

ACADEMIC AND PROFESSIONAL QUALIFICATIONS

B.Sc., (Civil Eng.), Portsmouth, U.K., 1973
H.N.D., (Civil Eng.), North East London Polytechnic, U.K., 1971
Member, Association of Professional Engineers, Geologists and Geophysicists of Alberta (P.Eng.)
Chartered Engineer, U.K. (C.Eng.).
Member, Institution of Civil Engineers (M.I.C.E.).
Fellow, Geological Society of London, U.K. (F.G.S.).
Member, British Geotechnical Society.
Member, International Society for Soil Mechanics and Foundation Engineering.

PROFESSIONAL HISTORY

1996 - Present
Norwest Mine Services Ltd., Calgary, Alberta
SENIOR GEOTECHNICAL ENGINEER: Consulting services to a major Canadian utility for civil and mining related work. Dam safety evaluations of ash lagoons and cooling ponds and design of incremental construction of ash tailings impoundments. Ongoing pit stability monitoring and input to mine planning. Remediation work associated with mine subsidence.

1980 - 1996
Monenco Agra, Calgary, Alberta
SENIOR SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department (1995 - October 1996). Responsible for mining, hydroelectric and process related projects. Specific projects include the design of the Snare Cascades Hydroelectric Project, Northwest Territories; design and reconstruction of Whiteman's Dam, Canmore, Alberta; Plant 4 Emergency Tailings at Suncor; design of a new sewage lagoon at Sundance Thermal Plant, Alberta; design of headpond impoundments, Miguillas Valley, Bolivia; upgrading power canal dykes, Brazeau, Alberta; seismic analysis of high head hydro developments, Zongo Valley, Bolivia, settlement monitoring and remediation of Highvale Mine Services Building, Alberta; geotechnical assessment of Highvale Mine long range plan area; dam safety assessment of the Wabamun Ash Lagoon, Alberta; and ongoing pit slope stability monitoring at Highvale and Whitewood Coal Mines.

MANAGER OF OPERATIONS: Miguillas Valley Hydroelectric Feasibility Study, Bolivia (1994 - 1995). Responsible for management and supervision of a nine month program of field investigations for four high head hydro schemes in the high Andes, including core drilling, geological mapping, hydrology, topographic, hydrographic and geophysical surveys, environmental and archaeological studies.

SENIOR SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department, Calgary (1989 - 1993). Responsible for mining, hydroelectric, and industrial projects. Geotechnical project coordination for open pit mine stability monitoring, groundwater monitoring and dewatering, mine design and planning at Highvale and Whitewood Mines, Alberta. Coordination, management and supervision of field investigations for Pasir Coal Project, Kalimantan, Indonesia; site selection and supervision of site investigations associated with Himalian and Panian Mine Feasibility Studies on Semirara Island, Philippines; geotechnical audits of a proposed coal mine in Colombia; and geotechnical assessment and coordination of investigations and review of geotechnical criteria for LP-2 coal

project, Thailand. Designs for Three Sisters Dam, Spray Canal, Glenmore Causeway and Ghost Dam, Alberta. Geotechnical Project Engineer involved with design of the Husky Bi-Provincial Upgrader at Lloydminster, the LNS pilot project at Cold lake and road upgrading at CFB Suffield.

SENIOR SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department, Calgary (1987-1989). Responsible for project coordination and geotechnical input to hydroelectric, mining and industrial projects including North Fork, Bearspaw, Bighorn, Ghost, Glenmore and Three Sisters Dam safety assessments and upgrading; Highvale and Whitewood Mine geotechnical assessments and stability monitoring, and foundation analysis for the LRT Crowchild Bridge, Calgary.

SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department, Calgary (1984 - 1987). Responsible for mining, hydroelectric and industrial projects. These include dam safety evaluations; the design of new spillway structures; slope stability analyses of mines in Alberta, Nova Scotia and Australia, including Leigh Creek and Lochiel in South Australia; foundation recommendations for industrial and gas plants in Alberta and Saskatchewan; settlement analysis of piled foundations for multi-storey structures in Alberta; substation site preparation and foundation design in upper New York state; bridge foundation and abutment design for county roads at Whitewood, Entwistle and Brazeau, Alberta.

DIRECTOR OF FIELD INVESTIGATIONS, Basha, Pakistan (1982 - 1984). CIDA funded feasibility study of a hydro site on the Indus river at Basha, Pakistan, where the construction of a 200 m high rockfill dam and 50 mile long reservoir was proposed. Responsible for managing the site office and all site activities including over 4000 metres of drilling in rock and overburden, topographical and hydrological surveys, geological mapping of outcrops, organization and supervision of the site soil testing laboratory, preparation of all site related data for input to the Feasibility Study Report and the general Hydroelectric Studies Report prepared by MCL in Lahore, Pakistan.

MANAGER SPECIAL DESIGN GROUP, Calgary (1981 - 1982). Seconded to the Yukon Pipeline Design Joint Venture, Calgary, for the design of the Yukon Section of the Alaska Highway Gas Pipeline for Foothills Pipelines. Responsibilities included the coordination of all geotechnical input to the pipeline design, together with supervising all special design aspects required for the 48 and 56 inch diameter warm and chilled sections of the line to be

constructed in intermittent permafrost, including geotechnical, geothermal, hydrological, drainage and erosion control and insulation. Specific geotechnical concerns included detailed analyses of frost heave and thaw settlement, pipeline restraint criteria and the stability of frozen and unfrozen excavated and natural slopes. An appraisal of site investigation methods in cold regions was carried out, together with a review of terrain analysis techniques and data from over one thousand boreholes along the entire route in the Yukon.

SENIOR GEOTECHNICAL SPECIALIST: Civil Engineering Department, Calgary (1980 - 1981). Responsible for investigation works, stability analysis using the Slope II computer model of existing hydroelectric developments for TransAlta Utilities. Foundation studies and recommendations for the Keephills Thermal Plant, Alberta, and recommendations involved in the planning and operating of the Highvale and Whitewood Coal Mines, Alberta.

1969 - 1980
Pell Frischmann and Partners, London, U.K.
SENIOR GEOTECHNICAL ENGINEER (1977 - 1980). Responsible for the planning, management and interpretation of site investigations; the design of foundations, deep basements and earth retaining structures for projects in the U.K., U.S.A., Nigeria and the Middle East, including multi-storey offices, hotels and hospitals, housing, industrial and civil engineering developments and offshore structures; the design and site supervision of land reclamation for British Steel Corporation's new Ore Terminal and direct Reduction Plant at Hunterston, Scotland; investigation and design of land reclamation for a Water Pollution Control Centre at Tubli, Bahrain; analyses of foundation design and operational behaviour of the Production Platform Jacket in the North Sea Brent Field for Shell; foundation design checking for the Bombay High Field Platform; state of the art study report on Containership Berthing Facilities with DMJM of Los Angeles for the Los Angeles Harbor Department; failure investigation of the fourteen berth extensions to the Port of Bandar Shahpour, Iran; slope stability analysis associated with deep excavations, embankments and dredged marine slopes; the investigation of and reporting on geotechnical failures for Insurers, and the completion of numerous feasibility studies for office and industrial developments in the U.K. and overseas.

GEOTECHNICAL ENGINEER (1973 - 1977). Responsible for the interpretation of site investigations, stability and settlement analyses, and the design of foundations.

ASSISTANT ENGINEER (1969 - 1973). Involved with site supervision of various large contracts in the U.K. and the design of multi-storey office and hospital buildings.

PAPERS PUBLISHED

1996 *"Collapse settlement of wetted mine waste - two case histories"*, with N.H. Wade, to be presented at Tailings and Mine Waste '97, Fort Collins, Colorado, January 1997.

1996 *"Whiteman's Earthfill Dam Internal Erosion"*, with L. Courage, A. Rothbauer, B. Pelz, to be presented at ICOLD, Florence, Italy, May 1997.

1993 *"Collapse and Consolidation Settlement in Mine Spoil Due to Saturation and Preloading"*, with N.H. Wade; 46th Canadian Geotechnical conference, Saskatoon, Saskatchewan, October.

1991 *"Graphical Database for Pit Slope Monitoring"*, with N.H. Wade, 2nd Canadian Conference on Computer Applications in the Mineral Industry, Vancouver, B.C.; Sept.

1991 *"Interpretation of Geophysical Logs Using a Scanning Routine"*, with N.H. Wade; ibid.

1988 *"Evaluation of Two Hydraulic Fill Dams in Alberta"*, with N.H. Wade, L. Courage, and R. Keys; Hydraulic Fill Structures '88 ASCE Speciality Conference in Fort Collins, Colorado, August, 1988.

1987 *"Interdisciplinary Mine Planning - The Geotechnical Component"*, with N.H.Wade, F. Naderi, CIM 3rd District Five Meeting, Fort McMurray, Alberta, September 1987.

1986 *"Highwall Monitoring, Instrumentation and Stability Analysis at Highvale Coal Mine, Alberta"*, with N.H. Wade, Symposium on Geotechnical Stability in Surface Mining, University of Calgary, Alberta, November 1986.

NAME	Richard Wright, C. Eng.
TITLE	Senior Mining Engineer
SUMMARY OF EXPERIENCE	Mr. Wright has over 20 years of mining related experience in operations, engineering and consultancy associated with both underground and surface mines in the USA, Canada, South Africa, Mexico and the U.K. His last two years were spent as project manager assisting an un derground longwall coal expansion program in Mexico. He has spent five years in the USA progressing coal prospects from the feasibility phase through to operations planning and engineering, including a mine that has recently been setting world longwall production records. In addition he has about 10 years of consultancy experience covering geotechnical, mining and ventilation engineering for a variety of projects and clients, including design, engineering and planning applications and associated public inquiries.
ACADEMIC AND PROFESSIONAL QUALIFICATIONS	M.Sc. (Mining/Geotechnical), University of Alberta, 1981. B.Sc. (Mining Engineering), Royal School of Mines, London, UK, 1977. B.Sc. (Engineering Science), University of Leicester, UK, 1974. European Engineer (Registration No: UK/IMM/EE/94/8852) Chartered Engineer (No.410430), Member of the Institution of Mining and Metallurgy
PROFESSIONAL HISTORY	**1998 – Present NorWest Mine Services Ltd., Calgary, Alberta, Canada** SENIOR MINING ENGINEER: Engineering and Management of underground mining and geotechnical projects. Providing operational and planning assistance with emphasis on underground coal mine design and planning, mine rehabilitation, stability of underground openings and blasting vibrations impact analysis **1989 – 1998 Wright Technical Services, Redruth, Cornwall, England** • MINING / GEOTECHNICAL CONSULTANT: Independent Mining and Geotechnical Engineering Consultant with emphasis on coal mining, underground construction and radioactive waste disposal. Projects included:

- Project Manager for operations and engineering assistance for upgrading of existing and new underground coal mines for MICARE, Coahuila, Mexico;
- design, data evaluation and shaft/tunnel surveying for the planned Sellafield underground radioactive waste repository in the UK;
- geotechnical site investigations and evaluation of the stability of foundations, slopes and underground openings for a number of clients;
- ventilation design and monitoring for construction of the UK side of the Channel Tunnel; and
- various coal and metal mine engineering and planning studies for a number of clients.

1987 – 1989 Jay Mineral Services Limited, Truro, Cornwall, England
MINING CONSULTANT: Responsible for a variety of mining engineering projects including:

- various economic evaluations of underground and surface coal and metal mines in the UK and overseas;
- prediction of blasting vibrations for surface coal mines and preparation of expert witness evidence for the Smotherfly planning inquiry in the UK;
- pillar design of coal and salt mines in the UK and Ireland; shaft winding and headframe design for underground coal mines and preparation of expert witness evidence for the Hawkhurst Moor public inquiry in the UK;
- market study for full face hard rock boring of tunnels and shafts; and
- electricity tariff study for gold mining in Ghana.

1986 – 1987 Battelle Project Management Division, Columbus, Ohio, USA
SENIOR GEOTECHNICAL ENGINEER: Assistant Project Manager of a $10 million contract for underground geotechnical testing as part of the site characterization for a proposed underground nuclear waste repository in salt strata. This included planning for major long term tests on the rock mass and engineered barriers in an exploratory shaft facility in Texas, USA. The tests were designed to assess the mechanical, thermal, chemical and hydraulic performance under nuclear safety requirement for containment over 10,000 years.

1983 – 1986 Twentymile Coal Company, Colorado, USA
CHIEF MINING ENGINEER: responsible for the mine planning and engineering department of an underground coal mine. This involved detailed planning for a 3.2 Mtpa operation with both longwall and room and pillar operations. This included ventilation survey and

design, geology, geotechnical, hydrology, coal quality, construction, equipment selection, environmental, permitting, financial evaluations, surveying, sequencing and subsidence prediction and monitoring.

1981 – 1983 Getty Mining Company, Salt Lake City, Utah, USA
PROJECT ENGINEER: responsible for underground coal mine planning, mine design, feasibility studies and exploration programmes for new projects and operating coal mines. Developed geotechnical programs for rock characterization and hazard analysis for mine design and strata control studies.

1977 – 1978 Anglo Power Collieries, Kriel, Transvaal, South Africa
MINE ENGINEER: responsible for an underground coal production section and surface mine planning and engineering of an opencast coal mine (pit design, sequencing, geology, coal quality, etc.).

1974 – 1975 Anglo American Corporation, Welkom, Orange Free State, South Africa
MINE OFFICIAL: Practical experience in production, preparation, ventilation, surveying, sampling and other service departments of deep underground gold mines.

PUBLICATIONS

1988 Blasting Vibes I and II, J.Stocks and R.Wright, Mineral Planning, UK.

1982 Technology Management for Risk Minimization, J.D.Spalding, E.N.Thurmond, J.M.Mercier and R.Wright, International Conference on Coal Research (ICCR), London.

1981 Stability Analysis in Room and Pillar Coal Mining, M.Sc. Thesis, University of Alberta, Canada.

APPENDIX D

CONFIDENTIAL MATERIAL USED IN DEVELOPING MINING SCENARIOS

The mining scenarios have been developed using the data defined in Section 1 and listed in Section 9. In addition the evaluation included a series of confidential documents that are listed in this Appendix.

CONFIDENTIAL REFERENCES

1. Digital Data Files in AutoCAD R14 format with geologic modeling data on seam thickness.

2. Original copies of borehole geophysical and cuttings logs for both the Tract and existing lease area.

3. Various mine plans with data relating to coal seam thickness for the Tract.

APPENDIX E

SDPS NUMERICAL SUBSIDENCE MODEL RESULTS

APPENDIX E

SDPS NUMERICAL SUBSIDENCE MODEL RESULTS

1. INTRODUCTION

Numerical modeling the RFDS Area was necessary to predict subsidence movements at specific locations. David Newman and his company, Appalachian Mining & Engineering, Inc. (AME) was authorized by NorWest Mine Services, Inc. (NorWest) to model and predict the subsidence, strains, and surface deformations resulting from longwall undermining. AME used the Surface Deformation Subsidence Prediction System (SDPS) program to predict subsidence and associated ground behavior for longwall mining of the Lower O'Connor B, Lower O'Connor A and Flat Canyon Seams. Because of mining and geologic constraints, no more than two seams will be mined at any one location.

A specific mining plan or mine layout does not currently exist for the Tract. Consequently, subsidence modeling focused on nine (9) specific sites across the Tract. These sites were selected based upon the surface features requiring evaluation. For each of the nine sites estimates were made concerning the mineable seams and extraction heights for either single of multiple seam mining.

Two mining layouts were developed based upon prior mining practices and typical mining parameters, including gate road pillar centers, longwall panel length and width, and fire barrier pillars used in the past by Canyon Fuel Company, LLC. (CFC). The objective of the multiple seam model was to incorporate the offsetting of gate road and fire barrier pillars to minimize adverse stress interactions. These two mining layouts are presented in Figures A.** and A.**. The outline of these mine layouts was simplified for the numerical models and is shown on each of the contour plots in Section **.

The first type of layout is for single seam mining and illustrates the effect of a combination abutment (non-yielding) and yield pillar for gate roads, with a fire barrier pillar that may be needed to restrict connected panels to a maximum of five.

A multiple seam layout type was also developed with the placement of gate roads in the lower seam below the de-stressed gob area of the upper seam. This layout incorporated an area where only the lower seam was mined to simulate areas where the upper seam was too thin to be mineable. Similarly, the fire barriers in the two seams were offset to reduce stress interactions. Of particular concern is the horizontal strain and resulting compression and tension zones. Horizontal

strain can result in tensile cracks in zones of tension and buckling in zones of compression.

For each model run, the following parameters were calculated at 16,610 individual calculation points spaced on fifty (50') foot centers across the model;

- vertical subsidence;
- horizontal strain (x direction, y direction, maximum strain, and direction of horizontal strain);
- percent slope (total slope and slope direction);
- curvature (x direction, y direction, maximum curvature, and direction of curvature);
- Maximum principal strain, minimum principal strain, and principal strain direction; and
- Horizontal displacement (x direction, y direction, maximum displacement, and direction of displacement).

The major parameters of concern included vertical subsidence (feet), maximum horizontal strain (millistrain) and induced slope (%). The values of these parameters were created for each model and contoured.

2. SDPS SUBSIDENCE MODELING

Surface subsidence was modeled using the Surface Deformation Prediction System (SDPS) subsidence package developed at the Virginia Polytechnic Institute and Virginia State University (VPI). SDPS has been adopted by the Office of Surface Mining (OSM) for subsidence analysis. The SDPS program uses the widely accepted influence area approach to determine the effect on the ground surface of complete and/or partial coal extraction within the proposed underground mine workings. Input parameters for the SDPS models were based on data supplied by CFC and modified by NorWest where necessary for anticipated conditions.

The input parameters required by SDPS include:

i) percentage of hard rock, including sandstones and sandy siltstones, in the overburden;

ii) average mining height for one or two seams;

iii) a high average estimate for overburden thickness above the upper seam;

iv) the tangent of the influence angle;

v) the coefficient of horizontal strain (0.35 is the SDPS default value);

vi) interburden interval between lower and upper seams; and

vii) subsidence factor estimated for single and multiple seam models.

The SDPS model can be run using theoretically derived parameters, but is more accurate where empirical data exists from monitoring of subsidence above previously mined panels. A process of back-calculation is used to estimate the parameters in this case and the process is referred to as model calibration and is discussed later.

Following model calibration a number of model runs were carried out to predict subsidence at the nine subsidence prediction points chosen for characterization.

3. CALIBRATION OF THE SDPS SUBSIDENCE MODEL

The SDPS program, in the absence of calibration data, uses regional default averages of the tangent angle of influence (2.31) and percent hard rock (50%) for the Appalachian coalfield in conjunction with the actual panel geometry to estimate surface subsidence. Site specific subsidence data greatly increases the accuracy of subsidence prediction and enables validation of the output data.

To accurately calibrate SDPS, the following information is required: longwall panel geometry, actual dimensions of the gateroad pillars, mining height, bottom-of-seam elevation, surface topography, percentage of hard rock within the overburden, interburden thickness (if multiple seams are to be mined), and the actual surveyed subsidence. The objective of calibration is to use back calculations to establish a site-specific angle of draw or tangent angle of influence and the subsidence factor. Once SDPS is calibrated, subsidence predictions are made based upon the derived site specific values.

Reports of previous subsidence studies were supplied by CFC regarding several areas that had been monitored over typical longwall panels. They included subsidence studies conducted at Burnout Canyon, Trough Springs Ridge, the Questar gas pipeline and State Highway SR 264. Of these studies, data from the State Highway SR 264 was best suited to calibration.

Calibration and determination of site-specific input data was accomplished by entering measured subsidence data at twenty-seven (27) data points into the SDPS program. Various combinations of the tangent of the influence angle and the subsidence factor were used in several hundred iterations to calculate the magnitude of subsidence. After each iteration, an error index is calculated by squaring the SDPS calculated value and the measured value for each point, then

summing the squared differences obtained at each measured subsidence point. The combination of tangent angle of influence and subsidence factor that produces the minimum error index is then the optimum value that can be used for modeling.

An edge effect, based upon the ratio of panel width to overburden depth was also used in the calibration. The tangent angle of influence and subsidence factor are used to accurately model the magnitude of subsidence and the edge effect is used to define the slope of the subsidence curve above the longwall panel. The edge effect incorporates the cantilevering of the overburden strata over the longwall gob to define the rate or slope of subsidence between the area of maximum subsidence in the center of the panel and point of zero subsidence outside the panel. The edge effect is adjusted until the slopes of the predicted subsidence curve matches the actual data. This procedure is repeated until the minimum error between measured and predicted subsidence has been obtained and the contours of predicted and measured subsidence agree as closely as possible, defined by the least squares error analysis.

This calibration methodology was used with measured subsidence data from monitoring of State Highway SR 264. The minimum prediction error was obtained for a tangent angle of 3.00, equivalent to an Angle of Draw of 18.4 degrees to the vertical and a subsidence factor of fifty (50%) percent. The output is tabulated below.

tanb= 3 smax factor= 50

Predicted and Measured Subsidence (ft)

PT#	Pred SU	Meas SU	Total Error
1	0.000	-0.090	0.0900
2	0.000	-0.060	0.0600
3	-0.051	-0.690	0.6881
4	-0.008	-0.570	0.5699
5	0.000	-0.560	0.5600
6	0.000	-0.570	0.5700
7	0.000	-0.530	0.5300
8	0.000	-0.530	0.5300
9	0.000	-0.510	0.5100
10	-0.168	-0.710	0.6898
11	-3.431	-2.990	1.6821
12	-4.201	-4.930	2.5799
13	-2.209	-2.070	0.7712
14	-0.041	-0.880	0.8791
15	-2.306	-1.190	1.9755
16	-2.003	-2.040	0.3886
17	-3.617	-3.620	0.1590

18	-4.160	-5.920	4.2121
19	-3.480	-3.640	1.0689
20	-0.613	-1.660	1.5427
21	0.000	-0.540	0.5400
22	0.000	-0.440	0.4400
23	0.000	-0.410	0.4100
24	0.000	-0.080	0.0800
25	0.000	-0.590	0.5900
26	0.000	0.000	0.0000
27	0.000	0.000	0.0000
		Total Error = 22.1	

For the purposes of the EIS it was agreed that the modeling should be conservative, especially given the preliminary level of exploration data and the limited data concerning the effect of multiple seam mining on the subsidence factor. The lack of conceptual mine layout increased the level of uncertainty. Consequently, a slightly conservative tangent angle of 2.48 (equivalent to an Angle of Draw of 22 degrees to the vertical) and subsidence factor of five-five (55%) percent were used in the single seam model runs. Although used in the calibration, an edge effect was not used in the model runs in order to examine the "worst-case" subsidence under each scenario.

4. SDPS MODELS

SDPS models were created for each of the nine (9) previously selected sites. The surface elevation for each model was set to a flat plane equal to the high average overburden because the exact orientation of the longwall panels with respect to the surface topography is unknown at this time. Northing and Easting coordinate values tied to the Utah state plane coordinate system were established for each model. Input data for each model is summarized in Table 1 on the following page. Additionally, the input data used in each run can be found in Table 1 and Section ** that have the results of the subsidence run for the first thirty (30) or so points. Each model generated information on the subsidence or vertical movement, horizontal displacement, strain, slope, and curvature for 16,610 individual calculation points. Results of the models are characterized as a series of subsidence, strain, and slope contour plots that can be found in Section **.

Sites 2 and 6 are used here to best illustrate the effect of the single seam model (Site 2) and multiple seam model (site 6) of longwall mining on the surface. As with all the models, subsidence, maximum horizontal strain, and slope are contoured. However, to better illustrate the distinction between tensile and compressive zones of horizontal strain, a color code has been superimposed on these models. Tensile strains are positive and compressive strains are negative. In the single seam model, the maximum tensile strains occur over the fire barrier

as shown in red, and to a lesser extent over the gate road pillars. For the multiple seam model, the strain distribution is far more complex. The effect of staggering gate roads and fire barrier pillars, in addition to shortening one side of the upper panels, produces an asymmetric distribution of tensile strain. Most importantly, the zone of tensile strain that is more damaging to surface structures is reduced where panel limits in both seams are not aligned.

Table E.1
Subsidence Model Input Data

Canyon Fuels Subsidence Models												
Input Data Requirements												
Site Number	**Easting**	**Northing**	**Single/ Multiple Seam Scenario**	**High Average Overburden (feet)**	**Interburden (feet)**	**Percent Hard Rock (%)**	**Subsidence Factor (%)**	**Upper Seam**	**Lower Seam**	**Upper Seam Thickness (feet)**	**Lower Seam Thickness (feet)**	**Total Thickness (feet)**
1	2,065,000	470,600	M	1,800	50	50	63.9%	LOB	LOA	10.0	8.0	18.0
2	2,070,800	490,300	S	1,600	-	65	55.0%	FC	-	10.0	-	10.0
3	2,066,300	484,600	M	1,700	130	65	64.7%	LOB	FC	8.5	8.0	16.5
4	2,070,600	484,500	M	1,100	130	65	65.0%	LOB	FC	10.0	10.0	20.0
5	2,066,300	478,700	S	1,500	-	60	55.0%	LOB	-	8.5	-	8.5
6	2,069,500	478,100	M	1,200	100	65	63.9%	LOB	FC	12.5	10.0	22.5
7	2,063,600	472,900	S	1,750	-	50	55.0%	LOA	-	9.0	-	9.0
8	2,066,800	474,400	M	1,500	50	50	64.1%	LOB	LOA	12.0	10.0	22.0
9	2,070,600	471,400	M	1,600	50	50	62.8%	LOB	LOA	12.5	8.0	20.5

Notes:

1. The interburden and lower seam thickness are only applicable in multiple seam scenario
2. High average overburden is for the upper seam.
3. % Hard Rock based on sst from geophysical logs and rounded to nearest 5%
4. Mining Height Limits (LOB = 8.5 to 12.5 ft., FC/LOA = 7.0 to 10.0 ft)
5. Percent subsidence = 55% for single seam, 75% for upper seam in multiple seam case
6. Multiple seam subsidence factor is based upon a weighted average of seam thickness.

