C/041/002 Incoming
#4079
K

Canyon Fuel Company, LLC
A Subsidiary of Arch Western Bituminous Group, LLC.

Sufco Mine
597 South SR24
Salina, Utah 84654
(435) 286-4880
Fax (435) 286-4499

April 6, 2012

Utah Coal Program
Utah Division of Oil, Gas & Mining
1594 West North Temple, Suite 1210
P. O. Box 145801
Salt Lake City, UT 84114-5801

Re: Northwater Mitigation Plan, Canyon Fuel Company, LLC, SUFCO Mine, C/041/002

Dear Permit Supervisor:

Canyon Fuel Company, LLC, SUFCO Mine is submitting this plan as the final mitigation for the Northwater area which was affected by longwall mining in 2005 and 2006. This plan addresses the loss of water to two troughs that are used by cattlemen to water cows in the area for approximately one month every other year.

Sufco feels that replacement of water to these troughs are the only mitigation required as no downstream water rights have been affected by the loss of surface water in the area, the Pines Vegetation Tract Study demonstrates no visual impact to the riparian area surrounding Pines 105, and with this plan, the land use (wildlife and livestock grazing) is unchanged from that prior to undermining the area.

This plan was presented to personnel representing the Division, Forest Service, Division of Water Rights and the Emery County Stock Growers Association, in October and November of 2011 and was deemed acceptable to address the issues and concerns of these parties.

Attached are Division forms C-1 and C-2 and Appendix 7-25 Northwater Mitigation Plan.
If you have any questions or need additional information, please contact Leland Roberts at (435) 286-4483.

Sincerely,
CANYON FUEL COMPANY, LLC
SUFCO Mine

Kenneth E. May
General Manager

RECEIVED
APR 13 2012
DIV. OF OIL, GAS & MINING

KEM/FLR:kb
Encl.

cc: DOGM - Price Field Office
DOGM Correspondence File
Sufpub\Govt2012\dogmmrp\Northwater Mitigation.ltr.doc

File in:
☐ Confidential
☐ Shelf
☒ Expandable
Date Folder 04/13/12 C/041/0002
Incoming

APPLICATION FOR COAL PERMIT PROCESSING

Permit Change ☒ New Permit ☐ Renewal ☐ Exploration ☐ Bond Release ☐ Transfer ☐

Permittee: CANYON FUEL COMPANY, LLC
Mine: SUFCO MINE **Permit Number:** C/041/0002
Title: 2012 Northwater Mitigation Plan

Description, Include reason for application and timing required to implement:
Final mitigation plan for the Northwater Spring Area

Instructions: If you answer yes to any of the first eight questions, this application may require Public Notice publication.

☐ Yes ☒ No 1. Change in the size of the Permit Area? Acres: _____ Disturbed Area: _____ ☐ increase ☐ decrease.
☐ Yes ☒ No 2. Is the application submitted as a result of a Division Order? DO# _____
☐ Yes ☒ No 3. Does the application include operations outside a previously identified Cumulative Hydrologic Impact Area?
☐ Yes ☒ No 4. Does the application include operations in hydrologic basins other than as currently approved?
☐ Yes ☒ No 5. Does the application result from cancellation, reduction or increase of insurance or reclamation bond?
☐ Yes ☒ No 6. Does the application require or include public notice publication?
☐ Yes ☒ No 7. Does the application require or include ownership, control, right-of-entry, or compliance information?
☐ Yes ☒ No 8. Is proposed activity within 100 feet of a public road or cemetery or 300 feet of an occupied dwelling?
☐ Yes ☒ No 9. Is the application submitted as a result of a Violation? NOV # _____
☐ Yes ☒ No 10. Is the application submitted as a result of other laws or regulations or policies?
Explain: _____
☐ Yes ☒ No 11. Does the application affect the surface landowner or change the post mining land use?
☐ Yes ☒ No 12. Does the application require or include underground design or mine sequence and timing? (Modification of R2P2)
☐ Yes ☒ No 13. Does the application require or include collection and reporting of any baseline information?
☐ Yes ☒ No 14. Could the application have any effect on wildlife or vegetation outside the current disturbed area?
☐ Yes ☒ No 15. Does the application require or include soil removal, storage or placement?
☐ Yes ☒ No 16. Does the application require or include vegetation monitoring, removal or revegetation activities?
☐ Yes ☒ No 17. Does the application require or include construction, modification, or removal of surface facilities?
☐ Yes ☒ No 18. Does the application require or include water monitoring, sediment or drainage control measures?
☐ Yes ☒ No 19. Does the application require or include certified designs, maps or calculation?
☐ Yes ☒ No 20. Does the application require or include subsidence control or monitoring?
☐ Yes ☒ No 21. Have reclamation costs for bonding been provided?
☐ Yes ☒ No 22. Does the application involve a perennial stream, a stream buffer zone or discharges to a stream?
☐ Yes ☒ No 23. Does the application affect permits issued by other agencies or permits issued to other entities?
☐ Yes ☒ No 24. Does the application include confidential information and is it clearly marked and separated in the plan?

Please attach three (3) review copies of the application. If the mine is on or adjacent to Forest Service land please submit four (4) copies, thank you. (These numbers include a copy for the Price Field Office)

I hereby certify that I am a responsible official of the applicant and that the information contained in this application is true and correct to the best of my information and belief in all respects with the laws of Utah in reference to commitments, undertakings, and obligations, herein.

KENNETH E. MAY	GENERAL MANAGER		Kenneth E May	4/10/12
Print Name	Position	Date	Signature (Right-click above choose certify then have notary sign below)	

Subscribed and sworn to before me this 12 day of April, 2012

Notary Public: _____, state of Utah.

My commission Expires: _____ }
Commission Number: _____ } ss:
Address: _____ }
City: _____ State: _____ Zip: _____ }

JACQUELYN NEBEKER
Notary Public
State Of Utah
My Commission Expires 3/24/201[illegible]
Commissi[illegible]

For Office Use Only:	Assigned Tracking Number:	Received by Oil, Gas & Mining
		RECEIVED APR 13 2012 DIV. OF OIL, GAS & MINING

Form DOGM- C1 (Revised December 10, 2007)

APPLICATION FOR COAL PERMIT PROCESSING
Detailed Schedule Of Changes to the Mining And Reclamation Plan

Permittee: CANYON FUEL COMPANY, LLC
Mine: SUFCO MINE **Permit Number:** C/041/0002
Title: 2012 Northwater Mitigation Plan

Provide a detailed listing of all changes to the Mining and Reclamation Plan, which is required as a result of this proposed permit application. Individually list all maps and drawings that are added, replaced, or removed from the plan. Include changes to the table of contents, section of the plan, or other information as needed to specifically locate, identify and revise the existing Mining and Reclamation Plan. Include page, section and drawing number as part of the description.

			DESCRIPTION OF MAP, TEXT, OR MATERIAL TO BE CHANGED
☒ Add	☐ Replace	☐ Remove	Appendix 7-25 Northwater Mitigation Plan
☐ Add	☐ Replace	☐ Remove	
☐ Add	☐ Replace	☐ Remove	
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Any other specific or special instruction required for insertion of this proposal into the Mining and Reclamation Plan.

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APR 13 2012

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Appendix 7-25

North Water Mitigation Plan

Background

During 2005 and 2006, longwall mining at Canyon Fuel Company, LLC's Sufco Mine occurred beneath the North Water Canyon tributary to the East Fork of Box Canyon (Figure 1). Subsidence-related effects apparently resulted in the cessation of spring discharge to the land surface from three springs in the North Water Canyon area (Pines 105, Pines 311, and Pines 310 lower). Longwall mining and related subsidence also occurred beneath the Joes Mill Pond area, approximately ½ mile south of North Water Canyon (Figure 2). Subsequent to mining in the Joes Mill Pond area, discharge from a seep that provided water to an adjacent small stock watering pond also ceased to flow at the ground surface.

