**U.S. Department of Energy**
200 Grand Avenue
Grand Junction, CO 81501
January 15, 2009

Mr. Myron Fliegel
Office of Nuclear Material Safety & Safeguards
U.S. Nuclear Regulatory Commission
Mail Stop T78J
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852-2747

Subject: Geologic Characterization for the Phase I Excavation of the Crescent Junction Disposal Cell

Dear Mr. Fliegel:

The enclosed report provides a geological characterization of the first phase of the Crescent Junction disposal cell excavation which was performed August-November 2008.

Please contact me at 970-257-2115 if you have any questions or concerns.

Sincerely,

Donald R. Metzler
Federal Project Director

cc w/o enclosure:
J. Berwick, DOE (e)
K. Wethington, DOE (e)
B. Anderson, RAC (e)
L. Brede, RAC (e)
Project File CRJ 2.12 (C. Smith)

T:\condor_doe\CRESCENT JCT\NRC\PhaseIGeolCharactization.doc

SM-4224-09-1051

# Geologic Characterization for the Phase I Excavation of the Crescent Junction, Utah, UMTRA Disposal Cell

**December 2008**

Stoller

Work Performed by S.M. Stoller Corporation Under Purchase Order No. 4926 for Energy*Solutions*, Moab, Utah. Energy*Solutions* Performs Work for the U.S. Department of Energy Under Task Order No. DE-AT30-07CC00014

# Geologic Characterization for the Phase I Excavation of the Crescent Junction, Utah, UMTRA Disposal Cell

December 2008

Work Performed by S.M. Stoller Corporation Under Purchase Order No. 4926 for Energy*Solutions*, Moab, Utah. Energy*Solutions* Performs Work for the U.S. Department of Energy Under Task Order No. DE-AT30-07CC00014

This page intentionally left blank

# Contents



# Figures

# Appendixes

# 1.0 Introduction

This report summarizes the geologic observations and measurements made from eight investigative visits to the Crescent Junction, Utah, Uranium Mill Tailings Remedial Action (UMTRA) disposal cell during the Phase I excavation of the cell in late summer and fall of 2008. Phase I consisted of excavation of the west end of the disposal cell – which is about 25 percent of the entire cell floor planned for excavation. Excavation visits started with a reconnaissance visit on August 22 and were scheduled to occur weekly thereafter. After two more weekly visits, the next five visits were at a longer frequency to correlate with the rate at which significant geologic features were exposed in the excavation. The last visit was on November 24 when most of the floor of the Phase I excavation was at final grade.

Investigative activities during each visit included:

- Determining the location of the contact of the unconsolidated Quaternary material and the top of weathered Mancos Shale bedrock on the excavation side slopes;
- Describing the lithologic characteristics of the weathered Mancos Shale exposed on the side slopes and floor of the excavation;
- Describing structural characteristics, such as strike and dip of bedding and joints, of the weathered Mancos Shale; and
- Checking for the presence of any seeps or moisture that would indicate ground water.

## 1.1 Data Collection and Presentation

For each visit, a brief field report was prepared containing the objectives/activities of the visit, observations/descriptions of significant geologic features found, a sketch of the status of the excavation and significant findings, survey locations that were staked, photographs taken and their description, and general comments. Descriptions and interpretations made in the field reports should be considered as preliminary, and final interpretations were made after analysis of all the field reports. These field reports are included in Appendix A of this report. Forty-six photographs were taken of significant geologic features at some survey locations and at other localities around the excavation. Each field report contains the photographs taken during that visit.

Locations of the contact of Quaternary material and bedrock were staked as well as significant lithologic variations and structural features in the bedrock. Sixty-seven staked locations from the field visits are plotted on the Map of Survey Locations for the Excavation shown in Figure B–1 in Appendix B. The locations were surveyed by GPS, and the x and y coordinates and elevations are also in Appendix B, Table B–1. Survey locations shown are numbered sequentially for the date of the visit.

Geologic features observed and measured in the Phase I excavation are described in this report as follows: Lithologic characteristics and thickness of the Quaternary material are followed by Mancos Shale bedrock characteristics and the configuration of the bedrock surface. Structural features seen mainly on the excavation floor in weathered Mancos Shale are then described. An evaluation is made of the stratigraphic and structural features found and how they affect the vertical drainage model for the cell, as described in the "Hydrologic Characterization – Lateral Spreading of Leachate," Attachment 3, Appendix G of the Final RAP (DOE 2008).

# 2.0 Quaternary Material

Unconsolidated Quaternary material overlies Mancos Shale bedrock and is exposed on the side slopes of the excavation. The heterogeneous material consists of mud, silt, sand, gravel, and cobble-sized clasts as large as 2 feet (ft) in diameter that were deposited by alluvial and colluvial processes from erosion of the lower and upper slopes of the Book Cliffs to the north. Coarser grained (sand- to cobble-size) material is found in shallow swales cut into bedrock, and finer grained (mud- and silt-size) material is found in successive sheet wash deposits up to the present ground surface. Included in the Quaternary material are eolian (silt-size material) deposits that are in discontinuous layers, generally in the lower part of the unconsolidated sequence. Geologic information notes for some of the survey locations involving Quaternary material is shown in Figure 1, the map of Lithologic and Structural Features for the Excavation, which is essentially a geologic map that contains information on features at, as well as away from, survey locations.

Swales that contain the coarse alluvial material appear to be only tens of feet wide where they are exposed perpendicular to their drainage direction in the north and south side slopes of the excavation. Resistant coarse clasts in the swales are typically 6 inches to as large as 2 ft in diameter (Figure 2) and consist of angular to subrounded cobbles and tabular fragments of sandstones from the Blackhawk Formation and Castlegate Sandstone, both of which cap the Book Cliffs. The coarse swale-fill is matrix supported by sand- and gravel-sized material; in places, this material is cemented by calcite.

Swales that contained coarse alluvial material were checked for moisture where exposed on the side slopes of the excavation. All were dry except for one small swale near the center of the south side slope. Slight moisture associated with this swale, noticed in the September 3 visit (Location 8), extended laterally about 20 to 30 ft, was about 1 to 2 ft thick, and was near the contact of the top of weathered bedrock and alluvial material. This location appears to be in a minor bedrock swale off the main north-striking bedrock ridge described in the Bedrock Surface Section. This moist location was rechecked in successive visits – on October 9, it was noted to be slightly moist and was photographed (Figure 3). On October 28, the location had dried out, and it remained so in the succeeding visits on November 13 and 24. Apparently, a small amount of water that had accumulated in this minor swale was exposed during August by the excavation. The source of the moisture is not known, but could be from water used during the excavation or from a rainfall event when the excavation depth was near the level of the swale. This small amount of moisture dried up over the next two months.

Fine-grained alluvial material, mainly in the form of silt to clayey silt that is highly calcareous and light brownish gray (10YR 6/2), overlies the coarse material in swales and, in places between swales, lies directly on weathered bedrock. These deposits are typically referred to as alluvial mud and were deposited by successive sheet wash erosion from the Mancos Shale (upper part of the Blue Gate Member) badlands on the lower slopes of the Book Cliffs.

Eolian material composed mainly of sandy silt is exposed along the side slopes of the excavation as a distinctive, but discontinuous, reddish layer that may be as much as 3 ft thick. Actual color of this material (which is loess) is light brown (7.5YR 6/4) and it may lie directly on weathered bedrock (Figure 4) or it may overlie coarse alluvial material in swales.

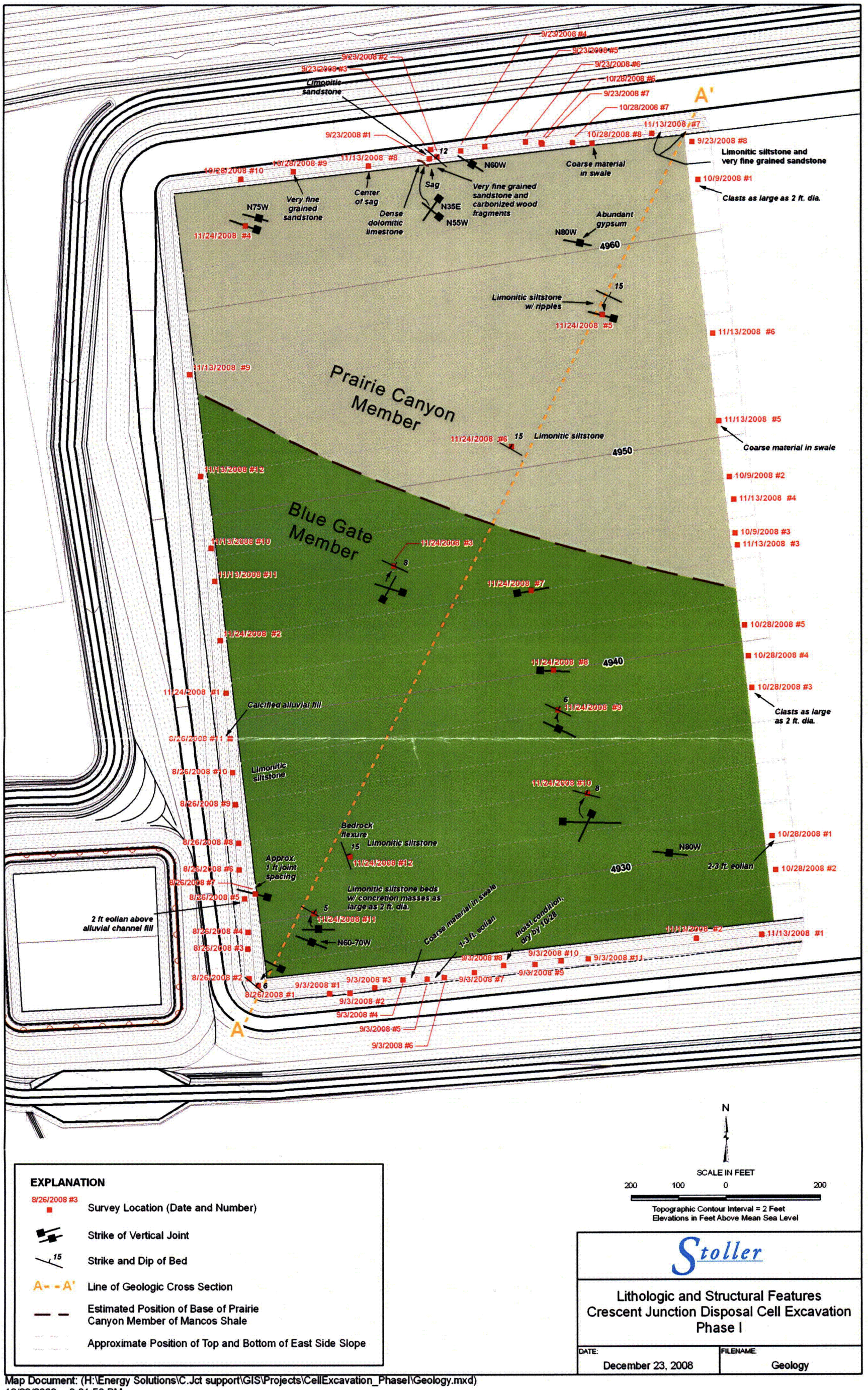



*Figure 1. Lithologic and Structural Features for the Excavation*

This page intentionally left blank

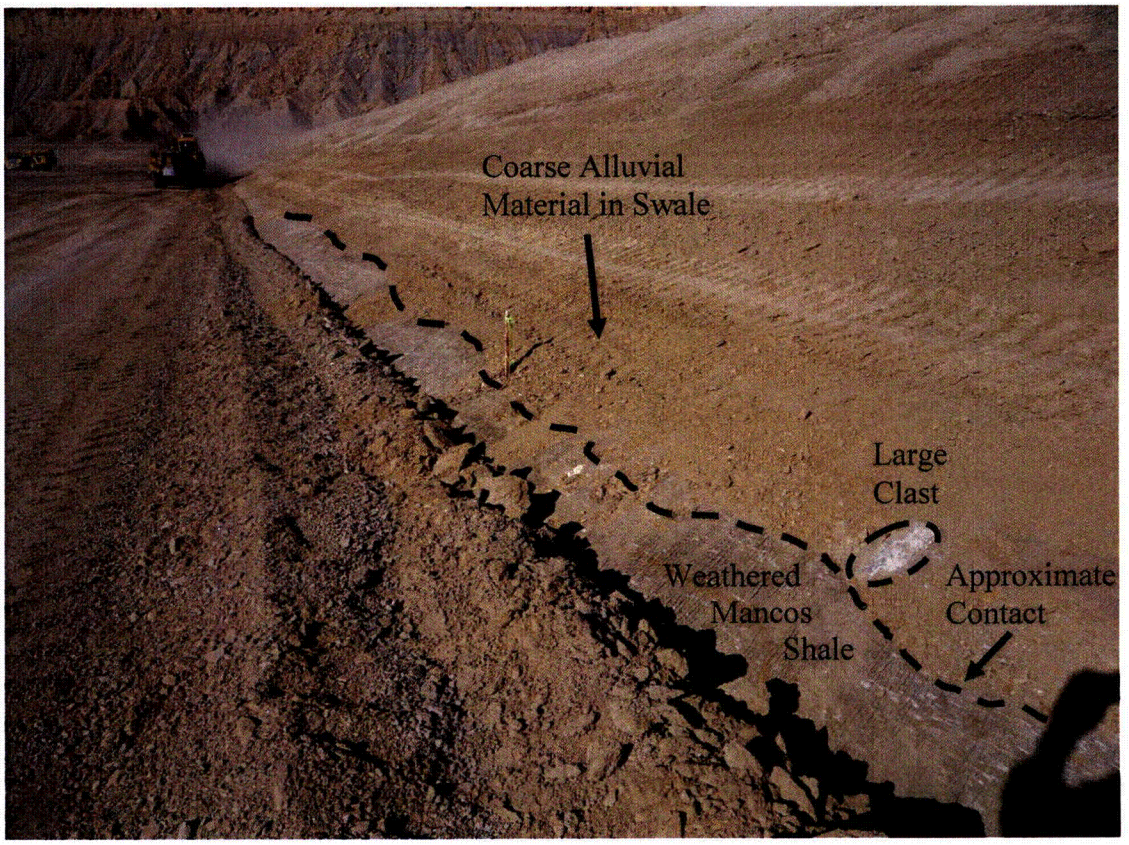



*Figure 2. View North of Contact of Weathered Mancos Shale Bedrock and Coarse Clasts in Overlying Swale*

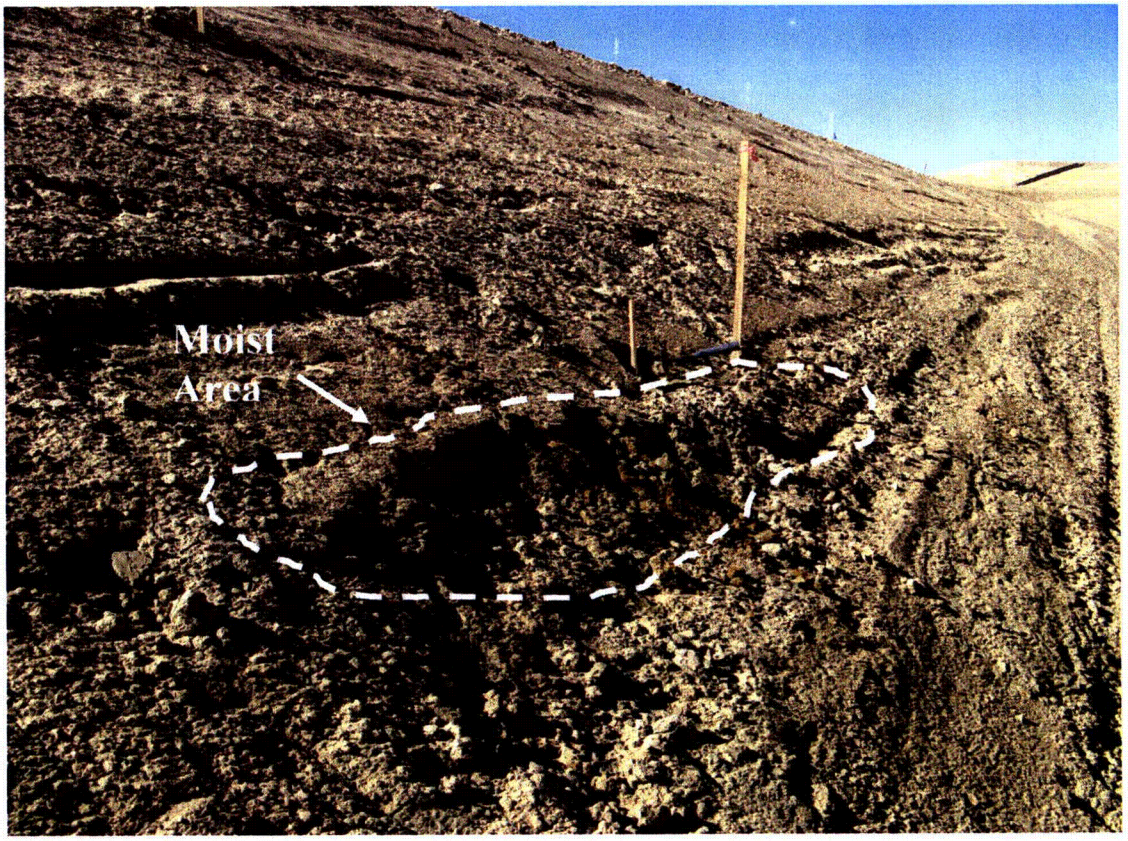



*Figure 3. Moist Area Around Location 8 (at the Short Stake) of September 3 on the South Side Slope*

*Figure 4. Reddish Eolian Material Overlying Weathered Mancos Shale Bedrock at Location 6 of September 3 on the South Side Slope*

A Depth to Bedrock map was prepared by subtracting the elevations of the top of the bedrock from those of the original ground surface. This map, presented as Figure 5, essentially shows the thickness of the Quaternary material. Depth to bedrock is least in a north-striking area corresponding to the bedrock ridge in the west part of the excavation where depths are as little as 4 ft or less. Greatest depths to bedrock are as much as 18 ft or more along the east side of the excavation from the center of the east side to the northeast corner.

## 3.0 Mancos Shale Bedrock

Weathered Mancos Shale bedrock was present at all places on the floor of Phase I of the excavation at final grade; however, exposures were poor in many places because of smearing by graders or a thin layer of broken rock covered the undisturbed bedrock. Deposited during the westward transgression of the shallow Late Cretaceous Western Interior Seaway, much of the Mancos Shale consists of calcareous mudstone from an open marine environment. As described in the "Surficial and Bedrock Geology of the Crescent Junction Disposal Site," Attachment 2, Appendix B of the Final RAP (DOE 2008), the disposal site is in the upper half of the Mancos Shale, partly in the Prairie Canyon Member, which represents a sandy interval deposited in a nearshore environment. Below the Prairie Canyon Member is the Blue Gate Member, which consists mostly of thick shale and mudstone deposited in an open marine environment, more typical of the Mancos.

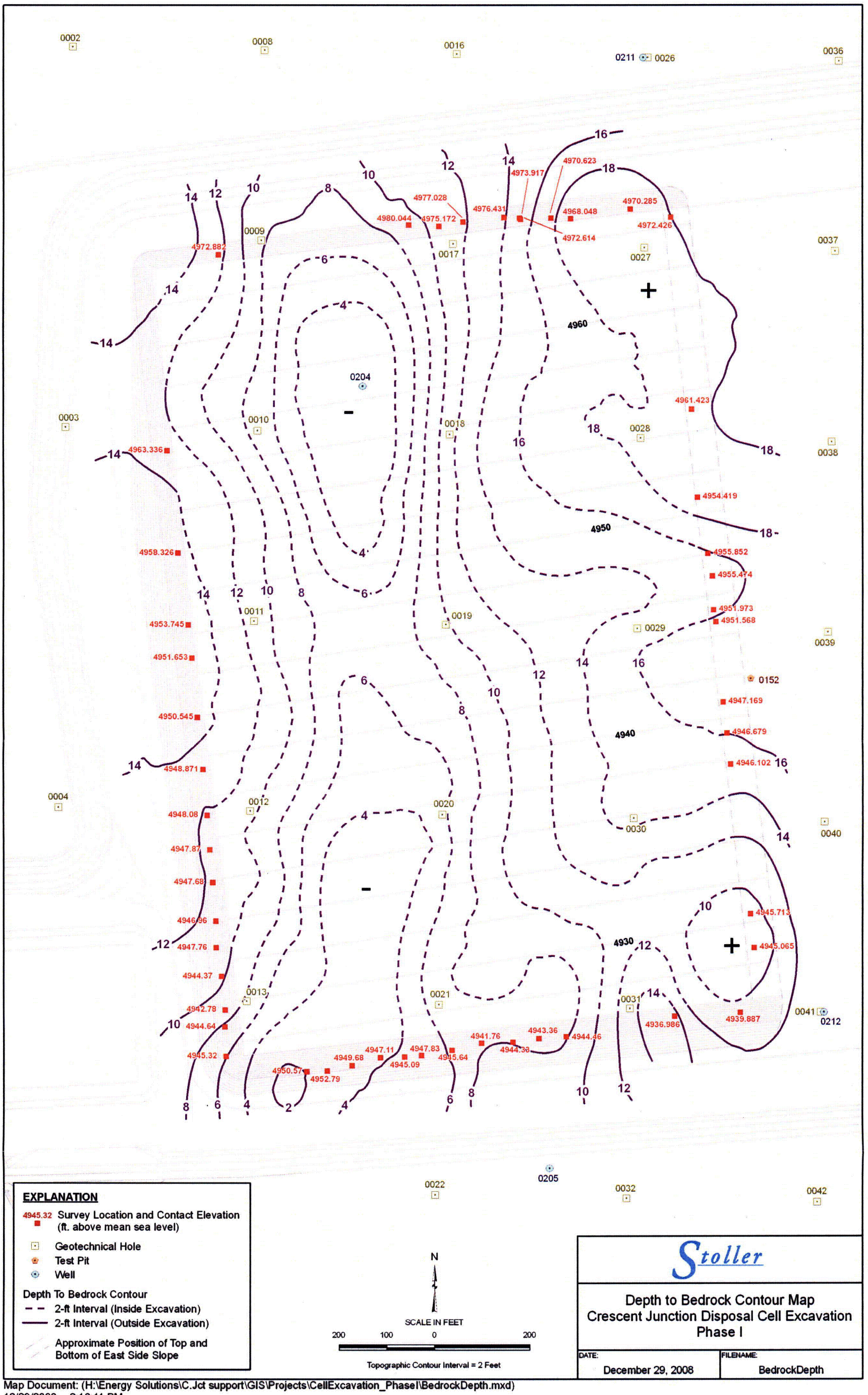



*Figure 5. Depth to Bedrock*

This page intentionally left blank

The most general lithologic characteristic of the Mancos Shale noticed in the excavation was that siltstone and very fine grained sandstone become more common from south to north across the excavation. From this lithologic character, the estimated boundary of the Blue Gate and Prairie Canyon Members was adjusted northward and to a northwesterly orientation from that shown in Plate 1 of the "Surficial and Bedrock Geology of the Crescent Junction Disposal Site," Attachment 2, Appendix B of the Final RAP (DOE 2008). The northwesterly orientation of the contact was modified to reflect and more closely parallel the northwest strike of beds measured on the excavation floor.

## 3.1 Blue Gate Member

Most commonly, the open-marine Mancos Shale representing the Blue Gate Member consists of silty shale or mudstone that is yellowish gray (5Y 7/2). This facies is also present but less common in the Prairie Canyon Member. In most places where the weathered silty shale is exposed on the excavation floor, white fibrous gypsum (of the satin spar variety) coats joints and bedding surfaces (Figure 6).

*Figure 6. Abundant White Gypsum (Satin Spar) Along Joints and Bedding Surfaces in Weathered Mancos Shale on Excavation Floor*

Thin limonitic siltstone beds, typically 6 inches or less thick that in places contain distinctive but rare limonitic concretionary masses, are in the southwest part of the excavation floor. These beds and concretionary masses are noticeable because they are harder than the weathered silty shale and because of their yellowish orange (10YR 6/6) color. Resistant concretionary masses are subrounded, as much as 6 inches thick, and as much as 2 ft long. The distinctive limonitic concretionary masses appear in the Blue Gate Member in the south part of the excavation, but were not in the Prairie Canyon Member in the north part of the excavation.

## 3.2 Prairie Canyon Member

In the north part of the excavation, limonitic siltstone beds become more common and very fine grained sandstone beds also appear near the north edge of the excavation. A distinctive resistant layer of dolomitic limestone as much as 3 ft thick, but of short horizontal extent, is exposed near the center of the north side slope of the excavation. These coarser grained and more resistant facies are characteristic of the Prairie Canyon Member, as defined by Cole and others (1997).

Indications of shallow water deposition were seen in the Prairie Canyon such as ripple marks (Figure 7) and fine carbonaceous material in siltstone beds and carbonized wood fragments and sole marks in very fine grained sandstone. Distinctive yellowish orange limonitic siltstone and very fine grained sandstone beds are exposed on the northeast floor and north side slope (Figures 8 and 9) of the excavation. Fine framboidal pyrite was seen in very fine grained sandstone beds on the north side slope. Only a trace of burrowing was noticed in the very fine grained sandstone, unlike the heavily burrowed and bioturbated sandstone described in the "Surficial and Bedrock Geology of the Crescent Junction Disposal Site," Attachment 2, Appendix B of the Final RAP (DOE 2008) that is exposed east of and stratigraphically higher than the sandstone in this Phase I excavation.