5. INPUT DATA FOR EACH SITE

Site 1

Surface Deformation Prediction System
SDPS version 5.1H 07/20/2000
Influence Function Method 13:27:57

Units: Imperial
Parameters: TanB = 2.48 Bs = 0.35
Def.Index Id: Multip
Deformation files: ".DAT"
Case Description
Model 1 - Multiple Seam Mining LOA & LOB

Subsidence (ft) and Slopes (%)

PT#	SU	Tx	Ty	Ta	Tm	AngTm
1	-0.010	-0.007	-0.009	0.000	0.011	231.0
2	-0.015	-0.012	-0.014	0.000	0.018	229.0
3	-0.022	-0.016	-0.018	0.000	0.024	227.0
4	-0.030	-0.022	-0.022	0.000	0.031	225.0
5	-0.042	-0.030	-0.027	0.000	0.040	223.0
6	-0.056	-0.039	-0.033	0.000	0.051	221.0
7	-0.073	-0.050	-0.039	0.000	0.063	218.0
8	-0.094	-0.064	-0.046	0.000	0.078	216.0
9	-0.117	-0.079	-0.052	0.000	0.094	213.0
10	-0.144	-0.096	-0.057	-0.017	0.112	210.0
11	-0.014	-0.010	-0.013	0.000	0.016	233.0
12	-0.021	-0.015	-0.018	0.000	0.023	231.0
13	-0.030	-0.020	-0.023	0.000	0.031	229.0
14	-0.042	-0.028	-0.029	0.000	0.040	227.0
15	-0.057	-0.037	-0.037	0.000	0.053	225.0
16	-0.077	-0.049	-0.045	0.000	0.067	223.0
17	-0.101	-0.064	-0.054	0.000	0.083	220.0
18	-0.129	-0.084	-0.063	0.000	0.105	217.0
19	-0.162	-0.105	-0.072	0.000	0.127	214.0
20	-0.198	-0.128	-0.079	-0.023	0.151	212.0
21	-0.019	-0.012	-0.018	0.000	0.022	235.0
22	-0.028	-0.018	-0.024	0.000	0.030	233.0
23	-0.040	-0.025	-0.031	0.000	0.039	231.0
24	-0.056	-0.034	-0.039	0.000	0.052	229.0

25	-0.077	-0.046	-0.049	0.000	0.067	227.0
26	-0.104	-0.063	-0.061	0.000	0.088	224.0
27	-0.136	-0.083	-0.073	0.000	0.110	222.0
28	-0.174	-0.105	-0.085	0.000	0.135	219.0
29	-0.218	-0.130	-0.096	0.000	0.162	216.0
30	-0.267	-0.159	-0.106	-0.029	0.191	214.0
31	-0.025	-0.015	-0.023	0.000	0.027	237.0
32	-0.037	-0.021	-0.030	0.000	0.037	235.0
33	-0.053	-0.030	-0.039	0.000	0.049	233.0
34	-0.074	-0.042	-0.051	0.000	0.066	231.0
35	-0.102	-0.058	-0.065	0.000	0.088	228.0
36	-0.137	-0.077	-0.080	0.000	0.111	226.0
37	-0.179	-0.100	-0.096	0.000	0.138	224.0
38	-0.229	-0.126	-0.111	0.000	0.168	221.0
39	-0.287	-0.157	-0.126	0.000	0.200	119.0

Site 2

Surface Deformation Prediction System
SDPS version 5.1H 07/19/2000
Influence Function Method 13:38:10

Units: Imperial
Parameters: TanB = 2.48 Bs = 0.35
Def.Index Id: Site 2
Deformation files: ".DAT"
Case Description
Site 2 - Single Seam Model - FC

Subsidence (ft) and Slopes (%)

PT#	SU	Tx	Ty	Ta	Tm	AngTm
1	-0.003	-0.002	-0.003	0.000	0.004	232.0
2	-0.005	-0.004	-0.005	0.000	0.006	231.0
3	-0.007	-0.006	-0.007	0.000	0.009	229.0
4	-0.012	-0.010	-0.011	0.000	0.015	226.0
5	-0.017	-0.017	-0.016	0.000	0.023	224.0
6	-0.025	-0.023	-0.020	0.000	0.030	222.0
7	-0.035	-0.031	-0.025	0.000	0.040	219.0
8	-0.047	-0.041	-0.030	0.000	0.050	216.0
9	-0.062	-0.052	-0.035	0.000	0.063	214.0
10	-0.080	-0.066	-0.039	-0.012	0.077	211.0
11	-0.004	-0.003	-0.004	0.000	0.005	235.0
12	-0.007	-0.005	-0.007	0.000	0.008	233.0
13	-0.011	-0.009	-0.011	0.000	0.014	231.0
14	-0.017	-0.015	-0.017	0.000	0.022	229.0
15	-0.025	-0.021	-0.022	0.000	0.031	226.0
16	-0.036	-0.029	-0.028	0.000	0.040	224.0
17	-0.051	-0.040	-0.035	0.000	0.053	221.0
18	-0.069	-0.053	-0.042	0.000	0.068	219.0
19	-0.091	-0.069	-0.050	0.000	0.085	216.0
20	-0.117	-0.088	-0.056	-0.016	0.104	213.0
21	-0.006	-0.004	-0.006	0.000	0.007	237.0
22	-0.010	-0.007	-0.010	0.000	0.012	236.0
23	-0.015	-0.012	-0.017	0.000	0.021	234.0
24	-0.024	-0.018	-0.023	0.000	0.029	231.0
25	-0.036	-0.026	-0.030	0.000	0.040	229.0
26	-0.052	-0.037	-0.039	0.000	0.053	226.0
27	-0.072	-0.051	-0.049	0.000	0.070	224.0
28	-0.098	-0.067	-0.059	0.000	0.090	221.0
29	-0.130	-0.088	-0.069	0.000	0.112	218.0
30	-0.166	-0.112	-0.079	-0.021	0.137	215.0

31	-0.008	-0.005	-0.008	0.000	0.010	240.0
32	-0.013	-0.010	-0.016	0.000	0.018	239.0
33	-0.021	-0.015	-0.023	0.000	0.027	236.0
34	-0.033	-0.022	-0.030	0.000	0.038	234.0
35	-0.049	-0.032	-0.041	0.000	0.052	232.0
36	-0.071	-0.045	-0.052	0.000	0.069	229.0
37	-0.100	-0.062	-0.066	0.000	0.091	227.0
38	-0.135	-0.083	-0.080	0.000	0.116	224.0

Site 3

Surface Deformation Prediction System
SDPS version 5.1H 07/20/2000
Influence Function Method 13:35:46

Units: Imperial
Parameters: TanB = 2.48 Bs = 0.35
Def.Index Id: Mult3
Deformation files: ".DAT"
Case Description
3 – Multiple Seam Mining FC & LOB

Subsidence (ft) and Slopes (%)

PT#	SU	Tx	Ty	Ta	Tm	AngTm
1	-0.005	-0.003	-0.004	0.000	0.006	232.0
2	-0.008	-0.005	-0.007	0.000	0.009	230.0
3	-0.011	-0.010	-0.011	0.000	0.015	228.0
4	-0.017	-0.014	-0.015	0.000	0.021	226.0
5	-0.024	-0.020	-0.019	0.000	0.028	224.0
6	-0.034	-0.028	-0.024	0.000	0.037	221.0
7	-0.046	-0.036	-0.029	0.000	0.047	219.0
8	-0.062	-0.047	-0.035	0.000	0.059	216.0
9	-0.079	-0.060	-0.040	0.000	0.072	213.0
10	-0.100	-0.075	-0.044	-0.013	0.087	211.0
11	-0.007	-0.005	-0.006	0.000	0.008	234.0
12	-0.011	-0.008	-0.011	0.000	0.013	233.0
13	-0.016	-0.013	-0.016	0.000	0.020	230.0
14	-0.024	-0.019	-0.021	0.000	0.028	228.0
15	-0.035	-0.026	-0.027	0.000	0.037	226.0
16	-0.049	-0.035	-0.033	0.000	0.049	223.0
17	-0.066	-0.047	-0.041	0.000	0.062	221.0
18	-0.088	-0.062	-0.049	0.000	0.079	218.0
19	-0.113	-0.079	-0.056	0.000	0.097	215.0
20	-0.142	-0.099	-0.063	-0.018	0.117	212.0
21	-0.009	-0.006	-0.009	0.000	0.011	236.0
22	-0.015	-0.011	-0.016	0.000	0.019	235.0
23	-0.023	-0.016	-0.021	0.000	0.027	233.0
24	-0.034	-0.023	-0.028	0.000	0.037	230.0
25	-0.048	-0.033	-0.036	0.000	0.049	228.0
26	-0.068	-0.045	-0.046	0.000	0.064	226.0
27	-0.092	-0.060	-0.056	0.000	0.082	223.0
28	-0.122	-0.079	-0.067	0.000	0.104	220.0
29	-0.158	-0.102	-0.078	0.000	0.128	217.0
30	-0.198	-0.128	-0.087	-0.024	0.155	214.0

31	-0.013	-0.008	-0.014	0.000	0.016	239.0
32	-0.020	-0.013	-0.020	0.000	0.024	237.0
33	-0.031	-0.020	-0.028	0.000	0.034	235.0
34	-0.045	-0.028	-0.037	0.000	0.047	232.0
35	-0.066	-0.040	-0.048	0.000	0.063	230.0
36	-0.092	-0.055	-0.061	0.000	0.082	228.0
37	-0.125	-0.075	-0.075	0.000	0.106	225.0

Site 4

Surface Deformation Prediction System
SDPS version 5.1H 07/20/2000
Influence Function Method 13:41:02

Units: Imperial
Parameters: TanB = 2.48 Bs = 0.35
Def.Index Id: Mult4
Deformation files: ".DAT"
Case Description
Model 4 - Multiple Seam Mining FC & LOB

Subsidence (ft) and Slopes (%)

PT#	SU	Tx	Ty	Ta	Tm	AngTm
1	0.000	0.000	0.000	0.000	0.000	999.0
2	0.000	0.000	0.000	0.000	0.000	999.0
3	0.000	0.000	0.000	0.000	0.000	999.0
4	0.000	0.000	-0.001	0.000	0.001	999.0
5	-0.001	-0.001	-0.001	0.000	0.001	224.0
6	-0.001	-0.002	-0.002	0.000	0.003	221.0
7	-0.003	-0.004	-0.003	0.000	0.005	218.0
8	-0.005	-0.007	-0.005	0.000	0.009	215.0
9	-0.008	-0.011	-0.007	0.000	0.013	211.0
10	-0.012	-0.018	-0.009	-0.003	0.020	207.0
11	0.000	0.000	0.000	0.000	0.000	999.0
12	0.000	0.000	0.000	0.000	0.000	999.0
13	0.000	0.000	-0.001	0.000	0.001	999.0
14	-0.001	-0.001	-0.001	0.000	0.001	229.0
15	-0.001	-0.002	-0.002	0.000	0.003	227.0
16	-0.003	-0.004	-0.004	0.000	0.006	224.0
17	-0.005	-0.008	-0.006	0.000	0.010	221.0
18	-0.010	-0.013	-0.010	0.000	0.017	217.0
19	-0.016	-0.025	-0.016	0.000	0.030	213.0
20	-0.024	-0.039	-0.022	-0.007	0.045	209.0
21	0.000	0.000	0.000	0.000	0.000	999.0
22	0.000	0.000	0.000	0.000	0.001	999.0
23	-0.001	-0.001	-0.001	0.000	0.001	999.0
24	-0.001	-0.002	-0.002	0.000	0.003	232.0
25	-0.003	-0.003	-0.004	0.000	0.005	230.0
26	-0.006	-0.007	-0.007	0.000	0.010	227.0
27	-0.011	-0.015	-0.014	0.000	0.020	224.0
28	-0.018	-0.027	-0.023	0.000	0.035	220.0
29	-0.030	-0.043	-0.032	0.000	0.054	216.0
30	-0.046	-0.063	-0.040	-0.011	0.075	213.0

31	0.000	0.000	0.000	0.000	0.000	999.0
32	0.000	0.000	-0.001	0.000	0.001	999.0
33	-0.001	-0.001	-0.002	0.000	0.002	238.0
34	-0.002	-0.003	-0.004	0.000	0.005	236.0
35	-0.005	-0.006	-0.007	0.000	0.009	233.0
36	-0.010	-0.011	-0.014	0.000	0.018	230.0
37	-0.019	-0.025	-0.027	0.000	0.037	227.0

Site 5

Surface Deformation Prediction System
SDPS version 5.1H 07/20/2000
Influence Function Method 13:46:46

Units: Imperial
Parameters: TanB = 2.48 Bs = 0.35
Def.Index Id: Site 5
Deformation files: ".DAT"
Case Description
Site 5 - Single Seam Model - FC

Subsidence (ft) and Slopes (%)

PT#	SU	Tx	Ty	Ta	Tm	AngTm
1	-0.001	-0.001	-0.001	0.000	0.002	233.0
2	-0.002	-0.002	-0.002	0.000	0.003	231.0
3	-0.004	-0.003	-0.004	0.000	0.005	229.0
4	-0.006	-0.005	-0.006	0.000	0.008	226.0
5	-0.009	-0.010	-0.010	0.000	0.014	224.0
6	-0.014	-0.015	-0.013	0.000	0.020	221.0
7	-0.021	-0.021	-0.017	0.000	0.027	219.0
8	-0.029	-0.029	-0.021	0.000	0.036	216.0
9	-0.039	-0.037	-0.025	0.000	0.045	213.0
10	-0.052	-0.049	-0.028	-0.008	0.056	210.0
11	-0.002	-0.002	-0.002	0.000	0.003	235.0
12	-0.003	-0.003	-0.004	0.000	0.005	233.0
13	-0.006	-0.005	-0.006	0.000	0.007	231.0
14	-0.009	-0.009	-0.010	0.000	0.013	229.0
15	-0.014	-0.014	-0.015	0.000	0.020	227.0
16	-0.022	-0.020	-0.020	0.000	0.028	224.0
17	-0.032	-0.028	-0.025	0.000	0.038	221.0
18	-0.044	-0.038	-0.031	0.000	0.049	219.0
19	-0.060	-0.051	-0.037	0.000	0.063	215.0
20	-0.079	-0.066	-0.042	-0.012	0.079	212.0
21	-0.003	-0.002	-0.003	0.000	0.004	237.0
22	-0.005	-0.004	-0.005	0.000	0.007	236.0
23	-0.008	-0.007	-0.010	0.000	0.012	234.0
24	-0.014	-0.012	-0.015	0.000	0.019	232.0
25	-0.021	-0.018	-0.021	0.000	0.028	229.0
26	-0.032	-0.026	-0.027	0.000	0.038	226.0
27	-0.047	-0.037	-0.035	0.000	0.051	224.0
28	-0.066	-0.050	-0.044	0.000	0.067	221.0
29	-0.089	-0.067	-0.052	0.000	0.085	218.0
30	-0.116	-0.088	-0.061	-0.016	0.106	215.0

31	-0.004	-0.003	-0.005	0.000	0.005	240.0
32	-0.007	-0.005	-0.008	0.000	0.009	238.0
33	-0.012	-0.009	-0.014	0.000	0.017	237.0
34	-0.019	-0.015	-0.021	0.000	0.026	234.0
35	-0.030	-0.022	-0.028	0.000	0.036	232.0
36	-0.046	-0.033	-0.038	0.000	0.050	229.0

Site 6

Surface Deformation Prediction System
SDPS version 5.1H 07/19/2000
Influence Function Method 13:27:14

Units: Imperial
Parameters: TanB = 2.48 Bs = 0.35
Def.Index Id: Mult6
Deformation files: ".DAT"
Case Description
Model 6 - Multiple Seam Mining FC & LOB

Subsidence (ft) and Slopes (%)

PT#	SU	Tx	Ty	Ta	Tm	AngTm
1	0.000	0.000	0.000	0.000	0.000	999.0
2	0.000	0.000	0.000	0.000	0.000	999.0
3	0.000	-0.001	-0.001	0.000	0.001	999.0
4	-0.001	-0.001	-0.001	0.000	0.002	226.0
5	-0.002	-0.003	-0.002	0.000	0.003	224.0
6	-0.003	-0.005	-0.004	0.000	0.006	221.0
7	-0.006	-0.008	-0.006	0.000	0.010	218.0
8	-0.010	-0.013	-0.009	0.000	0.016	215.0
9	-0.015	-0.024	-0.014	0.000	0.028	211.0
10	-0.022	-0.034	-0.018	-0.006	0.039	208.0
11	0.000	0.000	0.000	0.000	0.000	999.0
12	0.000	0.000	-0.001	0.000	0.001	999.0
13	-0.001	-0.001	-0.001	0.000	0.002	232.0
14	-0.002	-0.002	-0.003	0.000	0.003	229.0
15	-0.004	-0.004	-0.004	0.000	0.006	227.0
16	-0.007	-0.008	-0.007	0.000	0.011	224.0
17	-0.011	-0.015	-0.013	0.000	0.020	221.0
18	-0.018	-0.026	-0.020	0.000	0.033	217.0
19	-0.028	-0.039	-0.026	0.000	0.047	214.0
20	-0.041	-0.055	-0.032	-0.010	0.063	210.0
21	0.000	0.000	-0.001	0.000	0.001	999.0
22	-0.001	-0.001	-0.001	0.000	0.001	236.0
23	-0.002	-0.002	-0.002	0.000	0.003	234.0
24	-0.003	-0.004	-0.004	0.000	0.006	232.0
25	-0.006	-0.007	-0.008	0.000	0.010	229.0
26	-0.011	-0.014	-0.015	0.000	0.020	227.0
27	-0.020	-0.025	-0.024	0.000	0.034	224.0
28	-0.032	-0.039	-0.033	0.000	0.051	220.0
29	-0.049	-0.058	-0.043	0.000	0.072	217.0
30	-0.072	-0.081	-0.053	-0.015	0.097	213.0

31	-0.001	0.000	-0.001	0.000	0.001	999.0
32	-0.001	-0.001	-0.002	0.000	0.002	239.0
33	-0.003	-0.003	-0.004	0.000	0.005	237.0
34	-0.005	-0.005	-0.007	0.000	0.009	235.0
35	-0.010	-0.010	-0.013	0.000	0.017	233.0
36	-0.019	-0.022	-0.026	0.000	0.034	230.0
37	-0.033	-0.036	-0.038	0.000	0.053	227.0
38	-0.054	-0.055	-0.052	0.000	0.076	223.0
39	-0.082	-0.084	-0.069	0.000	0.109	220.0

Site 7

Surface Deformation Prediction System
SDPS version 5.1H 07/20/2000
Influence Function Method 13:59:11

Units: Imperial
Parameters: TanB = 2.48 Bs = 0.35
Def.Index Id: Site 7
Deformation files: ".DAT"
Case Description
Site 7 - Single Seam Model - FC

Subsidence (ft) and Slopes (%)

PT#	SU	Tx	Ty	Ta	Tm	AngTm
1	-0.006	-0.004	-0.005	0.000	0.006	232.0
2	-0.009	-0.006	-0.008	0.000	0.010	231.0
3	-0.013	-0.010	-0.012	0.000	0.016	229.0
4	-0.019	-0.015	-0.015	0.000	0.021	226.0
5	-0.026	-0.020	-0.020	0.000	0.028	224.0
6	-0.036	-0.027	-0.024	0.000	0.036	222.0
7	-0.049	-0.035	-0.029	0.000	0.046	219.0
8	-0.063	-0.045	-0.034	0.000	0.057	217.0
9	-0.081	-0.057	-0.039	0.000	0.069	214.0
10	-0.101	-0.070	-0.043	-0.012	0.082	211.0
11	-0.008	-0.005	-0.007	0.000	0.008	234.0
12	-0.012	-0.009	-0.012	0.000	0.015	233.0
13	-0.018	-0.013	-0.016	0.000	0.021	231.0
14	-0.026	-0.019	-0.021	0.000	0.028	229.0
15	-0.037	-0.025	-0.026	0.000	0.036	226.0
16	-0.050	-0.034	-0.033	0.000	0.047	224.0
17	-0.068	-0.044	-0.039	0.000	0.059	222.0
18	-0.088	-0.058	-0.046	0.000	0.074	219.0
19	-0.112	-0.072	-0.053	0.000	0.090	216.0
20	-0.140	-0.090	-0.059	-0.016	0.108	213.0
21	-0.011	-0.007	-0.011	0.000	0.013	237.0
22	-0.016	-0.011	-0.016	0.000	0.019	235.0
23	-0.024	-0.016	-0.021	0.000	0.026	233.0
24	-0.035	-0.022	-0.027	0.000	0.035	231.0
25	-0.050	-0.031	-0.035	0.000	0.046	229.0
26	-0.068	-0.042	-0.044	0.000	0.060	226.0
27	-0.091	-0.055	-0.053	0.000	0.076	224.0
28	-0.120	-0.071	-0.062	0.000	0.094	221.0
29	-0.152	-0.090	-0.072	0.000	0.115	219.0
30	-0.189	-0.111	-0.079	-0.021	0.136	216.0

31	-0.014	-0.009	-0.015	0.000	0.018	240.0
32	-0.021	-0.013	-0.021	0.000	0.024	238.0
33	-0.032	-0.019	-0.027	0.000	0.033	235.0

Site 8

Surface Deformation Prediction System
SDPS version 5.1H 07/20/2000
Influence Function Method 14:02:59

Units: Imperial
Parameters: TanB = 2.48 Bs = 0.35
Def.Index Id: Mult8
Deformation files: ".DAT"
Case Description
Model 8 - Multiple Seam Mining LOA & LOB

Subsidence (ft) and Slopes (%)

PT#	SU	Tx	Ty	Ta	Tm	AngTm
1	-0.002	-0.002	-0.002	0.000	0.003	232.0
2	-0.003	-0.003	-0.003	0.000	0.004	230.0
3	-0.005	-0.005	-0.005	0.000	0.007	228.0
4	-0.009	-0.008	-0.008	0.000	0.011	226.0
5	-0.014	-0.015	-0.014	0.000	0.020	224.0
6	-0.021	-0.022	-0.019	0.000	0.030	221.0
7	-0.030	-0.031	-0.025	0.000	0.040	218.0
8	-0.042	-0.043	-0.030	0.000	0.052	216.0
9	-0.057	-0.055	-0.036	0.000	0.066	213.0
10	-0.075	-0.072	-0.041	-0.012	0.083	210.0
11	-0.003	-0.002	-0.003	0.000	0.004	234.0
12	-0.005	-0.004	-0.005	0.000	0.007	233.0
13	-0.008	-0.007	-0.008	0.000	0.011	230.0
14	-0.014	-0.013	-0.015	0.000	0.020	229.0
15	-0.021	-0.021	-0.022	0.000	0.030	226.0
16	-0.032	-0.030	-0.029	0.000	0.042	223.0
17	-0.047	-0.042	-0.036	0.000	0.056	221.0
18	-0.065	-0.058	-0.045	0.000	0.073	218.0
19	-0.089	-0.077	-0.054	0.000	0.094	215.0
20	-0.116	-0.100	-0.062	-0.018	0.118	212.0
21	-0.004	-0.003	-0.005	0.000	0.006	237.0
22	-0.007	-0.006	-0.008	0.000	0.010	235.0
23	-0.012	-0.011	-0.014	0.000	0.018	233.0
24	-0.020	-0.018	-0.022	0.000	0.029	231.0
25	-0.032	-0.027	-0.031	0.000	0.041	228.0
26	-0.048	-0.040	-0.041	0.000	0.057	226.0
27	-0.069	-0.056	-0.052	0.000	0.077	223.0
28	-0.098	-0.078	-0.065	0.000	0.101	220.0
29	-0.132	-0.104	-0.078	0.000	0.130	217.0
30	-0.174	-0.135	-0.090	-0.025	0.163	214.0

31	-0.006	-0.004	-0.007	0.000	0.008	239.0
32	-0.011	-0.007	-0.011	0.000	0.014	237.0

Site 9

Surface Deformation Prediction System
SDPS version 5.1H 07/20/2000
Influence Function Method 14:10:58

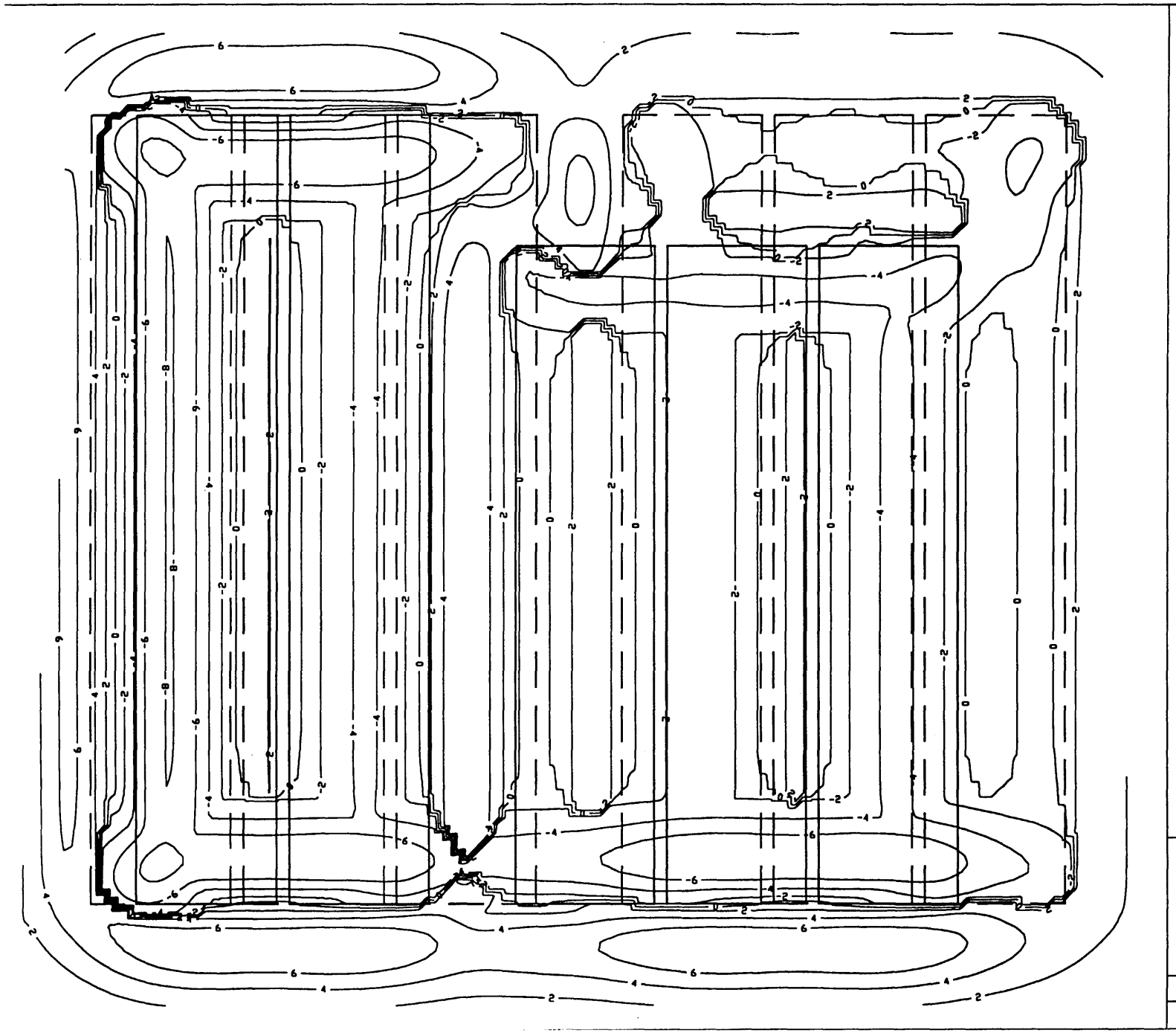
Units: Imperial
Parameters: TanB = 2.48 Bs = 0.35
Def.Index Id: Mult9
Deformation files: ".DAT"
Case Description
Model 9 - Multiple Seam Mining LOA & LOB

Subsidence (ft) and Slopes (%)

PT#	SU	Tx	Ty	Ta	Tm	AngTm
1	-0.001	-0.001	-0.002	0.000	0.002	232.0
2	-0.003	-0.002	-0.003	0.000	0.004	230.0
3	-0.004	-0.004	-0.004	0.000	0.006	228.0
4	-0.007	-0.007	-0.007	0.000	0.009	226.0
5	-0.011	-0.012	-0.011	0.000	0.017	224.0
6	-0.017	-0.018	-0.016	0.000	0.024	221.0
7	-0.025	-0.026	-0.020	0.000	0.033	218.0
8	-0.035	-0.035	-0.025	0.000	0.043	215.0
9	-0.047	-0.046	-0.029	0.000	0.055	213.0
10	-0.062	-0.060	-0.034	-0.010	0.069	210.0
11	-0.002	-0.002	-0.003	0.000	0.003	234.0
12	-0.004	-0.003	-0.004	0.000	0.006	232.0
13	-0.007	-0.006	-0.007	0.000	0.009	230.0
14	-0.011	-0.011	-0.012	0.000	0.016	228.0
15	-0.017	-0.017	-0.018	0.000	0.025	226.0
16	-0.026	-0.025	-0.024	0.000	0.034	223.0
17	-0.038	-0.035	-0.030	0.000	0.046	221.0
18	-0.054	-0.048	-0.037	0.000	0.061	218.0
19	-0.073	-0.064	-0.044	0.000	0.078	215.0
20	-0.096	-0.083	-0.051	-0.015	0.098	211.0
21	-0.003	-0.003	-0.004	0.000	0.005	237.0
22	-0.006	-0.005	-0.007	0.000	0.008	235.0
23	-0.010	-0.009	-0.012	0.000	0.015	233.0
24	-0.017	-0.015	-0.018	0.000	0.024	231.0
25	-0.026	-0.023	-0.025	0.000	0.034	228.0
26	-0.040	-0.033	-0.034	0.000	0.047	225.0

27	-0.058	-0.047	-0.043	0.000	0.064	223.0
28	-0.081	-0.065	-0.054	0.000	0.084	220.0
29	-0.110	-0.087	-0.065	0.000	0.108	217.0
30	-0.144	-0.113	-0.075	-0.021	0.136	213.0
31	-0.005	-0.004	-0.006	0.000	0.007	239.0
32	-0.009	-0.006	-0.010	0.000	0.011	237.0