Since that time Sufco has conducted and submitted several studies and potential mitigation plans to the Division to restore water at the affected areas, all these plans and studies with the exception of the report from the 2009 drilling actives have been submitted, therefore this report is included as Atttachement A. These plans have included the installation of piezometers to monitor ground water levels in the alluvium in the canyon bottoms, potential water collection systems, wells, and the final plan submitted in 2010 to pipe water from a spring several miles away. All these plans have been determined to be inadequate to restore the required amount of water or installation and maintenance issues too great to be feasible.

In addition to these studies and mitigation plans Sufco has also conducted the Pines Tract Vegetation Study. This study has permanent photo points established that are visited in July of each year. Photo point 10 and the riparian area adjacent to photo point 10 document the Pines 105 spring area. Over time these photos have shown that the riparian area that was supported by surface water from Pines 105 has not changed due to the loss of water. This would imply that ground water in the area is still sufficient to support this vegetation community. This study has been submitted each year as part of Sufco's annual report.

In the summer of 2009 Sufco installed a submersible solar pump in the perennial flowing section of the East Fork of Box Canyon that would deliver water back to the sump at Pines 105. This system would allow the Emery County Stock Growers Association (permitties) who have the grazing permit in the area to install their solar pump and pump water to their troughs on the canyon rim as they had done prior to the undermining of the area. As part of this project Sufco also installed two additional trough locations that allow forage in the area to be better utilized. One of these sets of troughs is located on the canyon rim directly above Sufco's pump. The other location to the east utilizes the permitties' pump to fill them as well as the troughs currently located above Pines 105.

The configuration of the system is as follows. Solar panels on the canyon rim power a submersible solar pump that is placed in the stream. A pipeline runs from the pump to set of

two 750 gallon troughs on the canyon rim. A float system closes off a valve to these troughs once they are full. This pushes water into a pipeline that runs back into the bottom of the canyon to the permitties' sump in the fenced off area surrounding Pines 105. Water fills the sump and overflows as long as the pump in the stream is running. A new pipeline was installed that runs from this sump to the existing troughs at Pines 105 and the far east troughs. The permitties' pump and panels are used to fill these two sets of troughs. When the troughs above Pines 105 are full a float system shuts off a valve allowing water to be pumped to the last set of troughs to the east. This system was installed in 2009 but not utilized until the fall of 2011 due to the allotment not being grazed as a result of vegetation manipulations that the Forest Service conducted in the area.

In the fall of 2011 the permitties where allowed to graze the area as they moved their cattle of the mountain for the year. In anticipation of this Sufco installed the in stream pump and restored water to the sump at Pines 105. However the permitties never installed their pump to complete the system. Inquires with permitties found that installation of the surface pump at Pines 105 was difficult due to the size and weight of the pump.

All the above mentioned factors led Sufco to develop a new mitigation plan that was presented to DOGM, Division of Water Rights, Forest Service and the Emery County Stock Growers Association in October and November of 2011. Support of the plan from all parties has led to the following mitigation plan being submitted to the Division.

Final Mitigation Plan

Sufco feels that the only mitigation required from the loss of surface water in the Northwater area are to the two troughs on the canyon rim above the Pines 105 spring and to the Joe's Mill Pond area for the following reasons: Water at Pines 310 Upper provides sufficient water for wildlife in the area of the Pines 310 and 311 seeps, this is also supplemented by other small seeps in the canyons around this area; Vegetation in the canyon bottom throughout the area seems unchanged since undermining occurred; Downstream water rights have not been affected and the Division has concluded that no material damage has occurred; Land use has remained unchanged since undermining occurred, meaning that wildlife and recreation still occur in the area and with this plan livestock grazing is not only maintained but enhanced.

The final mitigation plan uses the pump, solar panels, and some of the pipeline that Sufco installed in 2009 to deliver water to the two troughs of the rim of the canyon and then through a pipeline on to a trough that will be located at Joe's Mill Pond. A float and valve system will be installed to fill the troughs on the canyon rim prior to water being pumped to Joe's Mill. Water will no longer be delivered to the sump at Pines 105, instead Sufco will relocate the permitties' pump and solar panels to Trough location 1 (Figure 3). This pump will provide water to the

troughs currently in place above Pines 105 and the far east troughs Sufco installed in 2009. A new water line will be placed on the surface to connect trough location 1 to the troughs above Pines 105. This system will only be installed when necessary for watering of livestock. The 4 trough locations will disperse livestock throughout the area allowing for better utilization of feed.

Sufco will install all required equipment to pump water from trough location 1 using the permitties panels and pump, and protect this equipment from damage from livestock. This can include the following: a new pole and fencing for solar panels, cement pad to mount pump on, fencing to protect pump and plumbing from livestock disturbance. Permitties will still need to install their pump and panels at the new location.

Each year during Sufco's mine life that the system will be used, Sufco will place the pump in the stream and connect the solar panels to run this pump. At the end of each season of use Sufco will remove the in stream pump and panels.

Sufco will provide and maintain for life of mining the following:

- Solar pump in stream
- Solar panels to power pump in stream
- Water lines between 4 trough locations
- Water troughs at the 3 locations (those installed by Sufco at rim of the canyon, Joes Mill Pond and the far east location)

Upon completion of all mining activities Sufco will provide and ensure the following

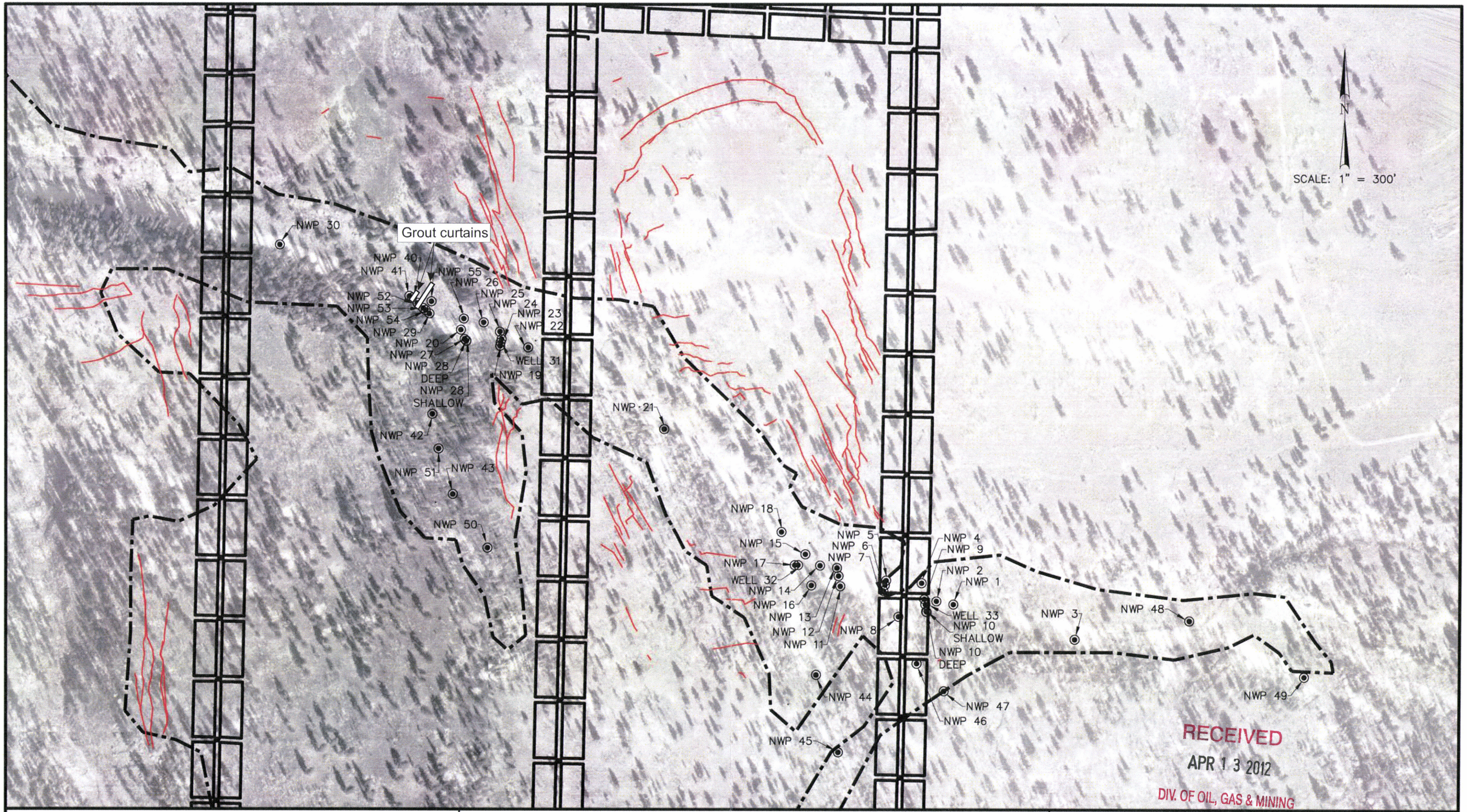
- New in stream solar pump and panels to Emery County Stock Growers Association
- Troughs and pipeline are in good working order

At this time installation and maintenance of the system will be the sole responsibility of the Emery County Stock Growers Association.