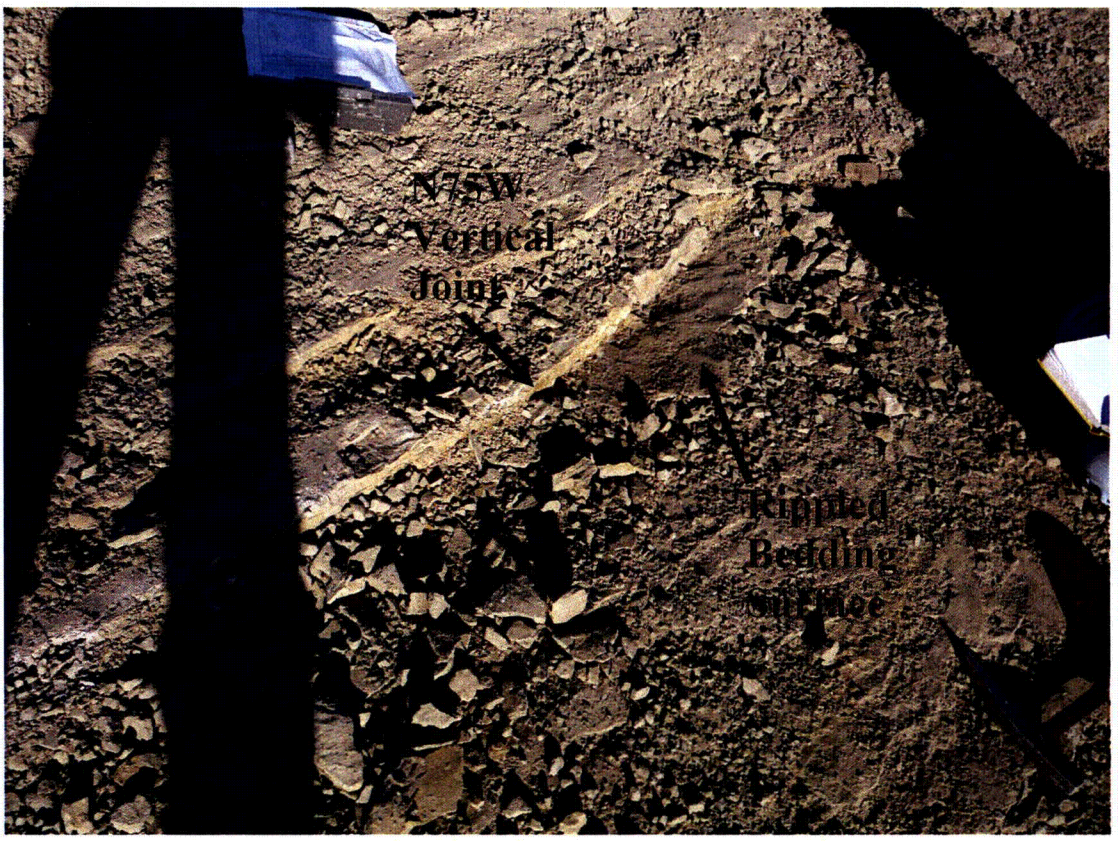



*Figure 7. Faintly Rippled Bedding Surface in Siltstone Bed with Vertical Joint Striking N75W at Location 5 of November 24 in the Northeast Floor of Excavation*

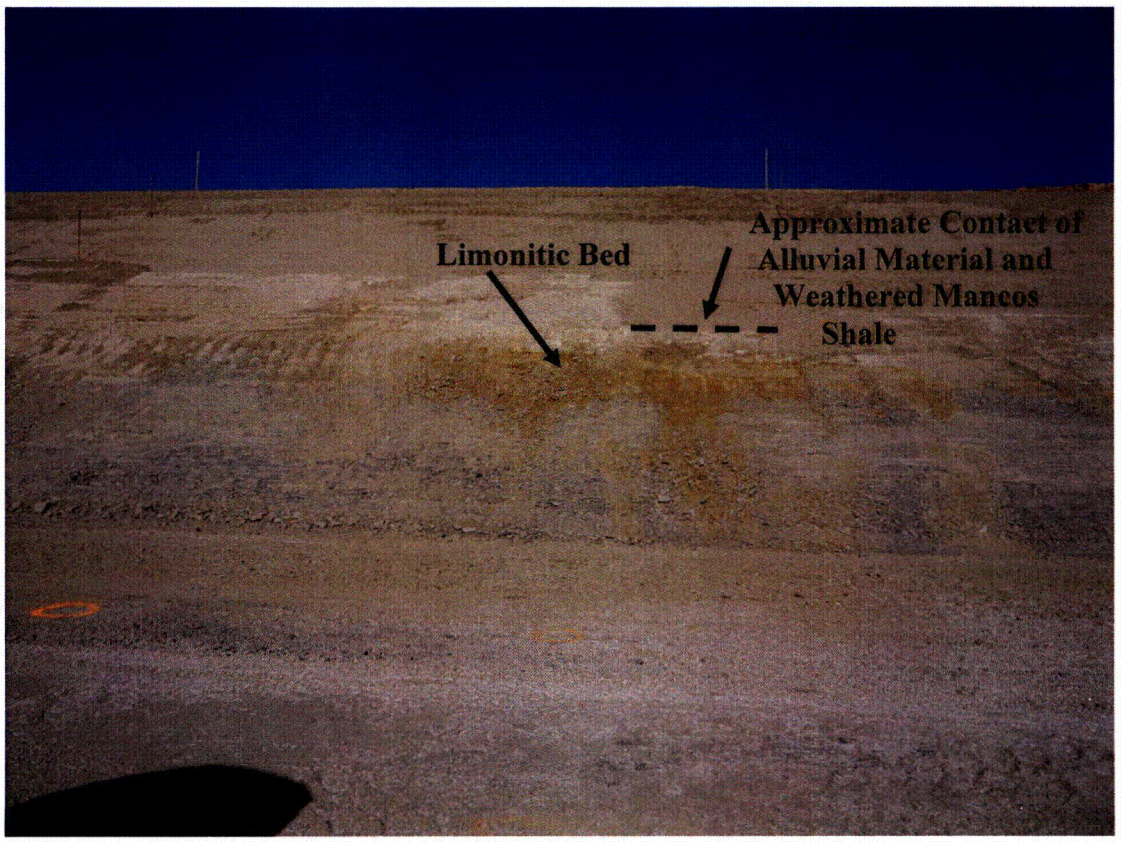



*Figure 8. Limonitic Siltstone and Very Fine Grained Sandstone Bed on North Side Slope Near Northeast Corner of Excavation*

*Figure 9. Very Fine Grained Limonitic Sandstone Bed About 6 Inches Thick Near Center of North Side Slope of Excavation*

Limonitic very fine grained sandstone beds overlie (Figure 9) and underlie the dolomitic limestone bed. A sandstone bed beneath the dolomitic limestone had carbonized wood fragments. These underlying and overlying coarse grained beds indicate local shoaling of the Mancos sea in short-lived regressive episodes. The occurrence of the dolomitic limestone and surrounding beds of very fine grained sandstone with carbonized woody material is similar to the lithologic facies described for the Prairie Canyon Member by Hampson and others (1999) who interpret the depositional environment as tidally influenced fluvial channels. This depositional occurrence may also be similar to that described by Chan (1992) for oolitic ironstone beds about 5 miles to the west of the site and at a similar stratigraphic level in the Prairie Canyon Member. There, small sandstone channels with carbonate beds as much as 1 meter thick are more resistant to weathering and are 10 to 20 meters across and 1 to 4 meters deep. The sandstones also contain carbonized wood and are interpreted as delta-front to prodelta channels that scoured into the fine-grained Mancos deposits below storm wave base.

Unique to this excavation and not seen elsewhere in the Prairie Canyon Member in the disposal site area is a dense, highly resistant, gray dolomitic limestone bed that is as much as 3 ft thick. Where the bed is exposed in the present excavation near the center of the north side slope, it is only as much as 1 ft thick and extends laterally for only 30 ft or less. Here, the bed is medium dark gray (N4) on a fresh surface, is limonite stained along the top surface and along joints, and contains no visible fossils (Figure 10). Just south of the small area of dolomitic limestone outcrop, a thick accumulation (as much as 3 ft) was encountered during initial excavation into bedrock. This thick resistant material was reportedly only 50 ft or less in lateral extent and was stockpiled for future use as riprap (Figure 11). The thick accumulation of dolomitic limestone in the stockpile was assumed to be a southward extension of the bed seen during excavation of the north side slope where the exposed bed did not exceed a thickness of 2 ft. The exposed lateral extent of this bed is small (30 ft or so), but the orientation or strike of this accumulation is not known.

# 4.0 Bedrock Surface

Fifty of the survey locations were staked for the elevation of the top of weathered Mancos Shale bedrock during the progress of the excavation on the four side slopes. It was not feasible or safe to stake top of bedrock locations as they were exposed during the early stages of excavation.

Top of bedrock elevations from the side slope locations were used to supplement and refine the bedrock contours derived from previous wells, test pits, and boreholes shown in the Bedrock Contour Map in Plate 3 of the "Surficial and Bedrock Geology of the Crescent Junction Disposal Site," Attachment 2, Appendix B of the Final RAP (DOE 2008). In this report, the Bedrock Contour Map, revised from the side slope locations from this Phase I of the disposal cell excavation, is shown in Figure 12.

*Figure 10. Dense Dolomitic Limestone Bed Near the Center of the North Side Slope at Location 1 of September 23*

*Figure 11. Stockpiled Dolomitic Limestone as Much as 3 Ft Thick Encountered During Initial Excavation Into Bedrock South of Location 1 of September 23*

Although the bedrock surface broadly mimics the gentle south slope of the surface topography in the site area, the bedrock surface contains some subtle ridges and swales. New bedrock contact data from this investigation further defines the north-striking bedrock ridge in the west part of the excavation. Along this ridge, the excavation has progressed the deepest into Mancos Shale – as much as 20 to 25 ft. Sites of least excavation into Mancos Shale (as little as 3 to 4 ft) are along the central and north parts of the east side slope. In the west part of the north side slope along the axis of the bedrock ridge, the contact of the top of bedrock is shallow and not exposed because the top of the side slope has been regraded (obscuring the contact). Notes of coarse alluvial material exposed along the side slopes shown in Figure 1 coincide in places to minor swales shown in the Bedrock Contour Map (Figure 12).

# 5.0 Structures

Structural features in bedrock were noted on the side slopes as the depth of the excavation advanced. Most observations were along the north side slope where the excavation cut deepest into Mancos Shale. Most lithologic and structural observations in Mancos Shale on the floor of the excavation were made during the last visit to the disposal cell on November 24 when final grade had been reached on most of the Phase I excavation floor. Structural measurements (joints and strike and dip of bedding) and lithologic information from exposed Mancos Shale are shown in Figure 1. Also shown in Figure 1 is the line of Geologic Cross Section A-A', presented as Figure 13, across the excavation from the southwest to the northeast corner. The cross section was prepared using structural, lithologic, and top of bedrock information from the field visits. This section is approximately perpendicular to the strike of bedding in the Mancos Shale.

Strike and dip of bedding was measured at only nine locations (Figure 1), mainly because bedding surfaces were poorly exposed on the excavation floor. Except for one strike of N20W measured on a minor bedrock flexure, strike of bedding varied from N50W to N80W and typically was N60W. Dip of bedding varied from 5 to 15 degrees NE. Except for one dip of 15 degrees measured on a minor bedrock flexure, dip of bedding measured in the south part of the excavation was from 5 to 8 degrees (Figure 14). Dip of bedding in the north part of the excavation was slightly steeper, from 12 to 15 degrees. In the north part of the excavation, limonitic siltstone beds of the Prairie Canyon Member were slightly more resistant than the silty shale beds of the Blue Gate Member and provided a few exposed bedding surfaces that could be measured (Figure 15).

The northwesterly striking bedding surfaces in the present excavation are slightly different than the westerly striking bedding measured on a few outcrops of dolomitic siltstone concretion beds north of the disposal cell shown in Plate 1 of the "Surficial and Bedrock Geology of the Crescent Junction Disposal Site," Attachment 2, Appendix B of the Final RAP (DOE 2008). Also, the dip of bedding measured in the present excavation is slightly steeper than what was measured (5 to 6 degrees) in outcrops to the north. The more northwesterly strike of bedding and steeper dip of beds in Mancos Shale may be because this west part of the disposal cell excavation is the closest part of the disposal site area to the salt-cored Salt Valley Anticline, only about 1 mile to the southwest. The northwest strike of bedding is parallel to the strike of the anticline, and steeper dips are probably the expression of minor flexures on the northeast flank of the anticline.

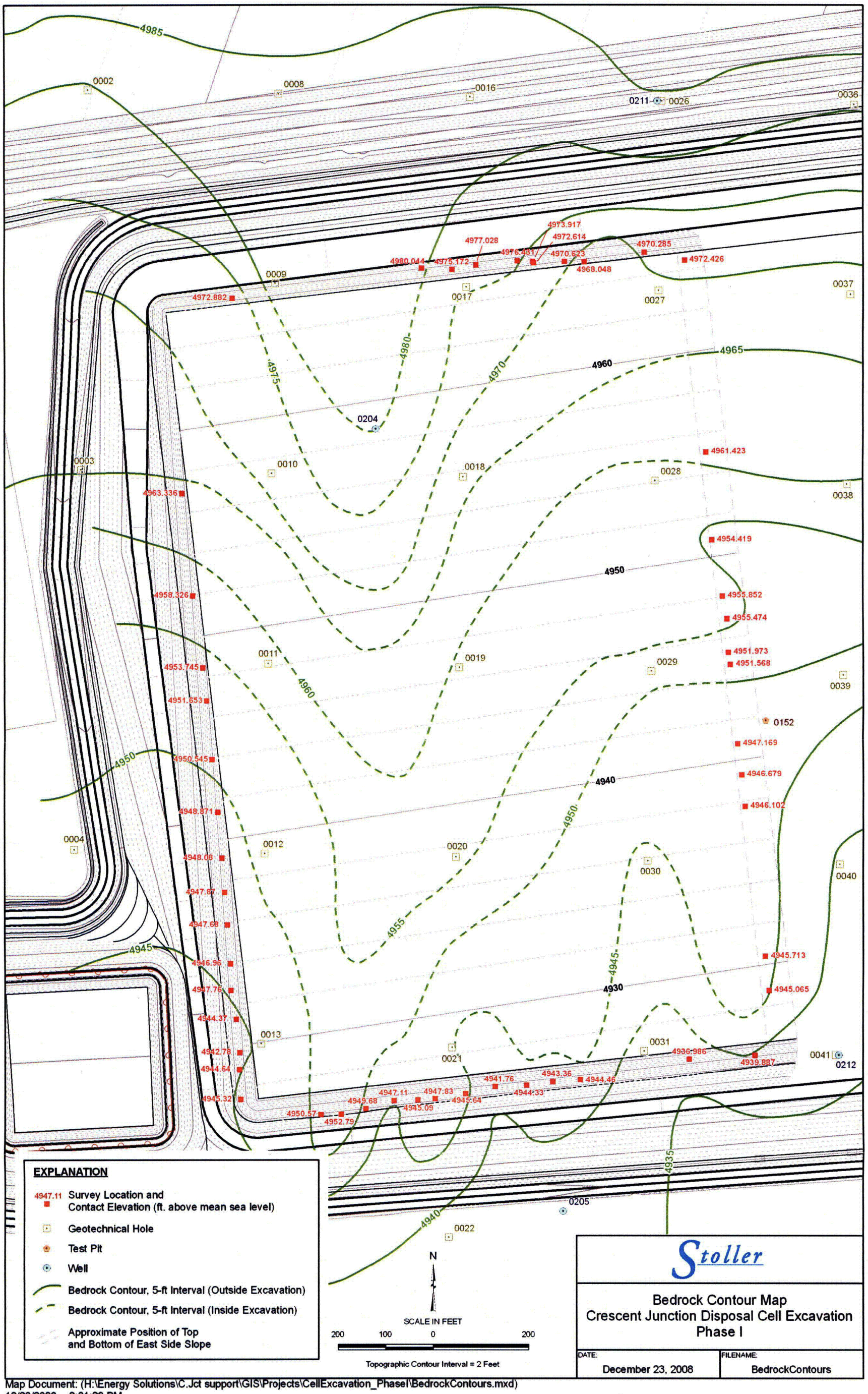



*Figure 12. Bedrock Contour Map*

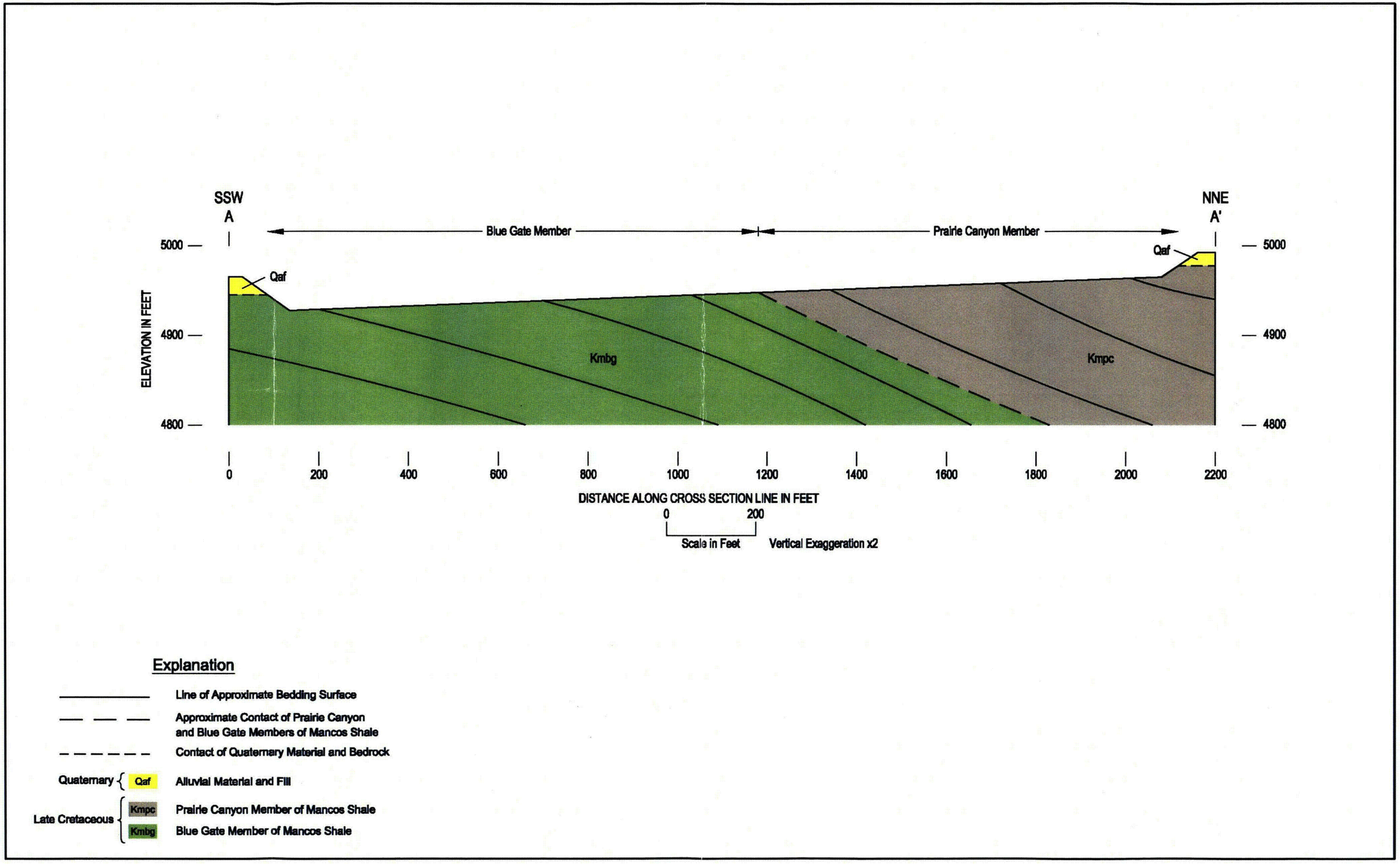



*Figure 13. Geologic Cross Section A-A'*

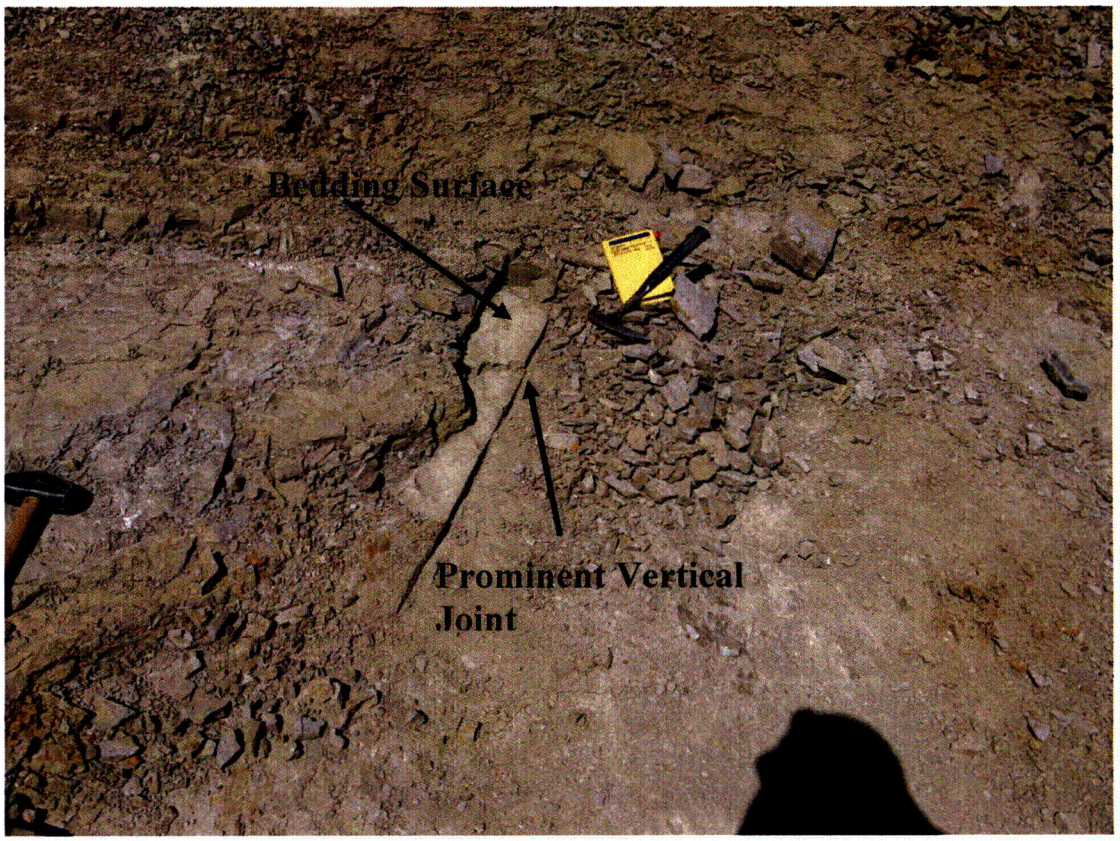



*Figure 14. In the Southwest Corner of the Excavation, Bedding Surface Strikes N50W and Dips 6 Degrees Northeast and Prominent Vertical Joint Strikes N57W*

*Figure 15. Bedding Surface Strikes N60W and Dips 15 Degrees Northeast in Limonitic Siltstone Bed at Location 6 of November 24*

Minor structural sags in Mancos Shale bedding were noticed in several places in the excavation. One sag in the southwest part of the excavation (Figure 1) appeared to be a flexure expressed by steeper dip (15 degrees) of bedding and a strike of N20W. Two other sags are well exposed near the center of the north side slope of the excavation. The two sags are about 100 ft apart and each one is about 50 ft long and 3 to 4 ft deep, as expressed by bedding (Figure 16). Also, yellowish orange (limonitic) coloration is characteristic of the bedrock in the sags, and beds outside the sag are the normal yellowish gray color.

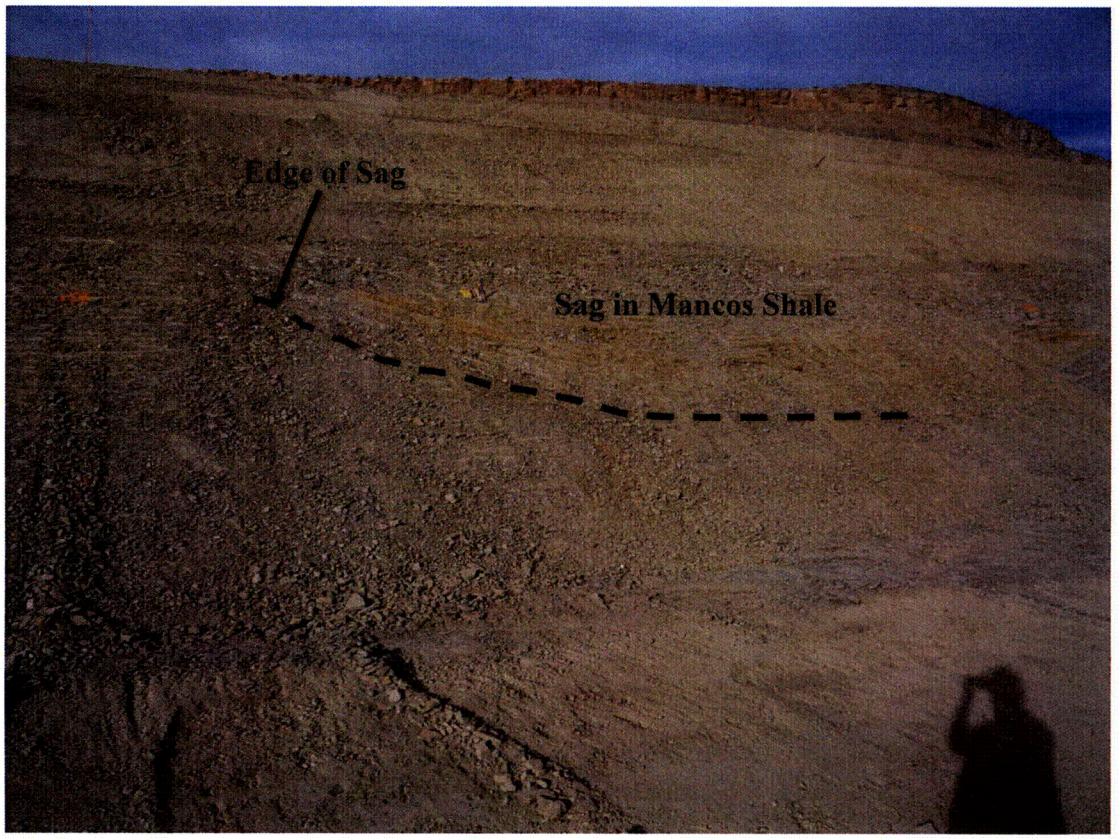



*Figure 16. View Northeast of Sag in Mancos Shale About 50 Ft Long and 3 to 4 Ft Deep with Yellowish Orange Limonitic Siltstone Beds at Location 8 of November 13*

The bed of dense, resistant dolomitic limestone also crops out in a slightly lower stratigraphic position between the two sags. The sags were only exposed in the side slope and were not seen when first exposed by the excavation; therefore, the strike of these structures is not known. The origin of these two sags is not clear from the exposures. Because the sags are on both sides of the dolomitic limestone, the most plausible explanation for their origin is that they represent local draping (during deposition) of strata over the thick dolomitic limestone bed. What is best exposed (Figure 16) is the abrupt change in bedding inclination and the yellow orange color of beds within the sag. The limonitic coloration could have been caused by the oxidation of iron (pyrite) in these siltstone beds by ground water that moved along fractures associated with the sag or flexure. The oxidizing ground water may have been present during periods of higher precipitation associated with several glacial periods in the late Pleistocene Epoch, as suggested in the "Surficial and Bedrock Geology of the Crescent Junction Disposal Site," Attachment 2, Appendix B of the Final RAP (DOE 2008). The structures are minor, occupy a small area, and no evidence of present water movement or moisture was seen. No evidence of these structures was seen immediately to the south on the excavation floor.