6. CONTOUR PLOTS OF SUBSIDENCE, MAXIMUM HORIZONTAL STRAIN, AND SLOPE FOR EACH SITE



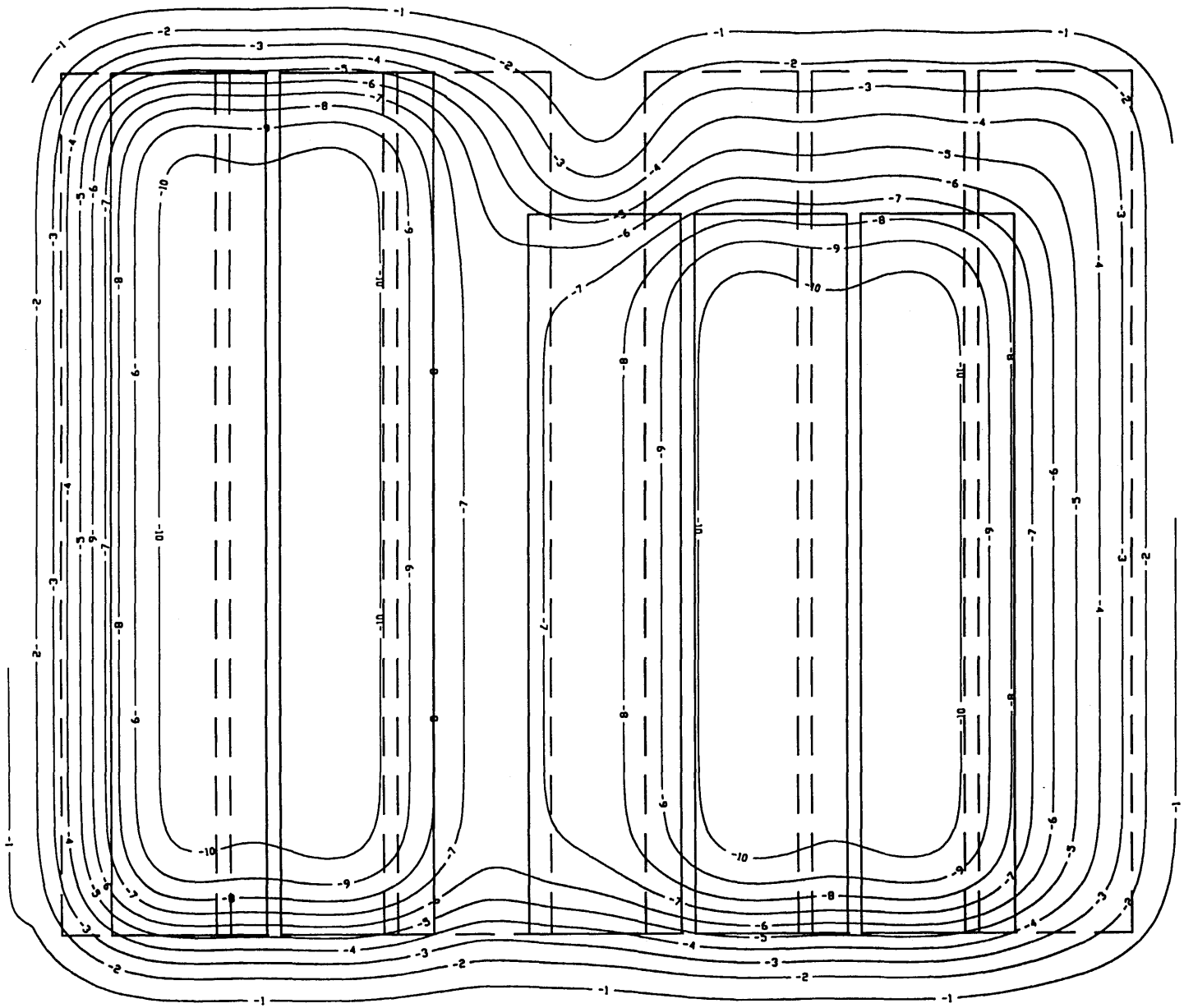
LEGEND

- LOWER PANEL
- UPPER PANEL
- STRAIN

FIGURE E.3
Site Number 1
Multiple Seam Model
Maximum Strain (Millistrain)

DWG: 2439A-S1
DATE: 7/25/2000

NorWest



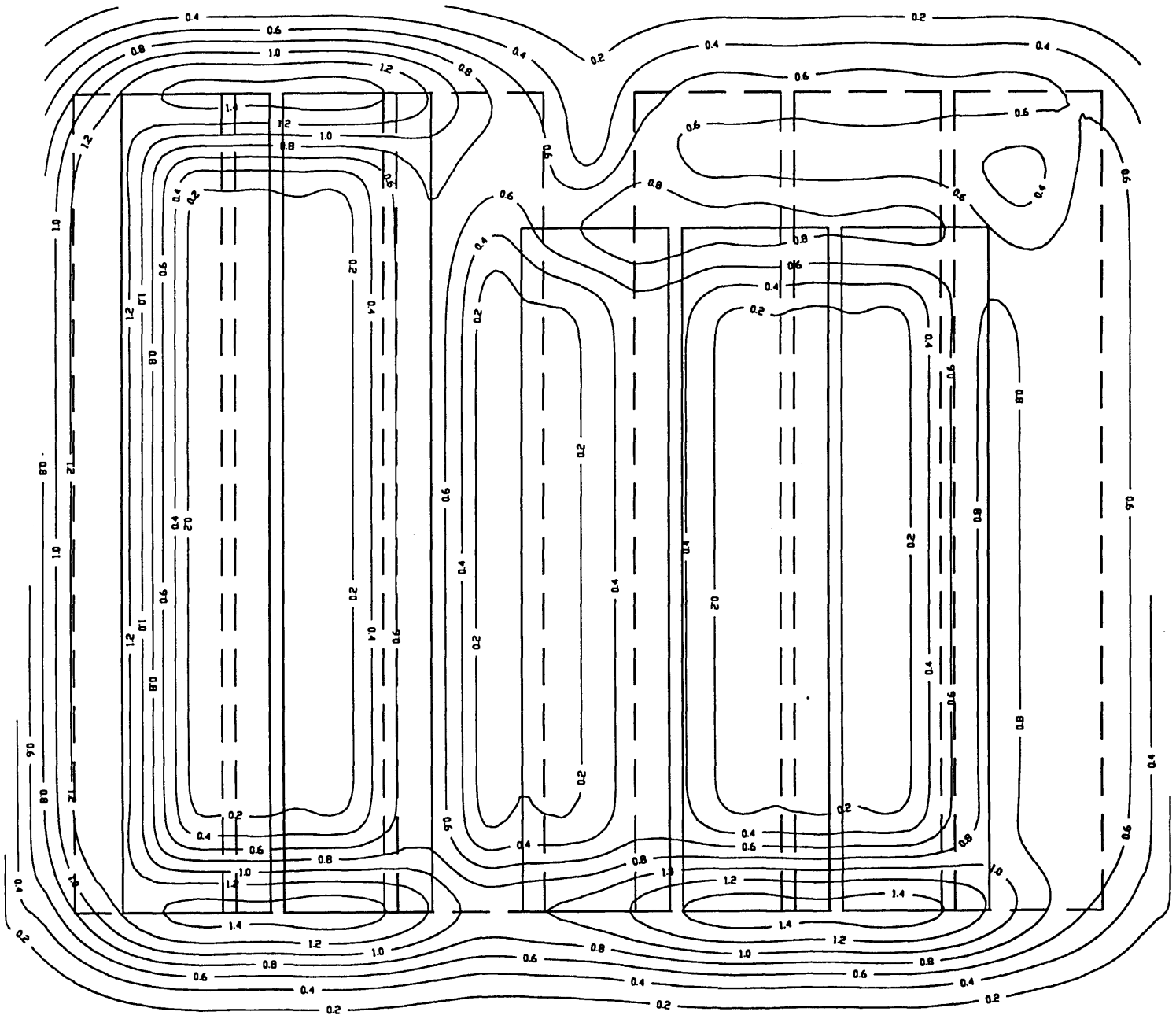
LEGEND

- LOWER PANEL
- UPPER PANEL
- SUBSIDENCE

FIGURE E.4
Site Number 1
Multiple Seam Model
Subsidence (feet)

DWG: 2439A-S1
DATE: 7/25/2000

NorWest



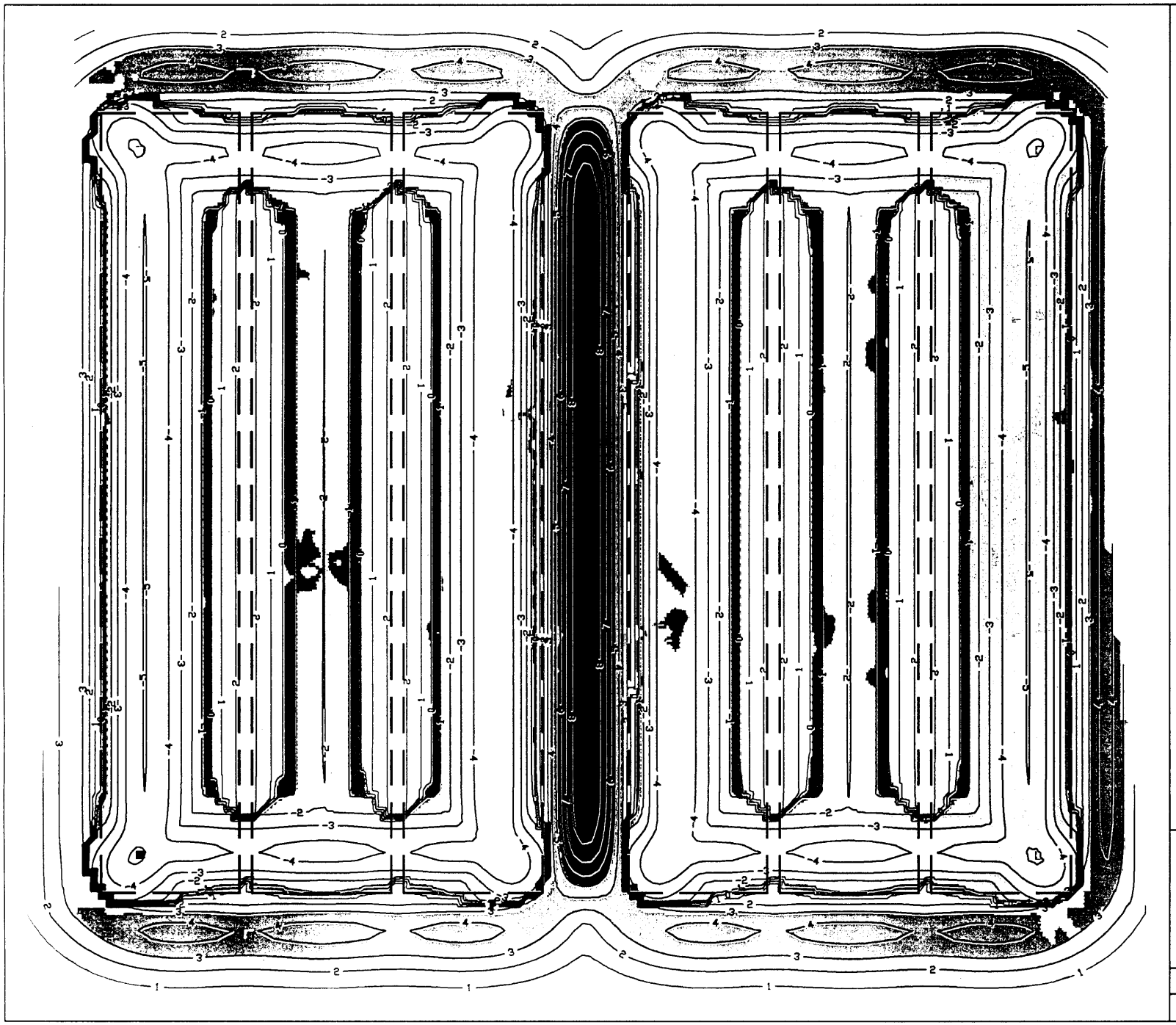
LEGEND

- LOWER PANEL
- UPPER PANEL
- SLOP

FIGURE E.5
Site Number 1
Multiple Seam Model
Total Slope (% Slope)

DWG: 2439A-S1
DATE: 7/25/2000

NorWest



LEGEND

PANEL

STRAIN

Horizontal Strain (millistrain)

- -5 <
- -5 to -3
- -3 to -1
- -1 to 0
- 0 to 1
- 1 to 3
- 3 to 5
- 5 to 8

Tensile Strain = positive

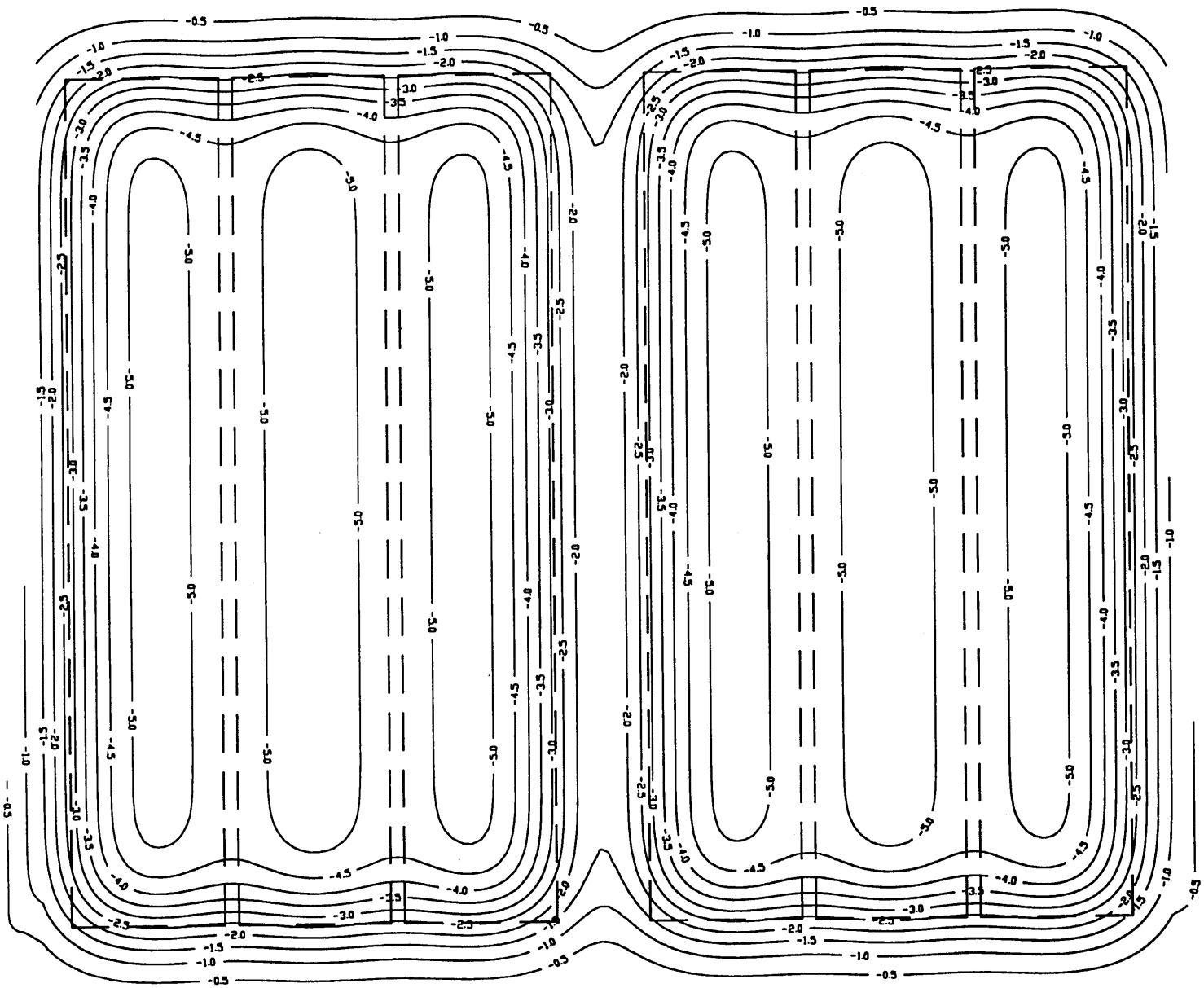
Compressive Strain = negative

FIGURE E.6
Site Number 2
Single Seam Model
Horizontal Strain

DWG: 2439A-S2

DATE: 7/25/2000

NorWest



LEGEND

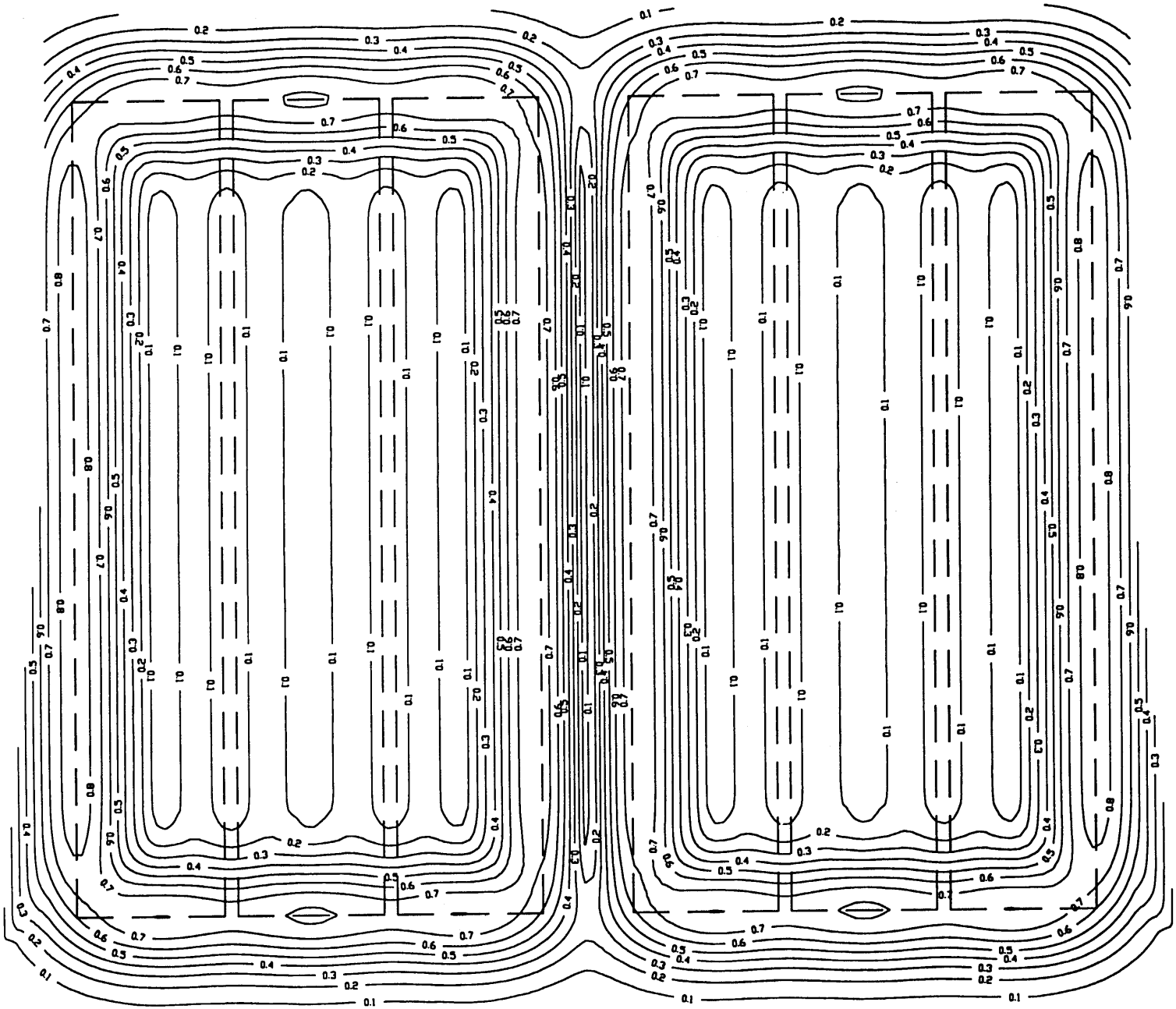
— — PANEL

——— SUBSIDENCE

FIGURE E.7
Site Number 2
Single Seam Model
Subsidence (feet)

DWG: 2439A-S2
DATE: 7/25/2000

NorWest



LEGEND

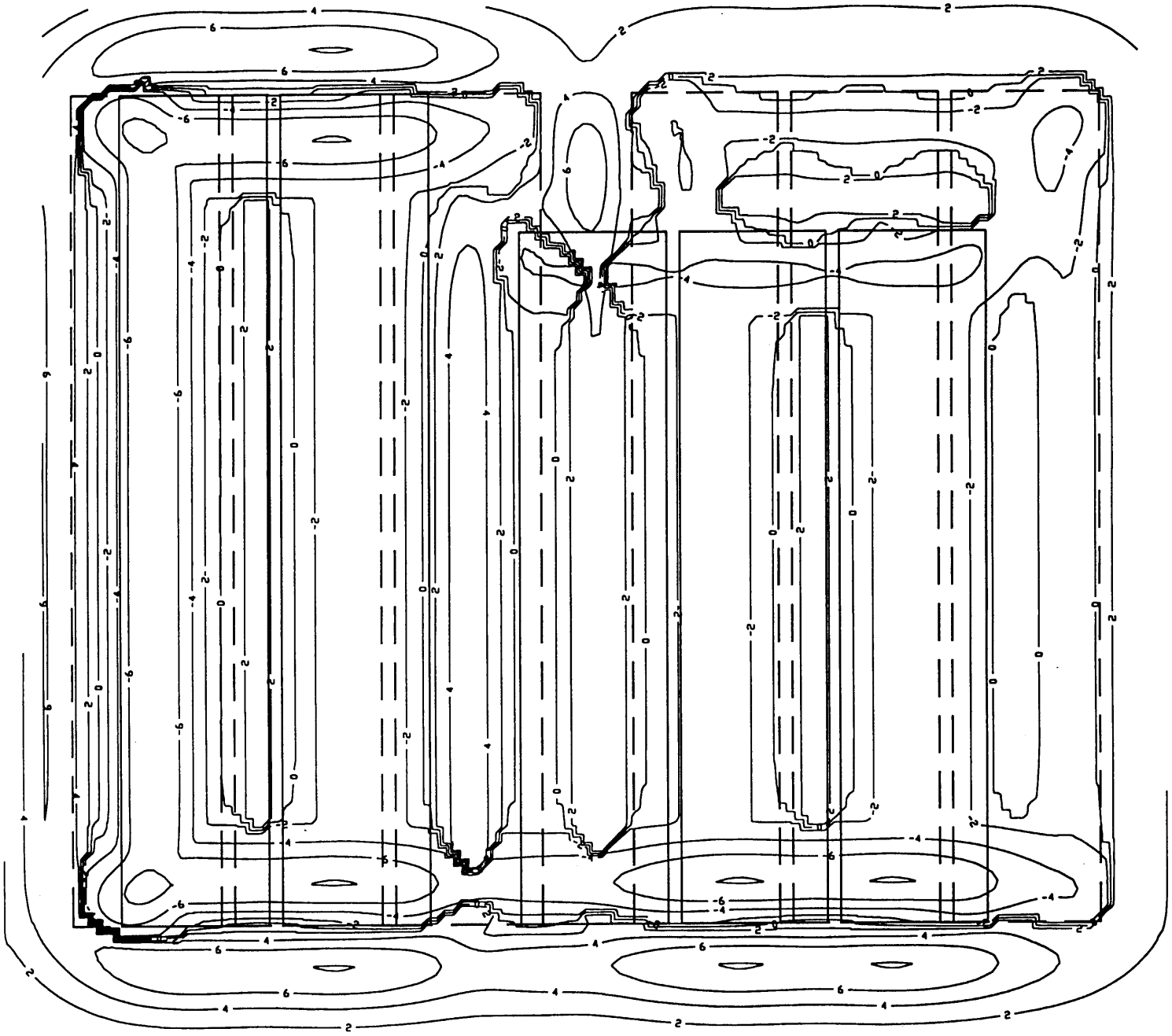
— — PANEL

——— SLOP

FIGURE E.8
Site Number 2
Single Seam Model
Total Slope (% Slope)

DWG: 2439A-S2
DATE: 7/25/2000

NorWest



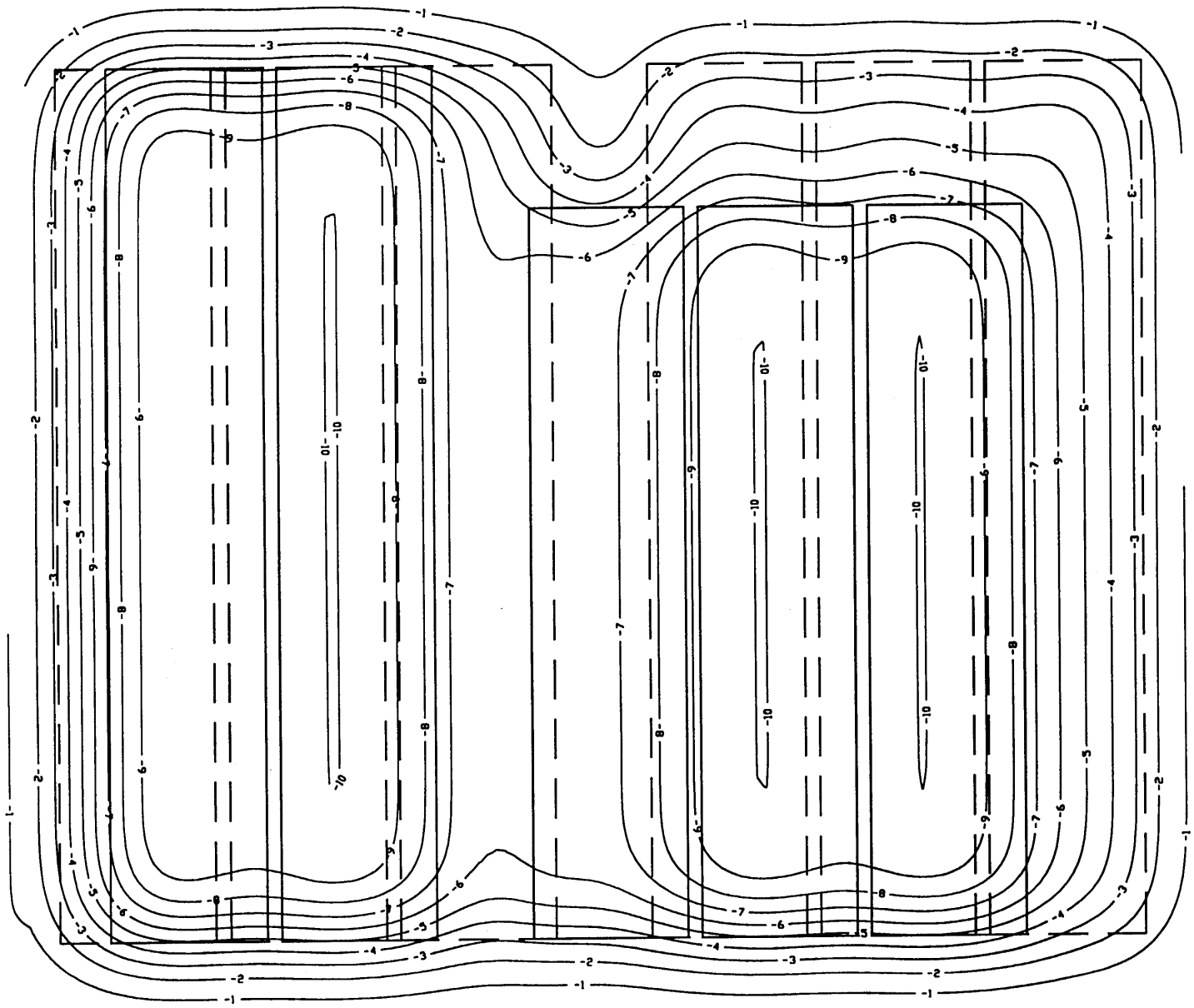
LEGEND

- LOWER PANEL
- UPPER PANEL
- STRAIN

FIGURE E.9
Site Number 3
Multiple Seam Model
Maximum Strain (Millistrain)