Prior to this submission Sufco met with personnel from the Division, Forest Service, and Division of Water Rights to go over this plan in October of 2011. All parties agreed that this plan would fulfill the water replacement requirements. The Division requested that the Forest Service file a Point of Diversion and Use at the location of the in stream pump since this was the final mitigation plan. Up to this point of time Sufco had been filing the Point of Diversion and covering the use with their water rights. The Forest Service also requested that the plan be presented to the permitties; this was done in the Town of Emery in November of 2011. The Permitties agreed to the plan as it made installation of their pump easier and provides two new

trough location that they had not previously had allowing them to better utilize the feed in the area.

Sufco will install all plumbing, waterlines and fencing prior to the next use of the area by livestock. This is currently anticipated to be in June of 2012.



Canyon Fuel Company, LLC
SUFCO Mine
397 South 800 West - Salina, UT 84654
(435) 286-4880 Phone
(435) 286-4499 Fax

North Water Area

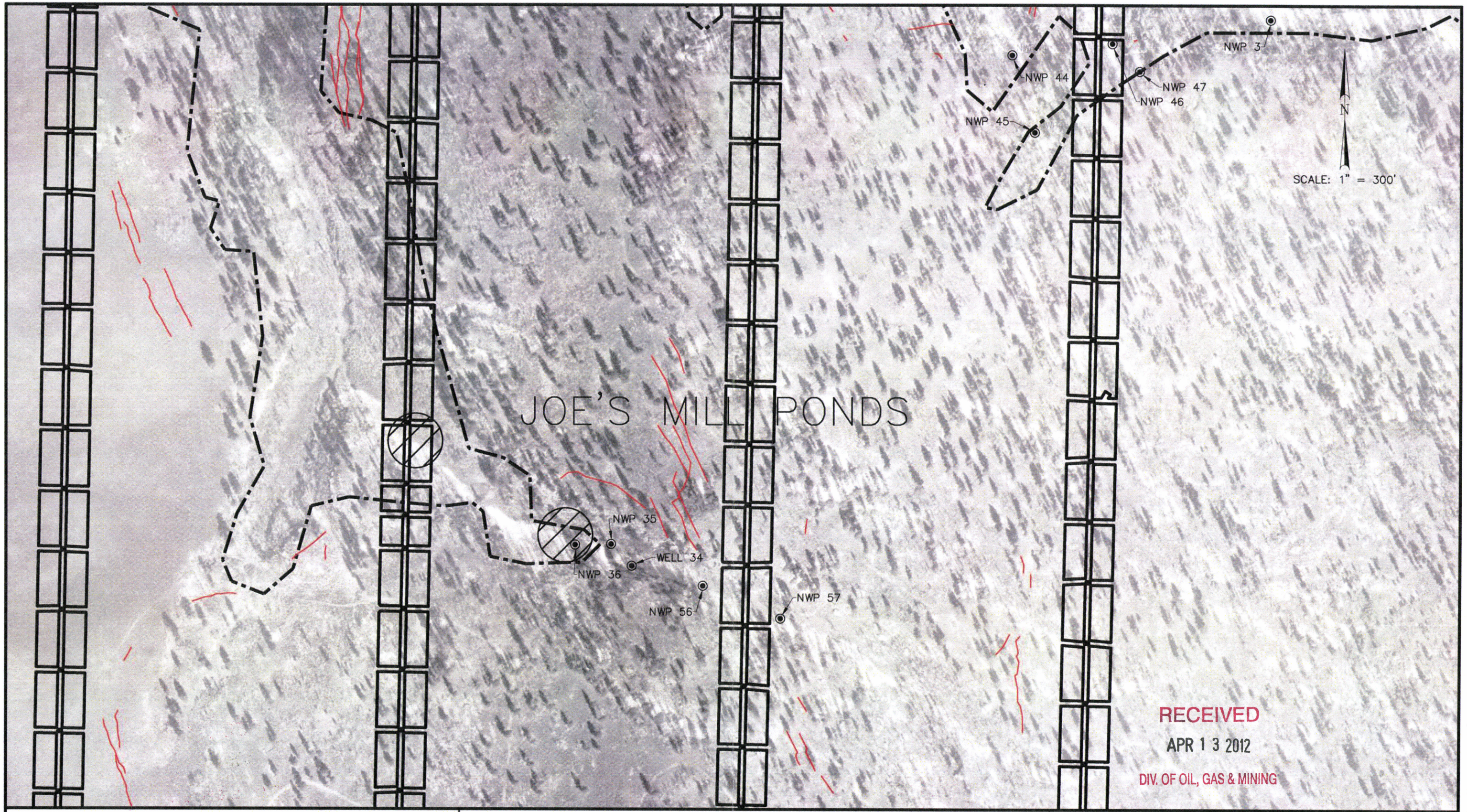
Subsidence Crack & Monitoring Well Locations

SCALE: 1" = 300'	DATE: Oct. 2007	DRAWN BY: K.B.B.	ENGINEER: M.L.D.	CHECKED BY: M.L.D.

FILE NAME: H:\

REVISIONS					SHEET NO.
NO.	DATE	REQ. BY	DWG. BY	REMARKS	1

Figure 1 Locations of piezometers and grout curtains in the North Water Canyon area.



Canyon Fuel Company, LLC
SUFCO Mine
397 South 800 West - Salina, UT 84654
(435) 286-4880 Phone
(435) 286-4499 Fax