Joints measured around the excavation (Figure 1) were essentially vertical and were exposed more commonly than bedding surfaces. Exposed in the weathered part of Mancos Shale, most joints in the excavation are tight, but some joints are open as much as 0.2 inch. Joints are commonly coated with gypsum (in a crystalline form as satin spar and in the form of powder) and are spaced about 1 to 2 ft apart (Figure 17). Joints are more common in the rock types in the Mancos Shale that are more competent and brittle than the silty shale, such as siltstone, very fine-grained sandstone, and dolomitic limestone. The orientation of the principal joint system varied from west to N55W, and most commonly was N60W to N80W. At a location where a bedding surface and the principal joint system were exposed, the strike of bedding was typically 10 to 20 degrees more northerly than the strike of the joint. Therefore, the principal joint system is slightly different than a strike joint (same as the strike of bedding).

*Figure 17. West-Striking Vertical Joint System Spaced about 1 to 2 Ft Apart with Gypsum Coatings at Location 11 of November 24*

A secondary vertical joint direction was noted in only three locations (Figure 1). The secondary joint system strikes from N15E to N35E, and with the principal joint system forms a roughly orthogonal or conjugate set. One of the orthogonal joint sets was measured in the dense dolomitic limestone bed about 2 ft thick when it was exposed on October 9.

No clearly exposed slickensides or other evidence of movement was seen on any of the joints. The presence of abundant gypsum along joints in the weathered Mancos Shale is evidence of previous movement of oxidizing ground water, probably during wetter times in the late Pleistocene Epoch, but no sign of current ground water was seen.

# 6.0 Geologic Findings

Significant geologic findings for the west end of the disposal cell exposed by the Phase I excavation are summarized below:

- Depth to bedrock (thickness of Quaternary material) is as little as 4 ft or less in the west part of the excavation along the axis of the north-striking bedrock ridge. Bedrock depth is as much as 18 ft or more in the northeast corner of the excavation.
- The strike of the siltstone and very fine grained sandstone beds observed in the excavation floor are to the northwest; therefore, the contact of the Prairie Canyon and Blue Gate Members of the Mancos Shale was adjusted slightly northward and to a more northwesterly orientation than what was described in the "Surficial and Bedrock Geology of the Crescent Junction Disposal Site," Attachment 2, Appendix B of the Final RAP (DOE 2008).
- A dense, highly resistant, gray dolomitic limestone bed of short lateral extent in the north-central part of the excavation may have formed in a delta-front channel during near-shoaling conditions in the Mancos sea. Sags in the overlying bedding on both sides of the dolomitic limestone bed may indicate draping of beds over this feature during or shortly after the limestone was deposited. Localization of limonitic coloration in siltstone beds in these sags indicates that movement of oxidizing ground water during wetter times in the late Pleistocene Epoch along these structures is probably responsible for the coloration. No evidence of present water was seen in these structures.
- Joints were mostly tight, but some were slightly open as much as 0.2 inch; they were typically coated or filled with white powdery or crystalline gypsum and had no clearly evident slickensides or other evidence of movement. Gypsum in the weathered Mancos Shale indicates previous movement of oxidizing ground water probably in the late Pleistocene Epoch along the joints, but evidence of present ground water was not seen.
- Fractures, joints, and other weathering effects in bedrock were observed to be less common where the depth of the excavation increased into the weathered Mancos Shale along the west part of the excavation floor in the area of the north-striking bedrock ridge. Conversely, weathering effects are more obvious and well expressed in the east part of the excavation floor where only a few feet of weathered bedrock have been removed.
- Dip of bedding in the north part of the excavation is slightly steeper (12 to 15 degrees) than what was described for the disposal cell area (5 to 6 degrees) in the "Surficial and Bedrock Geology of the Crescent Junction Disposal Site," Attachment 2, Appendix B of the Final RAP (DOE 2008).
- No evidence of present ground water was observed in the excavation.

# 7.0 Implications for the Vertical Drainage Model for the Disposal Cell

The vertical drainage of leachate from tailings placed in the disposal cell is described in "Hydrologic Characterization – Lateral Spreading of Leachate", in Attachment 3, Appendix G of the Final RAP (DOE 2008). According to the conservative assumption of the model, leachate will migrate vertically down through the weathered Mancos Shale and become perched above the unweathered Mancos. At the contact of the unweathered Mancos Shale, leachate will gradually spread laterally away from the disposal cell footprint and leachate will be consumed by slow vertical leakage downward into the unweathered Mancos.

Geologic findings from this characterization support the vertical drainage model. These findings pertain only to the west end of the disposal cell, or about 25 percent of the planned total cell excavation. None of the findings adversely affect or cast doubt on the model. Supportive findings and implications are as follows:

- No ground water was seen in the weathered Mancos Shale.
- Joints in weathered Mancos Shale were vertical and mostly tight, but some were open as much as 0.2 inch, which would facilitate leachate migration downward through the weathered zone.
- Bedrock of Prairie Canyon Member of the Mancos Shale in the north part of the excavation dips to the northeast at 12 to 15 degrees. The greater amount of siltstone and very fine grained sandstone in the Prairie Canyon, as compared to the Blue Gate Member to the south, could provide a more permeable pathway for leachate to migrate northward and downdip through the weathered zone. This coarser grained bedrock contains more joints than the finer grained silty shale typical of the Blue Gate Member, further facilitating leachate migration.

# 8.0 References


Cole, R.D., R.G. Young, and G.C. Willis, 1997. *The Prairie Canyon Member, a New Unit of the Upper Cretaceous Mancos Shale, West-Central Colorado and East-Central Utah*, Utah Geological Survey Miscellaneous Publication 97-4.

Hampson, G.J., J.A. Howell, and S.S. Flint, 1999. "A Sedimentological and Sequence Stratigraphic Re-Interpretation of the Upper Cretaceous Prairie Canyon Member ("Mancos B") and Associated Strata, Book Cliffs Area, Utah, U.S.A.," *Journal of Sedimentary Research*, v. 69, no. 2, p. 414-433.

Chan, M.A., 1992. "Oolitic Ironstone of the Cretaceous Western Interior Seaway, East-Central Utah," *Journal of Sedimentary Petrology*, v. 62, no. 4, p. 693-705.

DOE (U.S. Department of Energy) 2008. *Final Remedial Action Plan (RAP) and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site*, Revision 1, DOE-EM/GJ1547, Prepared for U.S. Department of Energy Office of Environmental Management, Grand Junction, Colorado, February.

This page intentionally left blank

# Appendix A

## Field Visit Reports

| Dates of Field Visits |
|---|
| August 22, 2008 |
| August 26, 2008 |
| September 3, 2008 |
| September 23, 2008 |
| October 9, 2008 |
| October 28, 2008 |
| November 13, 2008 |
| November 24, 2008 |

This page intentionally left blank

# Geologic Characterization of Crescent Junction Cell Excavation

Date: August 22, 2008 Geologist: Craig Goodknight and Ken Karp
Depth of Excavation: est. 15 ft BGS Amount of Material Excavated: 546,483 $yd^3$
Base Map Grid Number(s)

Observations: General flow (traffic pattern) of graders in excavation. South and west sides of excavation are available for observation, but bottom of excavation is still as much as 10 ft above final grade.

Photographs (ID number and description):

| Image | |
|---|---|
| 1042 | View N of graders |
| 1043 | View WNW of SW end of excavation |
| 1044 | " W of graders dumping in Mancos Shale stockpile |
| 1045 | " SSE of construction water storage pond |
| 1046 | " N of Mancos Shale (competent) on stockpile |
| 1047 | " NW across SW corner of disposal cell excavation |
| 1048 | " Mancos Shale bedding surface and prominent joint in SW corner of bottom of disposal cell excavation |

Survey points (ID number and location): No survey points were identified.

Comments: This was initial visit by C. Goodknight and K. Karp to disposal cell excavation. Hard hat, safety vest (Class 2), and radio required for visit to excavation. Warm/hot (80's+90's) and dry conditions, dry in excavation.

Date (continued): 8/22/08

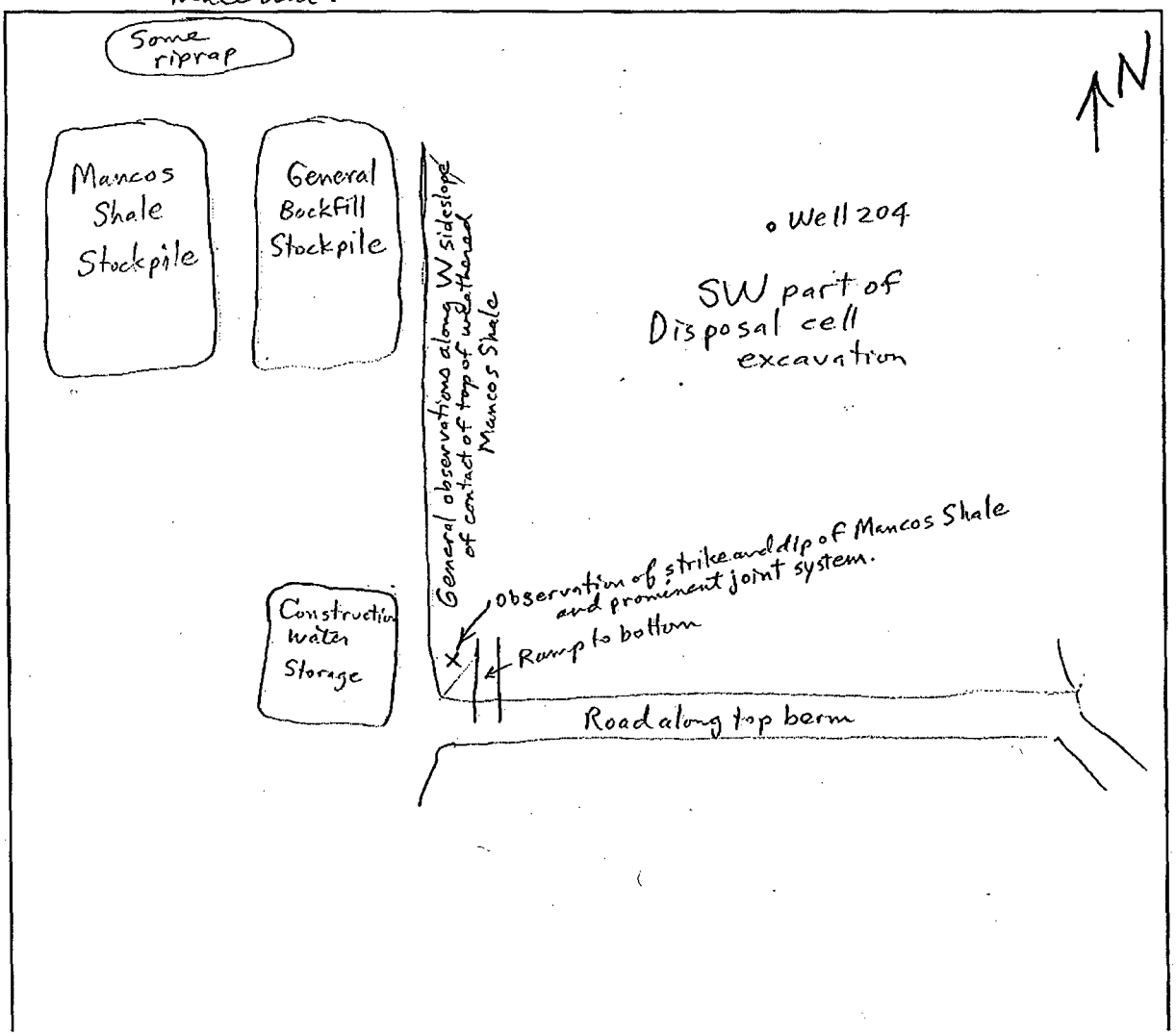
Description of significant geologic features (fractures, joints, weathering characteristics, lithologic variations, strike/dip, depth of overburden, Mancos Shale contract, etc):

In SW corner of bottom of disposal cell excavation in slightly weathered Mancos Shale, a well-exposed bedding surface was measured: Strike N50W and Dip to NE at 5-6°.
A prominent joint trend also was measured at N57W and vertical dip.

Limonitic concretions are visible in several beds of Mancos Shale in bottom of excavation. The concretions are tan to light orange and occur sporadically in several layers in the Mancos.

The contact of the top of weathered Mancos Shale and overlying Quaternary material is moderately well exposed along the West sideslope of the excavation. Reddish eolian material as much as 3 ft thick composes part of the Quaternary material.

Sketch:



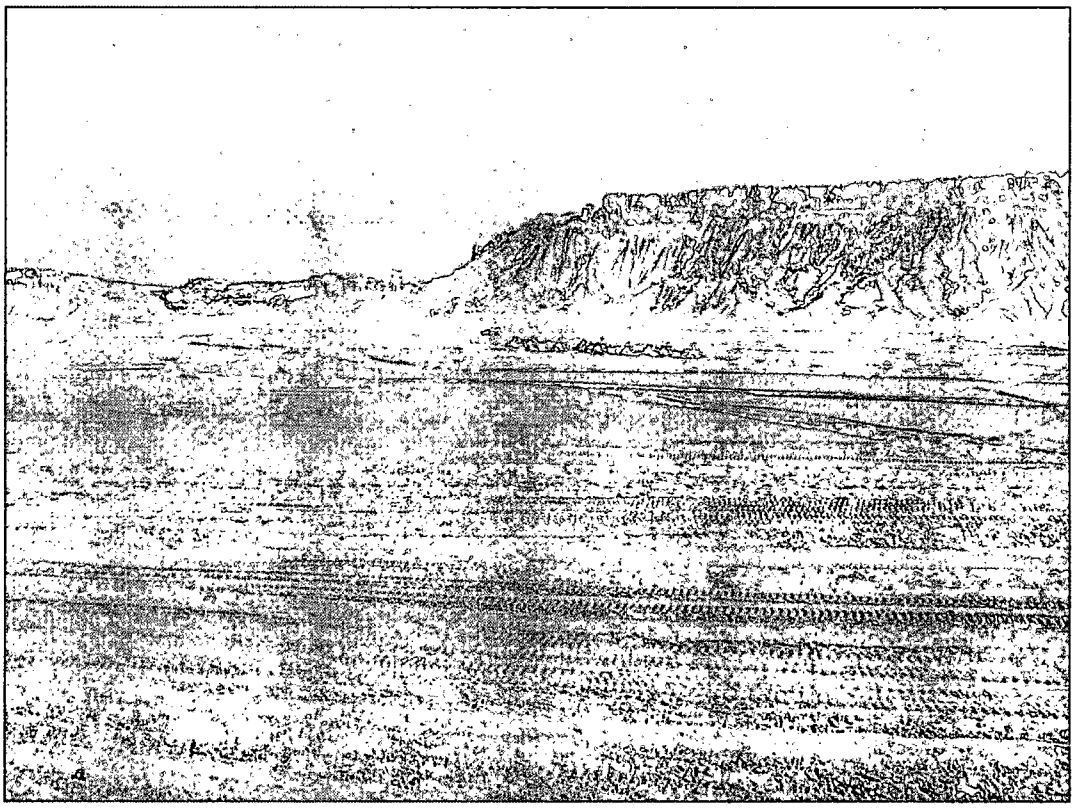


Image 1042

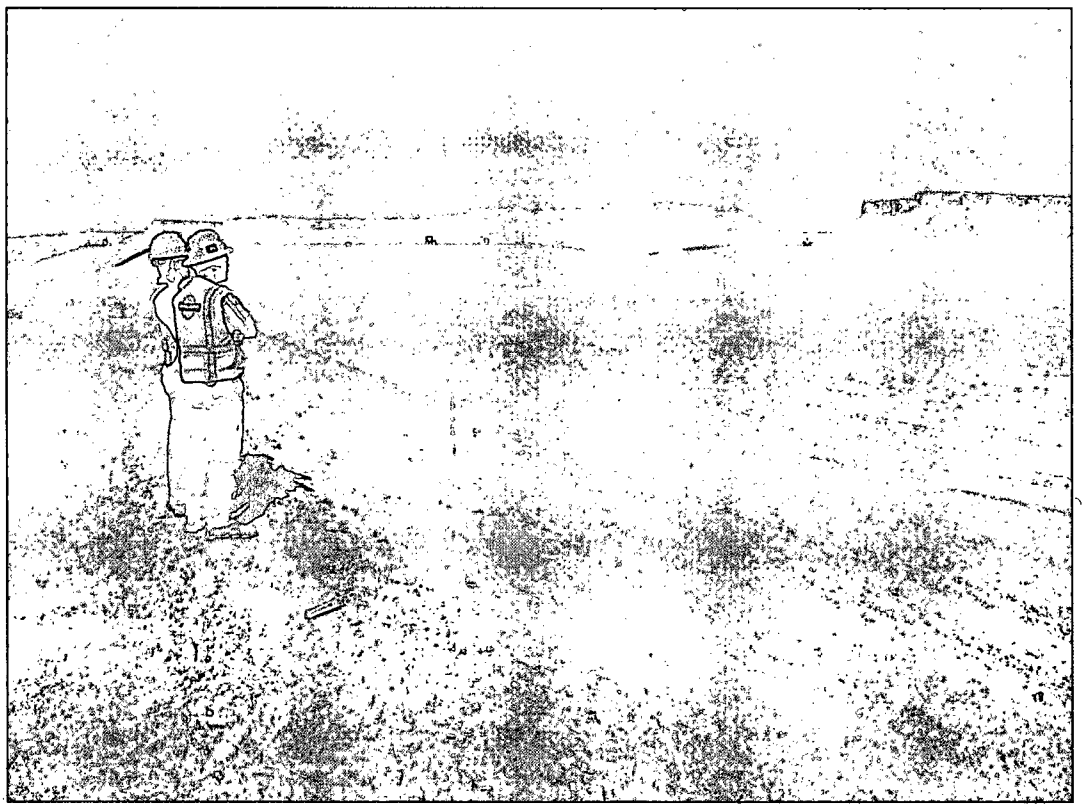


Image 1043

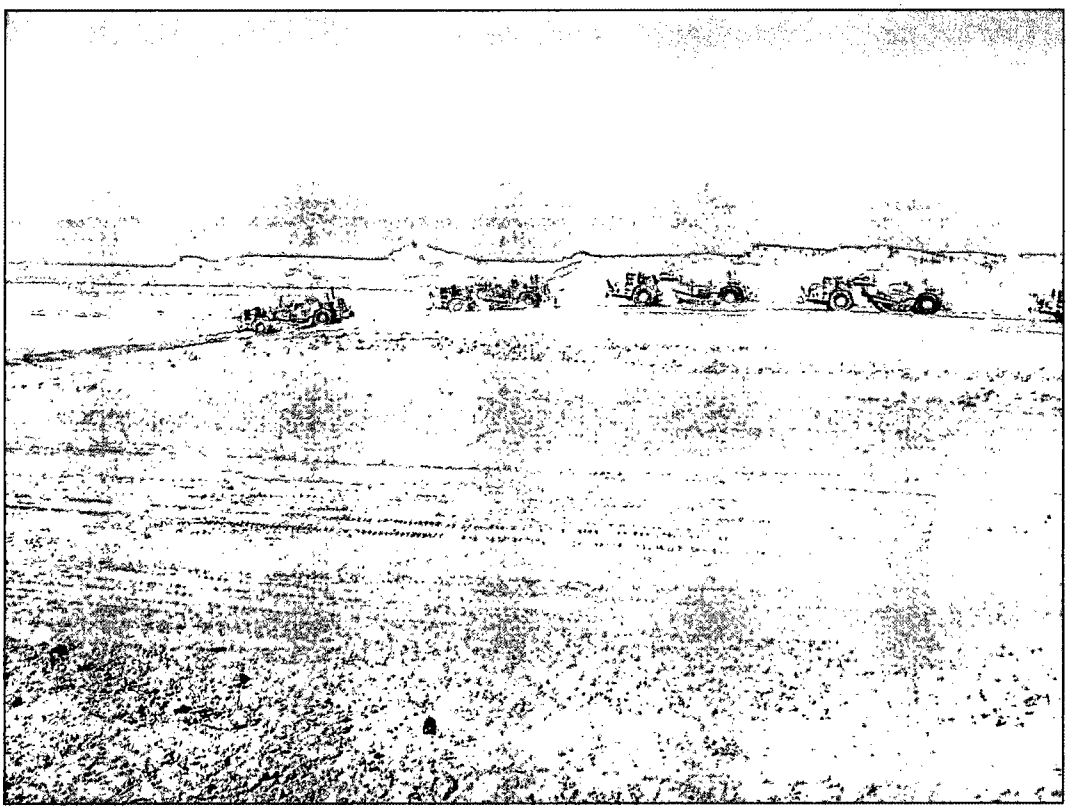


Image 1044

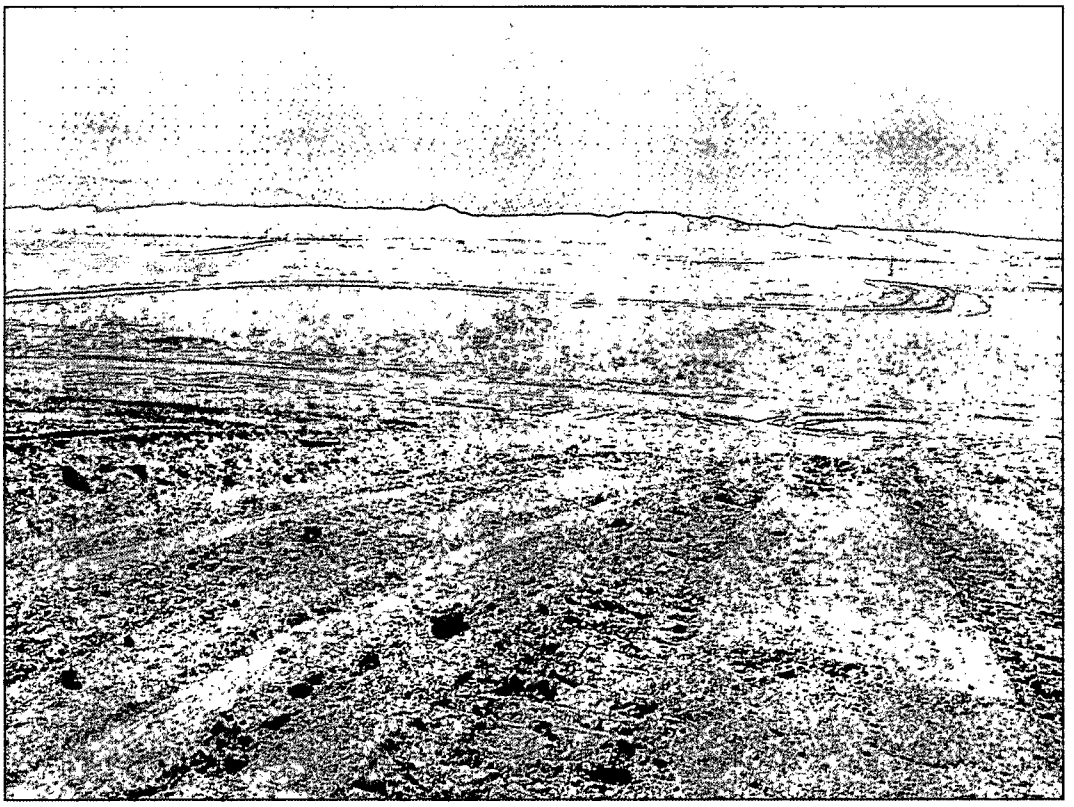


Image 1045

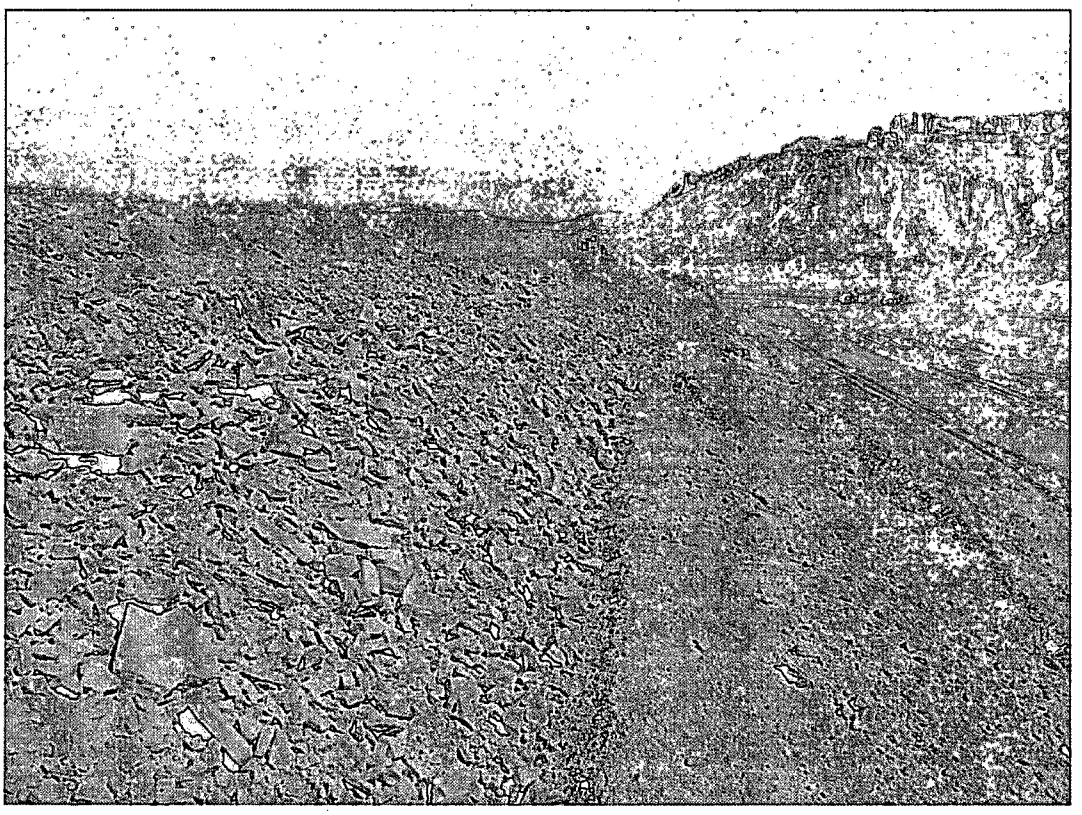


Image 1046

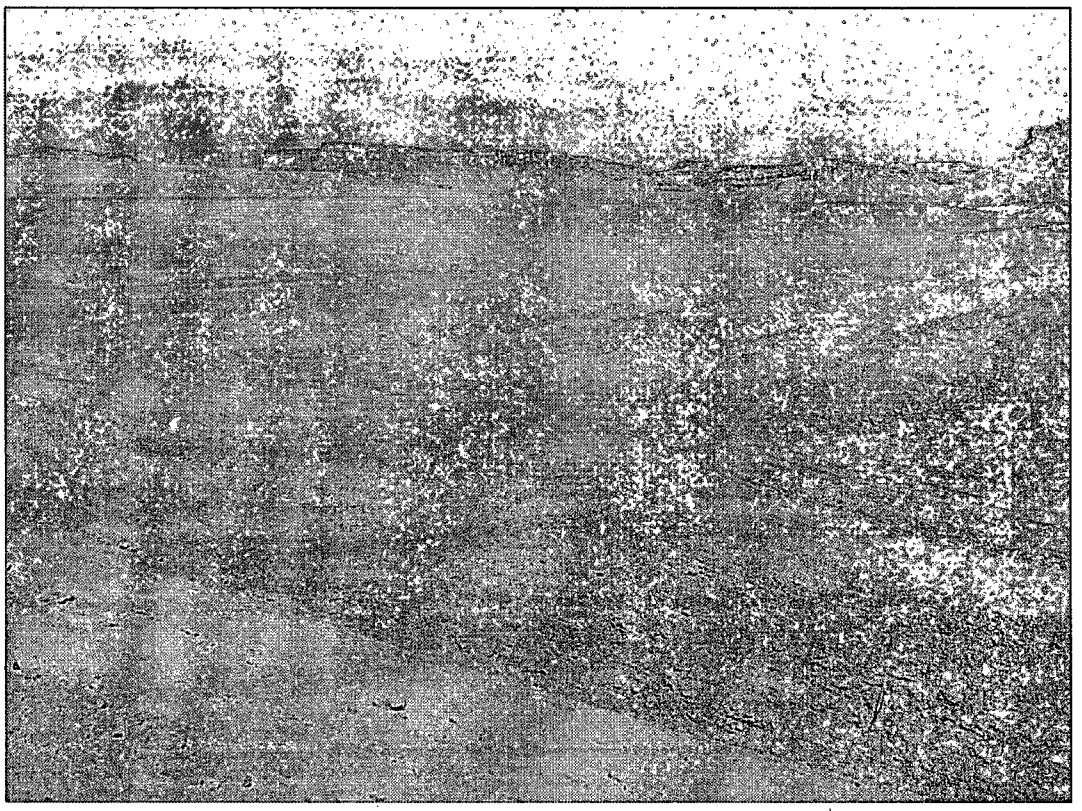


Image 1047

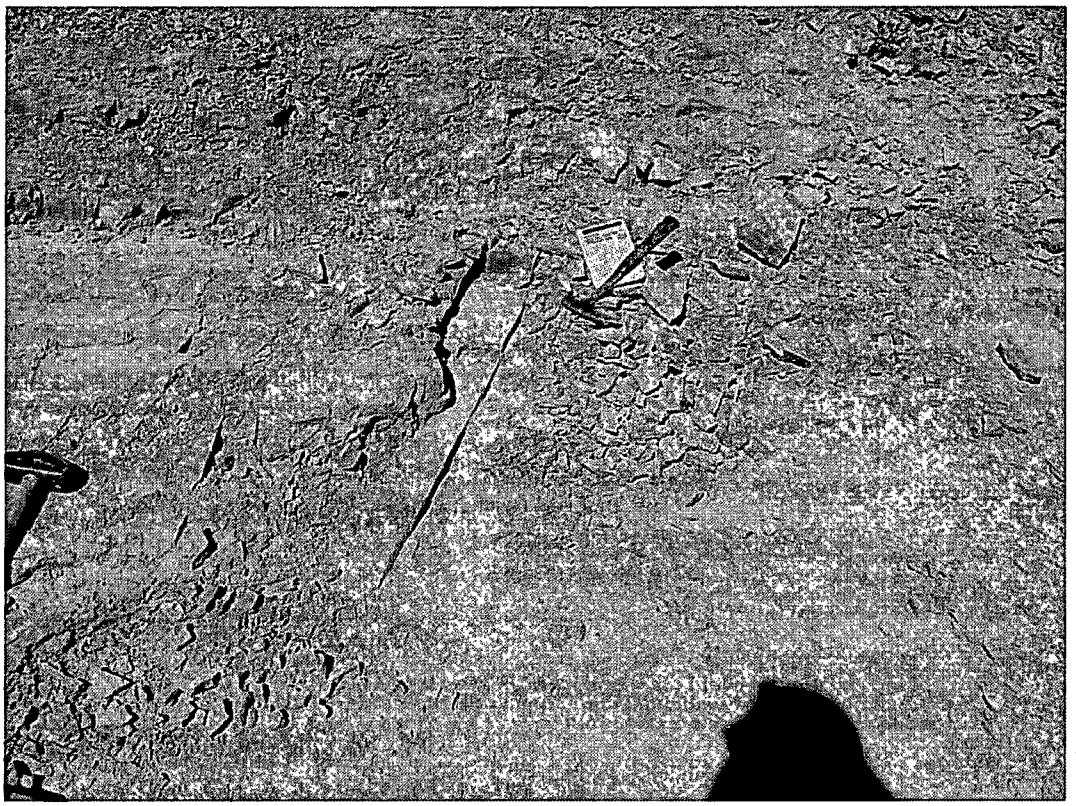


Image 1048

# Geologic Characterization of Crescent Junction Cell Excavation

Date: August 26, 2008 Geologist: Craig Goodknight
Depth of Excavation: est. 15 ft BGS Amount of Material Excavated: 581,083 yd$^3$
Base Map Grid Number(s)

Observations: Survey points were staked on the sideslope along the west side of the excavation. Two of the points were staked at the bottom of the excavation along the base of the west sideslope.

Photographs (ID number and description):

| Image | |
|---|---|
| 1056 | View of Location 1 in SW corner of excavation - Mancos Shale strike of NSOW and dip of 5-6°NE |
| 1057 | View of Location 3 - Contact of top of Mancos Shale and gravelly sand. |
| 1058 | View of Location 4 - Contact of top of Mancos Shale and a 12-15" cobble above in an old channel. |
| 1059 | View of Location 6 - Contact of top of Mancos Shale and eolian material about 2 ft thick above. |
| 1060 | View of Location 7 - Competent Mancos Shale with prominent joint N75W and 90° dip |
| 1061 | View NE of monitor well 204 sticking up ~10 ft to original ground surface |

Survey points (ID number and location):
Eleven survey points were identified and they were surveyed in; these are Locations 1 through 11.

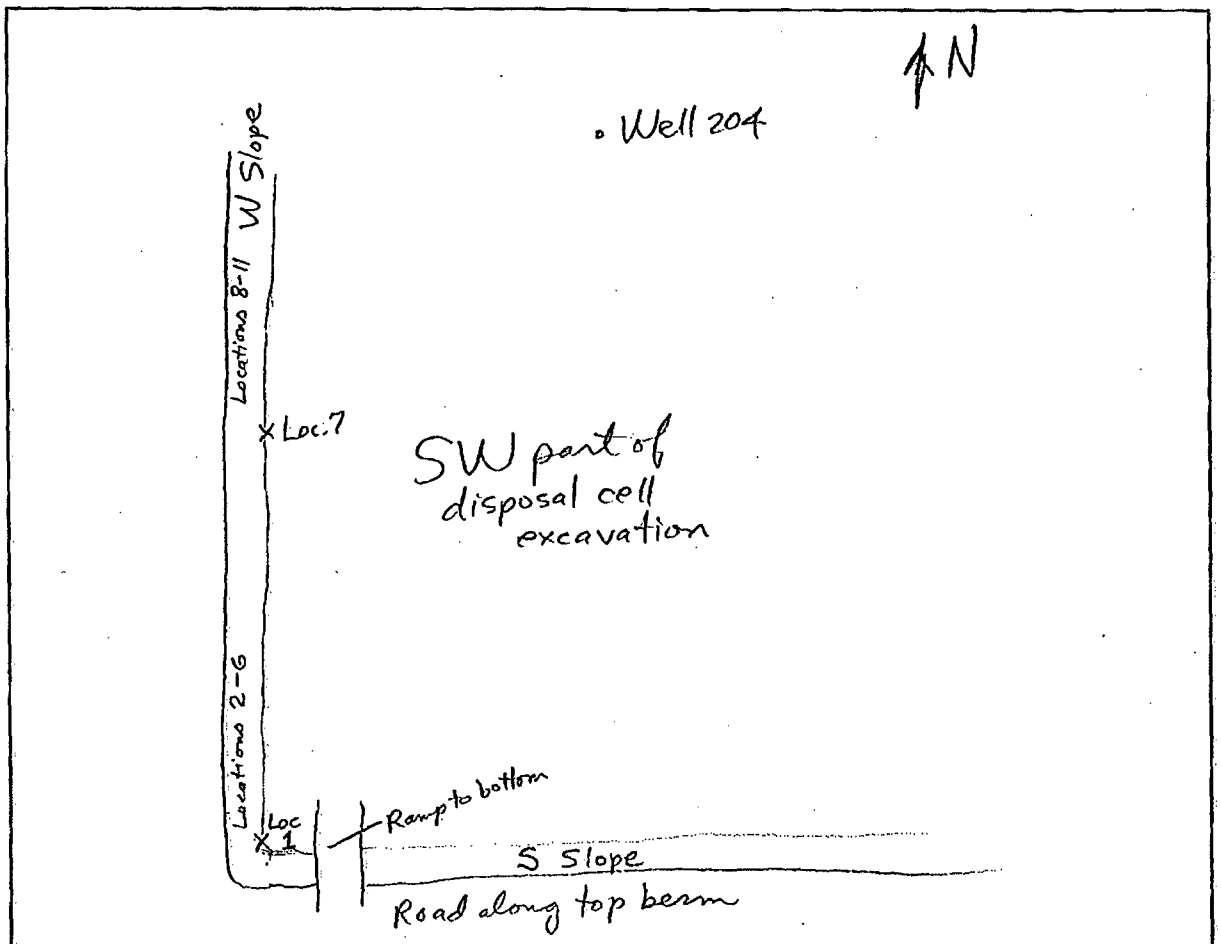
Comments: This was the first weekly visit to the disposal cell excavation to identify (stake) survey points marking geologic contacts and other geologic characteristics. Clear and warm/hot, 85-95°F, dry.

Date (continued): 8/26/08

Description of significant geologic features (fractures, joints, weathering characteristics, lithologic variations, strike/dip, depth of overburden, Mancos Shale contract, etc):

The contact of the top of Mancos Shale and overlying Quaternary material was staked and surveyed along the W side of the excavation. Little undulation of this contact surface was noted along this side of the excavation, probably because this slope is nearly parallel to the surface slope drainage direction. Weathered Mancos Shale is overlain by either alluvial material (mostly fine grained, but as large as 12-15" dia cobbles were noted) or eolian material (which was as much as 2ft thick).

Sketch:



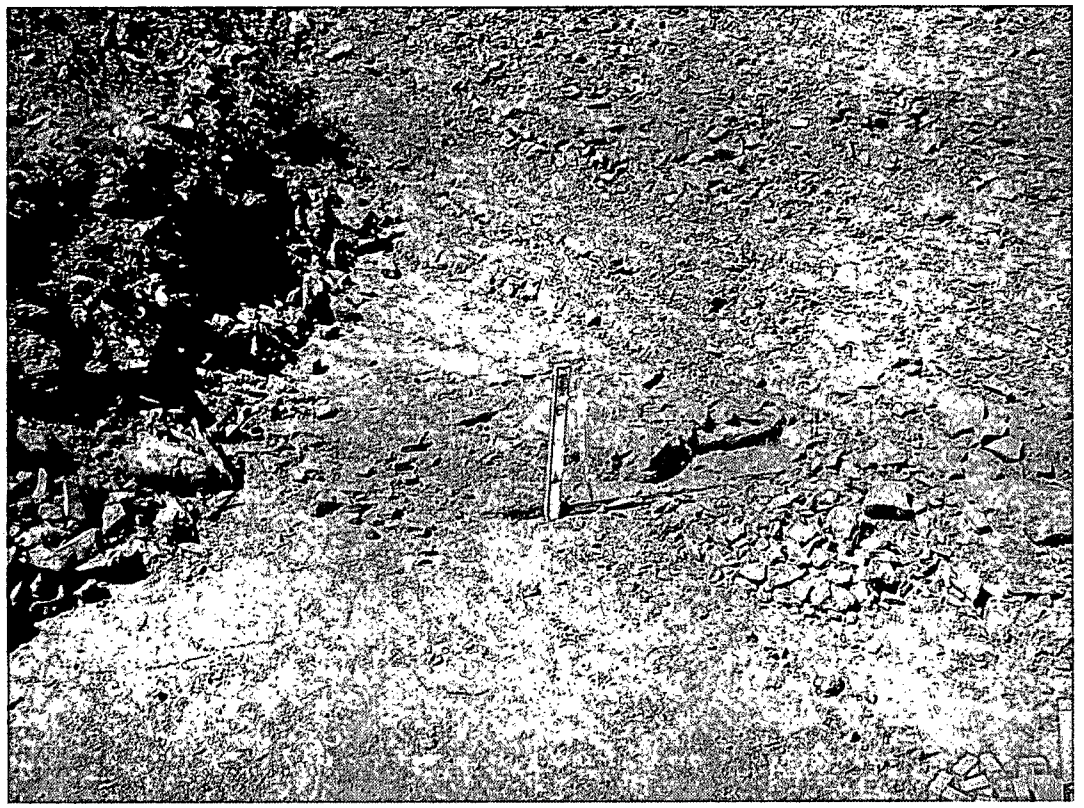


Image 1056

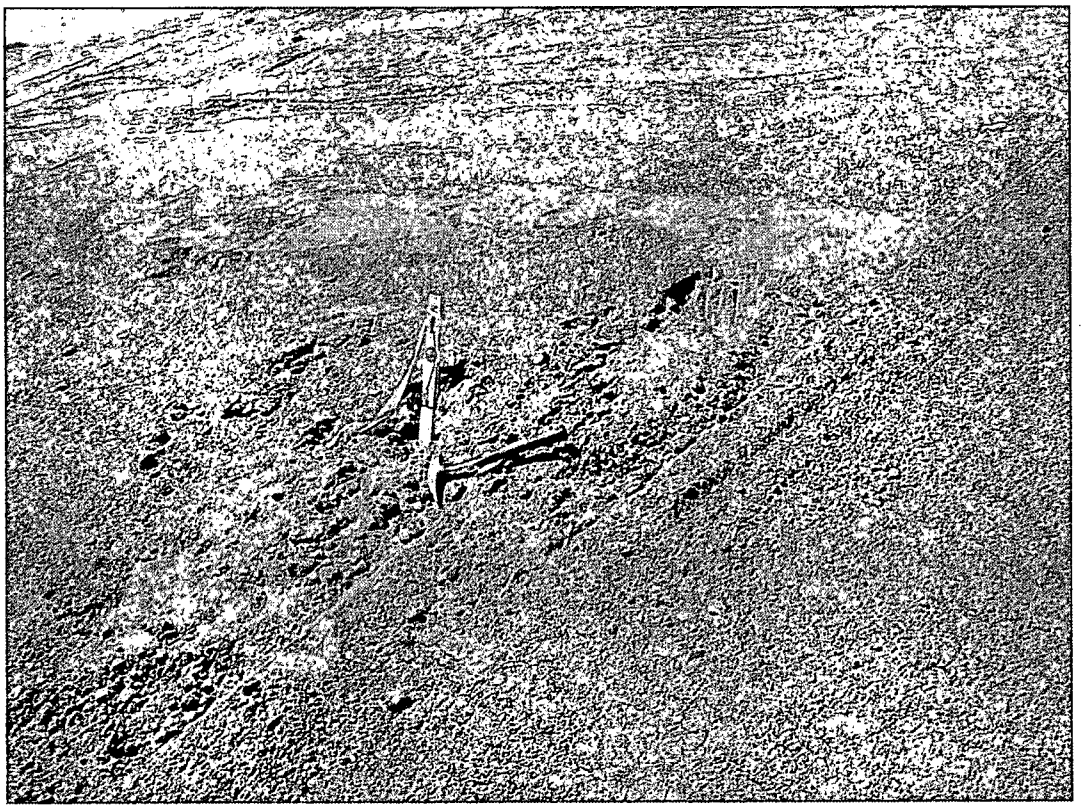


Image 1057

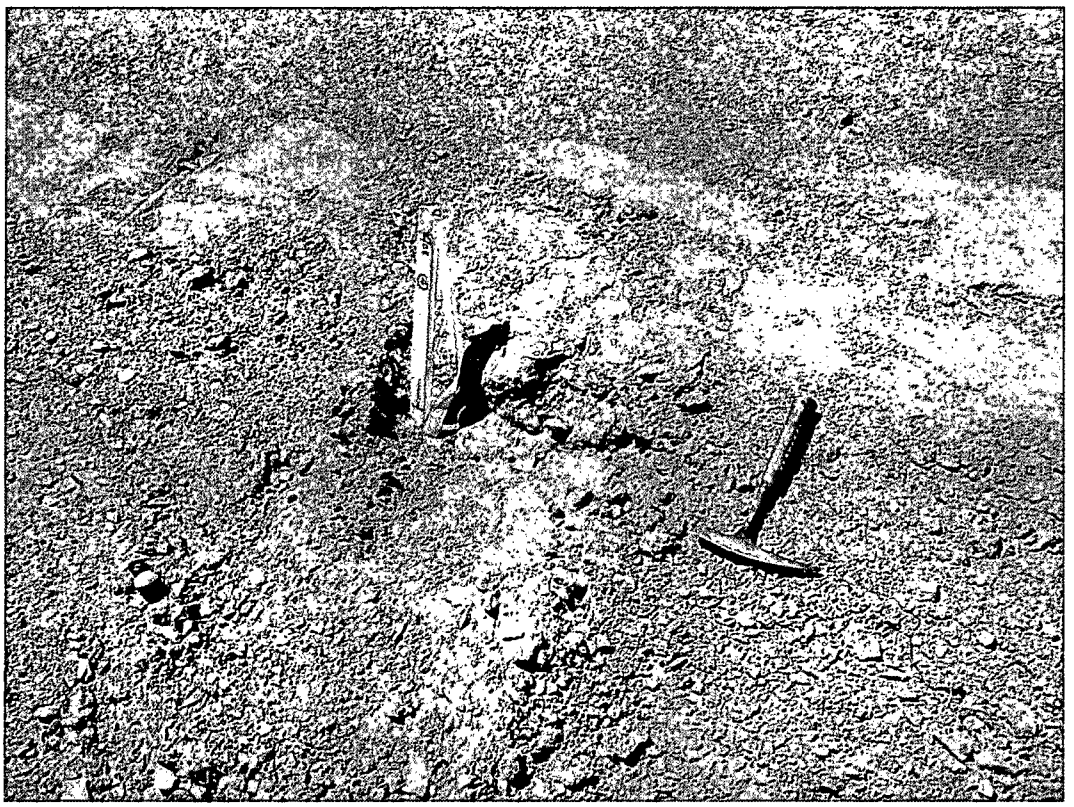


Image 1058

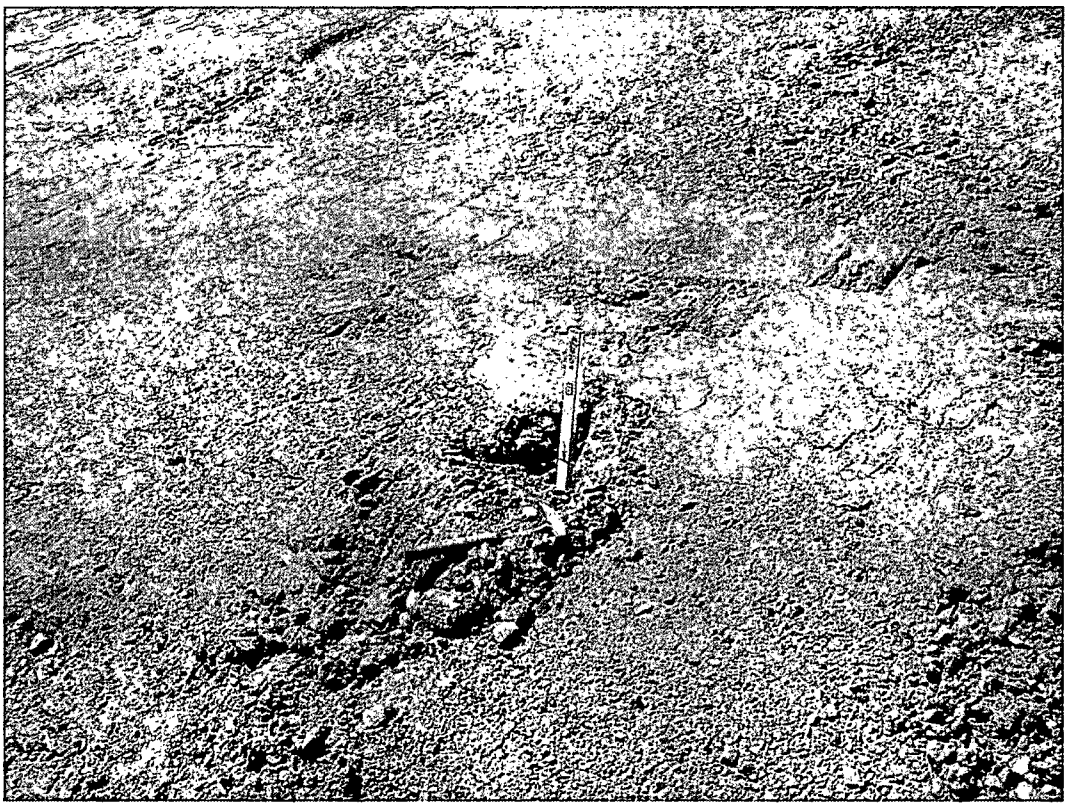


Image 1059

Image 1060

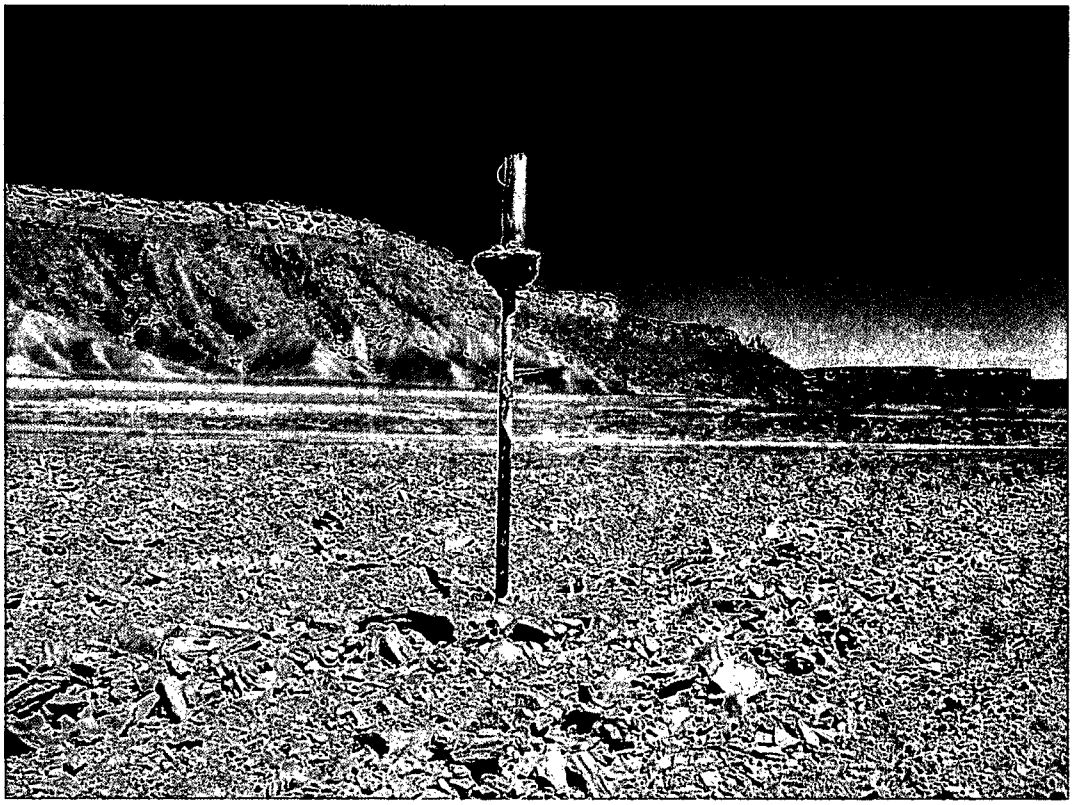


Image 1061

# Geologic Characterization of Crescent Junction Cell Excavation

Date: September 3, 2008 Geologist: Craig Goodknight
Depth of Excavation: est. 15 ft BGS Amount of Material Excavated: 671,488 yd$^3$
Base Map Grid Number(s)

Observations: Survey points were staked on the sideslope along the south side of the excavation.

Photographs (ID number and description):

Image
1071 View of Location 3 - Contact of weathered Mancos Shale overlain by alluvial mud w/some pebbles in area of small channel.
1072 View of Location 6 - Contact of top of Mancos Shale and overlying reddish eolian material about 1.5 ft thick.
1073 View E of S sideslope of excavation

Survey points (ID number and location):
Eleven survey points were identified and they were surveyed in; these are locations 1 through 11.

Comments: This was the second weekly visit to the disposal cell excavation to identify (stake) survey points marking geologic contacts. Clear and warm, 80-85°F; some rain had occurred on August 31, but site appeared mostly dried out.

Date (continued): September 3, 2008

Description of significant geologic features (fractures, joints, weathering characteristics, lithologic variations, strike/dip, depth of overburden, Mancos Shale contract, etc):

The contact of the top of Mancos Shale and overlying Quaternary material was staked and surveyed along the S side of the excavation. Moderate (5 to 6 ft) undulation of this contact surface was noted along this side of the excavation because this slope is nearly perpendicular to the surface slope drainage direction. Several channels in the basal alluvial material with clasts as large as 12 inches in diameter were seen. In a few locations, reddish eolian material 1-3 ft thick lied directly over the top of Mancos Shale. A condition of slightly moist (dark appearing soil) was noticed for about 10-15 ft both E and W of location 8. This narrow dark band was on or very near the bedrock contact; this area should be revisited from time to time in future visits to evaluate the persistence of this dark area and if it indicates recurring moisture.