DWG: 2439A-S3
DATE: 7/25/2000

NorWest



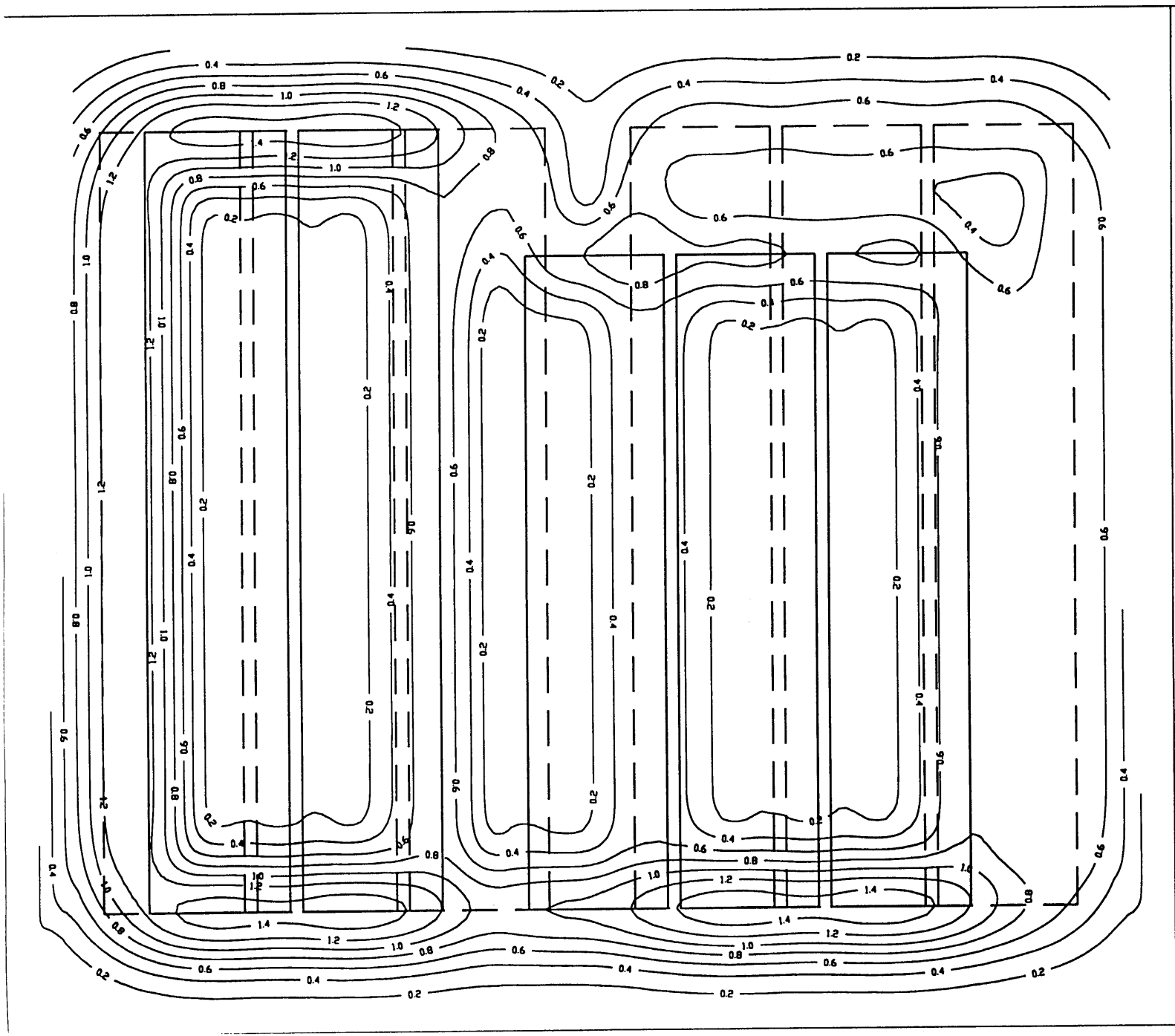
LEGEND

- LOWER PANEL
- UPPER PANEL
- SUBSIDENCE

FIGURE E.10
Site Number 3
Multiple Seam Model
Subsidence (feet)

DWG: 2439A-S3
DATE: 7/25/2000

NorWest



LEGEND

LOWER PANEL

UPPER PANEL

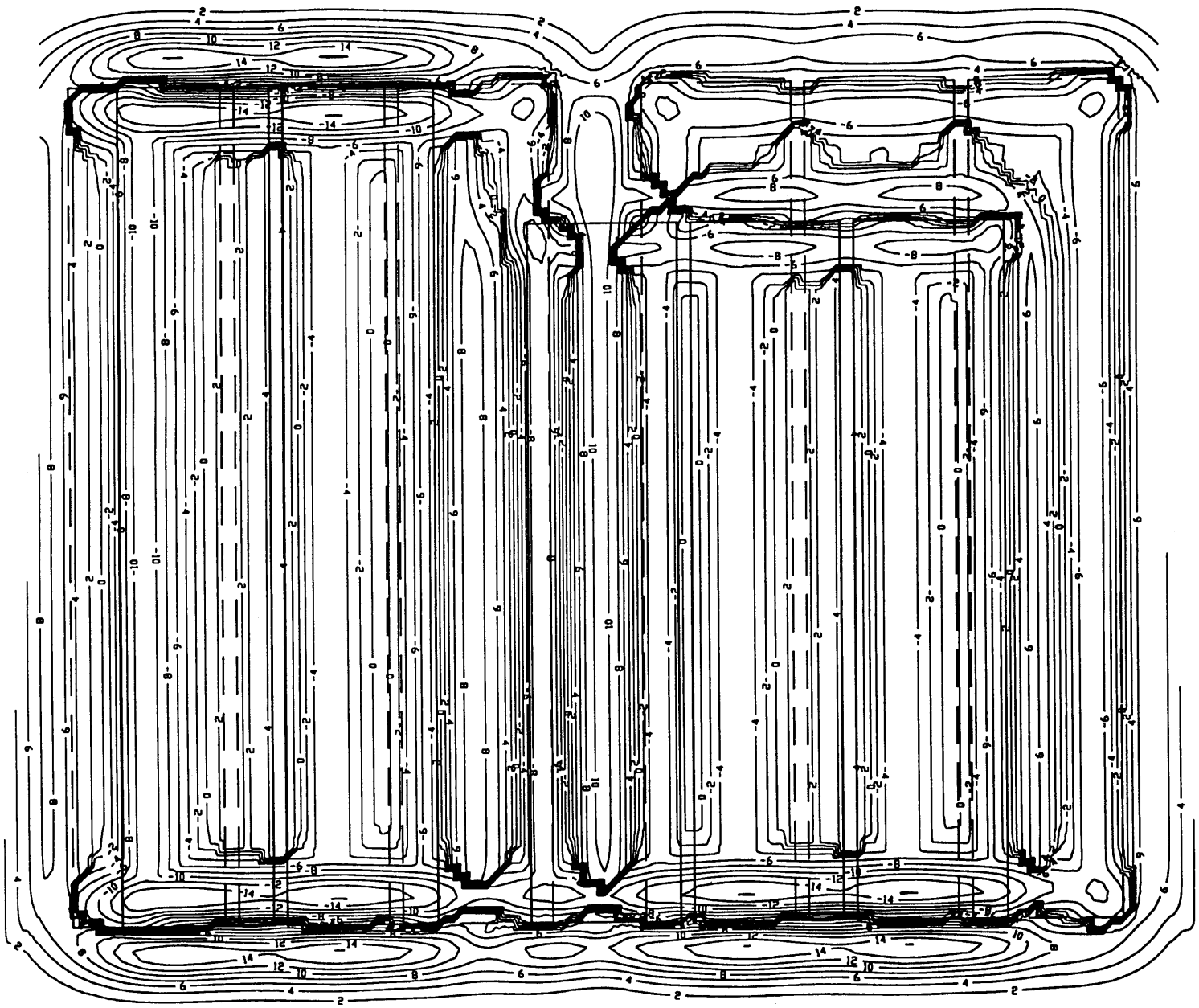
SLOP

FIGURE E.11
Site Number 3
Multiple Seam Model
Total Slope (% Slope)

DWG: 2439A-S3

DATE: 7/25/2000

NorWest



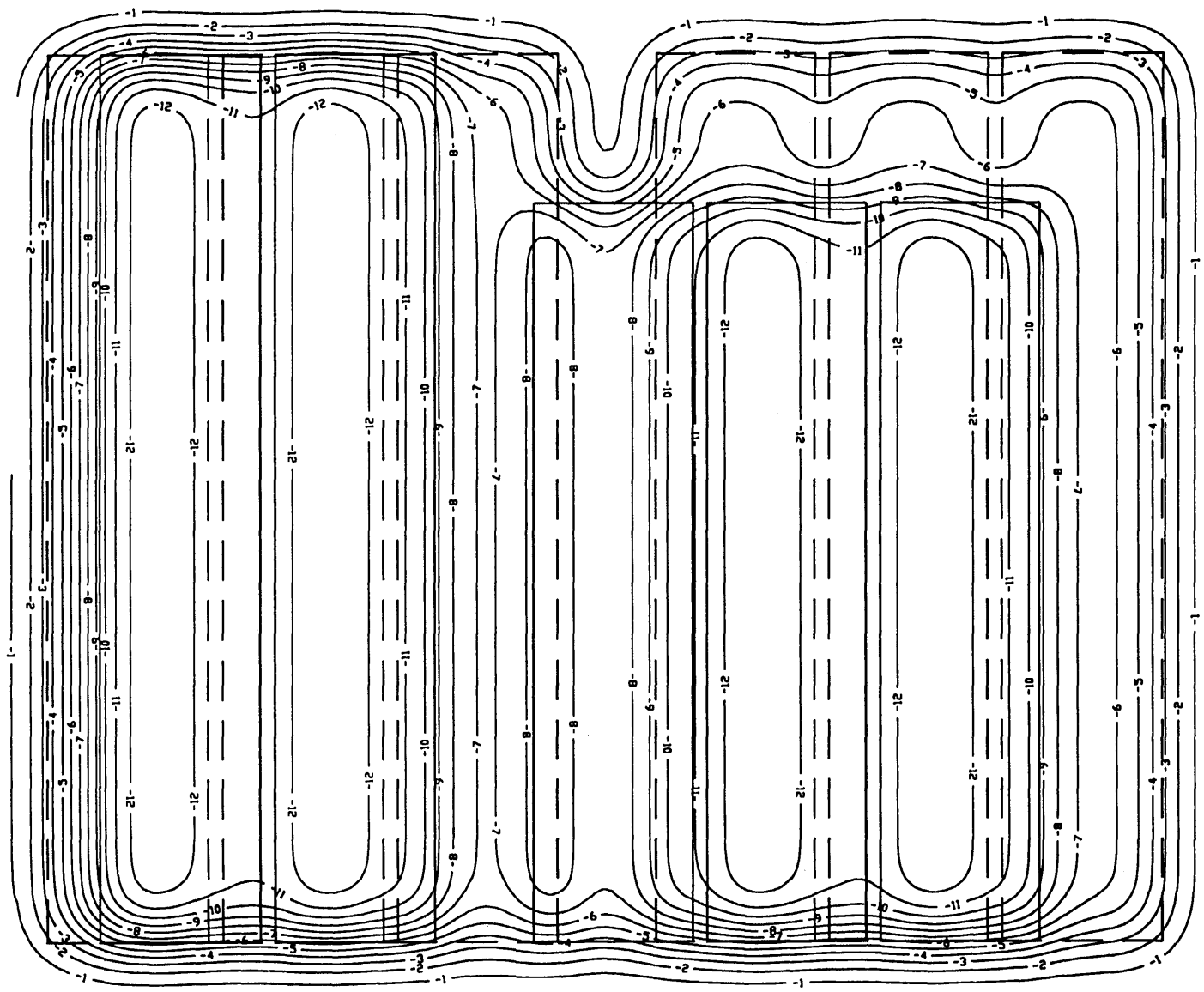
LEGEND

- LOWER PANEL
- UPPER PANEL
- STRAIN

FIGURE E.12
Site Number 4
Multiple Seam Model
Maximum Strain (Millistrain)

DWG: 2439A-S4
DATE: 7/25/2000

NorWest



LEGEND

LOWER PANEL

UPPER PANEL

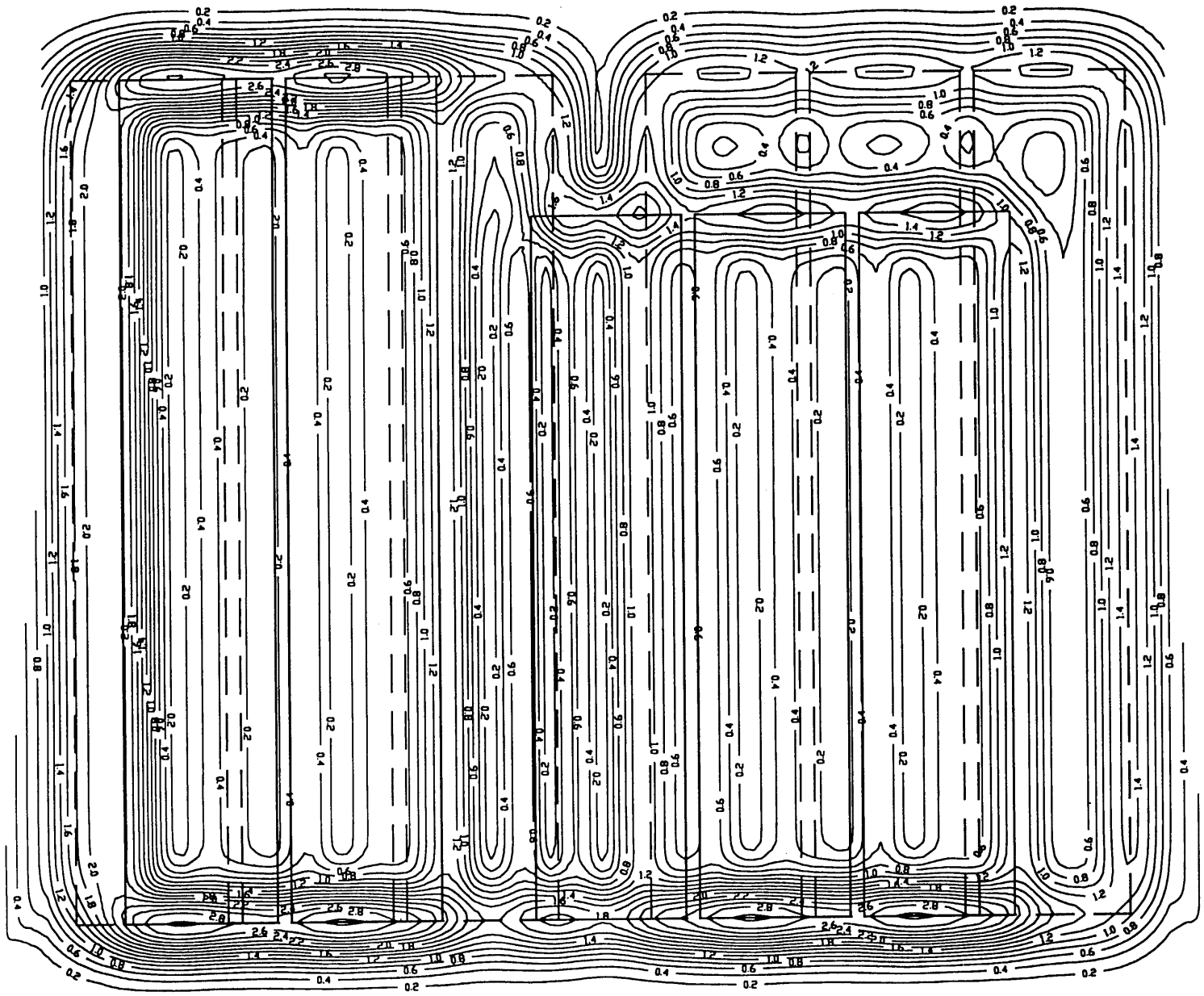
SUBSIDENCE

FIGURE E.13
Site Number 4
Multiple Seam Model
Subsidence (feet)

DWG: 2439A-S4

DATE: 7/25/2000

NorWest



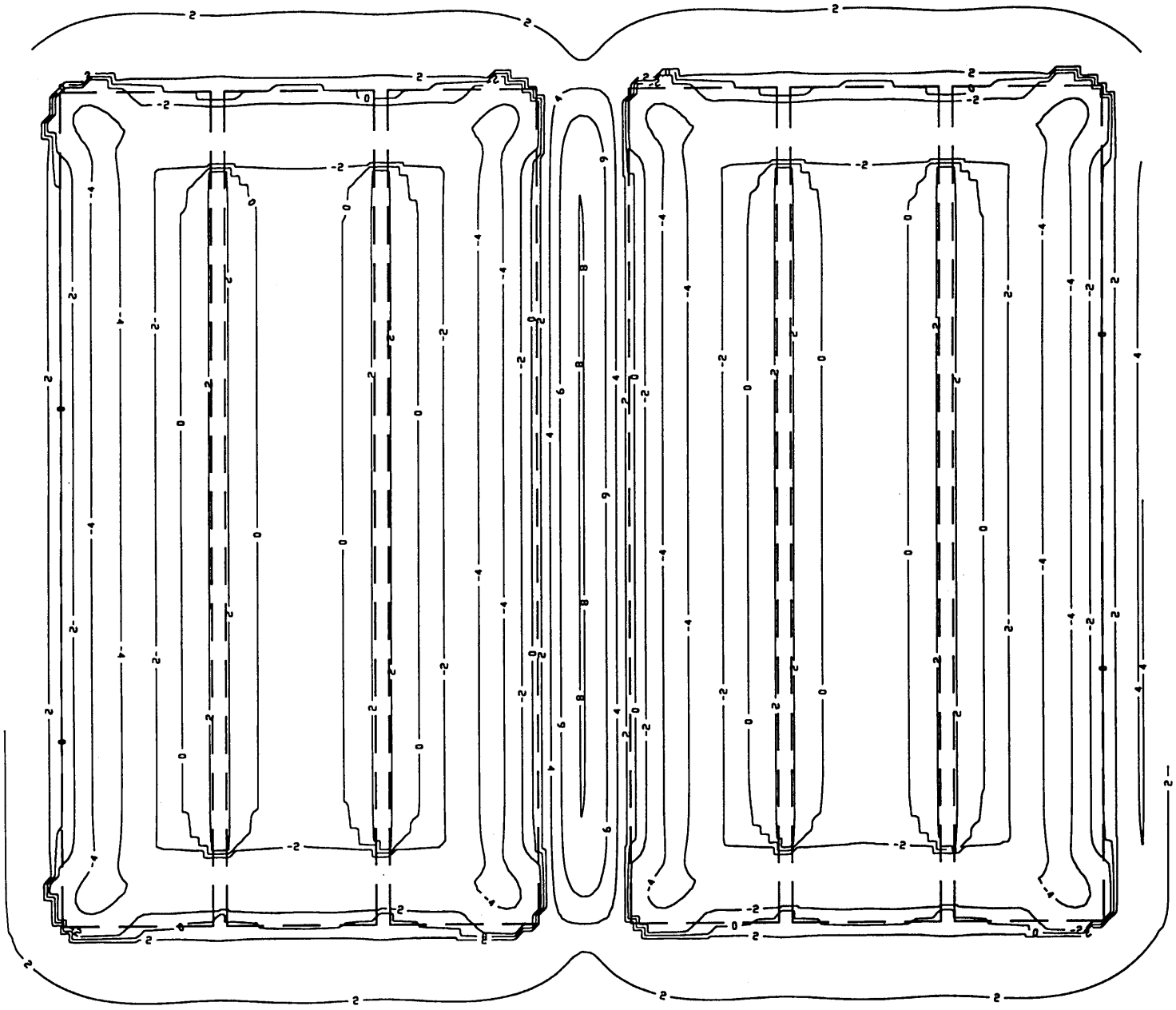
LEGEND

- LOWER PANEL
- UPPER PANEL
- SLOP

FIGURE E.14
Site Number 4
Multiple Seam Model
Total Slope (% Slope)

DWG: 2439A-S4
DATE: 7/25/2000

NorWest



LEGEND

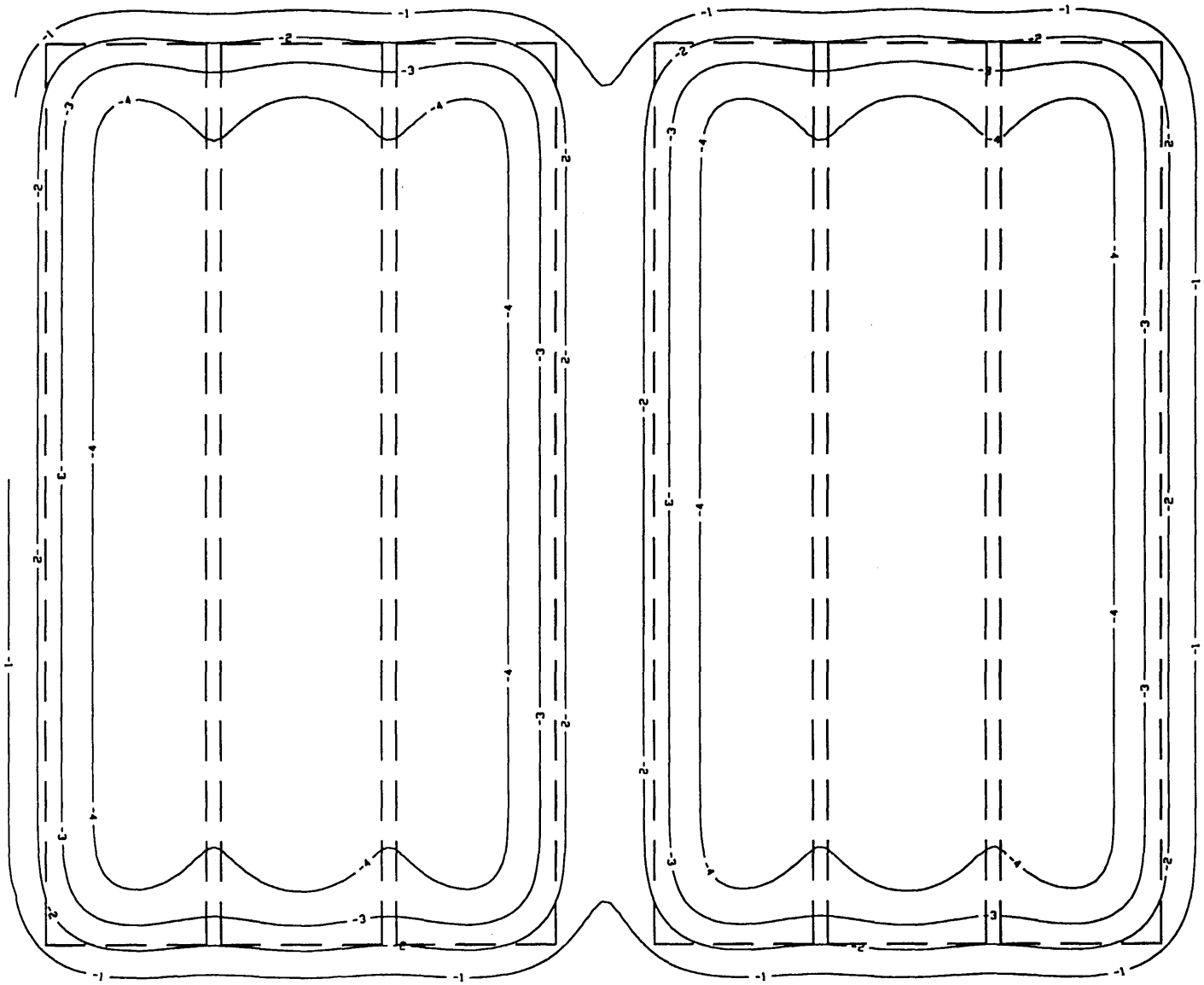
— — PANEL

——— STRAIN

FIGURE E.15
Site Number 5
Single Seam Model
Maximum Strain (Millistrain)

DWG: 2439A-S5
DATE: 7/25/2000

NorWest



LEGEND

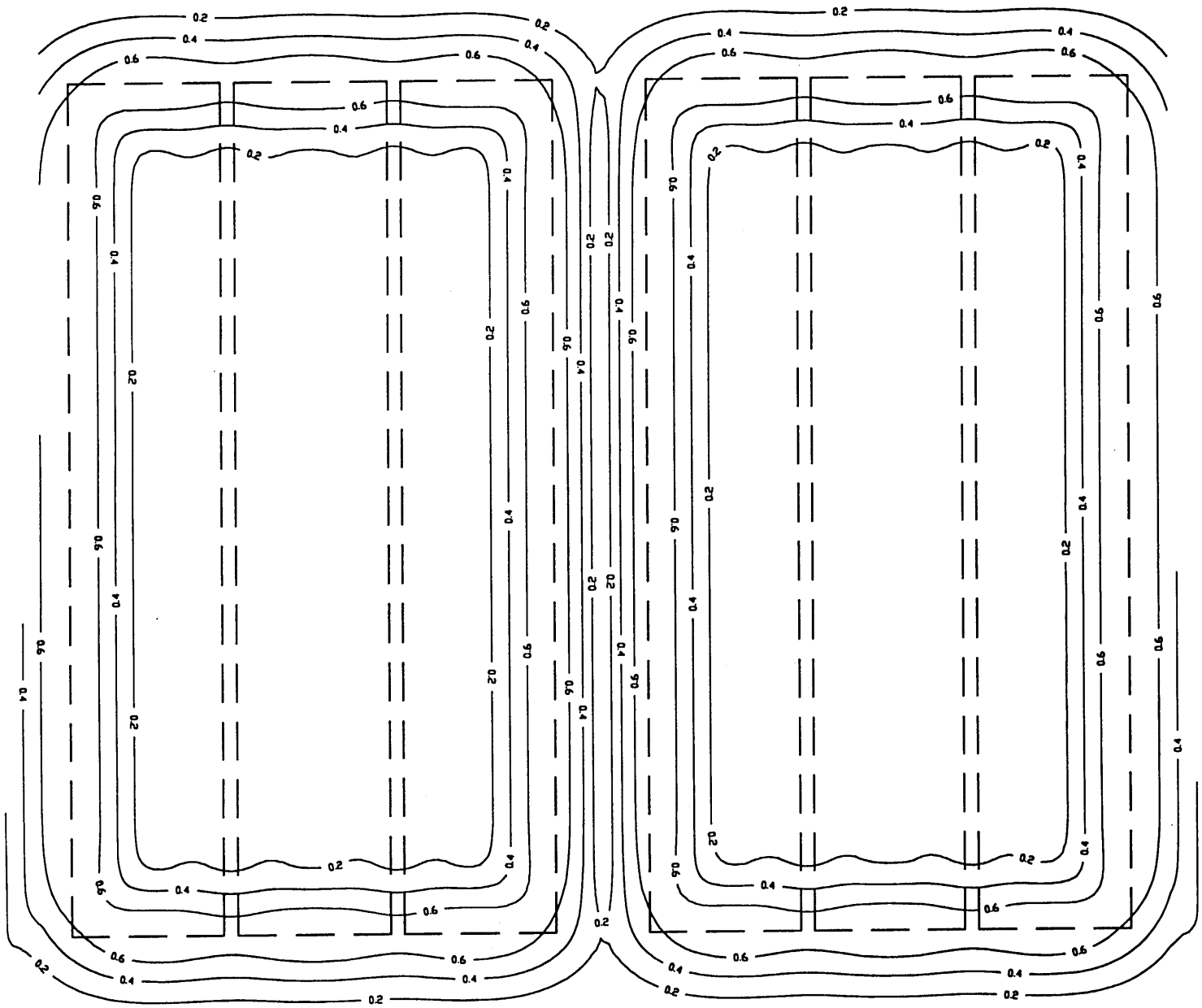
PANEL

SUBSIDENCE

FIGURE E.16
Site Number 5
Single Seam Model
Subsidence (feet)