Joes Mill Area

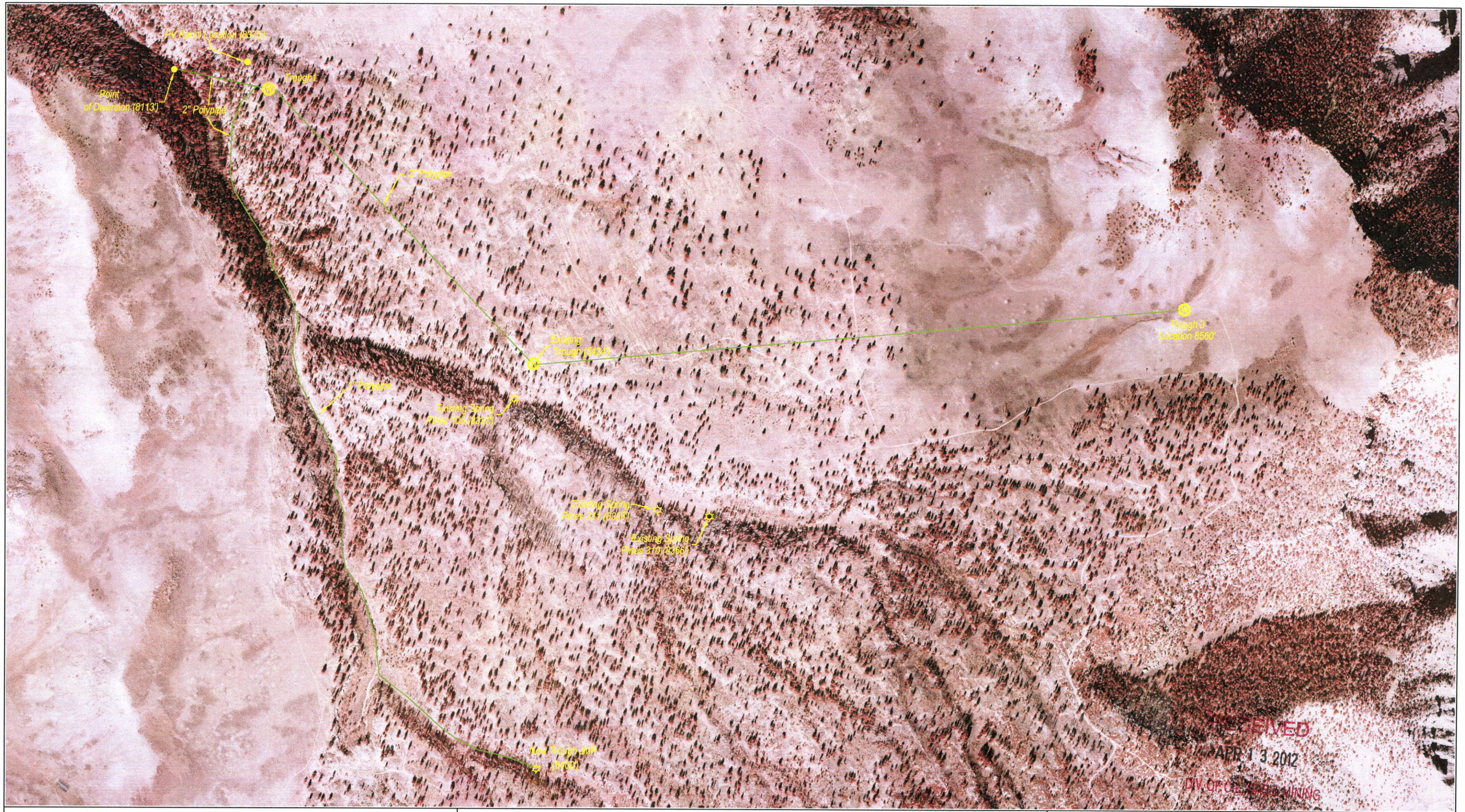
Subsidence Crack & Monitoring Well Locations

SCALE: 1" = 300'	DATE: Sept. 2007	DRAWN BY:K.B.B.	ENGINEER:M.L.D.	CHECKED BY:M.L.D.

FILE NAME: H:\

REVISIONS					SHEET NO.
NO.	DATE	REQ. BY	DWG. BY	REMARKS	1

Figure 2 Locations of piezometers in the Joes Mill area.



Canyon Fuel Company, LLC **SUFCO Mine** 397 South 800 West - Salina, UT 84654 (435) 286-4880 Phone (435) 286-4499 Fax	**East Fork Box Canyon Stock Watering** **Figure 3**			
SCALE:	DATE:10/3/2011	DRAWN BY:F.L.R.	ENGINEER:F.L.R.	CHECKED BY:F.L.R.
FILE NAME: H:\DRAWINGS\MAPSURF\EAST FORK BOX\StockWater\dwg\StockWater2011.dwg				

REVISIONS				
NO.	DATE	REQ. BY	DWG. BY	REMARKS
1	10/03/11	F.L.R.	F.L.R.	

SHEET NO. 1

Attachment A

Results of Well Drilling and Slug Testing of Castlegate Sandstone Bedrock Monitoring Wells in the North Water Canyon and Joes Mill Pond Areas, Canyon Fuel Company, LLC, Sufco Mine C/041/002

Results of Well Drilling and Slug Testing of Castlegate Sandstone Bedrock Monitoring Wells in the North Water Canyon and Joes Mill Pond Areas, Canyon Fuel Company, LLC, SUFCO Mine C/041/002

4 April 2010

Canyon Fuel Company, LLC
Sufco Mine
Salina, Utah

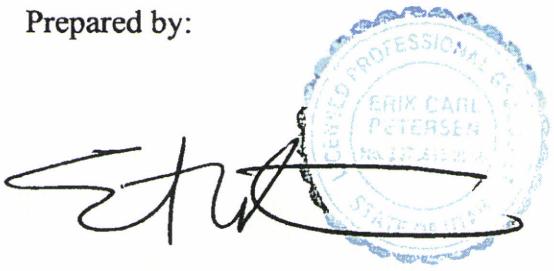
PETERSEN HYDROLOGIC, LLC
CONSULTANTS IN HYDROGEOLOGY

Results of Well Drilling and Slug Testing of Castlegate Sandstone Bedrock Monitoring Wells in the North Water Canyon and Joes Mill Pond Areas, Canyon Fuel Company, LLC, SUFCO Mine C/041/002

4 April 2010

Canyon Fuel Company, LLC
SUFCO Mine
Salina, Utah

Prepared by:



Erik C. Petersen, P.G.
Senior Hydrogeologist
Utah P.G. No. 5373615-2250

PETERSEN HYDROLOGIC, LLC
CONSULTANTS IN HYDROGEOLOGY

2695 N. 600 E.
LEHI, UTAH 84043
(801) 766-4006

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Results of Well Drilling and Slug Testing of

Castlegate Sandstone Bedrock Monitoring Wells

In the

North Water Canyon and Joes Mill Pond Areas,

Canyon Fuel Company, LLC, SUFCO Mine C/041/002

1.0 Introduction

During July and August of 2009, Canyon Fuel Company, LLC commissioned the drilling of five drill holes in the Castlegate Sandstone bedrock in the North Water Canyon and Joes Mill Pond areas overlying their Sufco Mine (Figure 1). The purpose of this drilling program was to further characterize groundwater systems in the Castlegate Sandstone and to evaluate the potential for production of groundwater from the Castlegate Sandstone for use in the mitigation of diminished groundwater flows that have occurred in the area subsequent to undermining and subsidence.

Previous investigations regarding groundwater and surface-water systems and the effects of mining subsidence on the hydrologic balance in the North Water Canyon and Joes Mill Pond areas have been performed. In 2006, Canyon Fuel commissioned Petersen Hydrologic, LLC to perform a hydrogeologic investigation of alluvial and shallow bedrock groundwater systems and subsidence-related impacts in the North Water Canyon and Joes Mill Pond

areas. In January 2007 a report of this investigation, including proposed mitigation activities, was prepared and submitted to the Utah Division of Oil, Gas and Mining. This report is entitled *Investigation of Subsidence-Related Impacts to Groundwater Systems in the North Water and Joes Mill Pond areas and Proposed Groundwater Mitigation Activities, Sufco Mine,* dated 29 January 2007 (Petersen Hydrologic, 2007a).

In November, 2007, an additional hydrologic investigation was performed in the North Water Canyon and Joes Mill Pond areas. A report summarizing the findings of that investigation is entitled: *Report of 2007 Hydrogeologic Field investigations; Supplemental information for the report: Investigation of Subsidence- Related Impacts to Groundwater Systems in the North Water and Joes Mill Pond areas and Proposed Groundwater Mitigation Activities, Sufco Mine,* dated 7 November, 2007 (Petersen Hydrologic, 2007b). This report was also submitted to the Utah Division of Oil, Gas and Mining.

The reader is referred to these documents for additional information on the geologic and hydrogeologic conditions and on the effects of mining-related activities in the North Water Canyon and Joes Mill Pond areas.

The purpose of this investigation is to present the results of the 2009 drilling program and to provide an analysis of the potential to produce groundwater from the bedrock formations underlying the North Water Canyon and Joes Mill Pond areas.