Sketch:

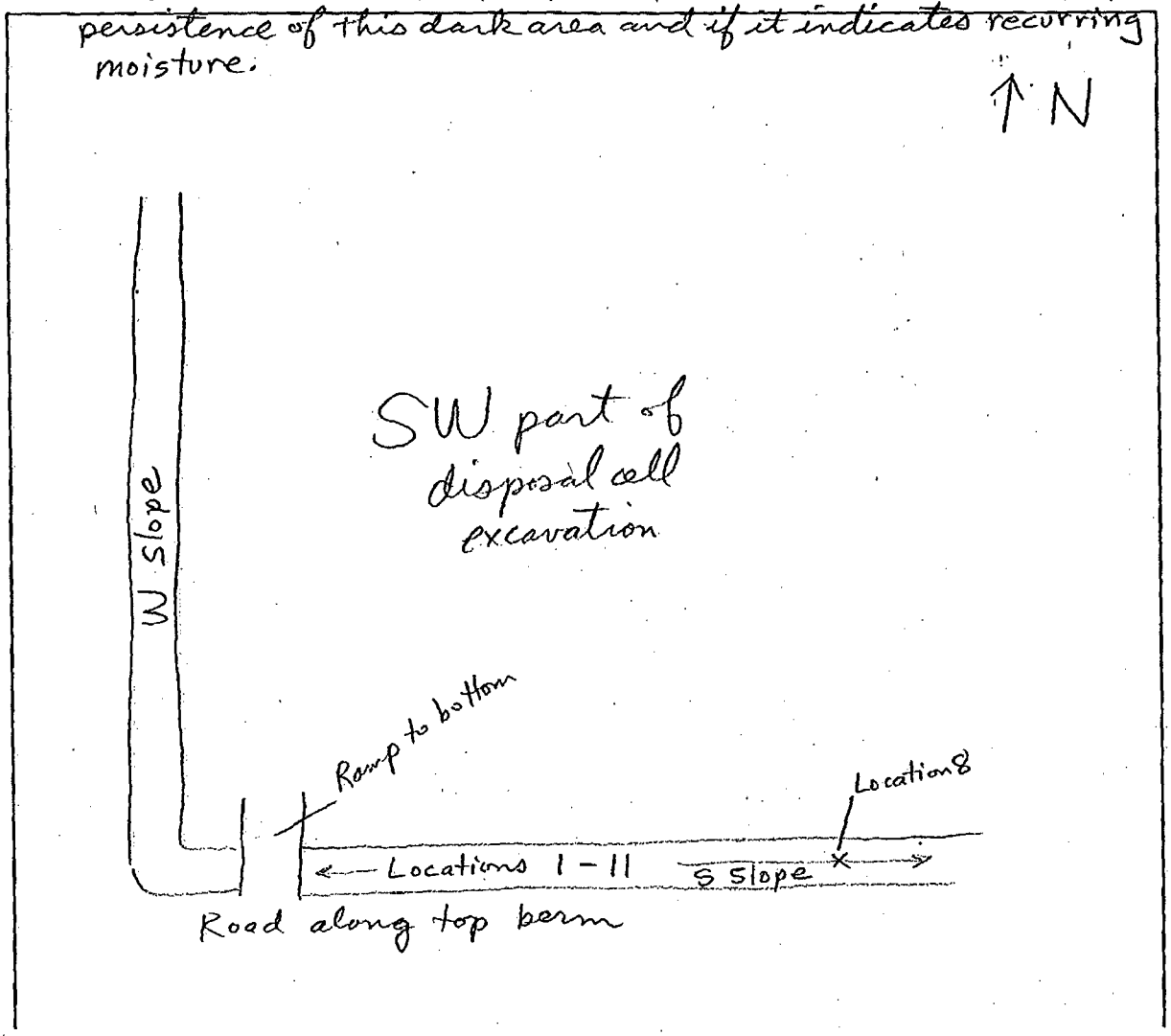


Image 1071

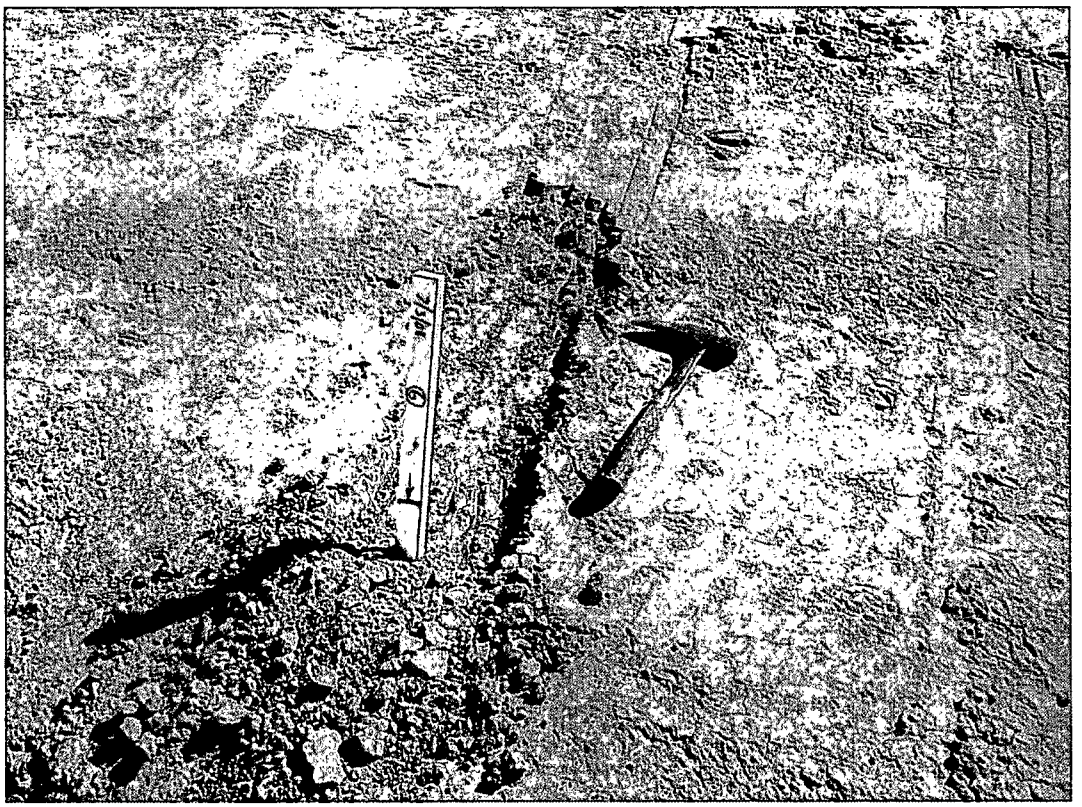


Image 1072

Image 1073

# Geologic Characterization of Crescent Junction Cell Excavation

Date: September 23, 2008 Geologist: Craig Goodknight
Depth of Excavation: est. 15 ft BGS Amount of Material Excavated: NA, as per Brent Anderson
Base Map Grid Number(s)

Observations: Survey points were staked on the side slope along the north side of the excavation.

Photographs (ID number and description):

| Image | |
|---|---|
| 1125 | View of Location 1 - Hard, resistant dolomitic limestone bed 1ft+ thick along base of north side of excavation. |
| 1126 | View of Location 2 - Bed of tan very fine grained sandstone with Fe and Mn staining on fractures. Strike and dip of bed is N55W and 12°NE. Bed is 2-3 ft above the dolomitic limestone. |

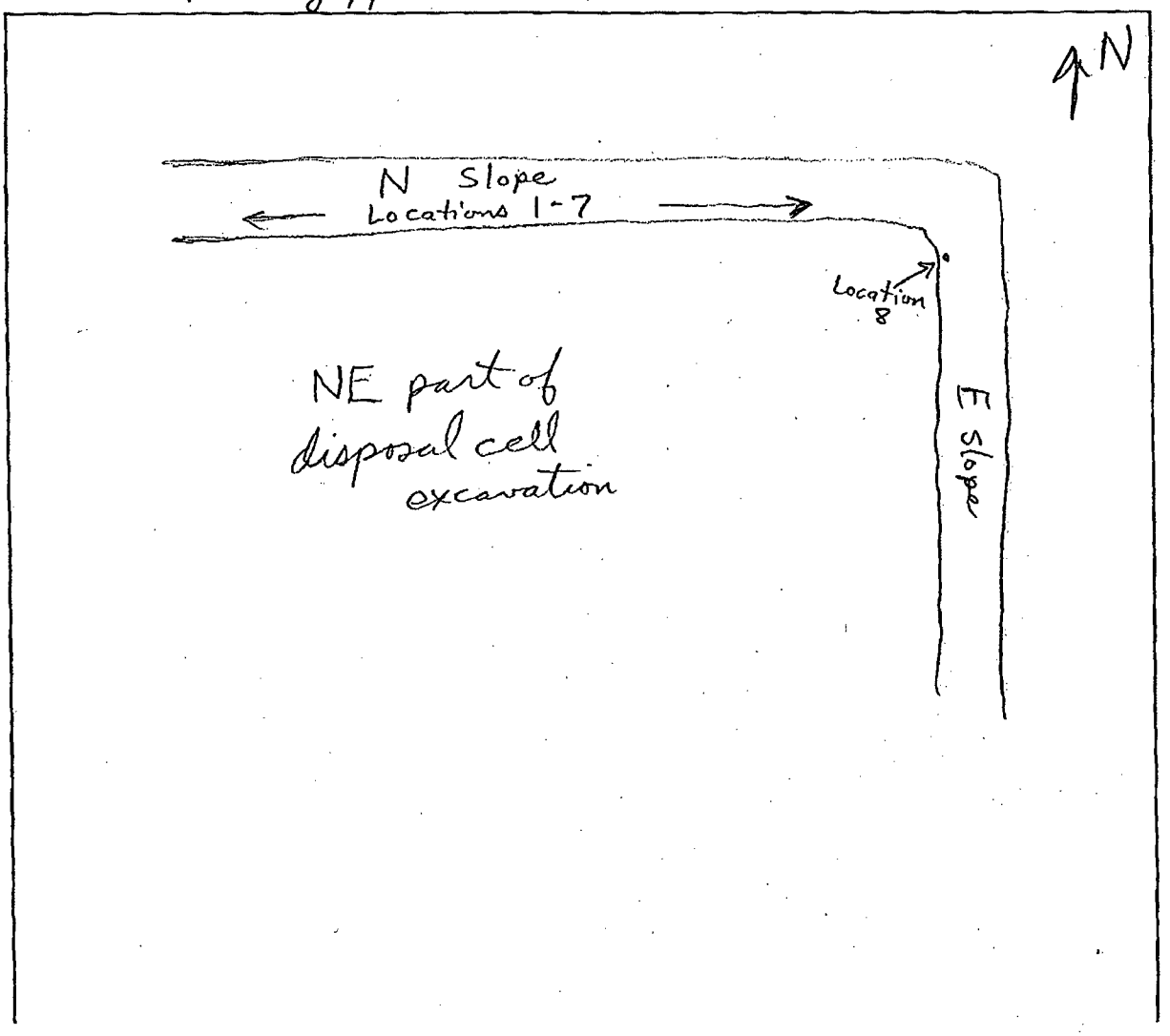
Survey points (ID number and location):
Eight survey points were identified. They will be surveyed in during the next several days. They are Locations 1 through 8.

Comments: This was the third weekly visit to the disposal cell excavation to identify (stake) survey points marking geologic contacts and other geologic characteristics.
Partly cloudy, warm (70s), dry, light winds.

Date (continued): September 23, 2008

Description of significant geologic features (fractures, joints, weathering characteristics, lithologic variations, strike/dip, depth of overburden, Mancos Shale contract, etc):
The contact of the top of Mancos Shale and overlying Quaternary material was staked (to be surveyed in the next few days) along the N side of the excavation. Moderate undulation of this contact was noted along this side of the excavation because this slope is nearly perpendicular to the surface slope drainage direction. One channel in the basal alluvial material with clasts 2 inches in diameter and larger was noted at Location 7. A hard dolomitic limestone bed 1+ ft thick is near the base of the N side slope at Location 1. About 2-3 ft above this bed is a tan very fine grained sandstone bed about 6 in thick; strike and dip on this sandstone at Location 2 was N55W and 12° NE. A slight flexure of bedding was noted around Location 2 and just to the west where bedding appeared to dip about 20°.

Sketch:



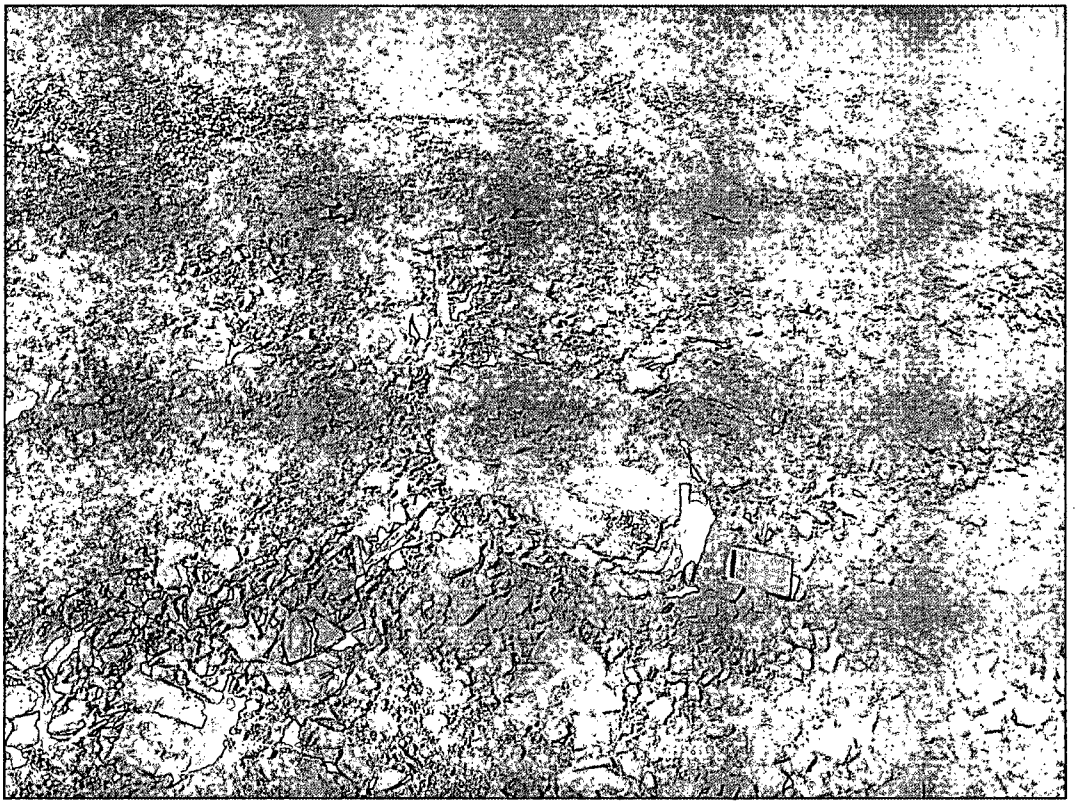


Image 1125

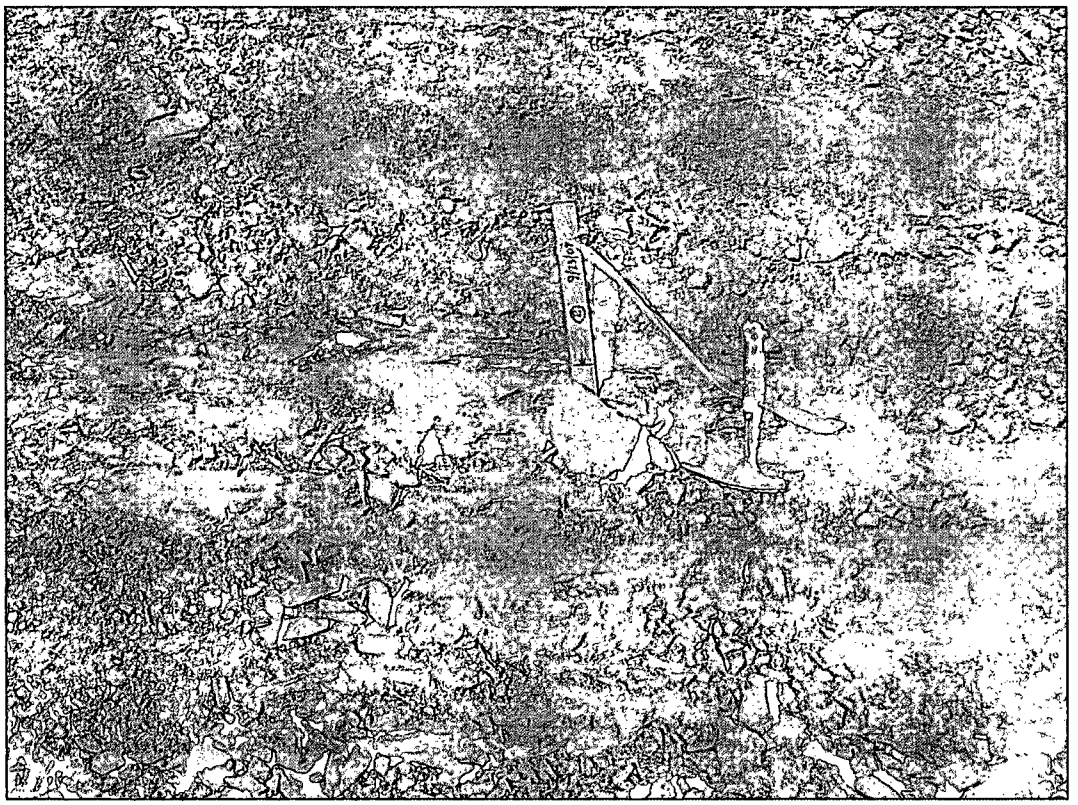


Image 1126

# Geologic Characterization of Crescent Junction Cell Excavation

Date: October 9, 2008 Geologist: Craig Goodknight
Depth of Excavation: est. 15 ft bgs Amount of Material Excavated: NA, as per Brent Anderson
Base Map Grid Number(s)

Observations: Moist condition persists at Location 8 (from 9/3/08) along S Slope of excavation. Stockpile of gray, resistant dolomitic siltstone and stockpile of hard, unweathered gray shale are at base of N Slope of excavation. Joints were noted in bottom of excavation. Survey points were staked on the side slope along the east side of the excavation.

Photographs (ID number and description):

| Image | |
|---|---|
| 1138 | View of moist area along S Slope at Location 8 from 9/3/08. |
| 1139 | View N of stockpile of thick dolomitic siltstone at base of N Slope. |
| 1140 | View NNE of orthogonal joints in dolomitic siltstone about 20 ft S of Locations 1 and 2 from 9/22/08. Strikes of joints are N55W and N35E. |
| 1141 | Abundant gypsum along fracture in bottom of excavation |
| 1142 | View NNW from NE corner of bottom of excavation. |
| 1143 | View of Location 1 - Sandstone clast ~2 ft diameter in Quaternary paleochannel fill. |

Survey points (ID number and location):

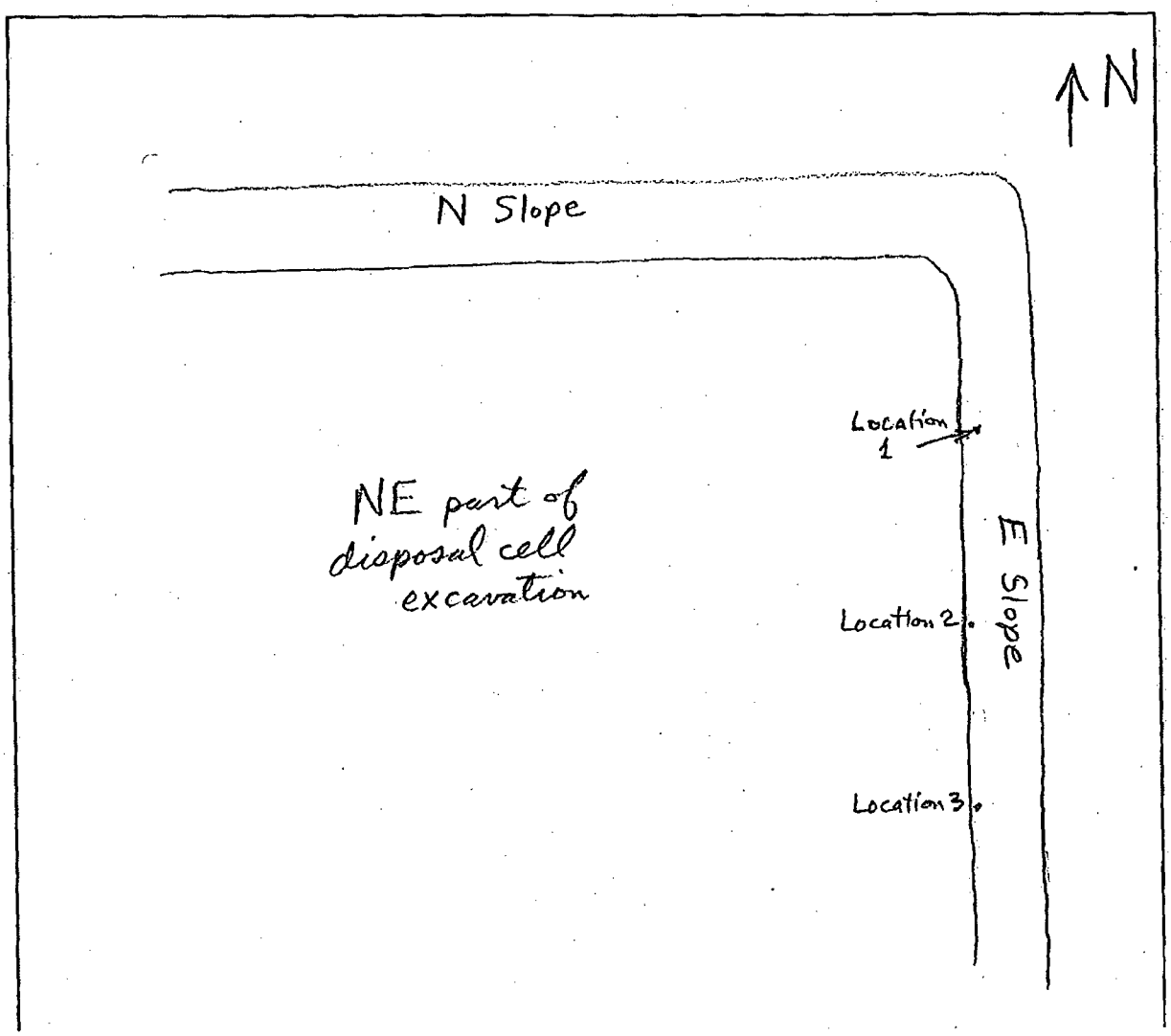
Three survey points were identified. They will be surveyed in during the next several days. They are Locations 1 through 3.
Location 1 - Paleochannel with large sandstone clasts in alluvial fill material.
Location 2 - Contact of weathered Mancos Shale bedrock and Quaternary alluvial material
Location 3 - " " " "

Comments: This was the fourth weekly visit to the disposal cell excavation to identify (stake) survey points marking geological contacts and other geologic characteristics.
Weather was warm (70s), clear, dry, w/ light S breeze. Some rain last weekend (4 days ago).

Date (continued): October 9, 2008

Description of significant geologic features (fractures, joints, weathering characteristics, lithologic variations, strike/dip, depth of overburden, Mancos Shale contract, etc):
Moist area on S Slope of excavation persists at Location 8 (from 9/8/08). About 100 yds W of Location 1 (from 9/23/08) is stockpile of gray resistant dolomitic siltstone (blocks from bed as thick as 3 ft). Stockpile of unweathered gray shale is just E of the dolomitic siltstone stockpile. Orthogonal joints striking N55W and N35E are in dolomitic siltstone 20 ft S of Locations 1 and 2 (from 9/23/08). Carbonized wood fragments in very fine grained sandstone was seen 20 ft S of Location 2 (from 9/23/08) as evidence of brief shoaling of the Mancos Sea. Prominent joint in bottom of excavation was N65W and an open fracture oriented N80W was noticed.
Location 1 was staked at large sandstone clasts (as large as 2 ft diameter) in paleochannel in Quaternary fill on the E Slope.
Locations 2 and 3 were the contact of the top of upper weathered Mancos Shale along the base of the E Slope.