DWG: 2439A-S5
DATE: 7/25/2000

NorWest



LEGEND

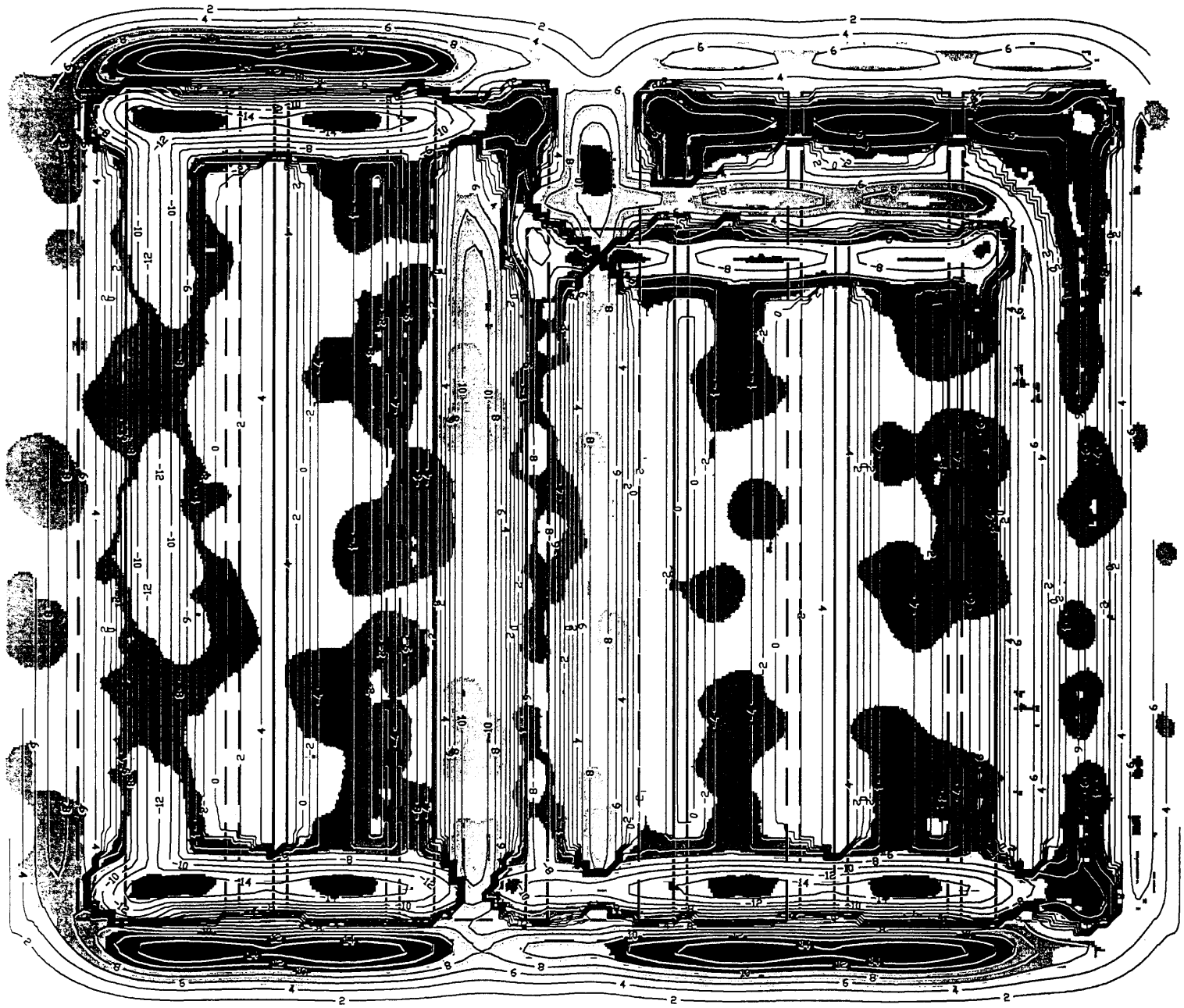
PANEL

SLOP

FIGURE E.17
Site Number 5
Single Seam Model
Total Slope (% Slope)

DWG: 2439A-S5
DATE: 7/25/2000

NorWest



LEGEND

LOWER PANEL

UPPER PANEL

STRAIN

Maximum Strain (millistrain)

-14 <

-14 to -10

-10 to -6

-6 to -2

-2 to 2

2 to 6

6 to 10

10 to 14

Tensile Strain = positive

Compressive Strain = negative

FIGURE E.18

Site Number 6

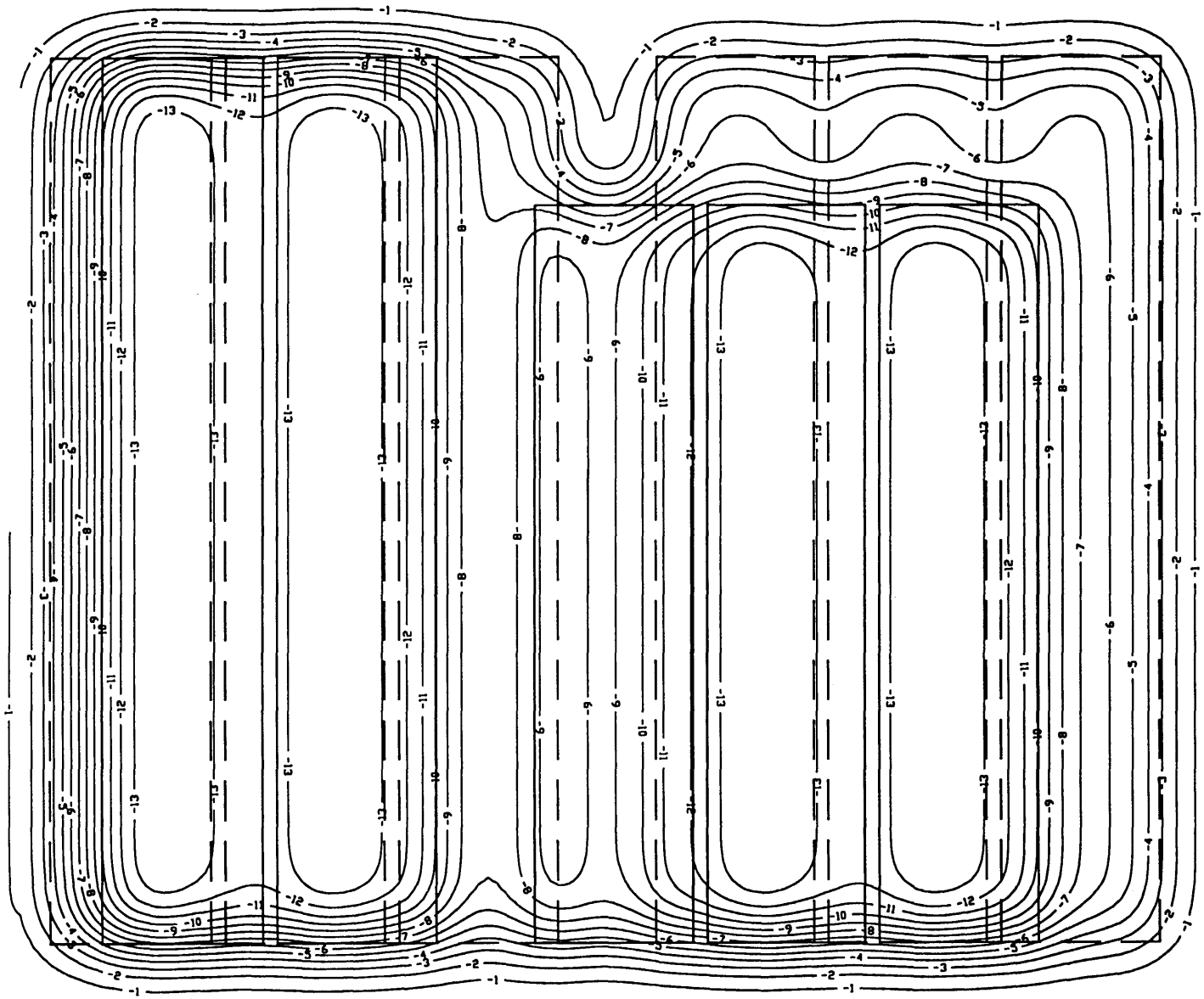
Multiple Seam Model

Maximum Strain (Millistrain)

DWG: 2439A-S6

DATE: 7/25/2000

NorWest



LEGEND

LOWER PANEL

UPPER PANEL

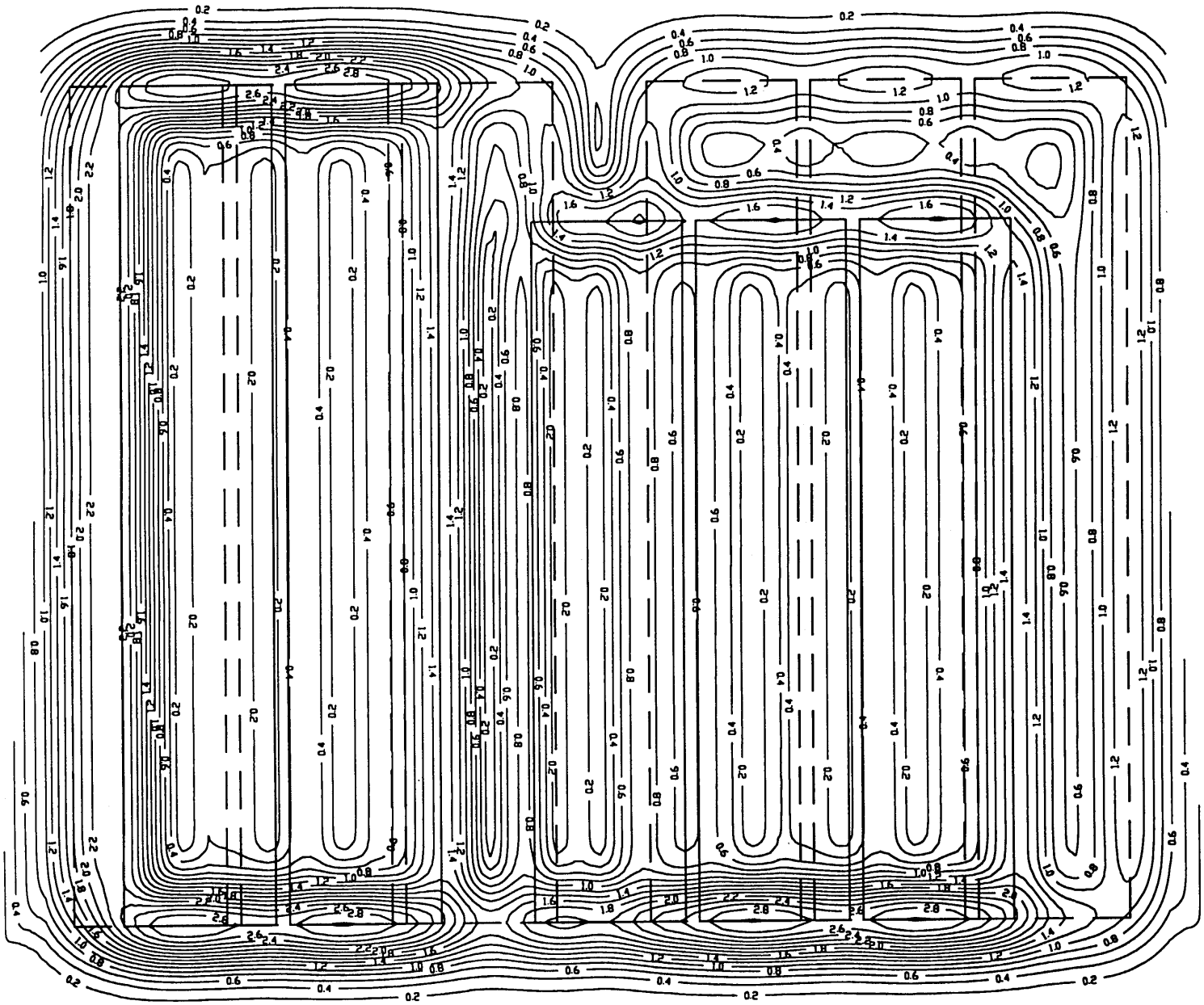
SUBSIDENCE

FIGURE E.19
Site Number 6
Multiple Seam Model
Subsidence (feet)

DWG: 2439A-S6

DATE: 7/25/2000

NorWest



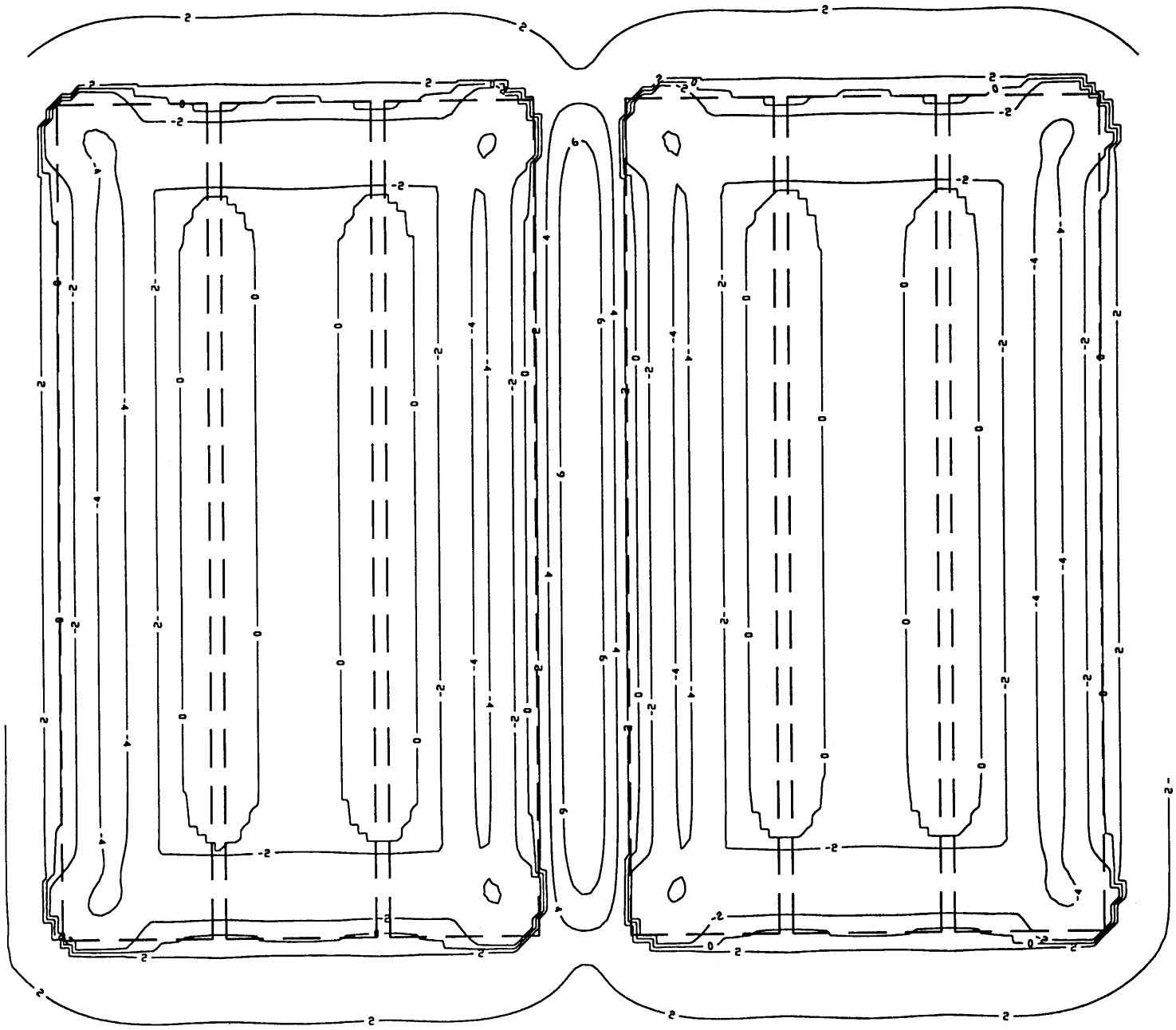
LEGEND

- LOWER PANEL
- UPPER PANEL
- SLOP

FIGURE E.20
Site Number 6
Multiple Seam Model
Total Slope (% Slope)

DWG: 2439A-S6
DATE: 7/25/2000

NorWest



LEGEND

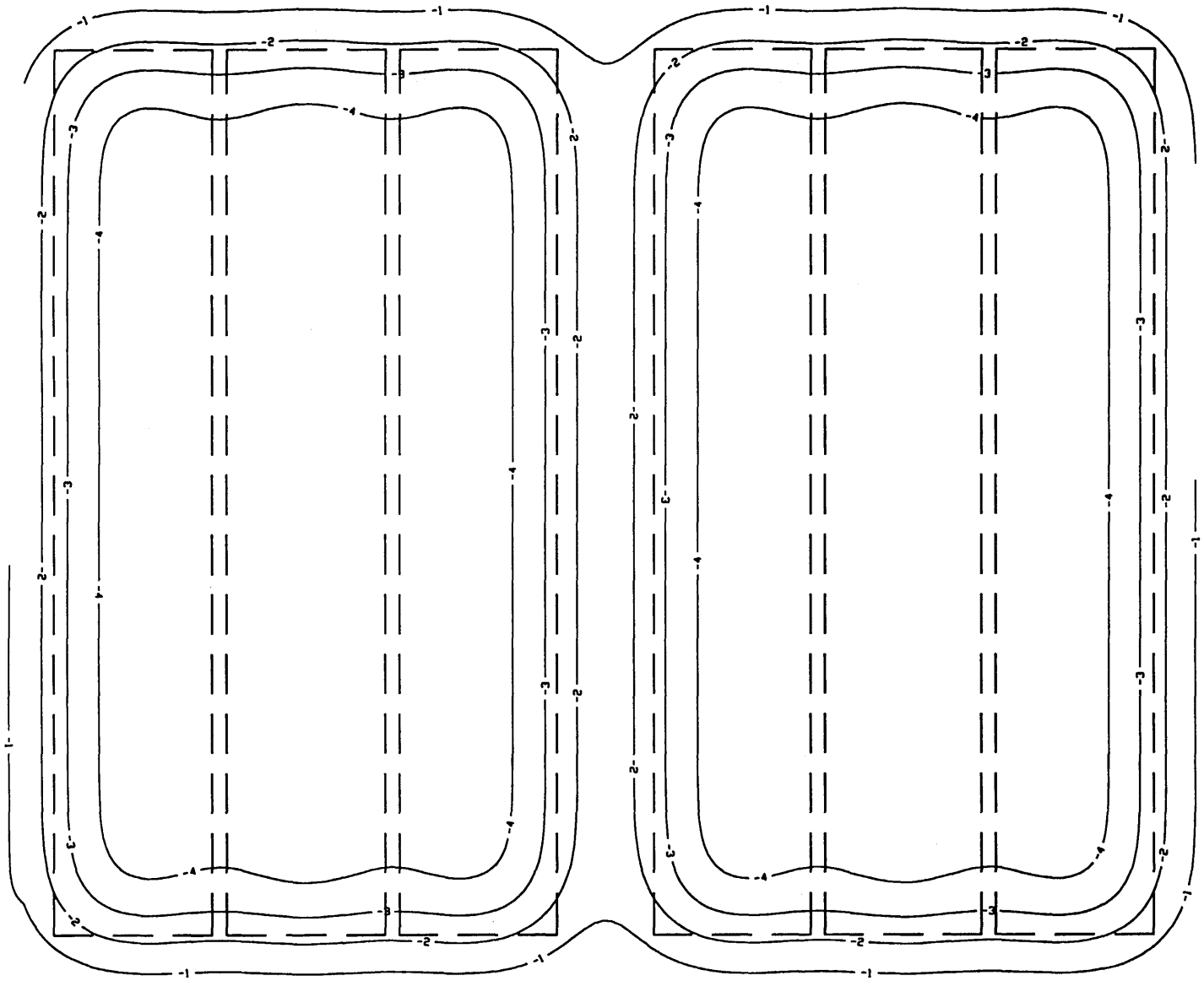
— — UPPER PANEL

——— STRAIN

FIGURE E.21
Site Number 7
Single Seam Model
Maximum Strain (Millistrain)

DWG: 2439A-S7
DATE: 7/25/2000

NorWest



LEGEND

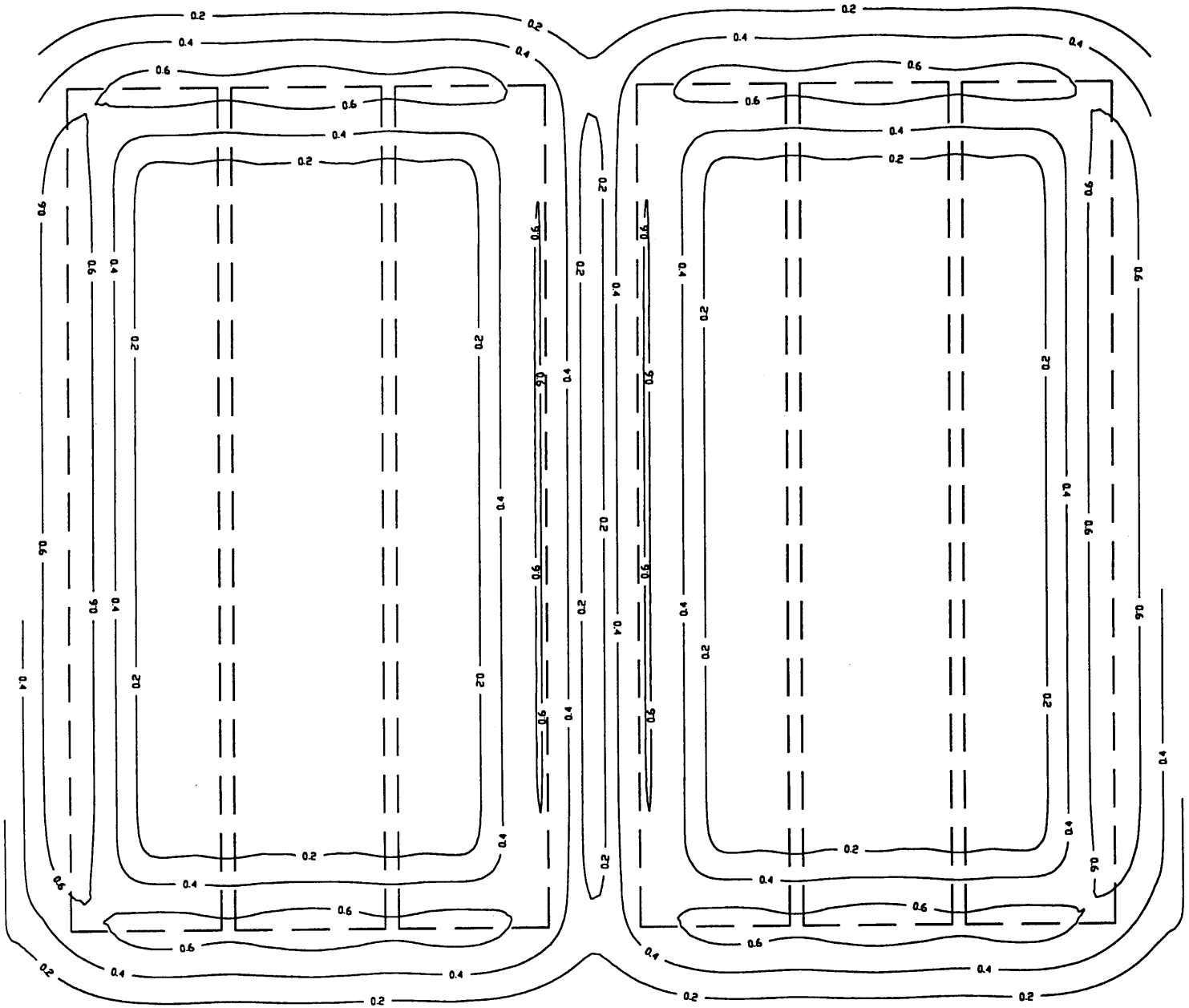
— — UPPER PANEL

——— SUBSIDENCE

FIGURE E.22
Site Number 7
Single Seam Model
Subsidence (feet)

DWG: 2439A-S7
DATE: 7/25/2000

NorWest



LEGEND

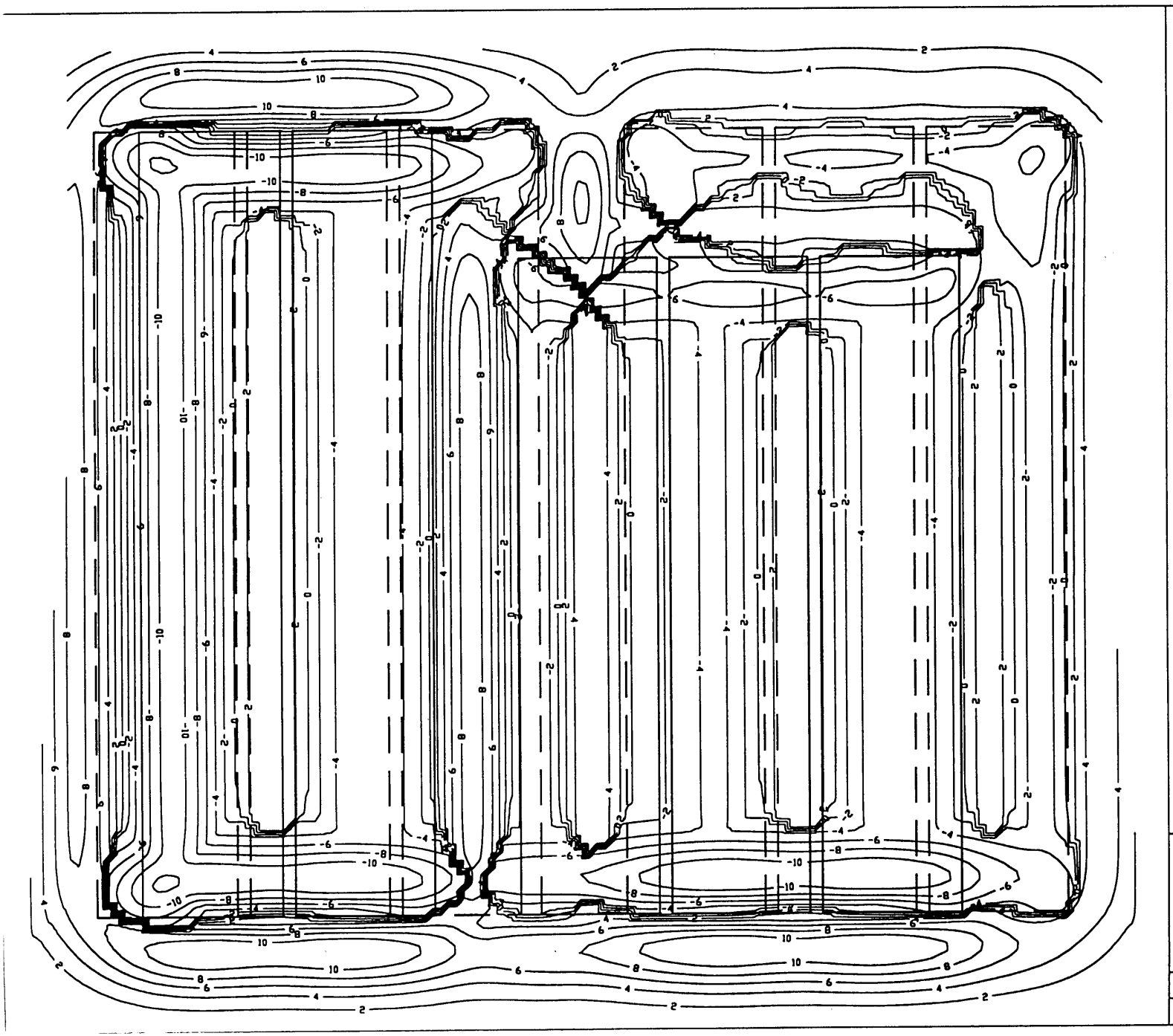
— — UPPER PANEL

——— SLOP

FIGURE E.23
Site Number 7
Single Seam Model
Total Slope (% Slope)