Including this introduction, this report contains the following sections:

- Methods of Study
- Presentation of Data
- Hydrogeologic Conditions
- Conclusions and Recommendations
- References Cited
- Appendices

2.0 Methods of Study

- The well drilling operations were performed by Lang Exploratory Drilling of Salt Lake City, Utah using continuous coring techniques. The five drill holes were drilled using HQ sized drilling equipment and a polymer-based drilling fluid. Drilling supervision and geologic logging of the drilling cores were performed by Mr. Craig Clement of Clement Drilling and Geophysical, Inc. of Cedar Hills, Utah. The drill cores were placed in core boxes and stored at the Salina, Utah offices of Canyon Fuel Company, LLC for future analysis.

- One-inch diameter PVC monitoring wells were installed in each of the five drill holes to allow the monitoring of water levels and for aquifer testing. The construction of the monitoring wells was supervised by Mr. Craig Clement of Clement Drilling and Geophysical, Inc., who is a Utah State licensed water well driller. Subsequent to the

construction of the wells, the wells were developed using surging and bailing techniques.

- Water levels in the five monitoring wells were monitored periodically after their construction using an EnviroTech model 500 water-level meter.

- Slug testing was performed on wells NW1-09, NW2-09, NW4-09, and JMP-09 on 6 November 2009. Slug testing was performed by rapidly introducing water into the well casing. Declining head levels during the slug testing were then monitored using an In-Situ Inc. brand LevelTROLL 500 model pressure transducer/data logger. A preliminary injection test was performed on well NW3-09. However, based on the results of the initial injection test, slug testing was not performed on well NW3-09.

- Slug test results were calculated using methods described by Hvorslev (1951).

3.0 Presentation of Data

The locations of the five Castlegate Sandstone bedrock monitoring wells are shown on Figure 1. A north-south cross-section through the North Water Canyon area is provided as Figure 2. Monitoring well completion data are depicted graphically in Figure 3. Completion information for the five monitoring wells is provided in tabular form in Table 1. Water level measurements for the wells are presented in Table 2. Slug test results are presented in Table 3. Geologic logs of the drill core from the five drill holes are presented in Appendix A.

Calculations and assumptions used in computing the slug test results are provided in Appendix B.

4.0 Hydrogeologic Observations

As indicated on Table 1, the five drill holes range in depth from 168 to 228 feet below the ground surface. Each of these holes penetrates some distance into the Blackhawk Formation, which directly underlies the Castlegate Sandstone in the North Water Canyon and Joes Mill Pond areas. It is noteworthy that the screened intervals for all of the five monitoring wells are all or in part located in the Blackhawk Formation as summarized below.

	Feet of well screen in the Castlegate Sandstone	Feet of well screen in the Blackhawk Formation	Percentage of screen in Castlegate Sandstone	Saturated thickness of Castlegate Sandstone*
NW1-09	0	40	0	1.2
NW2-09	3.8	16.2	19	18.3
NW3-09	0.5	19.3	3	4.5
NW4-09	5	15	25	2.3
JMP-09	11	29	37	7

*Note: Saturated thickness assumes unconfined conditions; water levels measured in November 2009 and February 2010. Figures are approximate.

Slug testing activities performed and the results of the slug tests on the four bedrock monitoring wells tested are summarized below.

It should be noted that while the conditions in the monitoring wells varied, the conditions strictly required to perform valid slug testing were not present in any of the wells. The conditions in the four tested monitoring wells are summarized below.

	Water level above well screen (required for valid test)	Water level above sand pack (required for low-K valid test)	Screened in Castlegate or Blackhawk
NW1-09	Yes	No	Blackhawk
NW2-09	Yes	No	Composite (almost all Blackhawk)
NW4-09	No	No	Composite (mostly Blackhawk)
JMP-09	No	No	Composite (mostly Blackhawk)

It is apparent from the information above that none of the wells met the criteria required for a valid slug test. Conditions at NW1-09 and NW2-09 were invalid because a portion of the sand pack was unsaturated, while the testing of wells NW4-09 and JMP-09 were invalid because an appreciable portion of the sand pack was above the water level and the well screens were partially above the water level. However, slug testing results were calculated for each of these four monitoring wells for general evaluative purposes. It should be noted that under the best of circumstances, slug tests are generally considered useful for making

order-of-magnitude determinations of hydraulic conductivity. Accordingly, this information should be considered in light of the less-than-optimal conditions that existed in the wells. The slug test results should be considered approximations only. Additionally, because of the nature of the completions of the wells (i.e., the well screened intervals are all or mostly in the Blackhawk Formation), it is should be noted that the hydraulic conductivity values reported above are not indicative of conditions in the Castlegate Sandstone.

	Hydraulic Conductivity* (well slotted screen length assumption)	Hydraulic Conductivity* (screen length equals sand pack length assumption)
NW1-09	1.56×10^{-5} cm/sec	8.13×10^{-6} cm/sec
NW2-09	1.41×10^{-4} cm/sec	5.94×10^{-5} cm/sec
NW3-09	Not tested	Not tested
NW4-09	2.11×10^{-4} cm/sec	1.04×10^{-4} cm/sec
JMP-09	2.04×10^{-4} cm/sec	1.55×10^{-4} cm/sec

*Note: As described in previous sections, one or more conditions required for a valid slug test were not present in the wells.

The values of hydraulic conductivity presented above were calculated using the Hvorslev (1951) method. The results listed in the first column were calculated using the assumption that the length of the well screen is equal to the physical length of slotted well screen (commonly assumed when slug testing in high-permeability strata. The results listed in the second column were calculated using the assumption that the screen length equals the total

length of the gravel pack. This assumption is commonly employed when testing low-permeability strata.

The order of magnitude estimates for hydraulic conductivity presented above for wells NW1-09 and NW2-09 are consistent with published values for sandstone bedrock (Freeze and Cherry, 1979). The hydraulic conductivity values for wells NW4-09 and JMP-09 are somewhat greater (near the upper end of the range for sandstone). It seems probable that the hydraulic conductivity values presented for these two wells are less reliable than are the other two wells tested. As depicted in Figure 3, the completion characteristics for these two wells are not favorable for a valid slug test. Additionally, as shown in Appendix B, the response of well JMP-09 during the slug test recovery period did not follow a typical well response pattern.

Based on the information above, it is apparent that there is only a limited thickness of saturated sandstone in the Castlegate Sandstone in the vicinity of the monitoring wells in the North Water Canyon and Joes Mill Pond areas. This observation is important, as it has previously been determined that, while there is a reasonable potential to produce moderate quantities of groundwater from fractured Castlegate Sandstone, there is a much more limited potential to produce useful quantities of groundwater from the Blackhawk Formation. This condition is principally related to the fact that permeable strata in the Blackhawk Formation commonly exist as lenticular, discontinuous sandstone channel deposits. These Blackhawk Formation sandstone channel deposits are typically encased vertically and horizontally by low permeability rocks. Consequently, while individual sandstone channels may be

permeable and contain water (often ancient), the potential for groundwater recharge to these sandstone channel deposits is low. Thus, while wells screened in Blackhawk Formation sandstones may initially yield modest quantities of water, the potential for long-term sustainability of the groundwater source is probably not good. It should be noted, however, that there may be a greater potential to produce groundwater from sandy strata in the uppermost Blackhawk Formation in the North Water Canyon and Joes Mill Pond areas if the sandstone strata directly underlying the Castlegate Sandstone is appreciably fractured.

5.0 Conclusions and Recommendations

Because the conditions in the wells do not satisfy all the requirements for valid slug testing, the results presented here are provided for general purposes only and should be evaluated in light of the limitations of the testing. Additionally, because of the locations of the well screened intervals, the characteristics indicated by the slug tests are generally not indicative of conditions in the Castlegate Sandstone.

The potential for the production of moderate quantities (a few gallons per minute) of groundwater from unfractured Castlegate Sandstone bedrock in the North Water Canyon and Joes Mill Pond areas is considered low. This is because of the limited saturated thickness of Castlegate Sandstone observed in the vicinity of the monitoring wells (from about 1 to 18 feet). If an attempt is made to produce groundwater from the Castlegate Sandston, the area of greatest potential seems to be near well NW2-09, which has the greatest saturated

thickness of Castlegate Sandstone of any of the wells (~18 feet). Because of the likely unsatisfactory long-term performance of a well screened in unfractured Blackhawk Formation rocks, such a production well is not recommended.