Sketch:



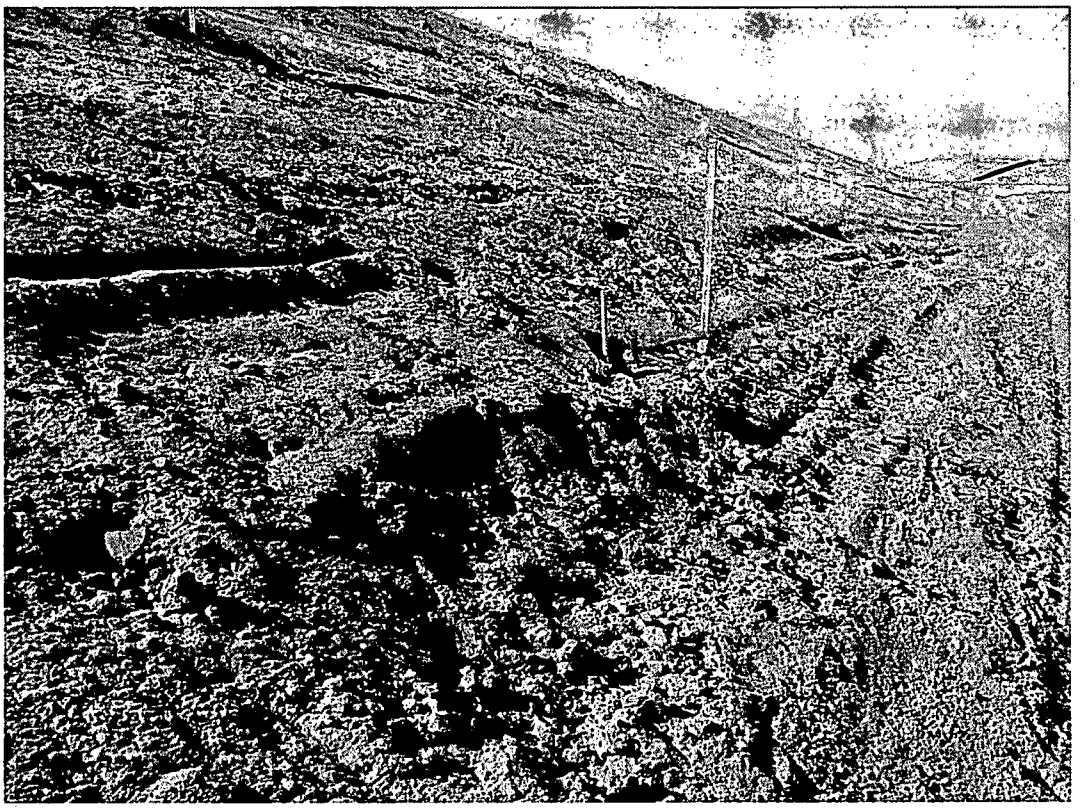


Image 1138

Image 1139

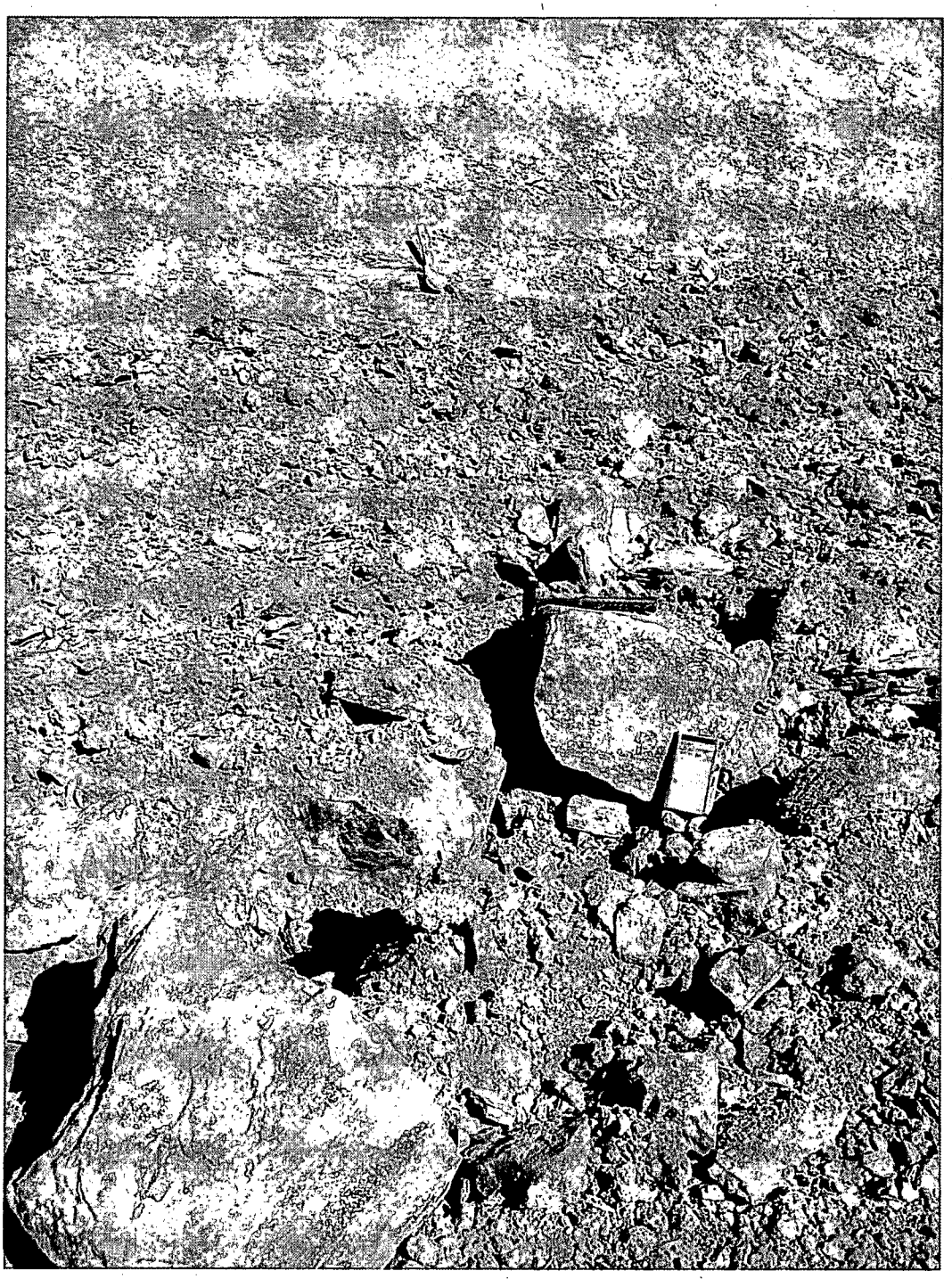


Image 1140

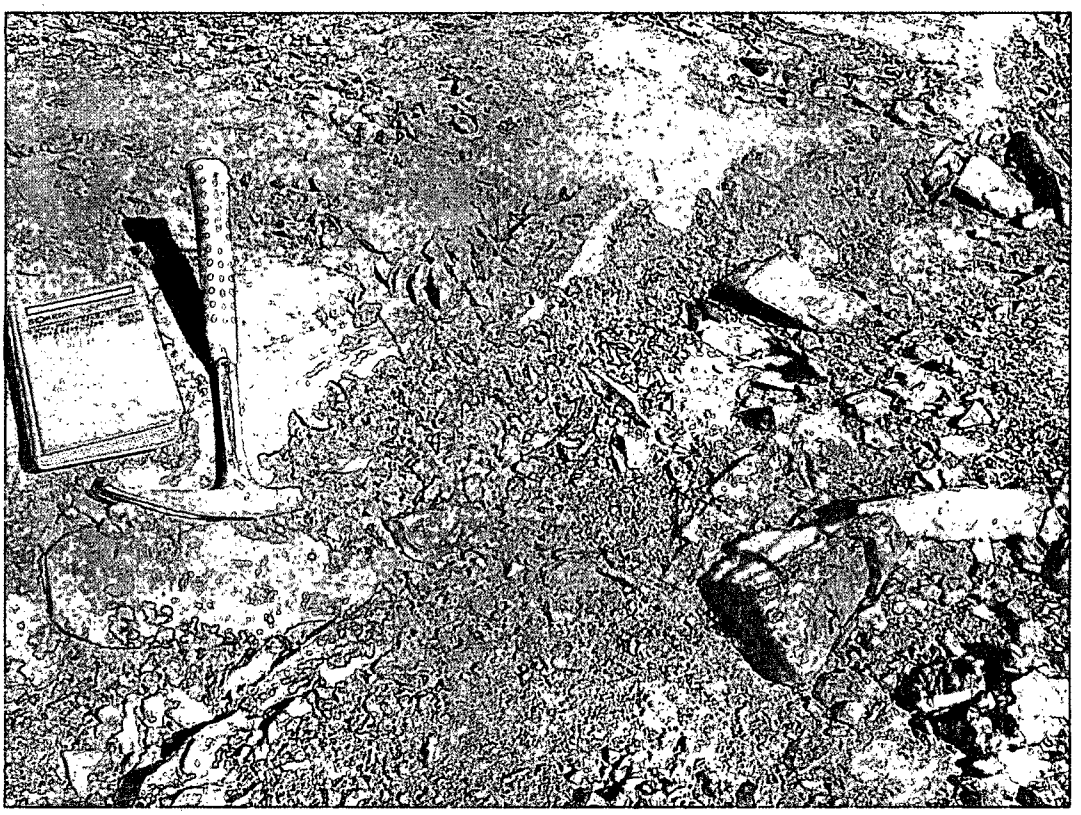


Image 1141

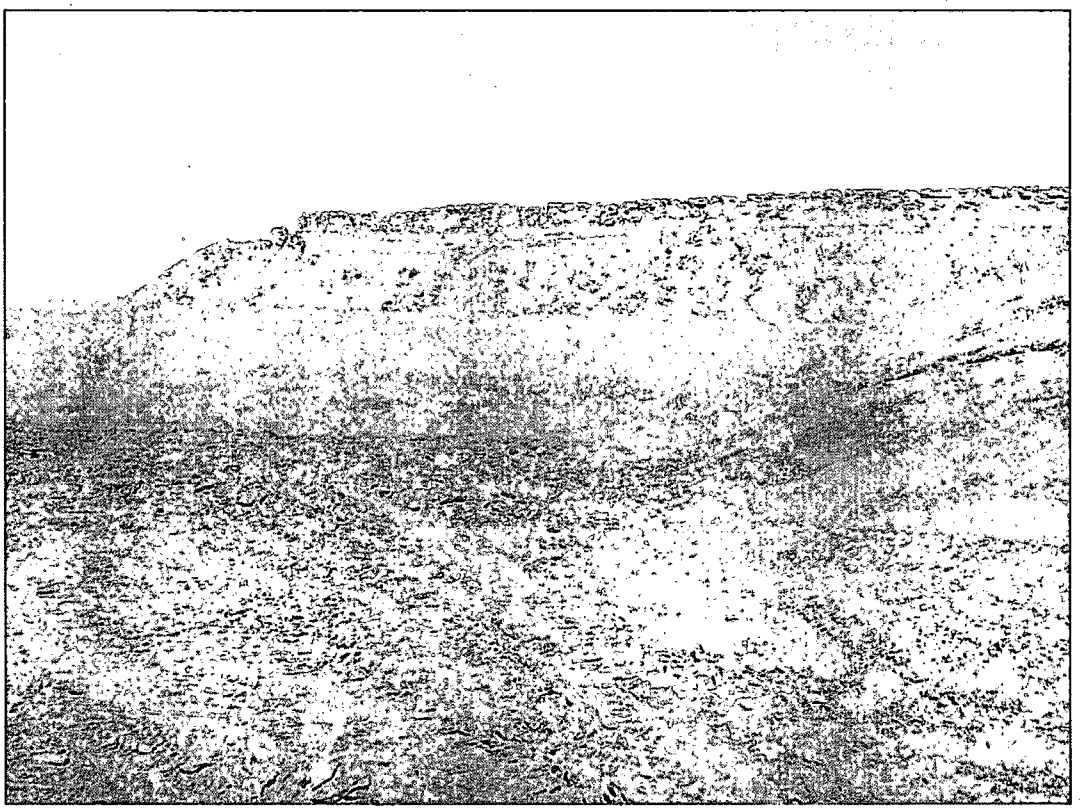


Image 1142

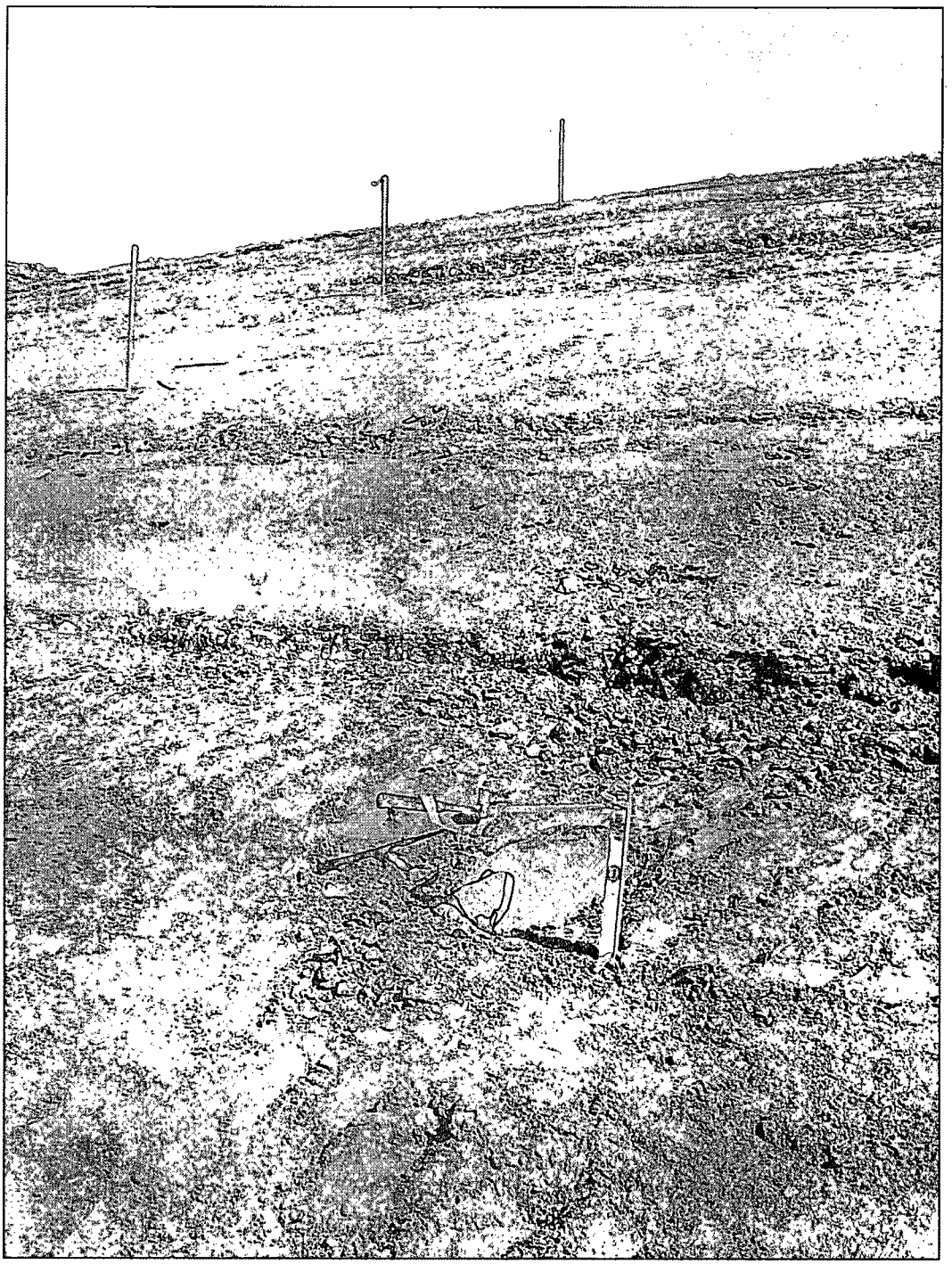


Image 1143

# Geologic Characterization of Crescent Junction Cell Excavation

Date: October 28, 2008 Geologist: Craig Goodknight
Depth of Excavation: 15-20 ft BGS Amount of Material Excavated: NA, as per Brent Anderson
Base Map Grid Number(s)

Objectives/Activities: Check moist condition along S sideslope of excavation.
Check newly exposed areas on bottom of excavation, where possible in avoidance of earthmoving equipment.
Check exposed contact of Mancos Shale bedrock and overlying alluvial material along the east and north sideslopes of excavation.
Check for outcrop of dense dolomitic limestone encountered during excavation of N part of disposal cell.

Photographs (ID number and description):

Image
1000010 View NW of bedrock exposed by ripping in SW part of excavation
1000013 Contact at Location 3 of weathered Mancos Shale overlain by coarse alluvial material with clasts as large as 2 ft diameter.
1000014 View NW of graders removing weathered Mancos Shale in central part of excavation.
1000015 Prominent vertical joint striking N60W along N side slope of excavation about 30 ft SE of Location 4 of 9/23/08.
1000016 View SE across excavation
1000017 View SE across excavation
1000018 Stockpile of dense dolomitic limestone that was moved from where it was encountered in the N part of the excavation.

Survey points (ID number and location): Ten survey points were identified. They will be surveyed during the next few days. They are locations 1 through 10.
Locations 1 through 8 and Location 10 - Contact of weathered Mancos Shale and Quaternary alluvial fill material.
Location 9 Very fine grained sandstone, yellowish gray to grayish brown, about 1 ft thick along N side slope

Comments: This was the fifth weekly visit to the disposal cell excavation to identify (stake) survey points marking geological contacts and other geologic characteristics. Weather was clear, warm (60s and 70s), and dry (a very dry month so far). At the excavation rate of about 20,000 $yd^3$/day, the excavation should be down to final grade in about 3 weeks.

Date (continued): October 28, 2008

Observations/Descriptions of significant geologic features (fractures, joints, weathering characteristics, lithologic variations, strike/dip, depth of overburden, Mancos Shale contact, etc):

Much weathered Mancos Shale bedrock has been removed from the SW part of the excavation. Color of the bedrock varies from the dark yellowish orange (10YR 6/6) of the limonitic concretionary beds to the typical shale that is yellowish gray (5Y 7/2).

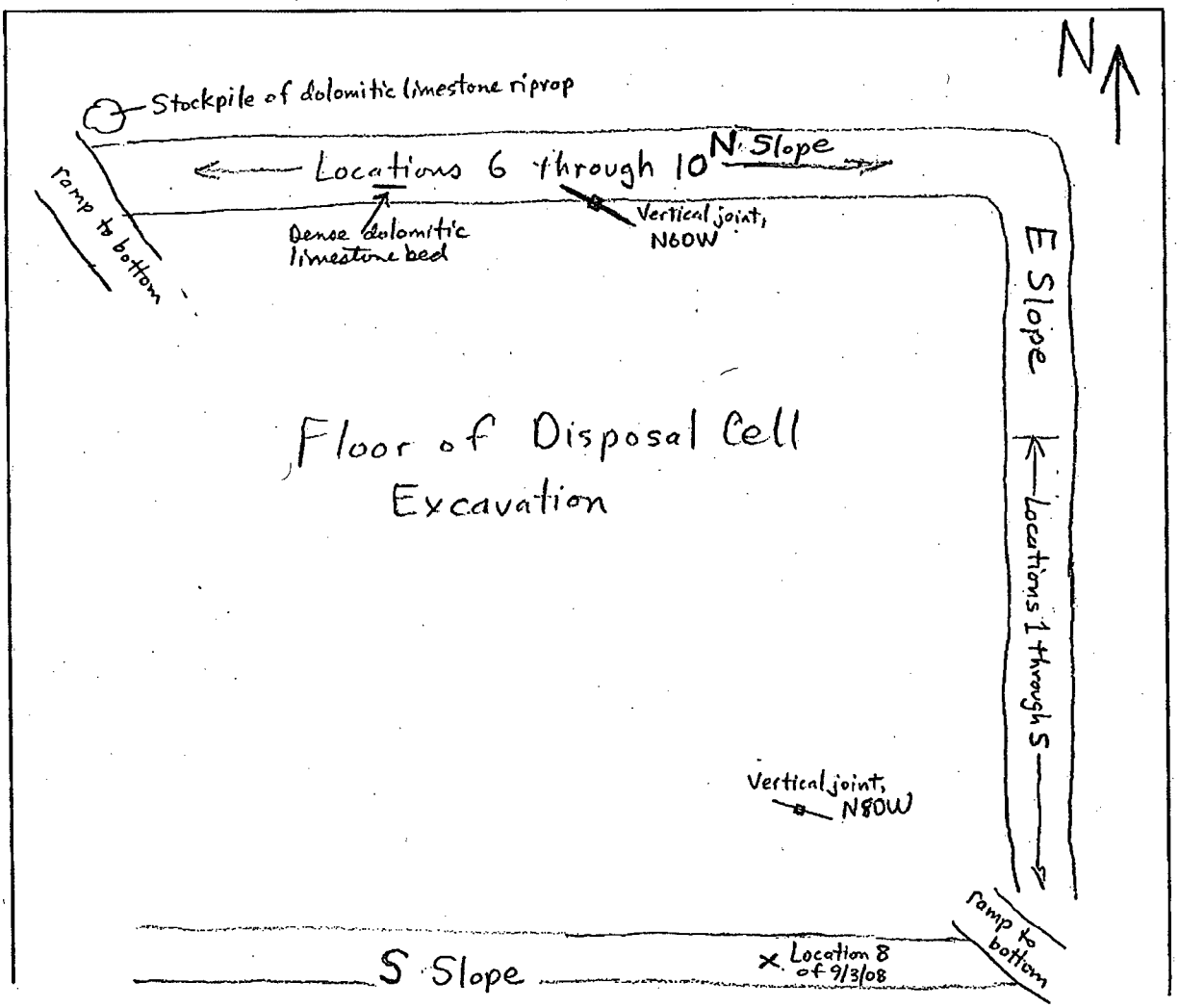
The area of moisture in the vicinity of Location 8 of 9/3/08 on the S slope was checked and no obvious moisture was seen. This may have been along a paleovalley on the Mancos contact that has dried out over the past 2 months.

Prominent vertical joints were seen in the SE part of the excavation that strike N80W and in the N edge of the excavation that strike N60W.

The contact of top of weathered Mancos Shale and overlying alluvial material was noted in 5 locations along the E slope of the excavation. Clasts of sandstone as large as 2 ft diameter were seen in the basal alluvium; most clasts were 1-2 inches or smaller.

The contact of top of weathered Mancos Shale and overlying alluvial material was noted in 4 locations along the N slope of the excavation. One location (9) on the N slope was for a yellowish gray to grayish brown, very fine grained sandstone bed about 1 ft thick. A dense dolomitic limestone bed about 1 ft thick is on the N slope about 30 ft SW of

Sketch: Location 3 of 9/23/08. Material removed during excavation of a thicker part of this same bed is stockpiled at the NW end of the disposal cell excavation, just above the N slope.