DWG: 2439A-S7
DATE: 7/25/2000

NorWest



LEGEND

LOWER PANEL

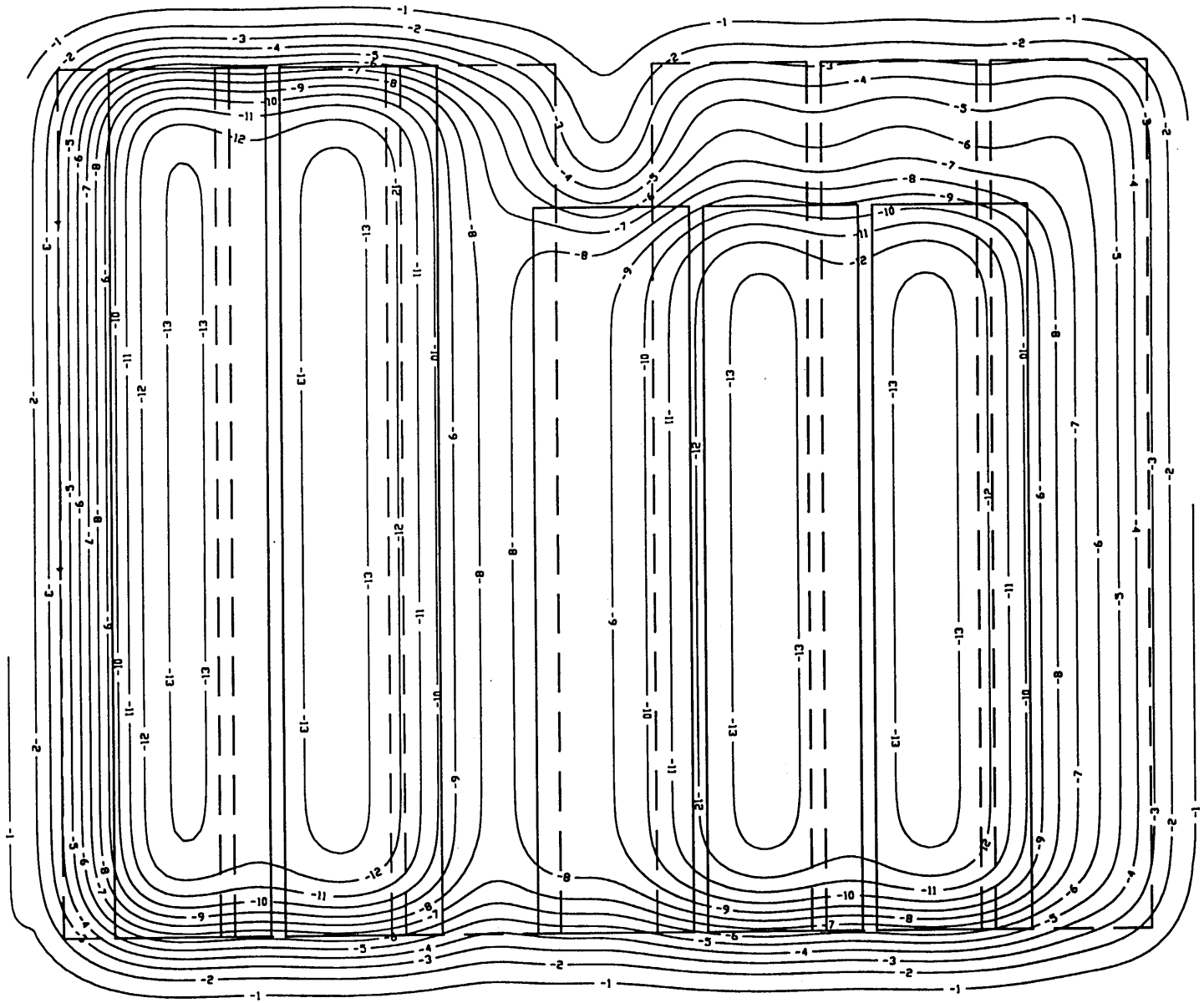
UPPER PANEL

STRAIN

FIGURE E.24
Site Number 8
Multiple Seam Model
Maximum Strain (Millistrain)

DWG: 2439A-S8
DATE: 7/25/2000

NorWest



LEGEND

LOWER PANEL

UPPER PANEL

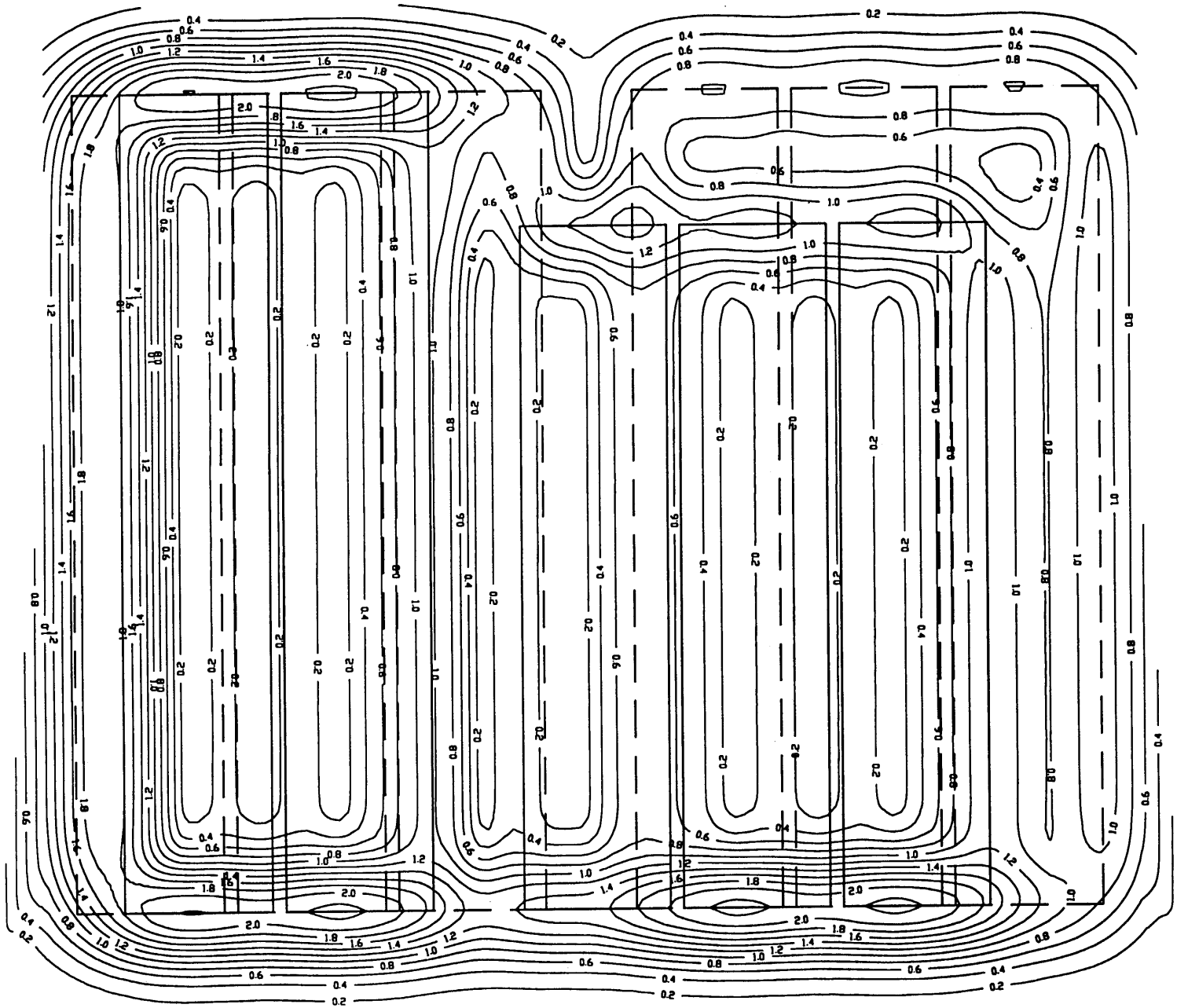
SUBSIDENCE

FIGURE E.25
Site Number 8
Multiple Seam Model
Subsidence (feet)

DWG: 2439A-S8

DATE: 7/25/2000

NorWest



LEGEND

LOWER PANEL

UPPER PANEL

SLOP

FIGURE E.26

Site Number 8

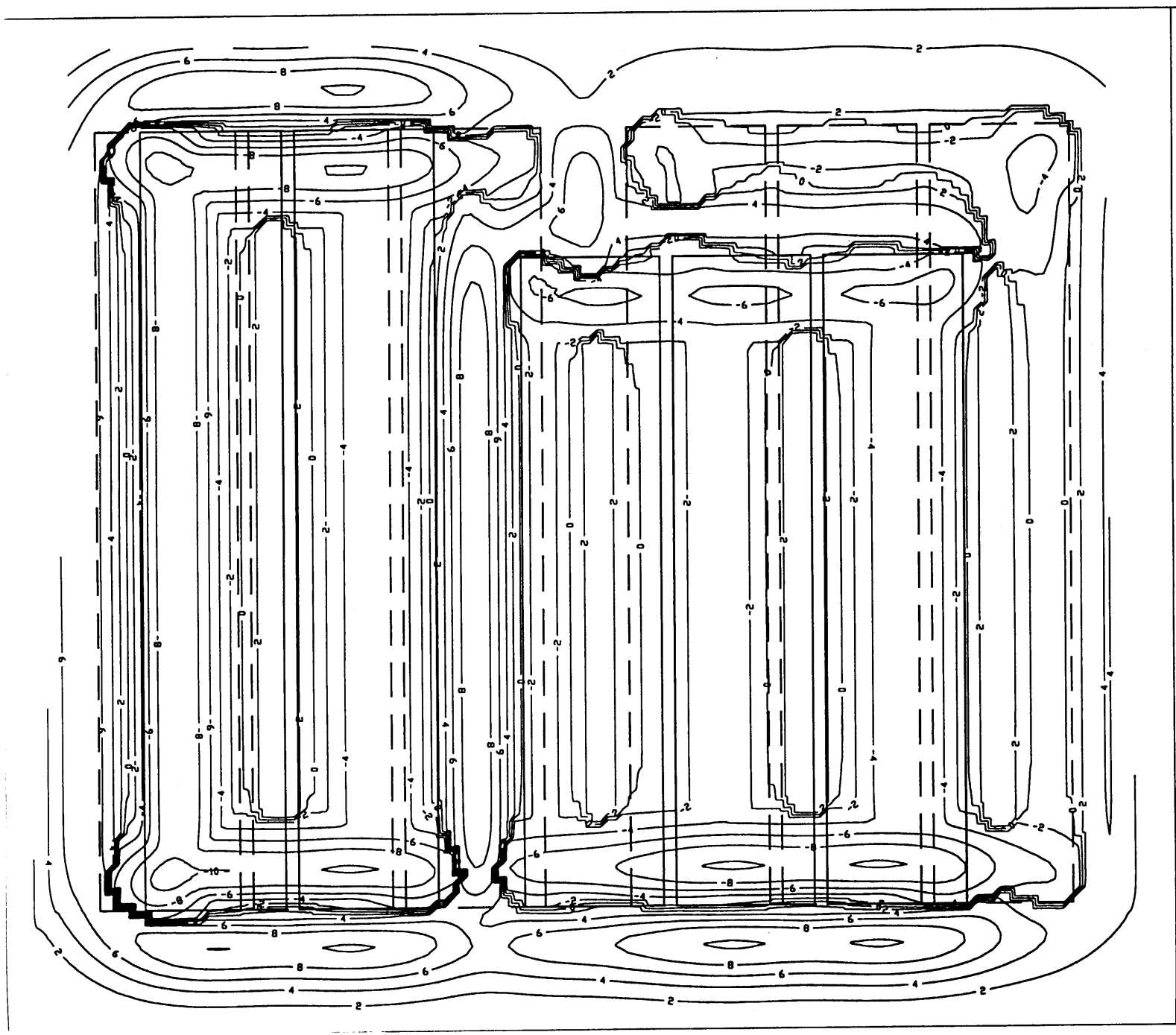
Multiple Seam Model

Total Slope (% Slope)

DWG: 2439A-S8

DATE: 7/25/2000

NorWest



LEGEND

LOWER PANEL

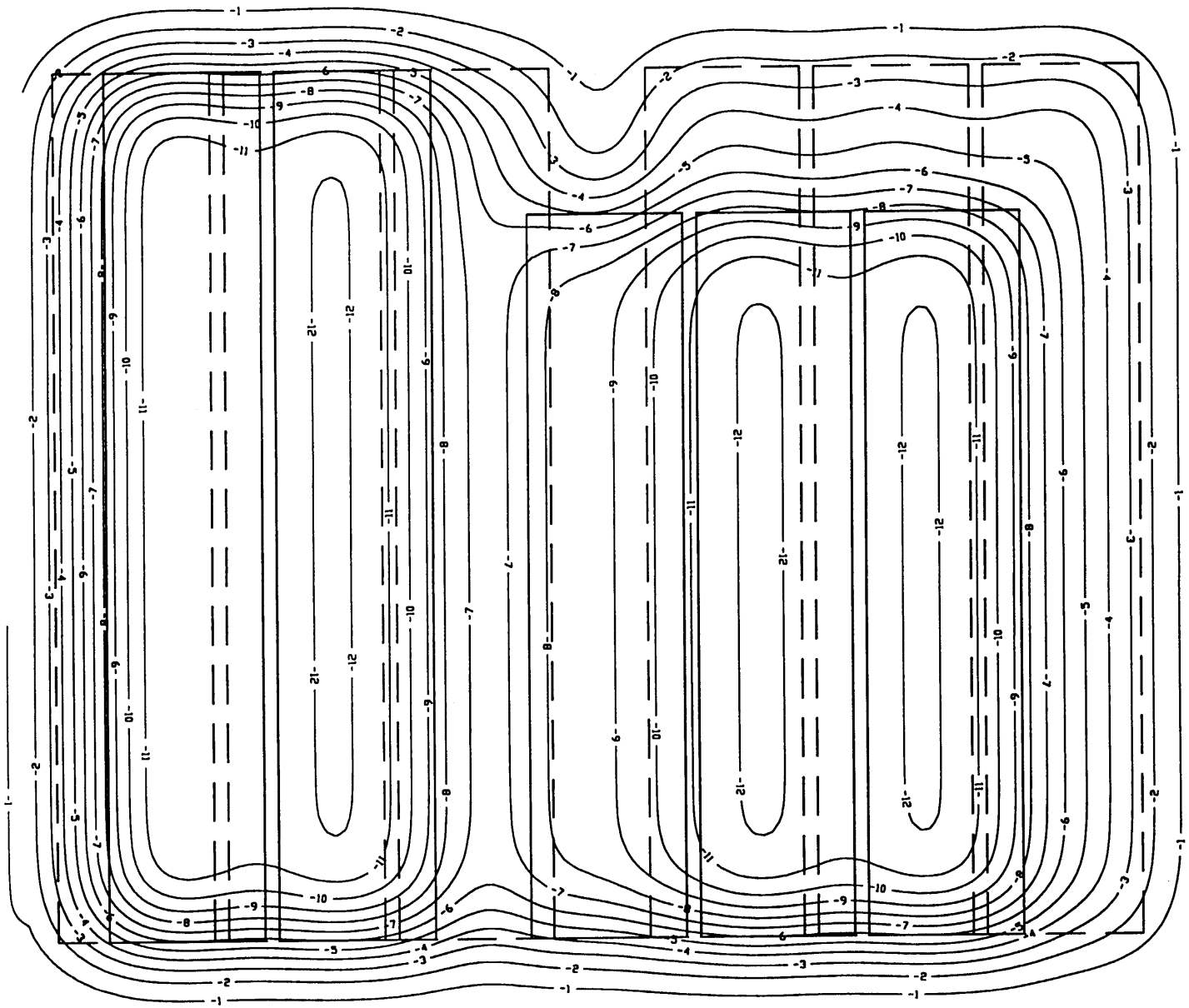
UPPER PANEL

STRAIN

FIGURE E.27
Site Number 9
Multiple Seam Model
Maximum Strain (Millistrain)

DWG: 2439A-S9
DATE: 7/25/2000

NorWest



LEGEND

LOWER PANEL

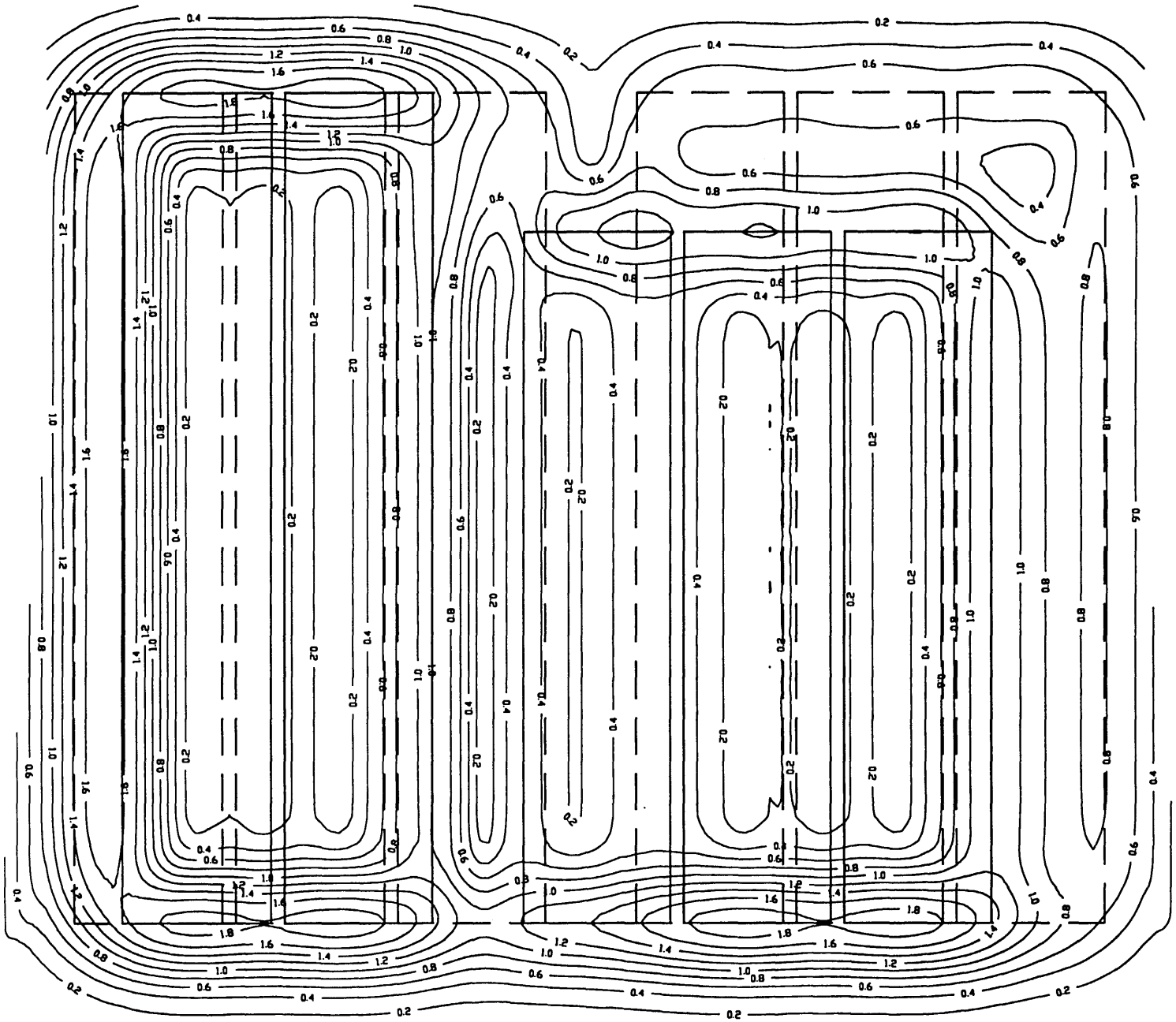
UPPER PANEL

SUBSIDENCE

FIGURE E.28
Site Number 9
Multiple Seam Model
Subsidence (feet)

DWG: 2439A-S9
DATE: 7/25/2000

NorWest



LEGEND

- LOWER PANEL
- UPPER PANEL
- SLOP

FIGURE E.29
Site Number 9
Multiple Seam Model
Total Slope (% Slope)

DWG: 2439A-S9
DATE: 7/25/2000

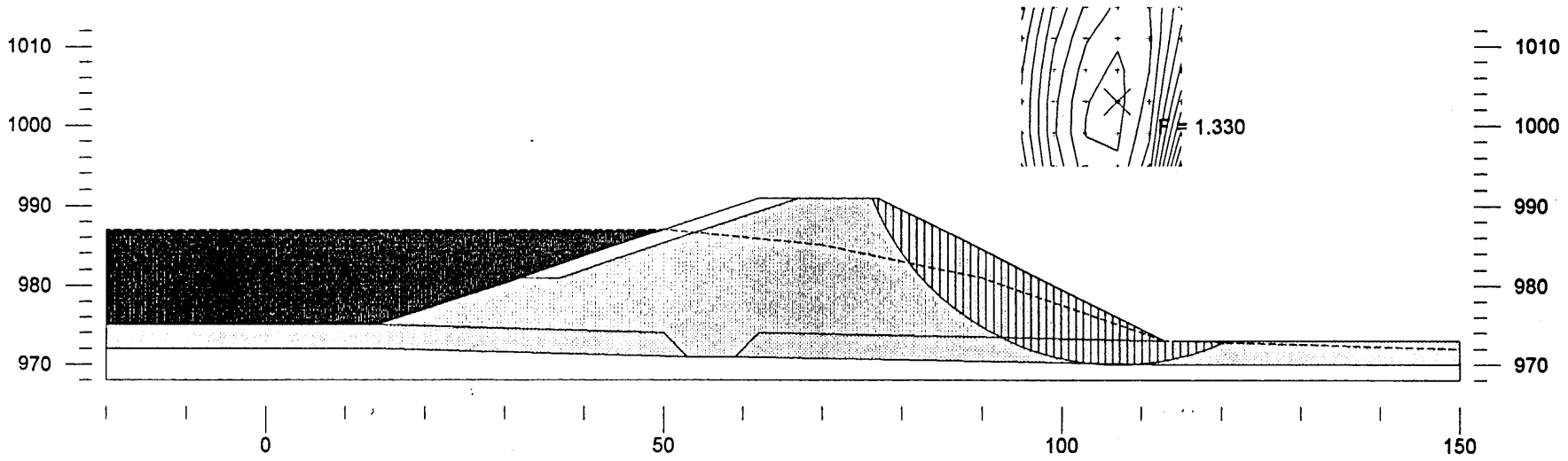
NorWest

APPENDIX F

PARAMETRIC STABILITY ANALYSIS FOR BOULGER

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.81	0	0	1	0
Riprap	22	0	40	1	0
Impervious Fill	20	10	35	1	0
Organics	18	10	28	1	0
Foundation	19.5	10	33	1	0

Norwest Mine Services - Calgary AB
00-1896
Flat Canyon Lease - Boulger Dam
2000-07-12
Normal Water Level

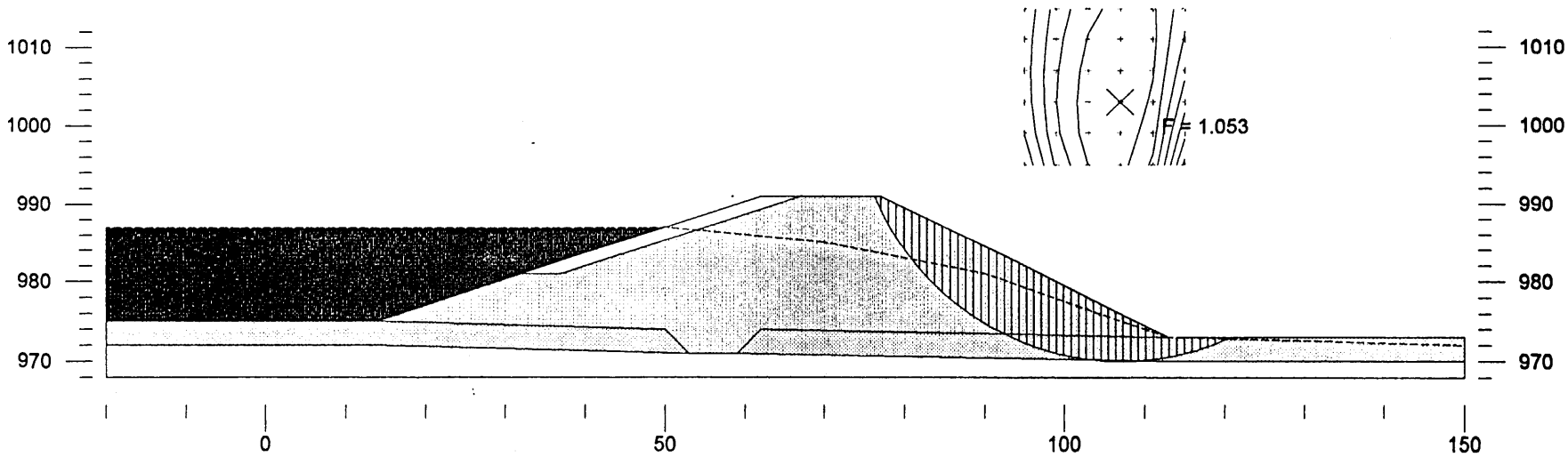


2000-07-12 11:55:54 AM C:\GSLOPE\BLGR_01.GSL Norwest Mine Services - Calgary AB F = 1.330

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.81	0	0	1	0
Riprap	22	0	40	1	0
Impervious Fill	20	10	35	1	0
Organics	18	10	28	1	0
Foundation	19.5	10	33	1	0

Seismic coefficient = 0.10

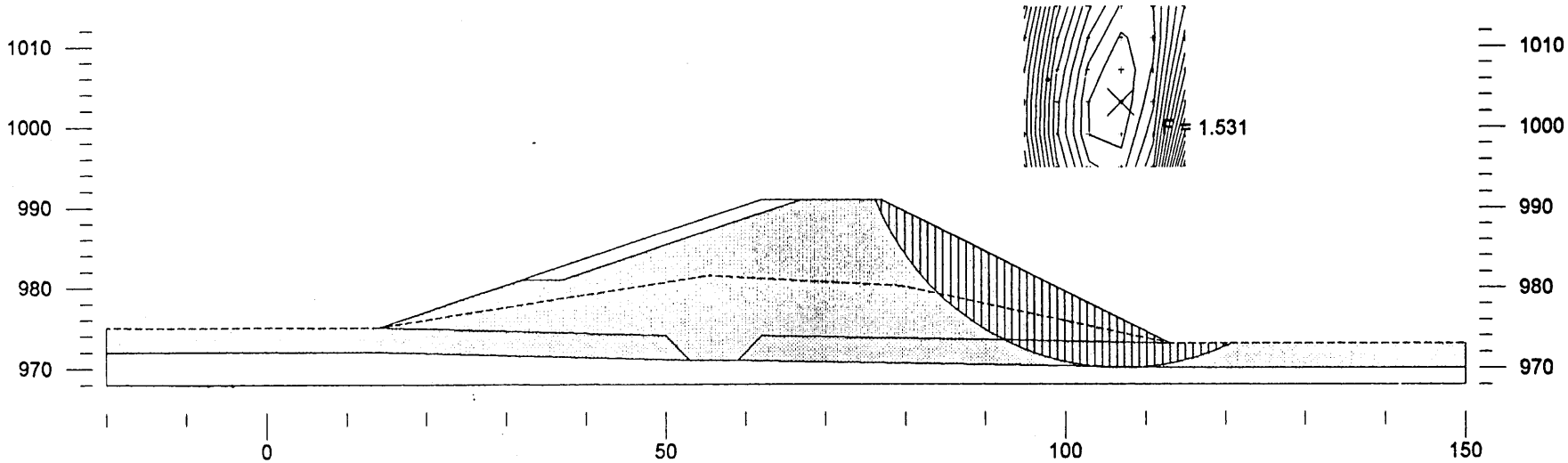
Norwest Mine Services - Calgary AB
00-1896
Flat Canyon Lease- Boulger Dam
2000-07-11
Normal Water Level
Seismic 0.1g



2000-07-12 11:54:31 AM C:\GSLOPE\BLGR_02.GSL Norwest Mine Services - Calgary AB F = 1.053

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.81	0	0	1	0
Riprap	22	0	40	1	0
Impervious Fill	20	10	35	1	0
Organics	18	10	28	1	0
Foundation	19.5	10	33	1	0