Alternatively, if an area of known subsidence fracturing could be intercepted, there may be increased potential for groundwater production from the base of the Castlegate Sandstone or possibly from the uppermost Blackhawk Formation if the strata in the well location were to be appreciably fractured and the fracture network was well interconnected with adjacent areas. The locations of subsidence fractures has been mapped in the area previously by Canyon Fuel Company, LLC (Petersen Hydrologic, 2007b).

4.0 References Cited

Freeze, R.A., and Cherry, J.C., 1979, Groundwater, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 604 p.

Hvorslev, M.J., 1951, Time lag and soil permeability in ground water observations, U.S. Army Corps of Engineers Waterways Experimental Station, Bulletin 36, 50 p.

Petersen Hydrologic, LLC, 2007a, Investigation of subsidence-related impacts to groundwater systems in the North Water and Joes Mill Pond areas and proposed

groundwater mitigation activities, Sufco Mine, unpublished consulting report for Canyon Fuel Company, LLC.

Petersen Hydrologic, LLC, 2007b, Report of 2007 Hydrogeologic field investigations; supplemental information for the report: investigation of subsidence- related impacts to groundwater systems in the North Water and Joes Mill Pond areas and proposed groundwater mitigation activities, Sufco Mine, unpublished consulting report for Canyon Fuel Company, LLC.

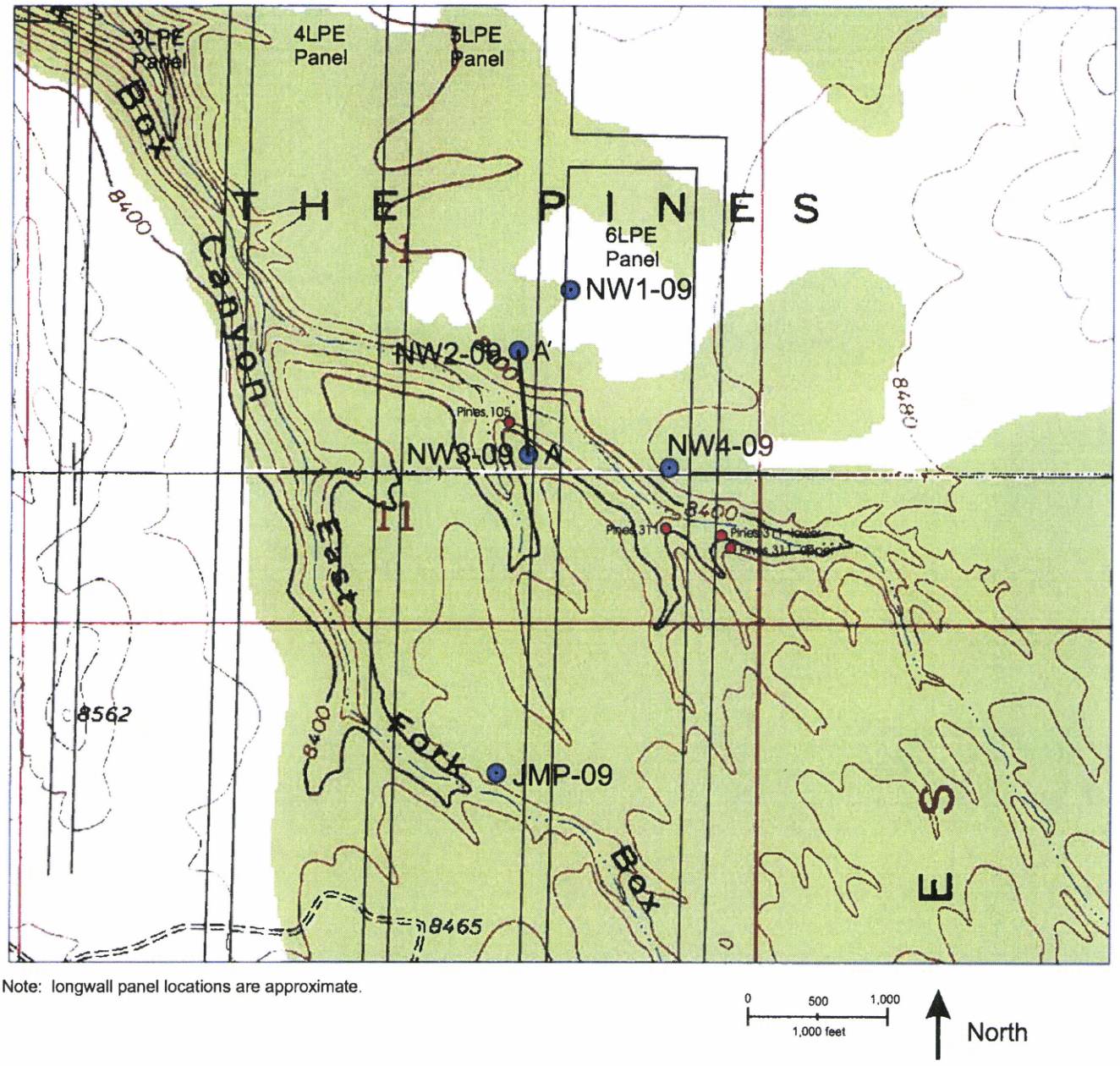


Figure 1 Locations of Castlegate Sandstone monitoring wells in the North Water Canyon area (see Figure X for cross-section A - A').