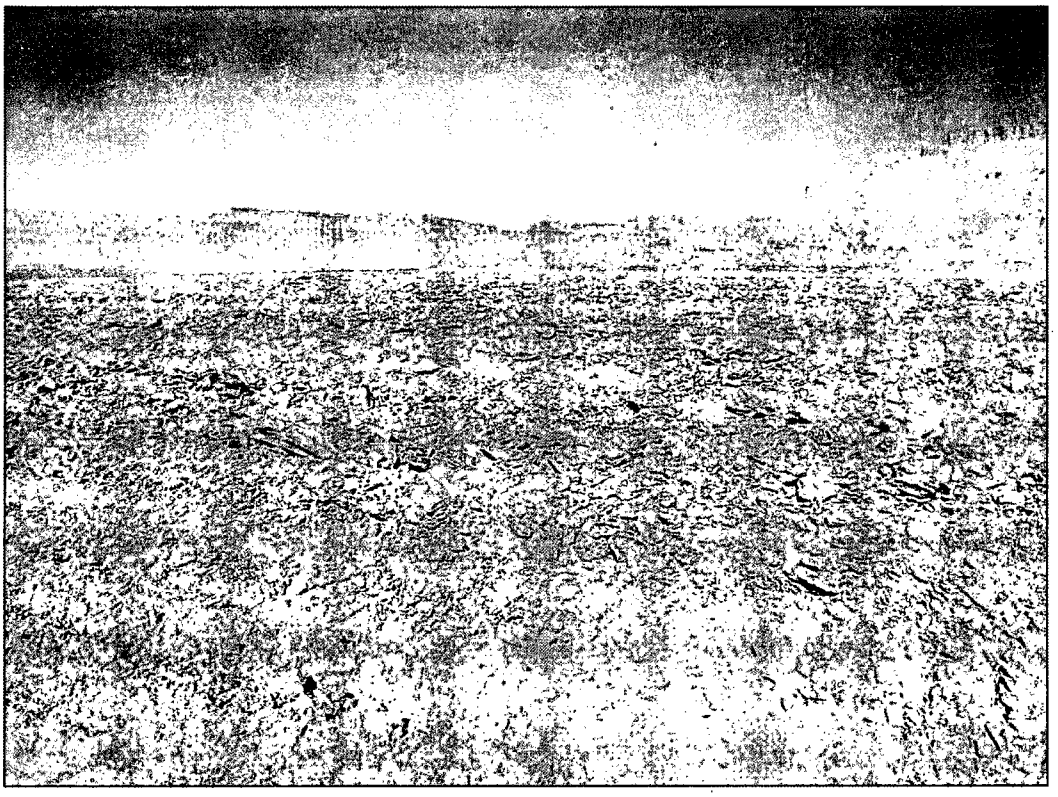


Image 1000010

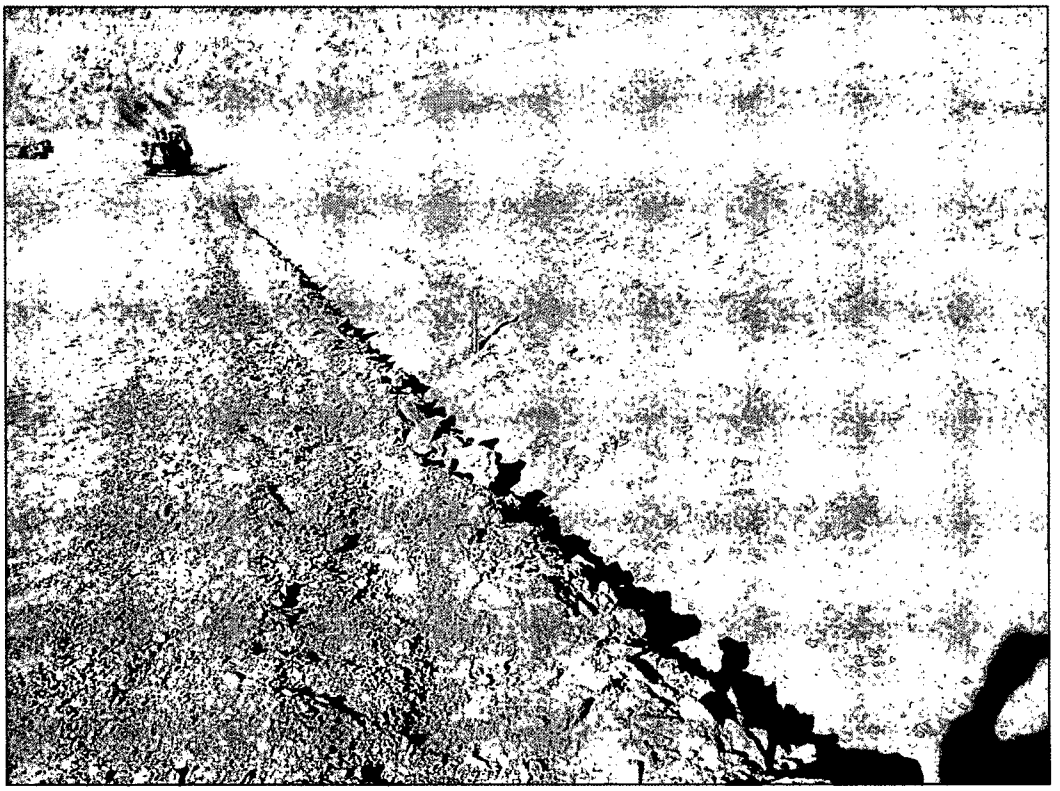


Image 1000013

Image 1000014

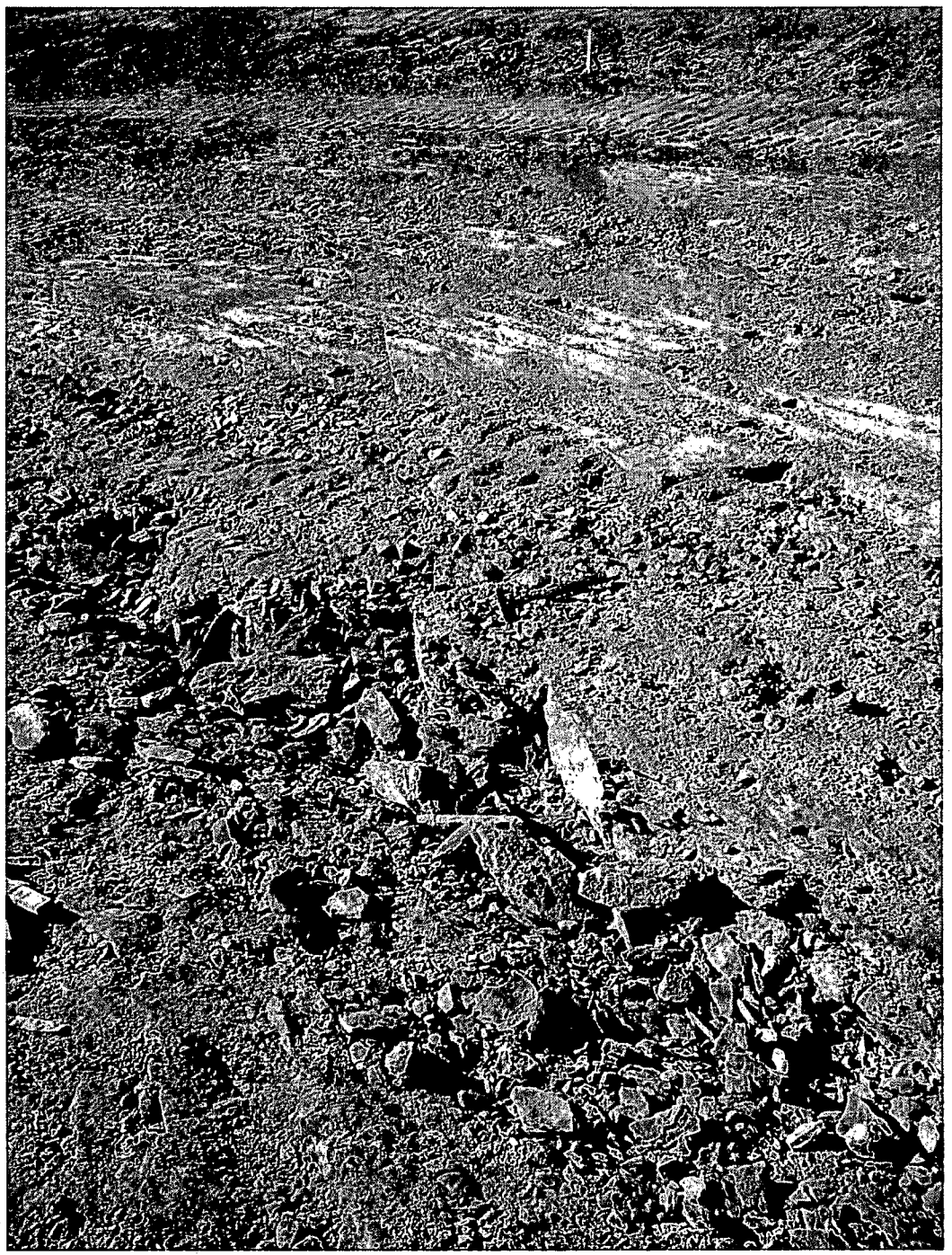


Image 1000015

Image 1000016

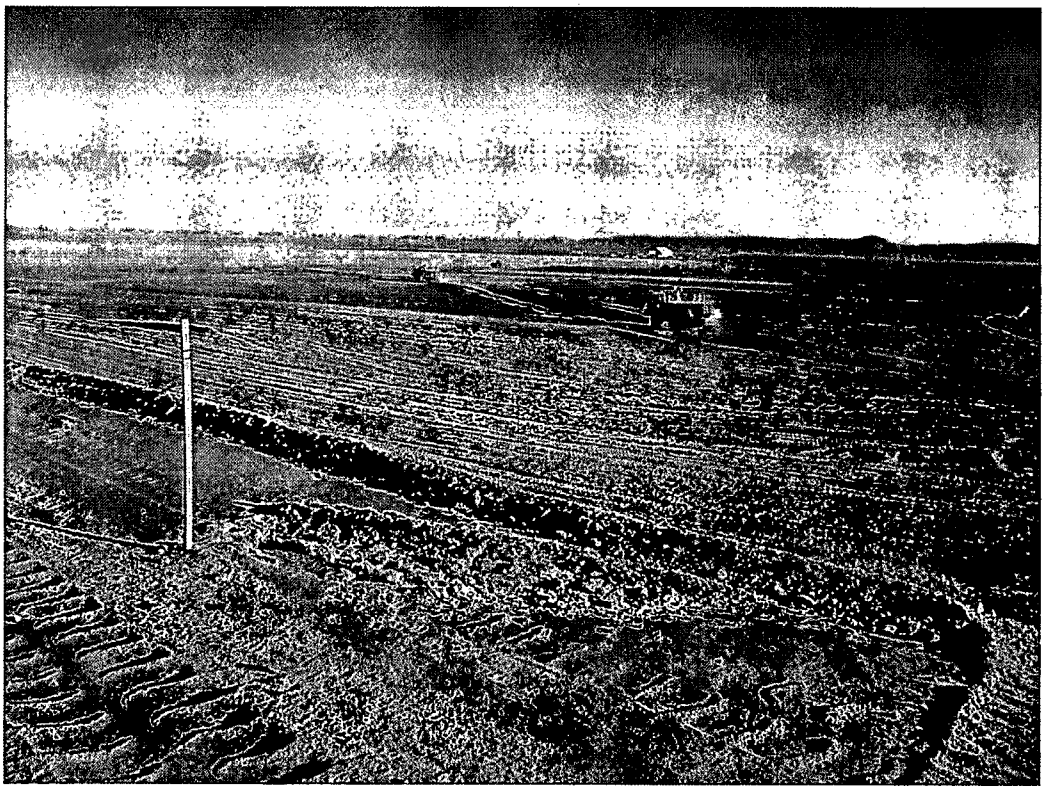


Image 1000017

Image 1000018

# Geologic Characterization of Crescent Junction Cell Excavation

Date: November 13, 2008 Geologist: Craig Goodknight
Depth of Excavation: 20-25 ft BGS Amount of Material Excavated: NA, as per Brent Anderson
Base Map Grid Number(s)

Objectives/Activities: Check former moist condition along S sideslope of excavation.
Check any newly exposed areas on bottom of excavation, where possible in avoidance of earthmoving equipment.
Check exposed contact of Mancos Shale bedrock and overlying alluvial material along the sideslopes of the excavation, particularly along the east and west sides where excavation depths previously were not deep enough to expose the contact.
Check for outcrop of dense dolomitic limestone along the N sideslope of the excavation and any geologic features that may explain its presence.

Photographs (ID number and description):

Image
1000019 View WNW of excavation activity in S part of cell.
20 View ENE of scrapers removing bedrock in SW part of cell.
21 View NE of apparent sag in Mancos Shale about 50 ft long and 3-4 ft deep and limonitic coloration to beds in the sag.
22 View SE of nearly completed Phase I excavation

Survey points (ID number and location): Twelve survey points were identified. They will be surveyed on November 14. They are locations 1 through 12.
Locations 1 through 7 and 9 through 12 - Contact of weathered Mancos Shale and Quaternary alluvial fill material.
Location 8 - Center of apparent sag in Mancos Shale along N side slope

Comments: This was the sixth weekly visit to the disposal cell excavation to identify (stake) survey points marking geological contacts and other geologic characteristics. Weather was mostly clear and relatively warm (50s) for mid November, and dry. It was predicted that the excavation will be down to final grade by late next week.

Date (continued): November 13, 2008

Observations/Descriptions of significant geologic features (fractures, joints, weathering characteristics, lithologic variations, strike/dip, depth of overburden, Mancos Shale contact, etc):

Bedrock was being actively removed from the south-central part of the excavation floor - the only part of the excavation that is not down to final grade.

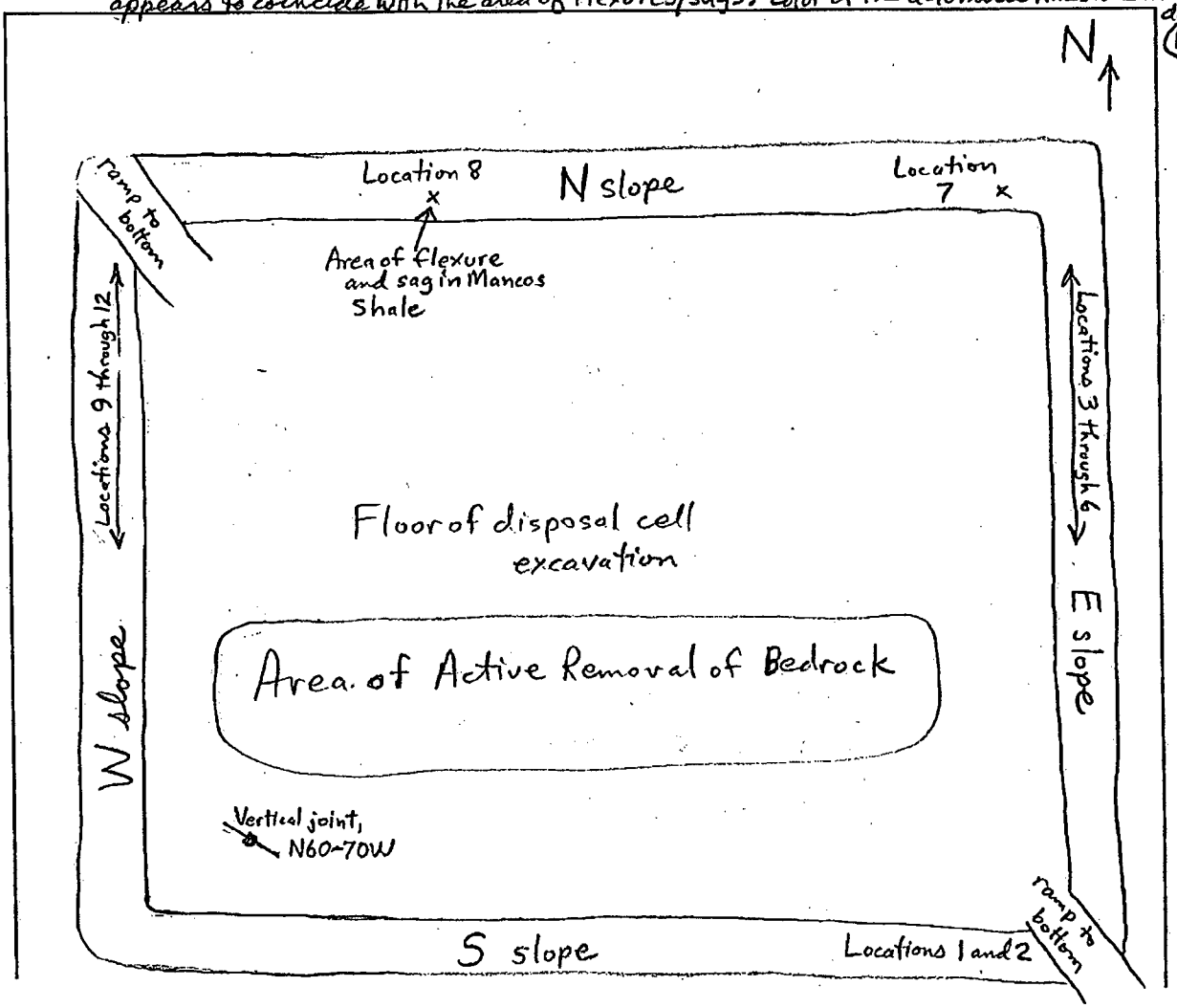
The area of former moisture in the vicinity of Location 8 of 9/3/08 on the S slope was checked and it continues to be dry.

A prominent vertical joint seen in the SW part of the excavation strikes N60 to 70W.

The contact of the top of weathered Mancos Shale and overlying alluvial material was noted in 2 locations on the S slope, 4 locations on the E slope, one location on the N slope, and 4 locations on the W slope. These locations provided information on the contact for most areas where the excavation was previously not deep enough to expose the contact.

In the area of the N slope near where a bed of dolomitic limestone is exposed (in area of Locations 1 and 2 from 9/23/08), an apparent flexure or sag about 50 ft long and 3-4 ft deep was noted in Mancos Shale. Limonitic (tan-orange) siltstone and very fine grained sandstone occur in the sag and do not appear to continue beyond it. The center of the sag is marked at Location 8 and the sag is

Sketch: just W of another flexure noted in Mancos Shale and the thin bed of dolomitic limestone. The dolomitic limestone bed outcrop can only be followed for about 30 ft and it appears to coincide with the area of flexures/sags. Color of the dolomitic limestone is medium dark gray (N4).



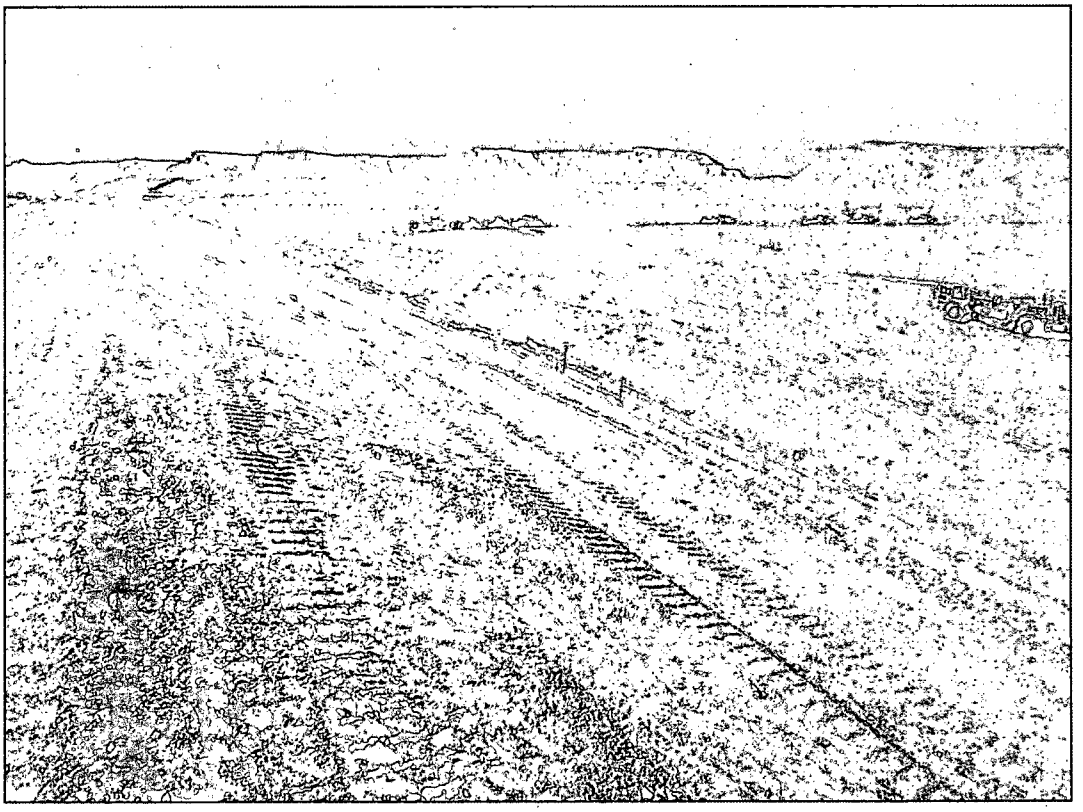


Image 1000019

Image 1000020

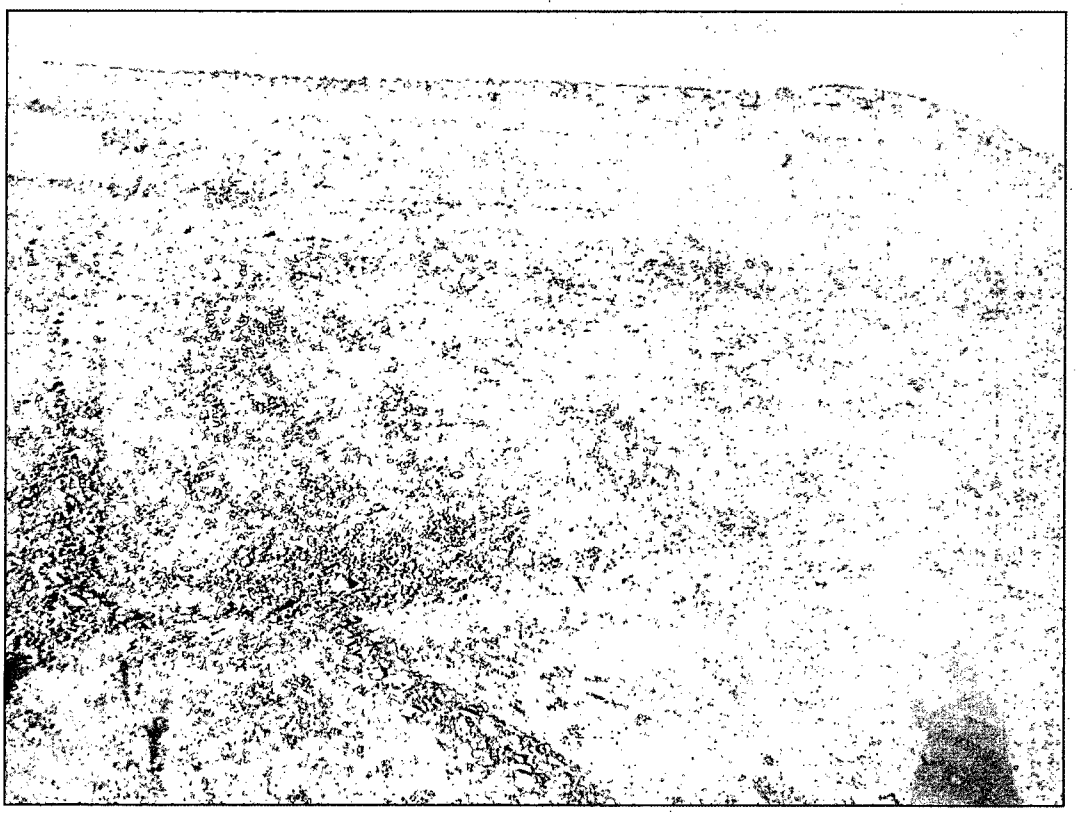


Image 1000021

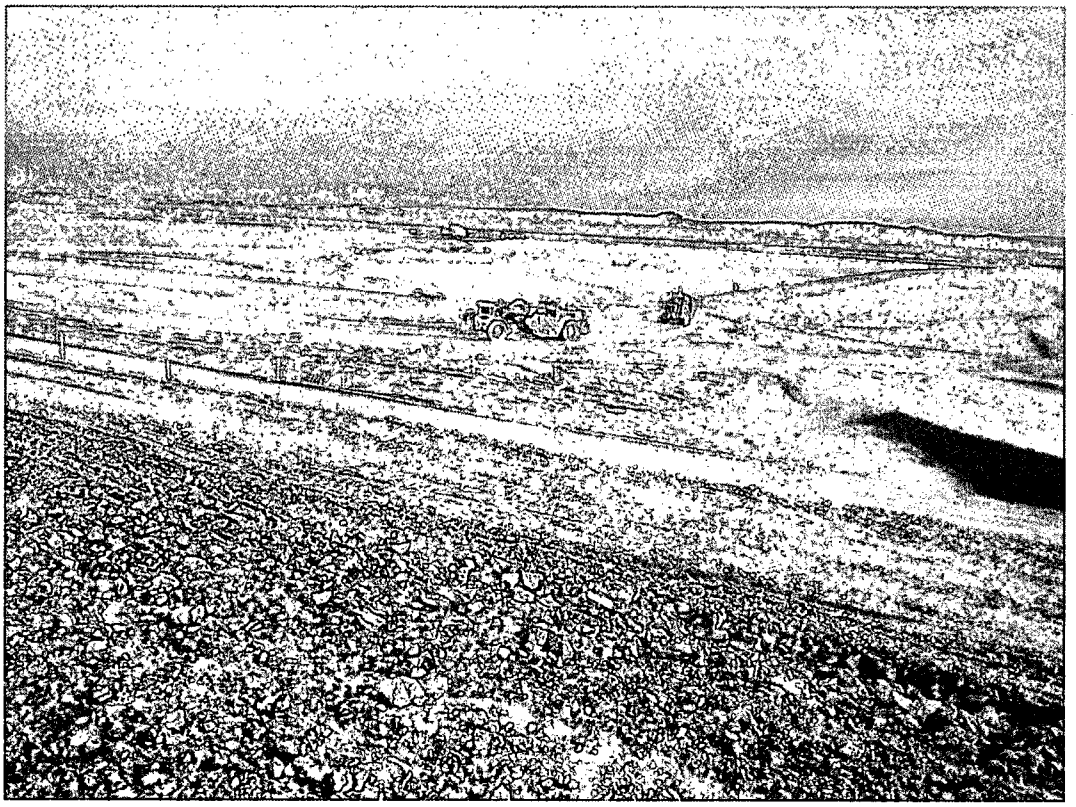


Image 1000022

# Geologic Characterization of Crescent Junction Cell Excavation

Date: November 24, 2008 Geologist: Craig Goodknight and Liz Glowiak
Depth of Excavation: 20-25 ft BGS Amount of Material Excavated: NA, as per Brent Anderson
Base Map Grid Number(s)

Objectives/Activities:
Examine/characterize geologic features exposed at final grade on the bottom of the disposal cell excavation.
Check exposed contact of Mancos Shale bedrock and overlying alluvial material along side slopes of the excavation where excavation depths previously had not been deep enough to expose the contact.
Check the outcrop of dense dolomitic limestone along the N side slope of the excavation and any geologic features that may explain its occurrence.
Check former moist condition along S side slope of excavation.

Photographs (ID number and description):
Image 1000023 View NNE of final excavation in SE part of cell.
24 Joint surface with limonite and calcite in large stockpiled boulder of dolomitic ls.
25 View E of limonitic siltstone and vfn gr sandstone in NE corner of excavation
26 View N of limonitic bed 1-2 ft thick (previous image) on N side slope
27 View NW of sag in Mancos Sh at Location 8 of 11/13/08 staked in center of structure.
28 Location 3, strike and dip in silty shale is N50W and 8°NE, vertical joint is N60W.
29 Location 4, prominent vertical joint, striking N70W coated with gypsum
30 Location 5, strike and dip on rippled bed is N60W and 15°NE, vertical joint is N75W.
31 View E of limonitic bed about 70 ft long and 2 ft above Location 5 to right.
32 View E of limonitic siltstone bed with strike and dip of N60W and 15°NE, Location 6
33 View W of W-striking vertical joint coated with gypsum, bedding strikes N60W and dips 5°NE Location 11.

Survey points (ID number and location): Twelve survey points were identified. They were surveyed on November 24 and are locations 1 through 12.
Locations 1 and 2 - Contact of weathered Mancos Shale and Quaternary alluvial fill material along the W side slope.
Locations 3 through 12 - Strike and dip of prominent joints and/or bedding surfaces in Mancos Shale at final grade around the bottom of the excavation.

Comments: This was the seventh weekly visit to the disposal cell excavation to identify (stake) survey points marking geologic contacts and other geological characteristics. Weather was mostly clear and warm (50s) for late November, and very dry. Much of the excavation was down to final grade, particularly the north half. Considerable final grading activity was still going on in the south part, particularly in the ramp area at the SE corner. The ramp in the NW corner was still in place.

Date (continued): November 24, 2008

Observations/Descriptions of significant geologic features (fractures, joints, weathering characteristics, lithologic variations, strike/dip, depth of overburden, Mancos Shale contact, etc):

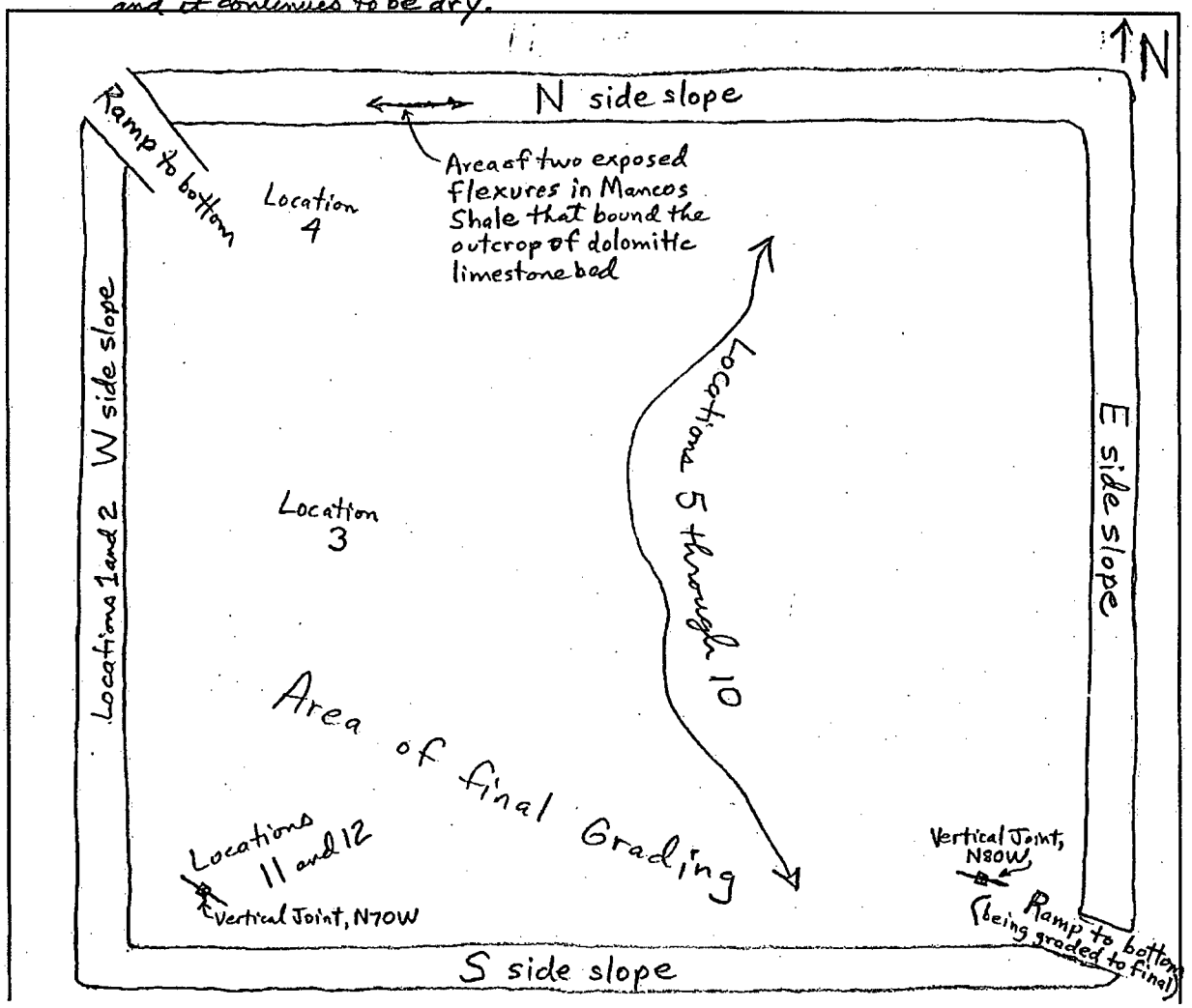
Final grading was still being conducted in part of the south area of the excavation floor and in the ramp at the SE corner of the excavation. Much of the bedrock on the excavation floor was poorly exposed because of smearing by graders or it was covered by a thin layer of broken material. Ten locations on the disposal cell floor were noted where strikes and dip of prominent joints and/or bedding surfaces in Mancos Shale were measured. In addition, vertical joints striking N70W and N80W were noted in the SW and SE corners of the excavation floor. Bedding surfaces dipped from 5 to 15° NE, joints were vertical with a dominant W to NW strike and a secondary joint system striking NE.