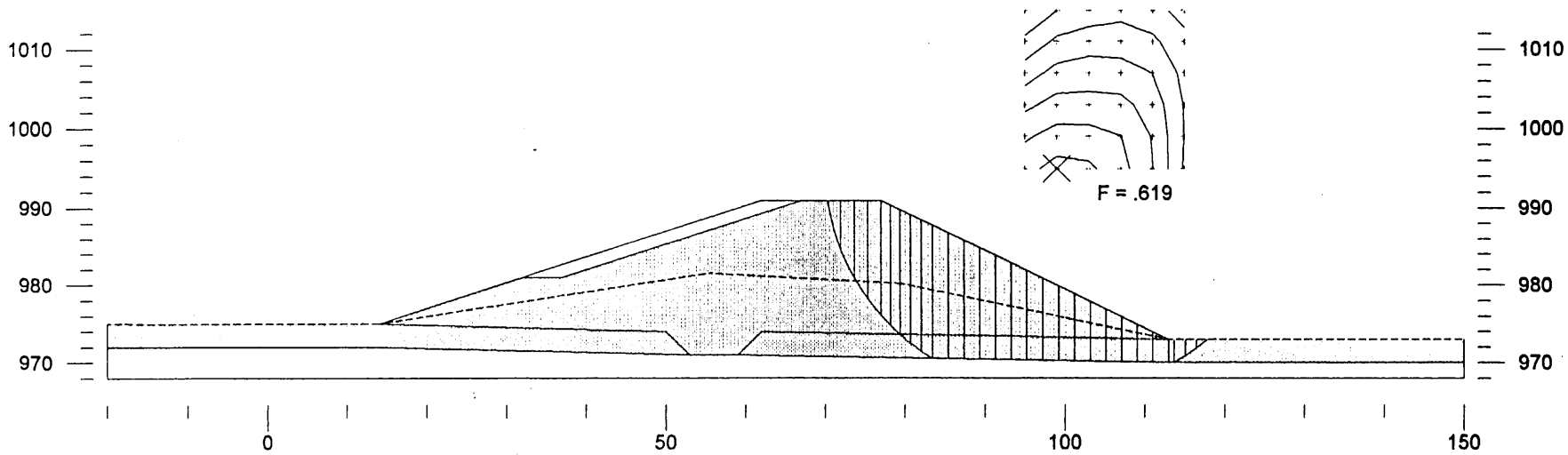
Norwest Mine Services - Calgary AB
00-1896
Flat Canyon Lease - Boulger Dam
2000-07-12
Drained



2000-07-18 4:32:09 PM C:\GSLOPE\FLATCA~1\BLGR_04.GSL Norwest Mine Services - Calgary AB F = 1.531

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.81	0	0	1	0
Riprap	22	0	40	1	0
Impervious Fill	20	10	35	1	0
Organics	18	5	5	1	0
Foundation	(Infinitely Strong)				

Norwest Mine Services - Calgary AB
00-1896
Flat Canyon Lease - Boulger Dam
2000-07-12
Drained
Subsicence - weak foundation

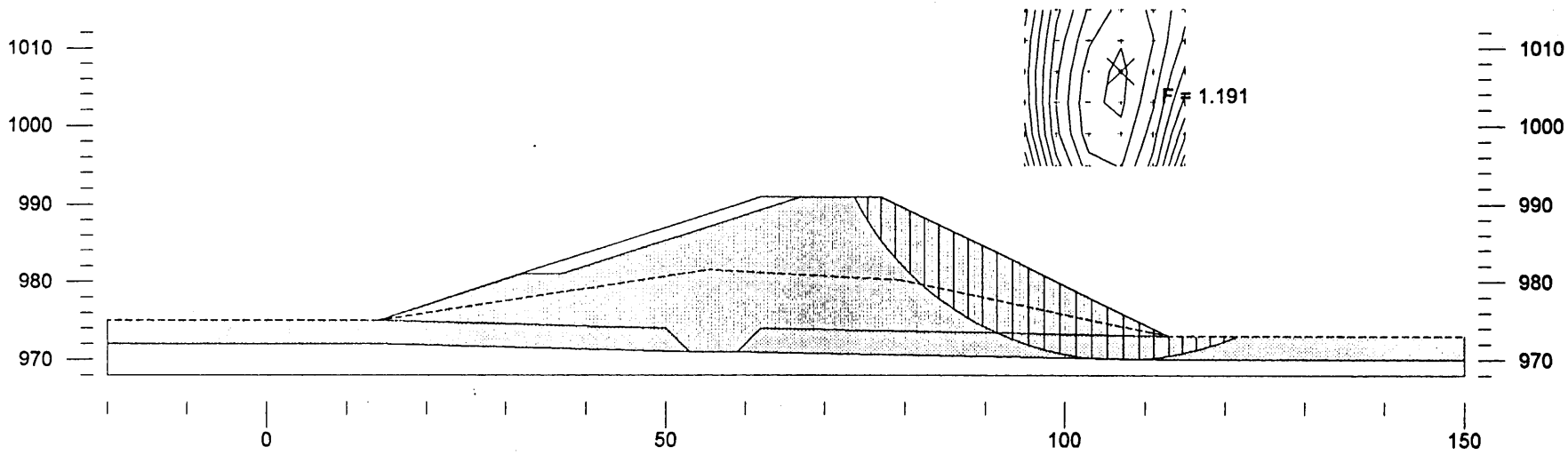


2000-07-18 4:34:25 PM C:\GSLOPE\FLATCA~1\BLGR_04.GSL Norwest Mine Services - Calgary AB F = .619

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.81	0	0	1	0
Riprap	22	0	40	1	0
Impervious Fill	20	10	35	1	0
Organics	18	10	28	1	0
Foundation	(Infinitely Strong)				

Seismic coefficient = 0.10

Norwest Mine Services - Calgary AB
00-1896
Flat Canyon Lease - Boulger Dam
2000-07-12
Drained
Seismic

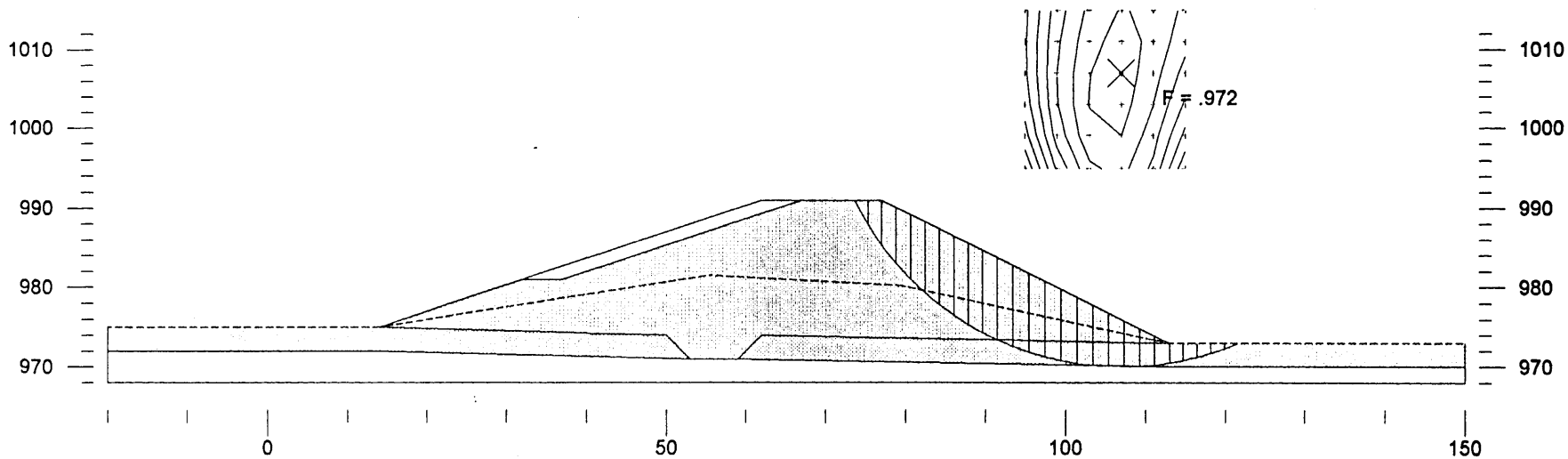


2000-07-18 4:35:45 PM C:\GSLOPE\FLATCA~1\BLGR_04.GSL Norwest Mine Services - Calgary AB F = 1.191

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.81	0	0	1	0
Riprap	22	0	40	1	0
Impervious Fill	20	10	35	1	0
Organics	18	10	28	1	0
Foundation	(Infinitely Strong)				

Seismic coefficient = 0.20

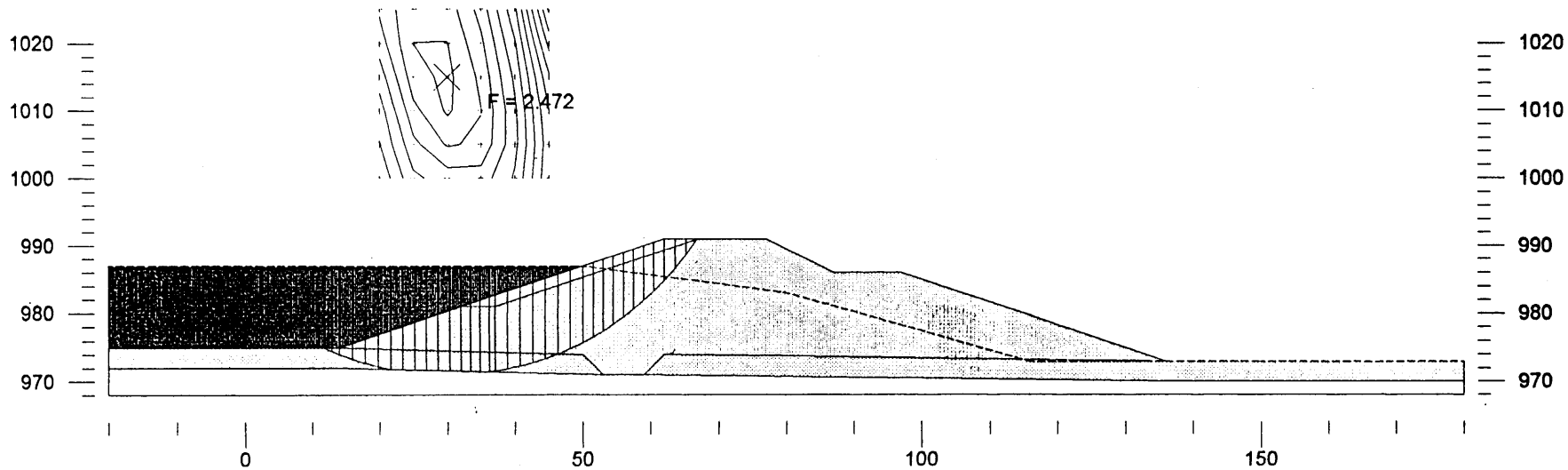
Norwest Mine Services - Calgary AB
00-1896
Flat Canyon Lease - Boulger Dam
2000-07-12
Drained
Seismic



2000-07-18 4:37:46 PM C:\GSLOPE\FLATCA~1\BLGR_04.GSL Norwest Mine Services - Calgary AB F = .972

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.81	0	0	1	0
Riprap	22	0	40	1	0
Impervious Fill	20	10	35	1	0
Organics	18	10	28	1	0
Foundation	(Infinitely Strong)				

Norwest Mine Services - Calgary AB
00-1896
Flat Canyon Lease - Boulger Dam
2000-07-12
Toe berm
u/s normal

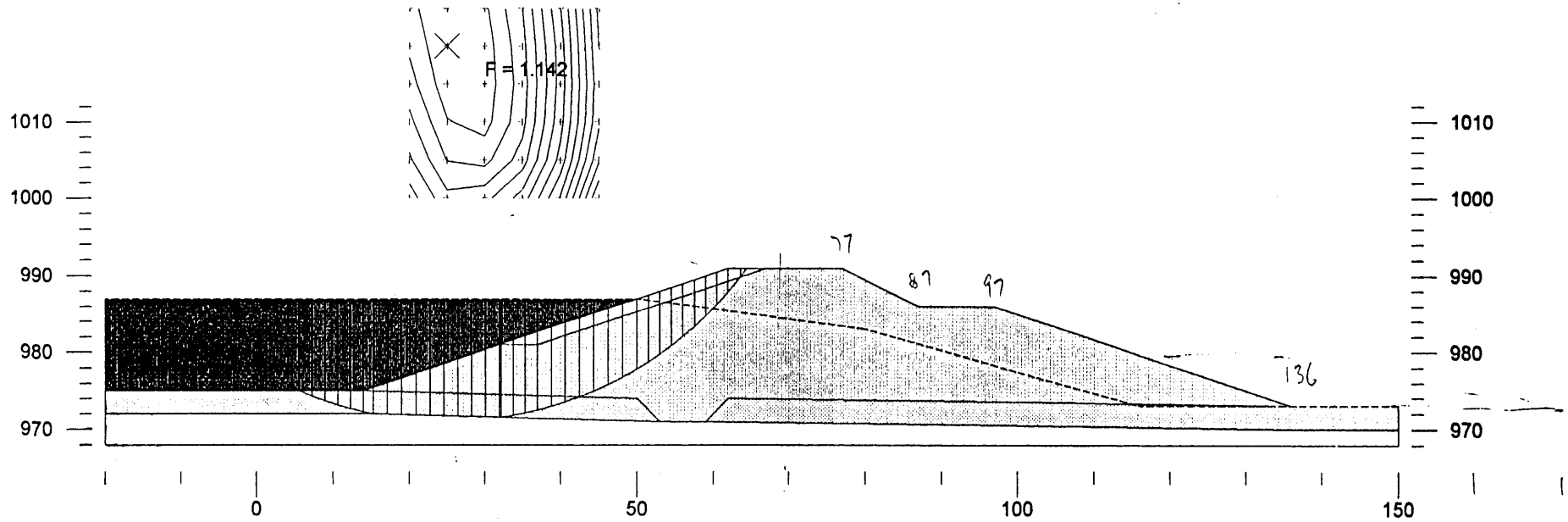


2000-07-18 4:45:40 PM C:\GSLOPE\FLATCA~1\BLGR_12.GSL Norwest Mine Services - Calgary AB F = 2.472

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.81	0	0	1	0
Riprap	22	0	40	1	0
Impervious Fill	20	10	35	1	0
Organics	18	10	28	1	0
Foundation	(Infinitely Strong)				

Seismic coefficient = 0.20

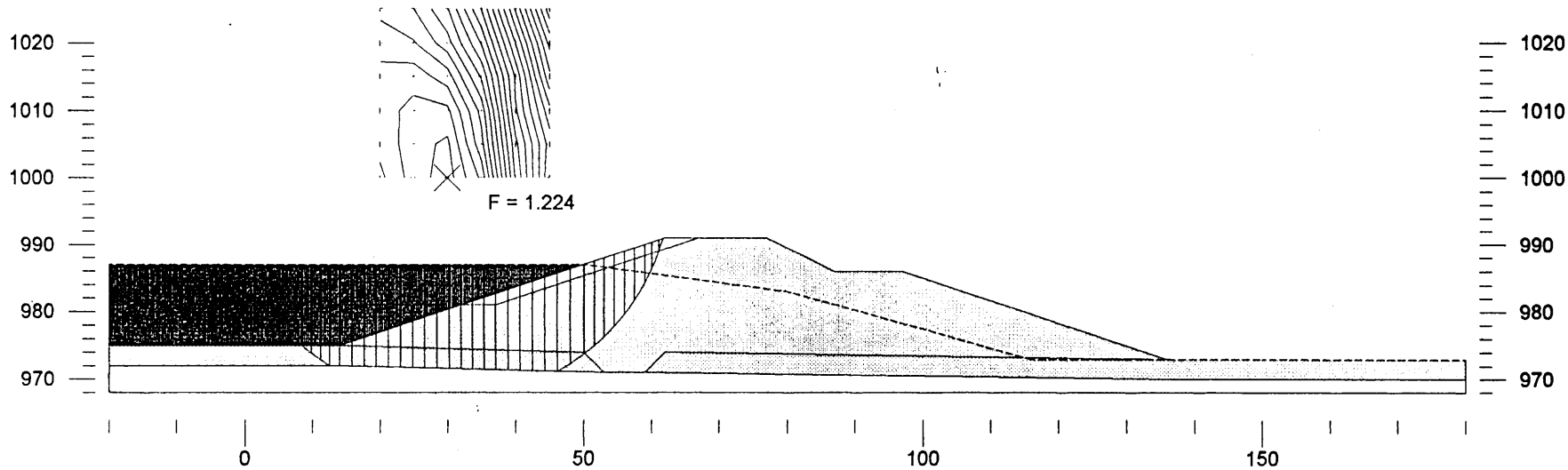
Norwest Mine Services - Calgary AB
00-1896
Flat Canyon Lease - Boulger Dam
2000-07-12
Toe berm
Seismic loading



2000-07-12 4:36:39 PM C:\GSLOPE\BLGR_06.GSL Norwest Mine Services - Calgary AB F = 1.142

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.81	0	0	1	0
Riprap	22	0	40	1	0
Impervious Fill	20	10	35	1	0
Organics	18	5	5	1	0
Foundation	(Infinitely Strong)				

Norwest Mine Services - Calgary AB
00-1896
Flat Canyon Lease - Boulger Dam
2000-07-12
Toe berm
weak foundation

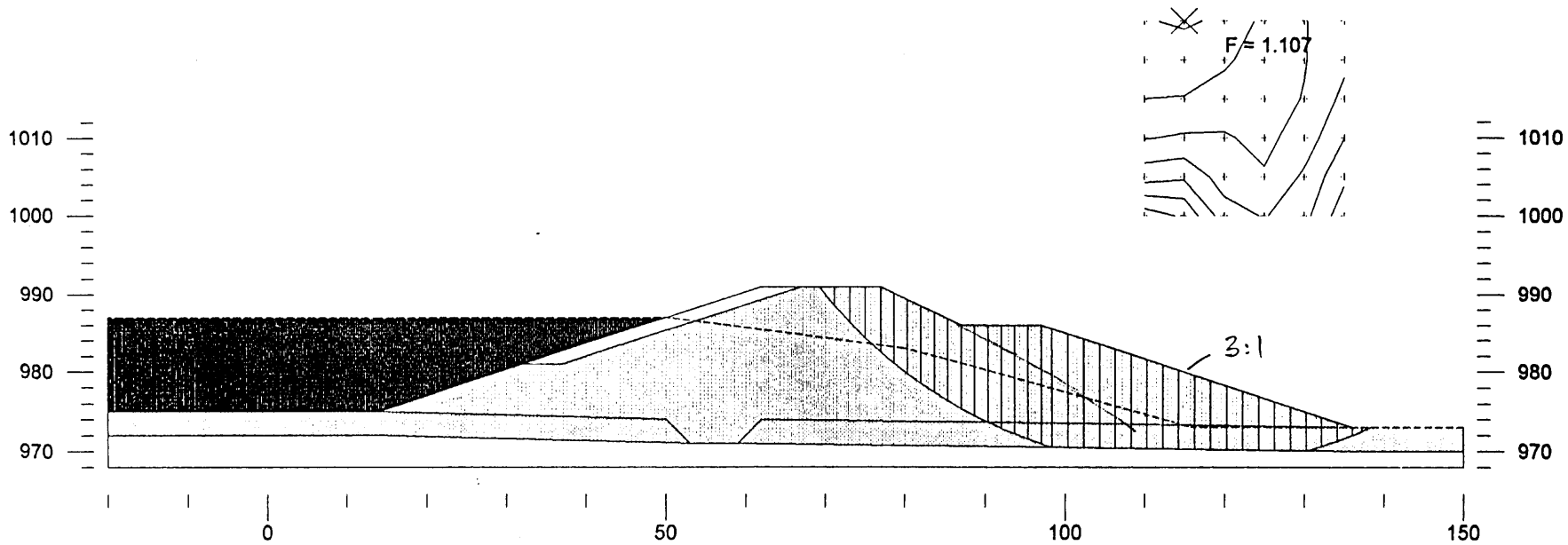


2000-07-18 4:47:53 PM C:\GSLOPE\FLATCA~1\BLGR_12.GSL Norwest Mine Services - Calgary AB F = 1.224

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.81	0	0	1	0
Riprap	22	0	40	1	0
Impervious Fill	20	10	35	1	0
Organics	18	10	28	1	0
Foundation	(Infinitely Strong)				

Seismic coefficient = 0.25

Norwest Mine Services - Calgary AB
00-1896
Flat Canyon Lease - Boulger Dam
2000-07-12
Toe berm
Seismic loading

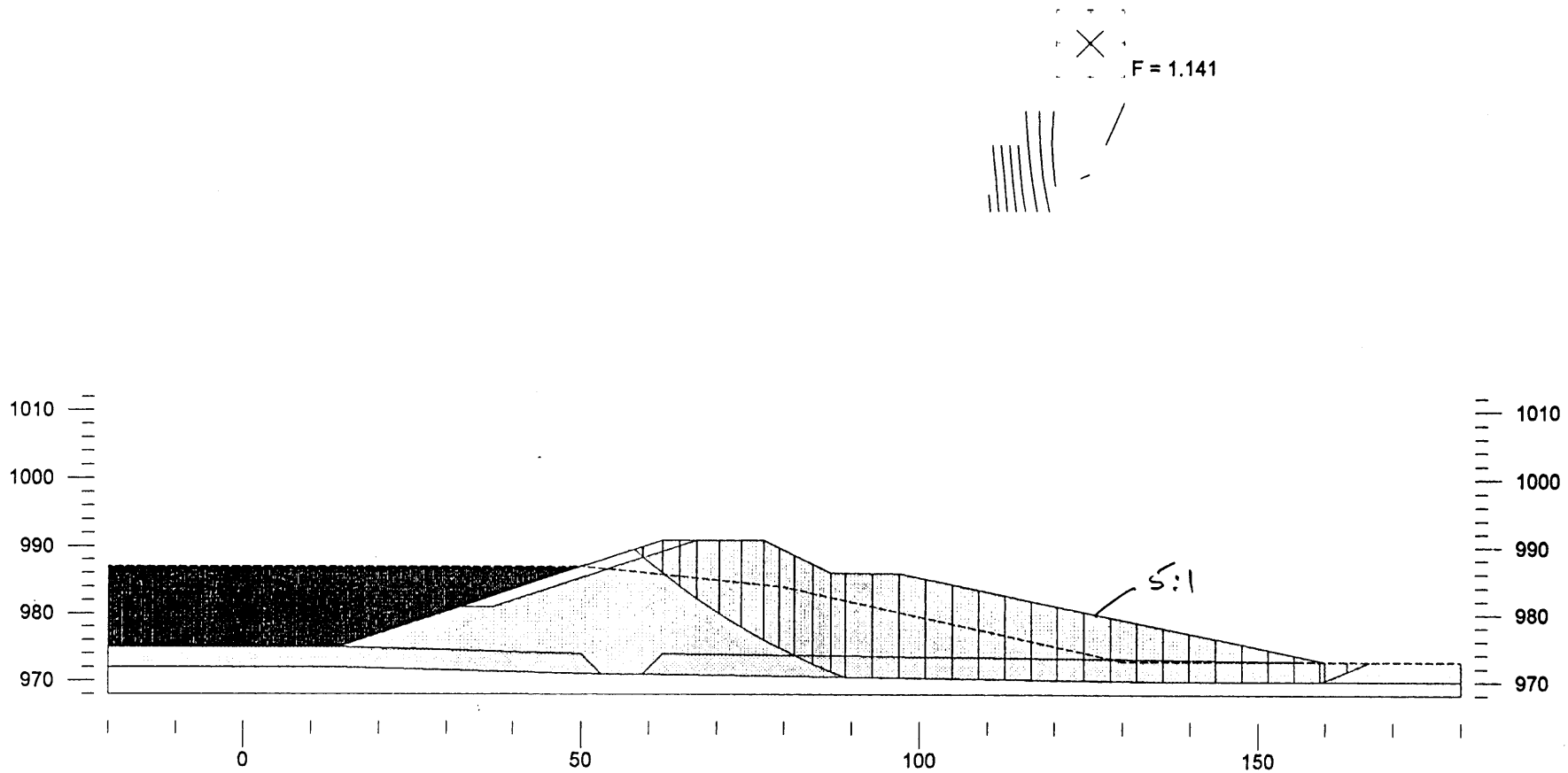


2000-07-12 4:32:25 PM C:\GSLOPE\BLGR_06.GSL Norwest Mine Services - Calgary AB F = 1.107

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.81	0	0	1	0
Riprap	22	0	40	1	0
Impervious Fill	20	10	35	1	0
Organics	18	10	28	1	0
Foundation	(Infinitely Strong)				

Seismic coefficient = 0.25

Norwest Mine Services - Calgary AB
00-1896
Flat Canyon Lease - Boulger Dam
2000-07-12
Toe berm
Seismic loading



2000-07-18 3:43:50 PM C:\GSLOPE\FLATCA~1\BLGR_09.GSL Norwest Mine Services - Calgary AB F = 1.141

NorWest
Mine Services, Inc.

RECEIVED
OCT 2 3 2000

October 20, 2000

Carter Reed
Forest Geologist
USDA Forest Service
599 West Price River Drive
Price, UT 84501

Dear Carter:

Enclosed are four copies of the Final Technical Report on Geology, Mining, Subsidence, Seismicity. The other copy will be delivered to BLM.

The Hydrology Report will follow tomorrow.

Our responses to each of your comments is attached to this letter.

We will look forward to your final approval of this report. It makes sense for us to wait and provide you with the electronic version of the reports and the hard copy of references until you have declared the three technical reports to be final.

Please contact me if you have any questions.

Yours truly
NorWest Mine Services, Inc.

Conrad B. Houser
Vice President

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Tel (801) 539-0044
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USFS Comments
Flat Canyon Tract Technical Reports
Final Draft Review

9/28/2000

I. General Comments

1. Copies of materials referenced in the Technical Reports must be submitted prior to acceptance of the final reports.

NorWest response: Copies of all references will be submitted separately in the next few days.

2. Final maps must be legible in black and white with see-through shading patterns. Color maps can be submitted but must be accompanied by twinned black and white maps that can be easily reproduced.

NorWest response: We assume black and white maps are needed only for those maps to be included in the EIS. Please let us know if further revisions of any maps are needed.

3. Electronic copies of the Technical Reports and Maps in the required formats will be required prior to acceptance of final reports.

NorWest response: Electronic copies of all reports, figures, tables, and maps will be submitted as soon as we are notified that the reports are acceptable / final.

II. Geology, Mining, Subsidence, and Seismicity

1. Section 4.4, Figure 4.1, and Section 5.6.3.5, Page 5-25 – This map shows a cabin in Swens Canyon on the south side just within the lease area on National Forest System lands. Our records show that this cabin is on private lands just west of the lease tract boundary. Please check this and correct the map and description of the cabin on page 5-25 as necessary.

NorWest response: The location of the cabin has been adjusted. The text has been revised.

2. Section 4.5.2, Page 4-7 and 4-8 (Alternative 2) – Be more specific regarding how the subsidence protection zones were determined. Include a description of the protection area (width of alluvium/floodplain, distance from structure, etc.).

NorWest response: Text has been added to page 4-8 regarding determination of subsidence protection zones.

3. Section 4.5.3, Pages 4-8 and 4-11 (Alternative 3) – Be more specific regarding how the subsidence protection zone for Huntington Creek was determined. Include how the width of the alluvium was determined, what angle-of-draw was used, how the angle-of-draw was applied, and what workings could be allowed under the protection zone without causing subsidence (other than the mains, such as bleeders, startup rooms, etc.).

NorWest response: Text has been revised accordingly.

4. Section 5.6.3.1, Pages 5-21 and 5-24 – This discussion and reference to the tables and figures is excellent. This detail of discussion needs to be continued in following discussions for the other features. However, the references to Tables 5.1 and 5.2 are incorrect. Change these and other references throughout the document to correctly reference Tables 5.2 and 5.3.

NorWest response: The discussion of features and reference to Tables 5.2 and 5.3 has been revised accordingly.

5. Section 5.6.3.2, Page 5-24 – Add more detail regarding the subsidence prediction points and "potential impact areas" (Figure 5.9) such as was done in the previous section. Identification of the "potential impact areas" is an excellent way to display potential effects but more explanation is needed to explain why they are of concern relative the type of subsidence predicted (permanent tension zone, etc.). Discuss how long it would take place for subsidence to be substantially complete following mining in each seam. This is needed to display the duration of impacts.

NorWest response: Further discussion has been included with reference to subsidence periods for each seam.

6. Sections 5.6.3.4 through 5.6.3.11 – Explain the "potential impact areas" in the appropriate sections to compliment Figure 5.9.

NorWest response: Further explanation has been added.