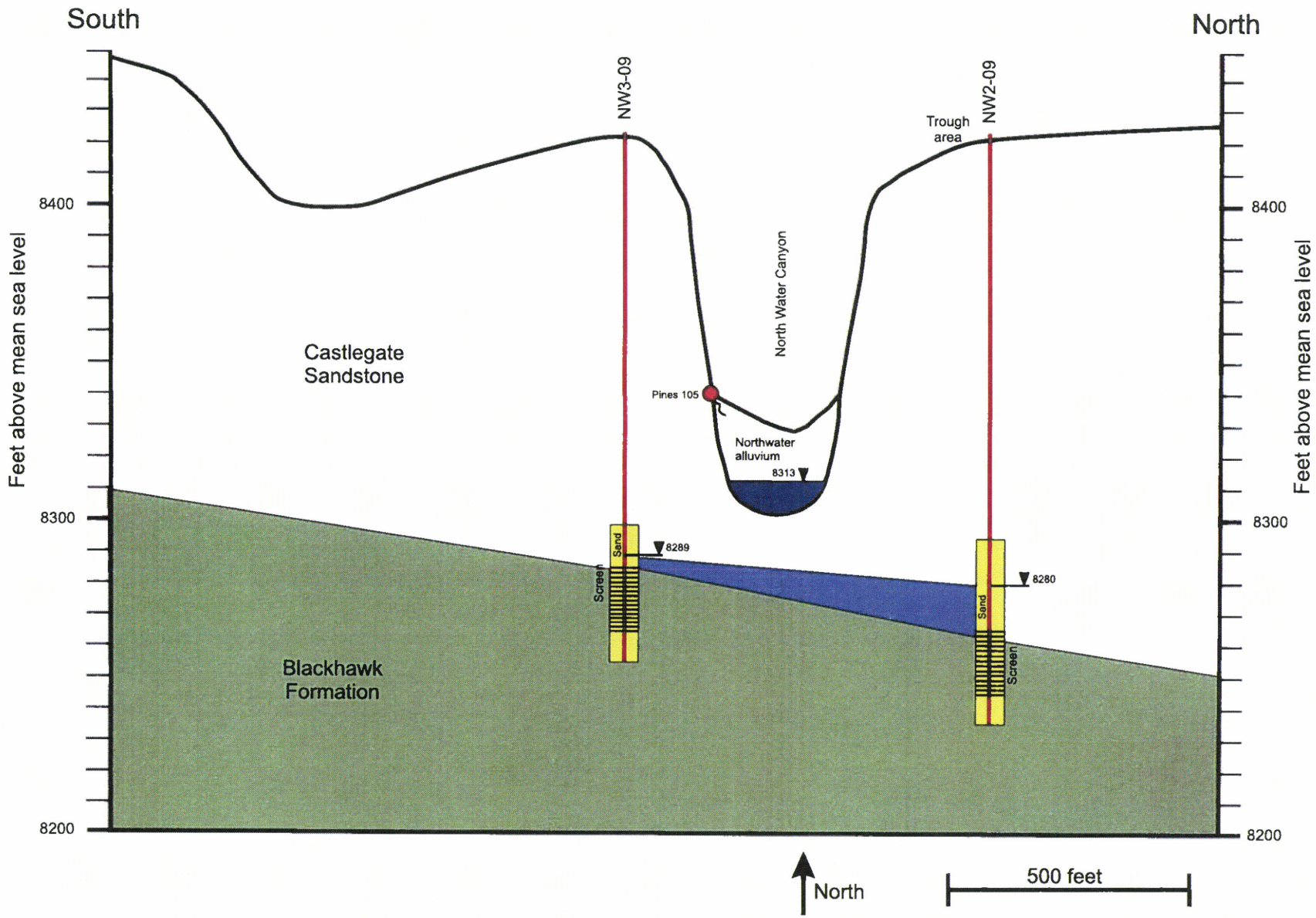


Figure 2 North-south cross-section through the North Water Canyon area (see Figure 2 for cross-section location).