Two locations were noted on the W side slope of the contact of weathered Mancos Shale and overlying alluvial material. No additional contacts were noted along the W part of the N. side slope because the contact is at a shallow depth and not exposed in the regraded part of the upper side slope.

Better exposure of the original flexure noted in Location 2 of 9/23/08 showed it to also be a sag in the Mancos Shale similar to the sag noted in Location 8 of 11/13/08. The thin bed of dolomitic limestone is exposed in the N side slope between the two sags, apparently in a slightly higher structural area.

The area of former moisture in the vicinity of Location 8 of 9/3/08 on the S side slope was checked and it continues to be dry.

Sketch:



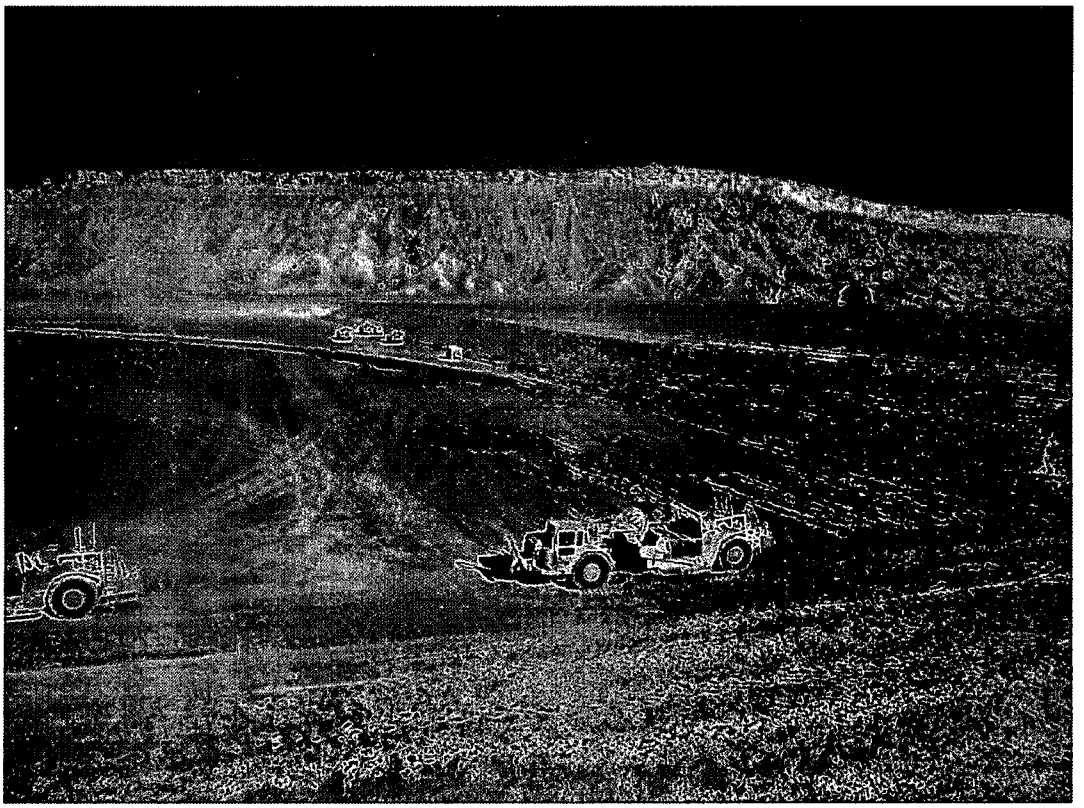


Image 1000023

Image 1000024

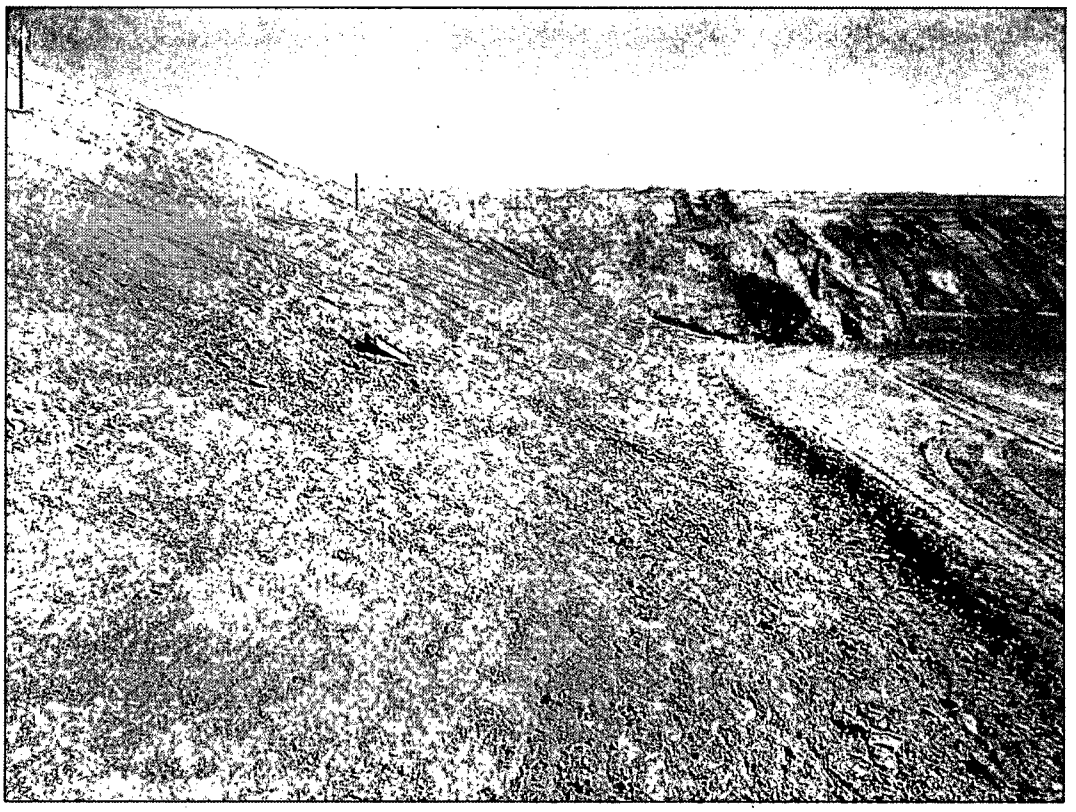


Image 1000025

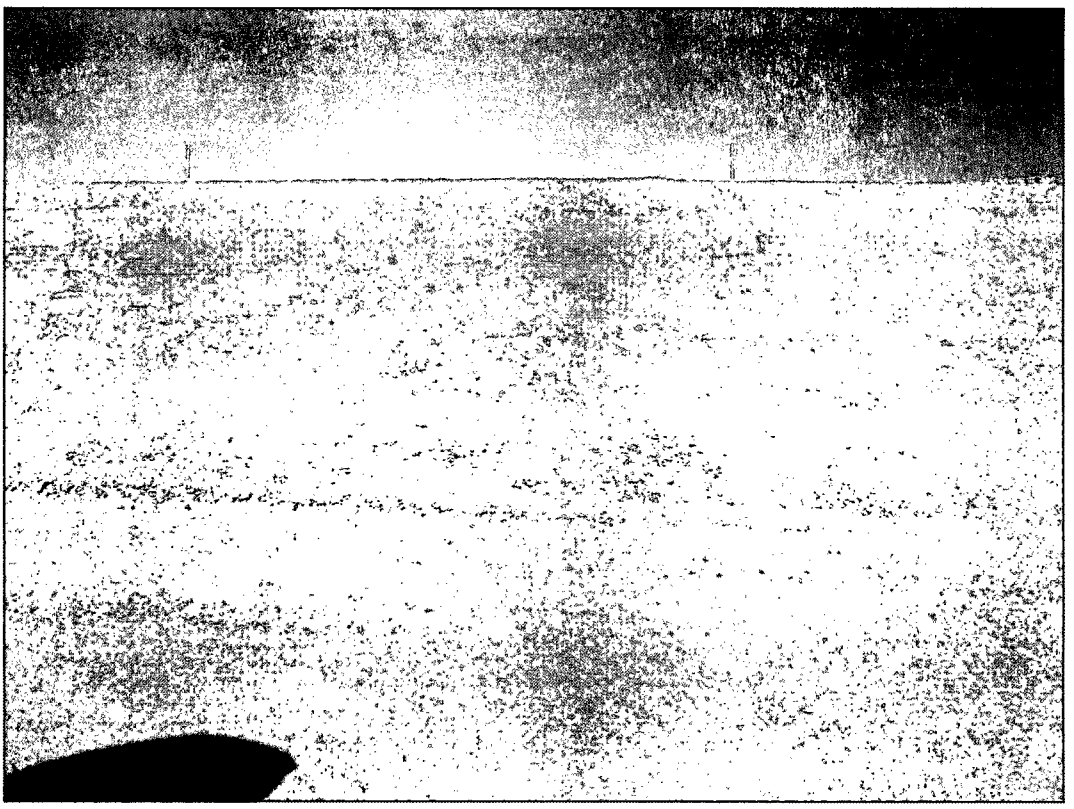


Image 1000026

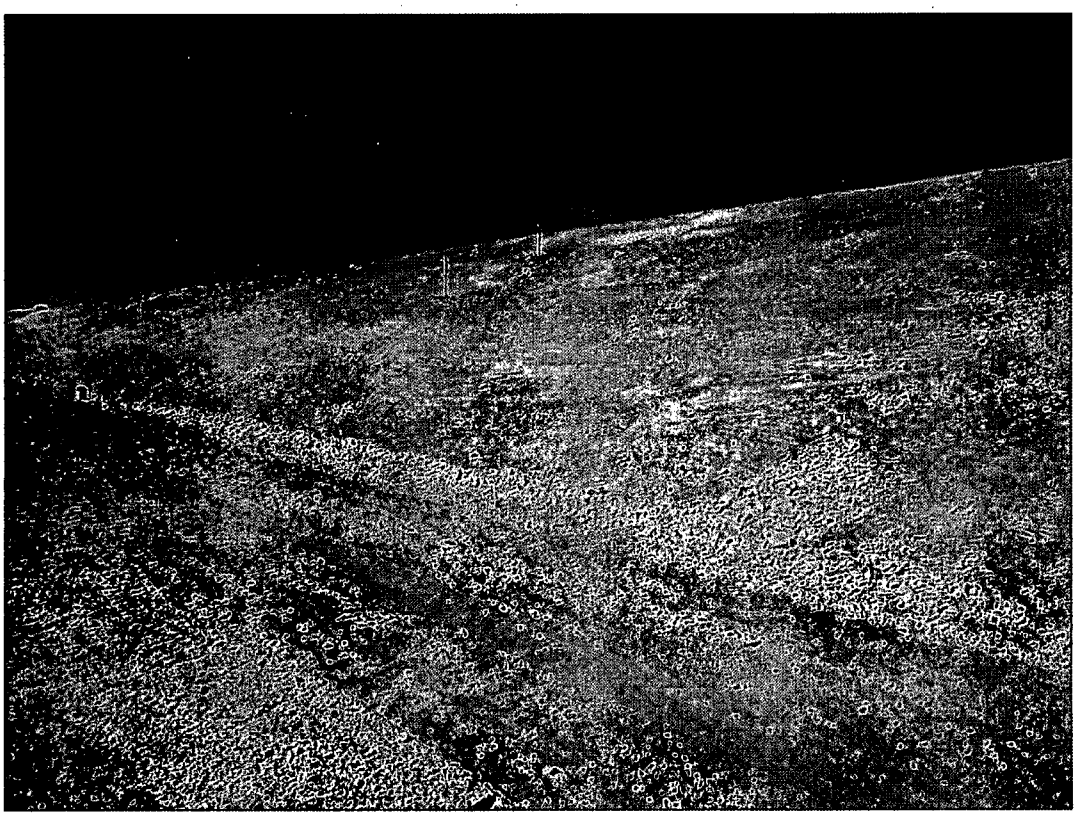


Image 1000027

Image 1000028

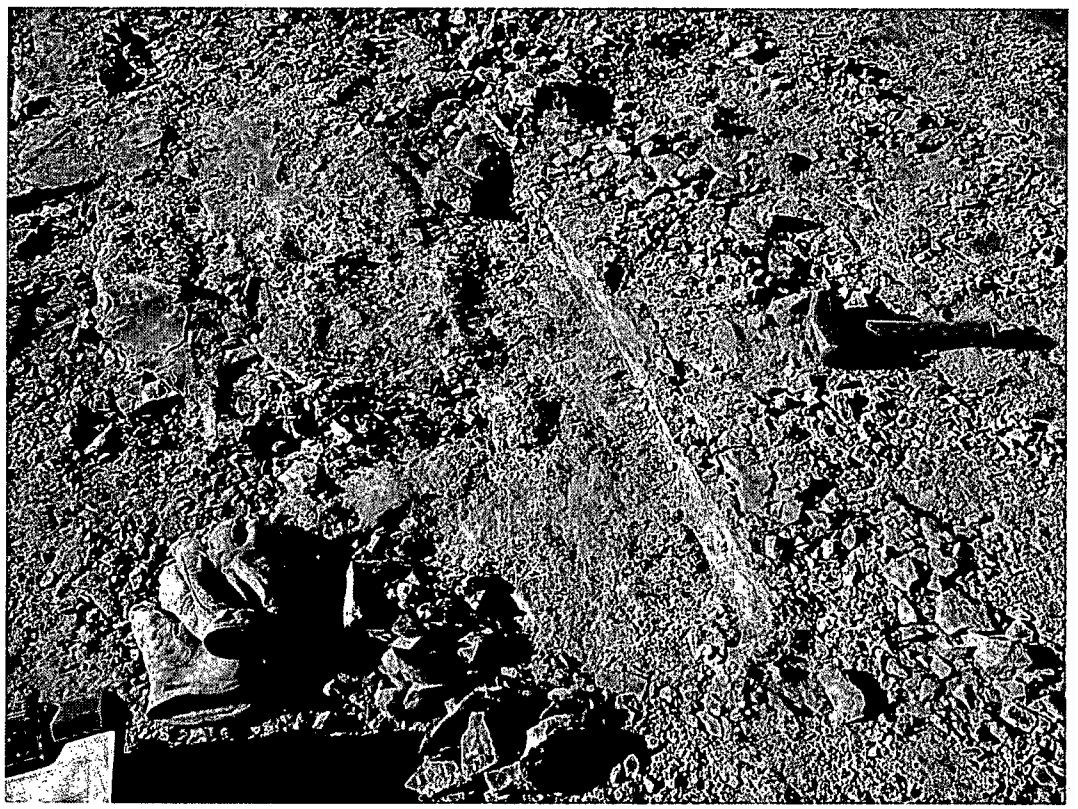


Image 1000029

Image 1000030

Image 1000031

Image 1000032

Image 1000033

# Appendix B

# Survey Locations, Coordinates, and Elevations

This page intentionally left blank

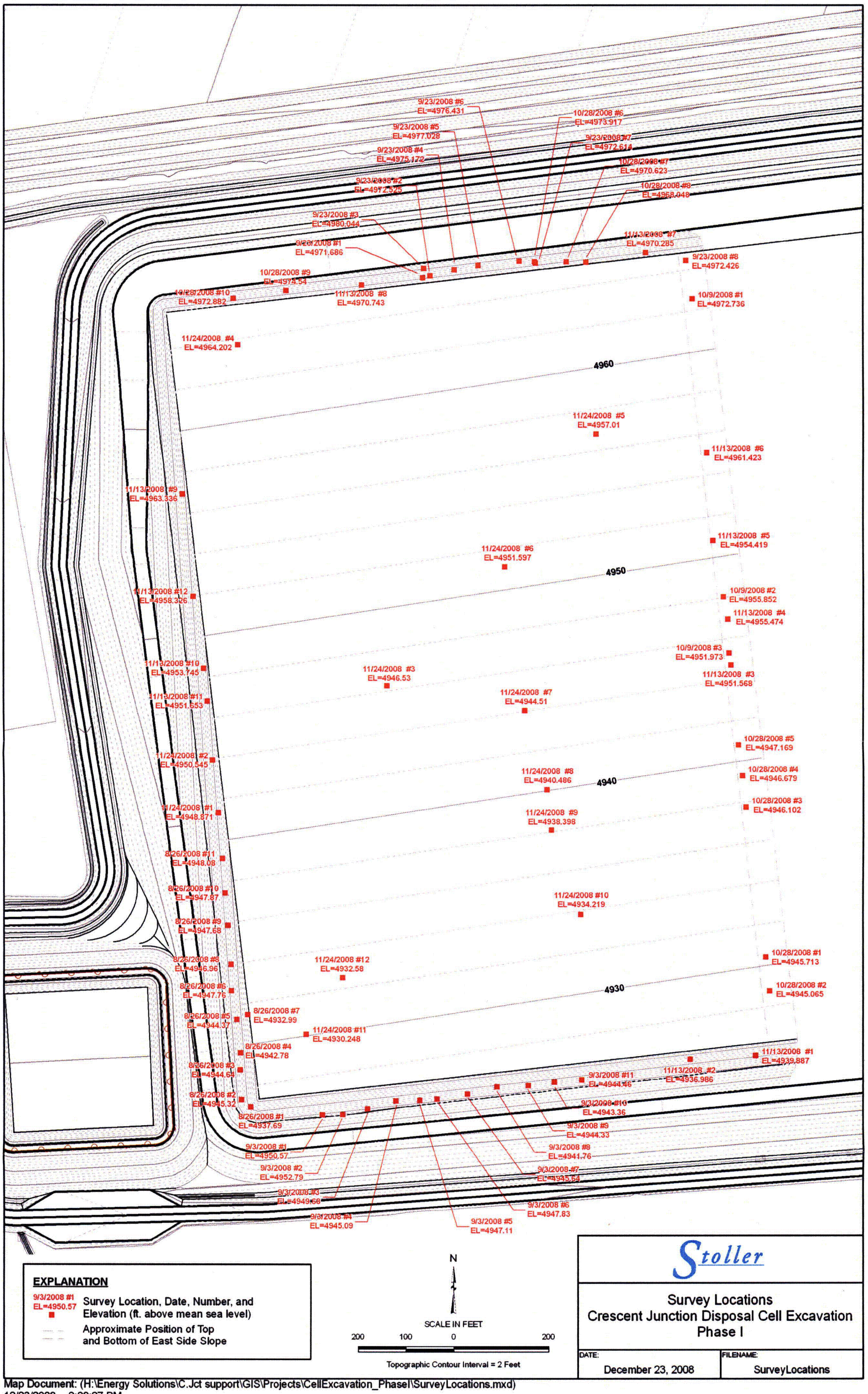



*Figure B–1. Map of Survey Locations for the Excavation*

This page intentionally left blank

*Table B–1. Survey Location Coordinates and Elevation*

| Survey Location Date and Number | Northing[a] | Easting[a] | Elevation[b] |
|---|---|---|---|
| Located on August 26, 2008, Site Visit | | | |
| 8/26/2008 #1 | 6794202.42 | 2122318 | 4937.69 |
| 8/26/2008 #2 | 6794217.32 | 2122299 | 4945.32 |
| 8/26/2008 #3 | 6794280.5 | 2122296 | 4944.64 |
| 8/26/2008 #4 | 6794316.27 | 2122296 | 4942.78 |
| 8/26/2008 #5 | 6794387.06 | 2122289 | 4944.37 |
| 8/26/2008 #6 | 6794447.84 | 2122278 | 4947.76 |
| 8/26/2008 #7 | 6794397.22 | 2122312 | 4932.99 |
| 8/26/2008 #8 | 6794503.9 | 2122277 | 4946.96 |
| 8/26/2008 #9 | 6794585.37 | 2122271 | 4947.68 |
| 8/26/2008 #10 | 6794654.1 | 2122265 | 4947.87 |
| 8/26/2008 #11 | 6794726.79 | 2122259 | 4948.08 |
| Located on September 3, 2008, Site Visit | | | |
| 9/3/2008 #1 | 6794185.5 | 2122467 | 4950.57 |
| 9/3/2008 #2 | 6794186.37 | 2122510 | 4952.79 |
| 9/3/2008 #3 | 6794197.99 | 2122562 | 4949.68 |
| 9/3/2008 #4 | 6794214.91 | 2122621 | 4945.09 |
| 9/3/2008 #5 | 6794216 | 2122672 | 4947.11 |
| 9/3/2008 #6 | 6794219.27 | 2122708 | 4947.83 |
| 9/3/2008 #7 | 6794229.93 | 2122771 | 4945.64 |
| 9/3/2008 #8 | 6794245.19 | 2122833 | 4941.76 |
| 9/3/2008 #9 | 6794247.56 | 2122899 | 4944.33 |
| 9/3/2008 #10 | 6794255.13 | 2122954 | 4943.36 |
| 9/3/2008 #11 | 6794259.34 | 2123011 | 4944.46 |
| Located on September 23, 2008, Site Visit | | | |
| 9/23/2008 #1 | 6795954.248 | 2122678 | 4971.686 |
| 9/23/2008 #2 | 6795958.389 | 2122694 | 4972.525 |
| 9/23/2008 #3 | 6795973.473 | 2122680 | 4980.044 |
| 9/23/2008 #4 | 6795970.858 | 2122744 | 4975.172 |
| 9/23/2008 #5 | 6795980.301 | 2122794 | 4977.028 |
| 9/23/2008 #6 | 6795989.163 | 2122880 | 4976.431 |
| 9/23/2008 #7 | 6795985.172 | 2122915 | 4972.614 |
| 9/23/2008 #8 | 6795990.248 | 2123231 | 4972.426 |
| Located on October 9, 2008, Site Visit | | | |
| 10/9/2008 #1 | 6795909.734 | 2123244 | 4972.736 |
| 10/9/2008 #2 | 6795281.275 | 2123309 | 4955.852 |
| 10/9/2008 #3 | 6795162.332 | 2123321 | 4951.973 |

*Table B–1. Survey Location Coordinates and Elevation (Continued)*

| Survey Location Date and Number | Northing[a] | Easting[a] | Elevation[b] |
|---|---|---|---|
| Located on October 28, 2008, Site Visit | | | |
| 10/28/2008 #1 | 6794519.303 | 2123399 | 4945.713 |
| 10/28/2008 #2 | 6794447.779 | 2123407 | 4945.065 |
| 10/28/2008 #3 | 6794835.501 | 2123357 | 4946.102 |
| 10/28/2008 #4 | 6794902.211 | 2123349 | 4946.679 |
| 10/28/2008 #5 | 6794967.642 | 2123341 | 4947.169 |
| 10/28/2008 #6 | 6795987.901 | 2122913 | 4973.917 |
| 10/28/2008 #7 | 6795987.899 | 2122979 | 4970.623 |
| 10/28/2008 #8 | 6795986.788 | 2123021 | 4968.048 |
| 10/28/2008 #9 | 6795926.655 | 2122392 | 4974.54 |
| 10/28/2008 #10 | 6795910.53 | 2122282 | 4972.882 |
| Located on November 13, 2008, Site Visit | | | |
| 11/13/2008 #1 | 6794310.946 | 2123377 | 4939.887 |
| 11/13/2008 #2 | 6794302.625 | 2123239 | 4936.986 |
| 11/13/2008 #3 | 6795136.911 | 2123326 | 4951.568 |
| 11/13/2008 #4 | 6795233.578 | 2123319 | 4955.474 |
| 11/13/2008 #5 | 6795399.373 | 2123287 | 4954.419 |
| 11/13/2008 #6 | 6795584.781 | 2123274 | 4961.423 |
| 11/13/2008 #7 | 6796007.122 | 2123146 | 4970.285 |
| 11/13/2008 #8 | 6795938.877 | 2122550 | 4970.743 |
| 11/13/2008 #9 | 6795497.374 | 2122175 | 4963.336 |
| 11/13/2008 #10 | 6795129.859 | 2122219 | 4953.745 |
| 11/13/2008 #11 | 6795060.2 | 2122227 | 4951.653 |
| 11/13/2008 #12 | 6795281.808 | 2122198 | 4958.326 |
| Located on November 24, 2008, Site Visit | | | |
| 11/24/2008 #1 | 6794823.826 | 2122250 | 4948.871 |
| 11/24/2008 #2 | 6794934.862 | 2122239 | 4950.545 |
| 11/24/2008 #3 | 6795093.019 | 2122603 | 4946.53 |
| 11/24/2008 #4 | 6795812.299 | 2122292 | 4964.202 |
| 11/24/2008 #5 | 6795624.381 | 2123042 | 4957.01 |
| 11/24/2008 #6 | 6795344.5 | 2122850 | 4951.597 |
| 11/24/2008 #7 | 6795040.423 | 2122892 | 4944.51 |
| 11/24/2008 #8 | 6794872.191 | 2122938 | 4940.486 |
| 11/24/2008 #9 | 6794787.356 | 2122948 | 4938.398 |
| 11/24/2008 #10 | 6794608.819 | 2123010 | 4934.219 |
| 11/24/2008 #11 | 6794355.488 | 2122434 | 4930.248 |
| 11/24/2008 #12 | 6794475.557 | 2122510 | 4932.58 |

[a] In feet, Modified State Plane Coordinate System, Utah Central NAD 27
[b] Feet above mean sea level