7. Use referenced materials regarding mine height vs. connection between surface cracks and fractured zone above workings. There are several references available. Also use the information derived from the Burnout Canyon Study vs. the USGS Miller Creek Study. At Miller Creek, the cracks dewatered the drainage and water was diverted to the mine level. Show similarities and differences to make conclusions.

NorWest response: Reference has been made to the Surface Water and Groundwater Technical Report regarding these impacts. Some text summarizing the relevant aspects of the findings of this report has been included where applicable.

8. Figure 6.1 – It appears that the seismic events have been plotted too far west. Please check the locations. If the map is correct, it indicates that mining in and directly adjacent to the tract can cause events up to a mile away from the mined area. If this is the case, it will be necessary to plot the locations of the 3.45 and 3.3 events that occurred to see if they lie directly over the mined area. In addition, it could be assumed for the purpose of the analysis that lower magnitude events could occur closer than the estimated distances and rely in the attenuation equation to predict potential accelerations from these smaller events from the structures to see if they present a concern.

NorWest response: As noted in the revised text, seismic events may be skewed west due to triangulation errors. The Figure agrees with materials available from the University.

9. Section 6.1, Page 6-3 – The 3.45 event has been attributed to mining. Unless it can be shown that this event was caused by conditions not present in the Flat Canyon Tract analysis area, this event must be evaluated as the MCE even if the probability is low.

   Calculate the probability/frequency of the 3.45 and other selected ranges of events from the historical information and present this information as required in the Scope of Work. This is needed to present a clear overall picture of seismic activity and mining-induced seismicity.

NorWest response: The quantitative definition of probability is not possible. A qualitative discussion has been added regarding the likelihood of the MCE occurring and possible frequency of this and lesser events. Additional discussion has been added concerning the MCE of 3.45 and the reasons for not presenting it as the main basis for analysis.

10. Section 7.2, Page 7-1 –The Contractor needs to provide information regarding pillar foundation conditions (clays that might become lubricated allowing pillars to slip laterally, etc.), in order to address the long-term pillar integrity issue and estimate whether or not there is reason to be concerned about the potential for pillars to fail by foundation failures or lateral slip. This occurred at the SUFCO mine where pillars were left in place to prevent escarpment failure in Quitchupah Creek. Empirical information from local mines should be sought and used if available to determine pillar longevity and potentials for failure.

NorWest response: Text has been supplemented to discuss pillar integrity, failure and slip potential.

11. Table 8.1, Page 8-12 – The cost of repairs to the Swens Canyon Cabin is included but not the Flat Canyon Cabins. Add this to the table and make it clear whether the cost numbers represent the total or individual costs.

NorWest response: Tables and text have been revised accordingly.

12. Sections 8.2 – The discussions for each structure are incomplete. Discuss potential mining scenarios needed to protect the structures from subsidence including full-support room-and-pillar mining. Discuss the angle-of-draw and any other buffer zones needed to assure subsidence of the structures would not occur. Discuss the pillar sizes needed to prevent subsidence under a full-support mining scenario. Discuss the duration of active subsidence to display the length of time impacts could occur.

NorWest response: Costs are shown. Further discussion and clarification has been added.

13. Section 8.2.1.1, Page 8-4 – Address the % probability of a mining-induced seismic event capable of producing 0.1g at the dam. Address how it was determined that the Boulger Reservoir Dam could withstand 0.1g.

NorWest response: The qualitative likelihood of MCE has been discussed. Limit Equilibrium Analysis was used to define the 0.1g strength and this has been clarified and included as an appendix.

14. Section 8.2.2, Page 8-6 –Address the potential impacts to concrete box culverts under the highway. There are at least two of them.

NorWest response: It is stated that the culvert near the east boundary of the RFDS may need to be replaced.

15. Section 8.2.3, Page 8-6 and 8-7– Considerable cracking of similar roads on Trough Springs Ridge and other areas has occurred from subsidence at the Skyline Mine that, for a short-term until repaired, presented a safety hazard to unsuspecting motorists, especially at excessive speeds. The cracks and potential public safety hazard need to be addressed.

NorWest response: The same conditions applicable to Trough Springs Ridge do not occur for State Highway SR264. The text includes a discussion of the safety aspects of highway subsidence.

16. Section 8.2.4, Page 8-7 – Include recommendations for ways to prevent or mitigate effects to the cabins. Describe what angle-of-draw and buffer zone would be needed to prevent subsidence of the cabins.

NorWest response: Further discussion has been added.

17. Appendices A and B – The tables appear to be identical. There is no need to include an identical table twice at different locations. Condense and simplify the Appendix A Table for the purposes of the EIS summary. The Appendix B table can be more technical and used as a Technical Report Summary Table rather than an EIS Summary Table. The tables need a title. The Appendix A Table should be titled "Comparison of Alternatives by Issue/Resource". The Appendix B Table should be titled "Technical Report Summary Table".

NorWest response: Tables have been revised accordingly.

18. Appendix A, Narrative – Add a discussion of effects of subsidence and seismicity. This must include a narrative description of effects to each resource/structure identified in the issue statements. This discussion is intended to be understandable by the general public without the technical jargon and description of methodologies presented in the technical reports, but with enough detail to understand the effects. This information is then abbreviated and summarized in the table. The table will be used in the EIS in Chapter 2 as a brief summary comparison of alternatives, not as the major description of effects to be presented in Chapter 4. The summary narrative will be included as the guts of the Environmental Consequences Section, Chapter 4.

NorWest response: Narrative and Table have been revised accordingly.

19. Appendix A – Define terms such as "minor effect" and "negligible effect" and be consistent between the narratives and the table. Do not use the term "significant or significant effect" because the term "significant" has a specific definition under NEPA that does not exactly coincide with how it is used in this summary. Suggest using the terms "no effect" where there would be no effect, "negligible effect" where the effects would not be noticeable or measurable, and "minor effect", "major effect" where effects would be measurable or noticeable, with appropriate definitions for each.

NorWest response: Terms have been defined as a footnote to the table in Appendix A.

20. Appendix A, Table of Effects - Exclude the recommendations from this table but keep them in the narrative. We will use the recommendations to define Alternative 4 that will be added to the table in the EIS.

    Exclude the descriptions of millistrains from the table because this is very technical and not understandable by the general public for a summary table. Replace this discussion with a little more narrative on compression zones or tensile zones produced from the mining and the potential for surface cracks.

NorWest response: The text and tables have been revised to be more understandable by the general public.

21. Appendix A, Summary Narrative and Table of Effects, Mining, General, Alternative 2 – Include your estimate of years of production. Consult with BLM on this to come up with a number.

NorWest response: This estimate has now been included.

22. Appendix A, Narrative and Table of Effects, Mining - Include the anticipated disturbance acreages for the vent holes and exploration drilling. Separate out access roads and pads.

NorWest response: Text has been revised accordingly.

23. Appendix A, Subsidence, General – It is not necessary to use general terms such as "minor effect" here where you are not addressing effects to some resource or structure where you are able to provide a quantitative analysis. Include potential widths and orientation of cracks and delete the term "significant cracks".

NorWest response: Further description has been provided.

24. Appendix A, Subsidence, Discussion for Specific Resources/Structures – State the resource/issue as "Potential subsidence effects to _____" for each of them to be consistent with the issue statements.

    Add a description of the potential damages to the structures and make references to the other tables for effects to drainages. Include estimated cost of repairs.

NorWest response: Text and tables have been revised.

25. Appendix A, Subsidence - Describe potential crack widths, etc. and probability in each resource category in this section rather than using the terms "minor cracking" and "significant cracking".

NorWest response: A semi-quantitative discussion has been added.

26. Appendix A, Boulger Dam and Reservoir – The protection distance of 1,500 feet was not quantified in the Technical Report or Summary Narrative. An explanation of how the 1,500 ft. protection zone must be included somewhere in the documents, not necessarily here in the table, to anchor this number.

NorWest response: Clarification has been added.

27. Appendix A, Table of Effects, Upper Huntington Creek Perennial Drainage – Alternative 2 should be changed to "no effect" or "negligible effect" instead of "insignificant effect". Under Alternative 3 use "negligible effect" or "minor effect" and be more specific on the angle-of-draw and stream area to be protected from subsidence. Rather than "negligible effect of main development corridor…", state that there would be less than ___ ft. of subsidence with a remote probability of pillar failure and subsidence.

NorWest response: Text has been revised accordingly.

28. Appendix A, Seismicity, General – See Items 19, 23, and 24 above.

    Alternative 3 – Include probabilities/frequencies the MCE and other ranges of events as discussed in Item 9 above.

NorWest response: A qualitative evaluation of probability and frequency of MCE and other ranges of events has been added.

29. Appendix A, Seismicity, Narrative and Table Discussions for Specific Structures/Resources – State the issue/resource as "Potential Seismicity Effects to _____".

    Include probabilities of seismic events that could cause the described damage.

NorWest response: Appropriate text has been added.

BLM Comments, Flat Canyon Technical Reports, Final Draft

9/28/2000

I. Geology, Mining, Subsidence, and Seismicity (George Tetreault, Stan Perks)

1. Figure 1.2: The map of the mine works should also show the projected panels just south of 16L, 15L and 14 L accessed from the mains that would go up Upper Huntington Creek Canyon.

NorWest response: We respectfully disagree. The figure is intended to show the detailed location of existing mine workings, proposed lease area and location of significant surface facilities. The mine workings projected by CFC are limited to those planned in the near future from development in the existing mine lease. It is not intended to show the RFDS on this figure and we propose that it not be revised.

2. Section 1.4 Reasonable Foreseeable Development Scenario (RFDS) – Summary: The statement Additional coal resources, **not feasible** for long wall mining..., needs to read not amenable.

NorWest response: Revision has been made.

3. Section 3.1 Proposed Mining Methods: Where long wall mining is **not feasible** then partial..., needs to read not amenable.

NorWest response: Revision has been made in this section and in other places in the report. Feasible has been changed to amenable where applicable.

4. Section 3.1.2 Long wall production, last sentence 3rd paragraph: Drop "where feasible" and have the sentence read," Additional production may come from room and pillar extraction."

NorWest response: Revision has been made.

5. Section 3.1.2 Long wall production: It is unacceptable for you to designate mineable seam heights by specifying certain long wall equipment or defining practical operational heights. **Long wall mining will be specified from a 6-foot seam height, not 8.5 or 7.** If the successful bidder can show that with a 7 or 8.5 foot minimum long wall height they can achieve MER, then they can produce their evidence in a mine plan submittal. This

technical report is not the place to be specifying mining heights or equipment. The main point you need to specify is the height of the coal being mined, i.e. 8 to 13 feet of coal in seam A and 7 to 9 feet in seam B.

NorWest response: We believe that the defined equipment constraints represent a <u>reasonable</u> approach to representing the expected range of extraction heights that we have subsequently used for subsidence predictions. We do not intend to infer that these are rigid technical or economic limitations or that an operator could not mine outside of these height ranges. We have revised the text to indicate that the zones presented are not mineable zones, but longwall <u>mining</u> zones and room and pillar <u>mining</u> zones (based on reasonable equipment constraints). Where these ranges are referenced in the text they has been qualified by indicating that they are not rigid limits and that some of the reserves may be amenable to longwall mining down to 6 feet. The mining zones will <u>not</u> be revised to reflect a 6 foot limit on longwall mining shown in Figures 3.1 and 3.2.

6. Section 3.1.3 Room and Pillar Production, pg. 3-7: The statement "We have made a reasonable assumption that room and pillar mining is not technically feasible at depths greater than 1800 ft based on experience in other mines." There has been room and pillar mining down to 2500 ft in several mines. Not technically feasible should be changed to safety and economic issues.

NorWest response: The text has been revised to indicate that room and pillar retreat mining will not take place at depths greater than 1800 feet based on safety and economic issues.

7. Section 4.3 Design Basis For Predictions: See item 5.

NorWest response: See response to Comment 5. We revised text in Section 4.2 to indicate that the mining scenarios are based on <u>reasonable</u> mining constraints presented in Section 3 (reference to mineability has been removed). Where height limits are given a qualification statement has been added to indicate that they are not rigid and longwall mining could be carried out down to 6 feet in some places.

8. Section 4.3 Design Basis For Predictions, pg. 4-3, last bullet: Change not feasible to not amenable.

NorWest response: The text has been revised.

9. Section 4.5.3 Alternative 3: Change feasible to amenable.

NorWest response: The text has been revised.

10. Section 5.1.1 Tension Fractures & Hydraulic Communications: The 5 foot wide cracks occurred on Trough Springs Ridge, not Burnout Creek. There have been detailed studies done on Burnout Creek. No cracks at all have been mapped in the Canyon Bottoms, including Burnout Creek. The locations where they see tension cracks are on ridge crests. The particular locations that Skyline has seen tension cracks form is on the ridge crests where they go from no mining to 2-seam mining. This is an example of Trough Springs Ridge cracks. Even in this environment cracks formed within only 900 feet of the 5000-foot long stacked fire barrier. Where Skyline has gone from no mining to one-seam mining thy see minor cracking on the ridge crests in the 1-2" range, which quickly heal. No tension cracks have yet been mapped within the canyons.

    There should be some discussion as to frequency, severity of, and percentage of tension cracks above the Skyline Mine. One severe case should not be highlighted; the usual normal occurrences should be specified instead. Instead of focusing on potential "worst case" potentials, a discussion as to what happens based upon present conditions.

NorWest response: The discussion of tension fractures has been revised to present a more balanced approach to their variation with mining layout and near surface geologic conditions. This has been presented in a semi-quantitative manner, as there have been no definitive quantitative studies carried out at Skyline to our knowledge.

11. Section 5.6 Prediction Results, pg 5-13, second paragraph: Explain what exactly is 1 unit for each 1000 units of length, what millistrain measurements mean to size of tension cracks, and what millistrain means in relation to subsidence.

NorWest response: The discussion has been expanded to explain the definition and interpretation tensile strain predictions.

12. Effects by Alternative, Boulger Dam: "strain of 28 millistrains with significant cracks and major damage to the dam." Page 5-14, Boulger Dam Maximum Horizontal Tensile Strain (16 millistrains), Page 5-15, Boulger Dam, Maximum Horizontal Tensile Train (28 millistrains) - stacked Fire Barrier. COMMENT: There seems to be a problem between page 5-14 and 5-15 for maximum horizontal tensile strain. The mining company can locate the fire barriers where necessary and do not have to put them under the dam. The mining company stated that they would not put them under the dam. THIS IS WORST-CASE AND SHOULD BE IDENTIFIED AS SUCH. Any time the worst-case is used it should be identified as such.

NorWest response: The discussion of prediction results has been revised to indicate that some of the parameters include worst case estimates and that they do not include any mining restrictions imposed to limit their magnitude.

13. Page 5-13, paragraph 2: "Horizontal strains are expressed in millistrain in this Report, with 1 millistrain being equivalent to a net change of 1 unit for each 1000 units of length. Tensile strains are positive and are equivalent to extension of the ground surface and compressive strains are negative. A measure of the degree of strain intensity is given by the maximum strain value and width of the zone of tension. The total extension possible over the tensile zone gives an indication of the degree to which discontinuous tensile strains have the potential to result in opening of tension cracks at [the] surface." COMMENT: This statement may be correct but it does not tell the whole story. This is a quantitative way to express qualitative field results. We do not have information to correlate the amount of millistrain with the width of the cracks that have been observed in the field. There have been not measurements taken and the near surface geology will govern how the loads (strain) is distributed and exhibited at the surface. The amount of extension does not directly correlate with the width of a crack. For example, an 8-millistrain event over a 500-foot tension zone will not create a crack of 4 feet in width, because the strain is not located at one point. The table 5.2 is entitled "Subsidence Point Characteristics and Maximum Predicted Values". This could be misleading. The maximum values are in-fact "worst case" and have been determined by the model having stacked fire barriers or abutments in the mining plan. The mine has some ability to work around these issues in the mine planning stages by not placing fire barriers under the areas of most concern. Just because there is a high tensile strain in the strata does not mean that there will be cracks. Trough Springs was over the top of a stacked fire barrier but the length of the cracks were limited in extent and did not run the entire length of the fire barrier. The experience at Skyline Mine has shown that there is very little expression of cracking at the surface due to mining in two seams. Our concern is that the results not be misinterpreted and the model, table and results needs to be explained in detail so the results are not taken out of context.

NorWest response: The text and Table 5.2 title have been revised to indicate that the predictions refer to maximum worst case predicted values. The discussion of Tables 5.1 and 5.2 has been expanded to better explain the results and provide further assistance in their interpretation.

14. Page 5-16, Maximum Horizontal Tensile Strain (millistrain): Explain what moderate values and maximum values mean exactly. There seems to be a preponderance to quantify millistrain as "worst-case" scenario. While the discussions and charts model the potential maximum affect of the maximum horizontal tensile strain (millistrain) that may occur, the experience Skyline Mine has shows that these "worst-case" effects have not occurred.

NorWest response: Further discussion has been included to discuss the range of predicted values and their implications. The maximum or worst case values have been identified and the relation of these values to experience at Skyline has been referenced where applicable.

15. Page 5-17 par 4 it states; "It would be possible to extract coal within the angle of draw using partial extraction room and pillar production methods without subsidence. This is technically feasible, although it may have some operational limitations for practical scheduling with long wall mining and a separate development access may be needed." These two statements don't seem to be the same. It is true that it is technically feasible to partially mine under these features, but as the comment on page 5-17 states it will have operational limitations for practical scheduling with long wall mining. This equates to a major loss of reserves not only under the feature that has to be mined, but due to timing issues further loss of reserves next to the features is a reality.

NorWest response: Definitive reference to the viability of room and pillar mining has been removed from Section 5.6.2.

16. Page 5-28 paragraph 3: "The numerical model predictions indicate that total vertical subsidence would vary from about 14.4 ft in the east to 5.0 ft in the west. If stacked abutments were located nearby, the maximum horizontal tensile strain is estimated to be in the range of 7 to 16 millistrain from southwest to northeast . . ." COMMENT: what is the meaning of "nearby". It looks like from the model about 0-200 feet away from the panel. The write-up seems to imply that the entire area would have this type strain instead of and elongated ellipse located about 200 feet away from the abutment.

NorWest response: The text has been revised to clarify the zone of influence for subsidence related effects and the limited extent where applicable.

17. Figure 6.1: Why are the majority of the seismic events outside of the mining area? Is there a coordinate translation problem or are the x-y coordinates that far off. It appears that the points are shifted about 1 mile to the west.

NorWest response: As noted in the revised text, seismic events may be skewed west due to triangulation errors. The Figure agrees with materials available from the University.

18. Section 6.2 Methods of Prediction: Spelling of Electric Lake **Cam**.

NorWest response: The typo has been corrected.

19. Section 6.2.3 Attenuation Equation: I am still concerned with using McGarr's equation when real time seismic events have shown it to be invalid in the Wasatch Plateau.

NorWest response: We agree that the McGarr equation is overly conservative, but without a better predictive relationship we have used it in defining a conservative approach. We believe there is currently no better approach. We have not revised the report.

20. Page 6-3 paragraph 1: "This shows that the maximum seismic event in the vicinity of the Mine was a magnitude 3.45 event, followed by three events with magnitudes of about 3.3 and a total of eight events with a magnitude of 3.1 or greater." COMMENT: Was this 3.45 magnitude event triggered while mining through the fault in Mine 3, in 4th Right? If so then the text should reflect this condition and the fact that the fault may have had something to do with this high of an event.

NorWest response: As discussed in the text, the 3.45 event was at 18,000 feet and not related to mining induced events.

21. Page 6-9, paragraph 5: "The variation of peak particle acceleration with distance from an event of magnitude 3.3 is presented in Table 6.1." COMMENT: The MCE is based on events from 1993 to 1996. There were approximately 50 events (page 6-4) and 3 events exceeded the 3.3. This means that 17% of the events were over or near the MCE level and that 83% were lower than the MCE. This means that there is a low probability of this event happening. The probability of the events should be taken into consideration and should be discussed. Did the circles take into account the depth of the coal seam or only the horizontal distance?

NorWest response: The probability of the event happening at least once during the period of mining is high, but the frequency of events is low. Discussion on the definition of probability and frequency has been added. The circles took into account the location of an event being at a depth of about 1000 feet which is near to the seam or above the seam for the majority of the area.

22. Page 6-10, paragraph 3: " This would most likely be prominent during first mining and less likely with mining of lower seams in multiple seam mining scenarios." COMMENT: Do you mean mining the first seam instead of first mining?

NorWest response: Yes, mining of the first seam was intended. The text has been revised accordingly.

23. Page 6-10, paragraph 4: "It is recommended that prior to production mining within the 0.1g acceleration zone around sensitive structures (Boulger and Hunt Dams) a comprehensive study is carried out to evaluate the site specific parameters likely to affect the magnitude of mining induced ground vibrations, combined with a site investigation of the strength of the structure." COMMENT: Clarify what the 0.1g acceleration zone represents. Is it from 0 - 0.1g or from 0.1g - 0.2g?

NorWest response: The 0.1g acceleration zone circle represents an area that if longwall mining is carried out inside then the vibrations from an MCE could produce accelerations at the dam structure of 0.1g or greater. The text has been revised to clarify this.

24. Page 7-5, paragraph 7: "The impact of the predicted subsidence is not expected to be major, although some inspection and repair work for Highway SR264 may be required over a time period that might extend over centuries." COMMENT: On page 7-2 paragraph 6, it states "Operational conditions are, therefore more stringent than long term stability requirements." and on page 7-4 paragraph 1 it states " . . . overall safety factor (tributary area basis) of 1.74. These results indicate acceptable safety factors for these pillar dimensions." This seems to indicate that the analysis has shown that there is a low probability of a subsidence event happening. The text on page 7-5 paragraph 7 then states "The impact of the predicted subsidence is not expected to be major, although some inspection and repair work for highway SR 264 may be required over a time period that might extend over centuries." This sentence states that there will be an event that happens "The impact of the predicted subsidence . . . "and there will be repair work on the highway that will extend over centuries. There seems to be a lack of continuity in these paragraphs. It seems that assuming the mains will subside that this should be the absolute worst-case condition that can arise since the more stringent operational conditions will exist.

NorWest response: The predicted subsidence refers to the estimated subsidence should the worst case scenario of pillar failure take place. This is not expected and the text has been revised to clarify this.

25. Section 8.2.1.1 Stability of the Dam, pg. 8-4, second paragraph: This should read, "...could induce a seismic event of sufficient magnitude with the potential to fail the dam."

NorWest response: The text has been revised.

26. Page 8-3 and page 8-4: "Under these conditions, and with the foregoing assumptions with regard to material strengths, Limit Equilibrium Analyses indicates that the Dam would likely withstand a seismic event with an equivalent horizontal ground acceleration of about 0.1g. Any acceleration greater that this could induce failure of the downstream slope and a potential breach." COMMENT: The term "about 0.1g" may not be consistent with the word "Any ""acceleration greater than this could induce failure of the downstream slope and a potential breach." What is the probability of this happening, since the McGarr equation appears to be conservative, and the material properties are conservative? The Equilibrium Analysis should be included in an Appendix in the final report.

NorWest response: The text has been revised to indicate the dam would likely withstand a seismic event with an equivalent horizontal ground acceleration of up to 0.1g. The Limit Equilibrium Analysis has been included as an Appendix.

27. Page A-8 Reasonably Foreseeable Development Scenario, Seventh paragraph: See item 5.

NorWest response: The reference to longwall mining heights has been clarified to be consistent with the response to comment 5.

28. Page A-8 Reasonably Foreseeable Development Scenario, Fifth paragraph: Change feasible to amenable.

NorWest response: Agreed and changed.

Table A.1 Range of Predicted Parameter Values at Different Mine Features, Under the Maximum Horizontal Tensile Strain (millistrain): A discussion as to what the values under a given parameter means is needed, i.e. under a stacked fire barrier 32 millistrain means, versus at the gate roads, 2 millistrain means?

NorWest response: Discussion with clarification has been added.

Appendix B: Define what "significant cracks" means. (versus 8 millistrain with possibility of cracks versus 16 millistrain, etc.)

NorWest response: A definition for the range of impact has been added and the table has been revised to be consistent with the qualitative definitions..

Appendix B, Mining Alternative 2, Effects by Alternative: "Two Seams over majority of area mined with mainly long wall and partial extraction Room-and-Pillar mining below perennial drainages." Fill in the question marks.

NorWest response: The extension of the mine life has been stated to be from 9 to 12 years for Alternative 3. For Alternative 2 the extension of the mine life has been defined as significantly less than Alternative 3.

Ia. Geology, Mining, Subsidence, and Seismicity (Max Nielson)

Pg. 8-1 Boulger Dam and Reservoir: State data for Dam No. 00695 (Boulger Dam) indicates the storage of this dam at 45 acre feet at dam crest which you have incorrectly identified as the maximum storage capacity. This is a meaningless number and creates the wrong

impression about this reservoir as it significantly over calculates the size and capacity of this reservoir. The fish ladder modification likely changed this reservoir significantly as it is set some 6 feet or so below the crest. The structure was built in 1937 and is also filled with sediment likely 60 to 70 percent and in all likelihood holds only 12 to 15 AF of water.

Hunt Dam that is identified by the State as Provo-Orem L.D.S. Camp (Dam No. 00512) has 3 acres of reservoir area and 10 AF of storage at spillway crest. The small reservoir is therefore some 3 feet deep. Your write-up should recognize the fact the camp has authority to only impound water for 2 or 3 months when the camp is being used during the Summer Youth Camp and does not store water otherwise.

NorWest response: The text has been revised to indicate that the original storage capacity of Boulger Dam was reported to be 45 acre-ft. and this has most likely been significantly reduced by lowering of the water level, by construction of the fish ladder, and extensive siltation over a 62 year period.

2. Pg. 8-5 Drain the Reservoir, Unrestricted Mining and Rebuild Dam: This discussion does not cover all alternatives such as the least cost alternative like pumping before mining followed by close monitoring and inspection of the structure and repair of the damage if necessary which is likely to be at significantly lower cost.

The write-up needs more specifics on the basis of the anticipated "loss of use cost" at $10,000/Mo. which is not explained other than it is an order of magnitude estimate. The higher use areas like the campground and Boulger Dam (used for fishing) are likely used for no more than 6 months/year at this elevation.

NorWest response: These options are presented in the text. The $10,000 per month does not have a rigorous basis and that is why it was referred to as an 'order of magnitude estimate'. We anticipated that the FS would provide a more accurate figure if available. It appears that the FS/BLM believe that this figure is high and we reduced it to $5,000 per month and indicate in the text that it has not been definitively estimated.

3. Pg. A-16 Alternative 3: The assumptions that have gone into the analysis of impact on small dams from longwall mining is most certainly flawed based on the impacts projected for these small structures and the fact that CFC has mined directly under stock ponds larger than these structures at 800 feet overburden without failing the structures. This analysis indicates longwall mining within 5500 feet will fail the dam. (Note from Carter – *We need to discuss this comment before any changes are made.*)

   Based on what is already known about the dams in question, (they are not intensively engineered structures built from poorly compacted sediments from upstream of the dams)

what information from costly monitoring, investigation, and evaluation would help in any way concerning this problem?

The logical choices here are:

- Don't mine or lease as most of the tract is within 5500 feet of these structures. - The Government will be making a choice on this matter.

- Drain the reservoirs to the point failure wouldn't hurt downstream users or resources. - This is the number one mitigating measure that should be identified by this study.

NorWest response: It was not intended to define a mining exclusion zone in the report. We agree that this zone is better defined by recommending that a monitoring and mitigation program should be implemented by the operator prior to longwall mining within the defined zone. The likely downstream hazard resulting from a possible dam failure has been discussed.

4. Pg. A-17 Recommendations for Monitoring and Mitigation: Other than monitoring at Electric Lake Dam, the monitoring and investigations make little sense. They are costly, time-consuming and do not fit the objective of moving this project forward and mining the area in 6-7 years. Logically the placement of fire barriers or abutment pillars is a mitigating measure concerned with surface disturbance from mining that would be considered in the mining plan. The most sensitive points such as the campground or Boulger Dam would not likely be placed in the fire barrier where you get maximum disturbance.

   Mitigation Measures

   Number one: Drain the reservoirs to a safe level (Hunt reservoir is already drained 3/4ths of the year)

   No 1. (A technical question). Doesn't restricted longwall mining of Boulger Dam place it in the same strain as you get with the fire barrier?

NorWest response: The recommendations for monitoring of the Boulger and Hunt Dams have been clarified to provide more detail or revised to be more flexible.