NW2-09

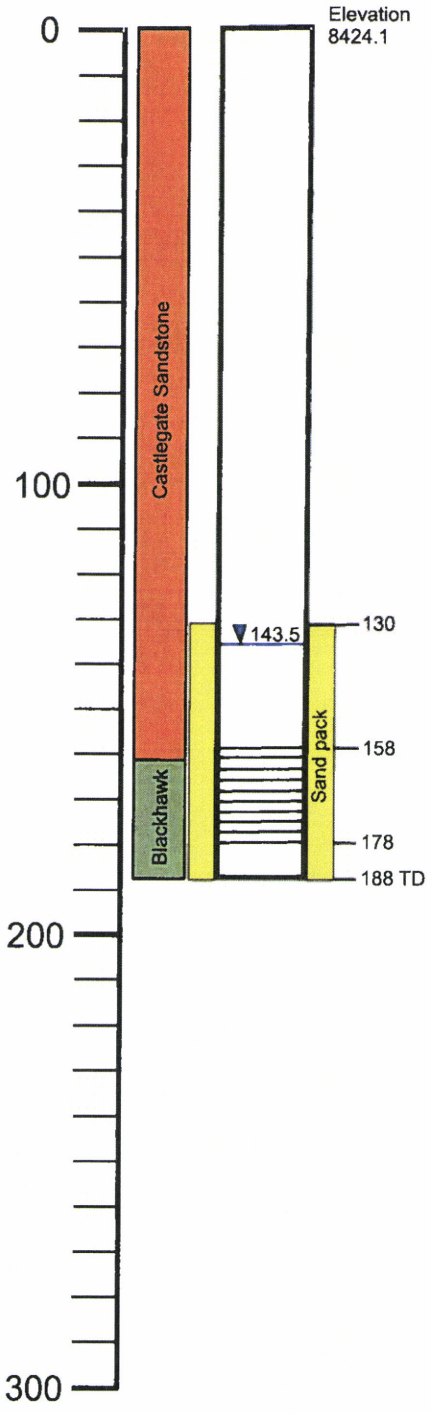


Figure 3b Construction details for NW2-09

NW1-09

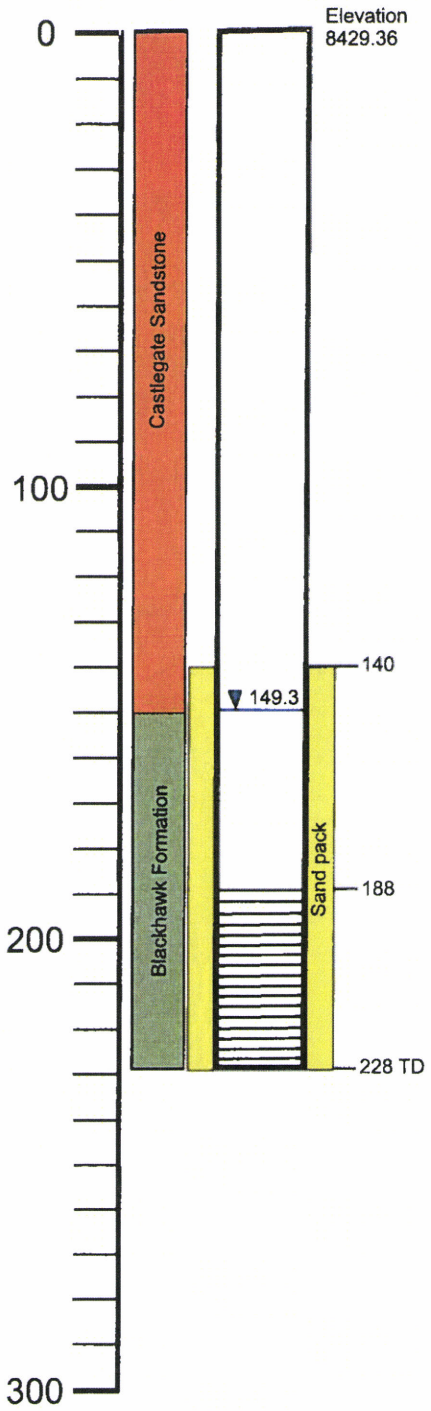


Figure 3a Construction details for NW1-09

NW3-09

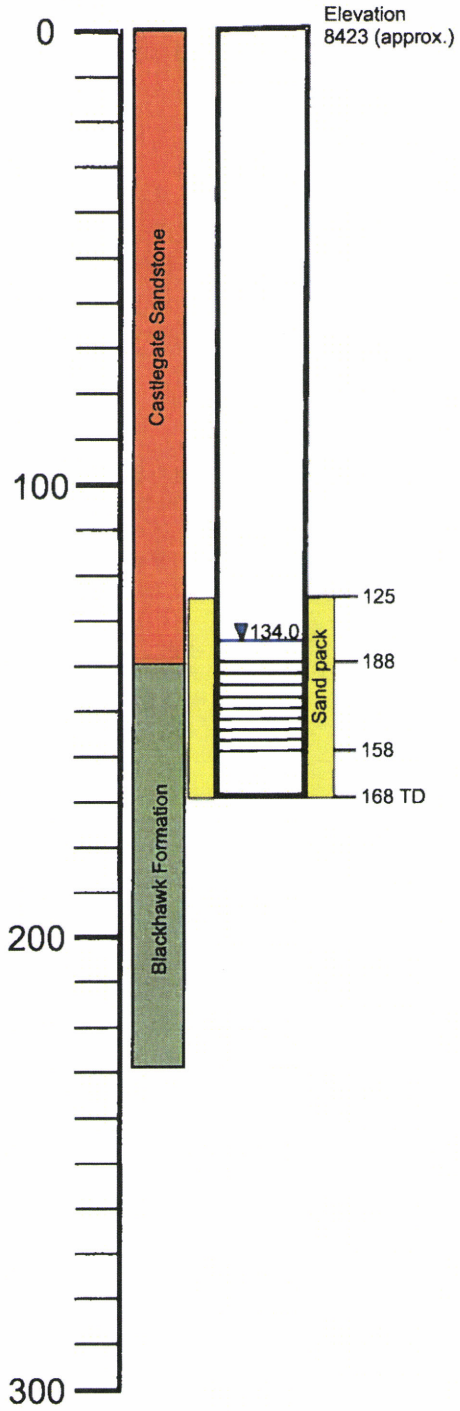


Figure 3c Construction details for NW3-09

NW4-09

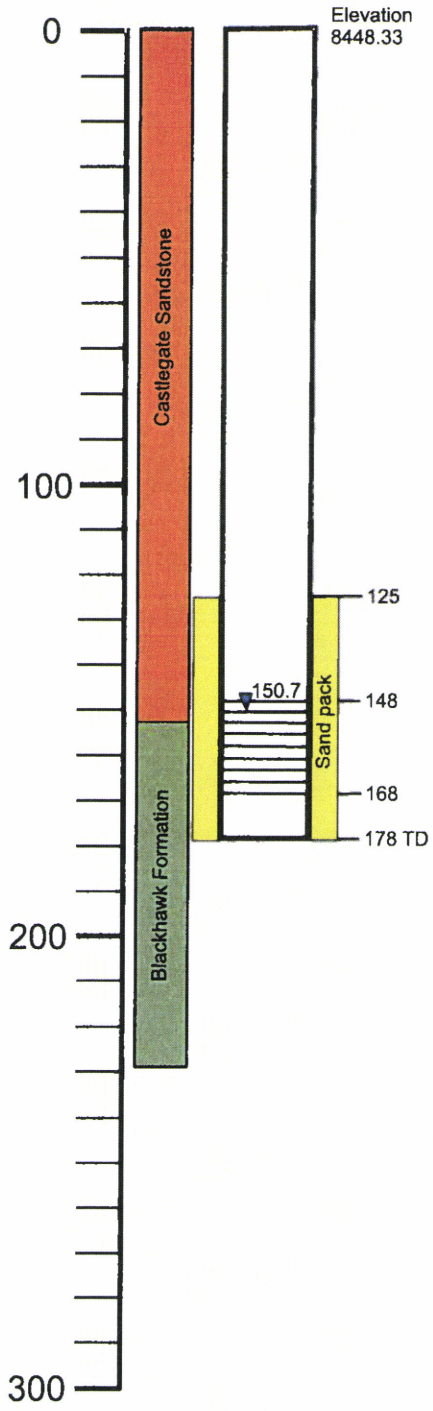


Figure 3d Construction details for NW4-09

JMP-09

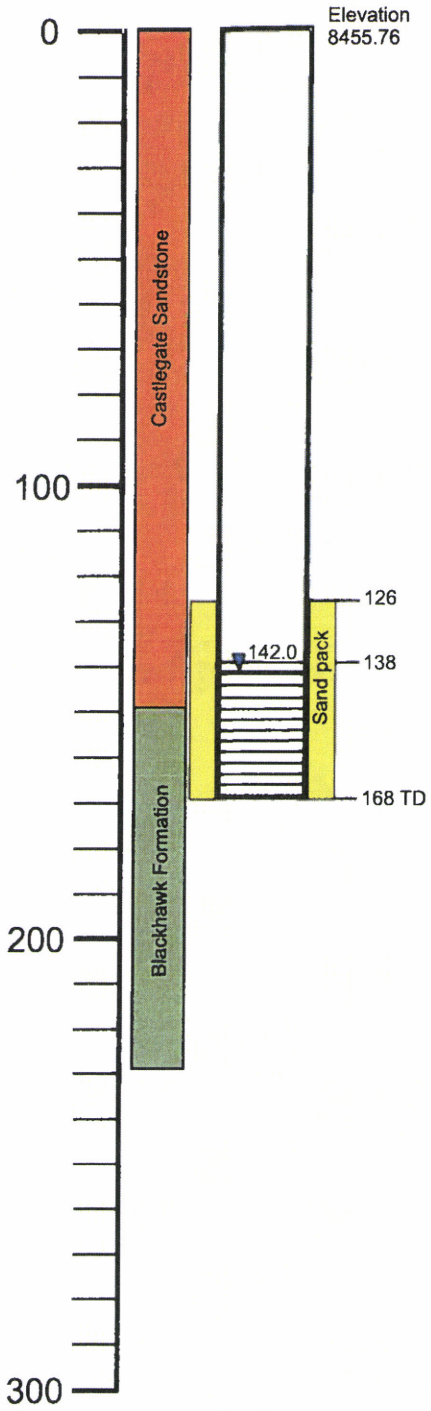


Figure 3e Construction details for JMP-09

Table 1 Completion information for Castlegate Sandstone monitoring wells.

	NW1-09	NW2-09	NW3-09	NW4-09	JMP-09
Well depth (feet below surface)	228	188	168	178	168
Well borehole diameter (feet)	0.333	0.333	0.333	0.333	0.333
Well casing ID (feet)	0.0833	0.0833	0.0833	0.0833	0.0833
Well screen from (feet below ground surface)	188	158	138	148	138
Well screen to (feet below ground surface)	228	178	158	168	168
Well screen length (feet)	40	20	20	20	30
Sand pack from (feet below ground surface)	140	130	125	130	126
Sand pack to (feet below ground surface)	228	188	168	178	168
Sand Pack length (feet)	88	58	43	48	42
Well screen slot size	0.010	0.010	0.010	0.010	0.010
Depth to Castlegate/Blackhawk contact (feet)	150.5	161.8	138.5	153	149
Static water level - 11/09 and 2/10 (feet below top of cas	149.27	143.54	134.02	150.73	142.01

Note: All wells drilled in July and August 2009

Table 2 Water level measurements from Castlegate Sandstone monitoring wells.

	28-Aug-09	11-Sep-09	6-Oct-09	2-Nov-09	4-Nov-09	6-Nov-09	12-Feb-10
NW1-09	148.86	148.21	148.49	148.57	149.27	—	—
NW2-09	143.94	143.07	143.44	143.55	143.45	143.38	—
NW3-09	133.78	—	—	—	—	—	134.02
NW4-09	151.60	150.35	—	150.49	150.41	152.13	—
JMP-09	144.89	149.1	145.11	139.21	138.78	142.01	—

Note: All measurements are in feet relative to top of PVC casing.

Table 3 Slug test results for Castlegate Sandstone monitoring wells.

	Hydraulic Conductivity* (well slotted screen length assumption)	Hydraulic Conductivity* (screen length equals sand pack length assumption)
NW1-09	1.56×10^{-5} cm/sec	8.13×10^{-6} cm/sec
NW2-09	1.41×10^{-4} cm/sec	5.94×10^{-5} cm/sec
NW3-09	Not tested	Not tested
NW4-09	2.11×10^{-4} cm/sec	1.04×10^{-4} cm/sec
JMP-09	2.04×10^{-4} cm/sec	1.55×10^{-4} cm/sec

*Note: One or more conditions required for a valid slug test were not present in each of the tested wells.

Appendix A

Geologic Logs

Appendix B

Slug Testing Information

Appendix A Hvorslev Method slug test calculations.

Hvorslev Equation for slug test:
$K = r^2 \ln (L/R) / 2LT_o$

K = hydraulic conductivity
r = radius of well casing
R = radius of well screen
L = length of well screen
T_o = time it takes for the water level to fall to 37% of the initial change

Assumptions: specified screen length, screen diameter = 4 inches

	r (feet)	R (feet)	L (feet)	T_o (seconds)
NW1-09	0.0417	0.167	40	232
NW2-09	0.0417	0.167	20	45
NW4-09	0.0417	0.167	20	30
JMP-09	0.0417	0.167	30	22.5

Hydraulic Conductivity values (feet/second)

NW1-09	5.13E-07	ft/sec
NW2-09	4.62E-06	ft/sec
NW4-09	6.93E-06	ft/sec
JMP-09	6.69E-06	ft/sec

Hydraulic Conductivity values (centimeters/second)

NW1-09	**1.56E-05**	**cm/sec**
NW2-09	**1.41E-04**	**cm/sec**
NW4-09	**2.11E-04**	**cm/sec**
JMP-09	**2.04E-04**	**cm/sec**

Appendix A Hvorslev Method slug test calculations.

Hvorslev Equation for slug test:
$K = r^2 \ln (L/R) / 2LT_o$

K = hydraulic conductivity
r = radius of well casing
R = radius of well screen
L = length of well screen
T_o = time it takes for the water level to fall to 37% of the initial change

Assumptions: Sand pack = screen length, 4-inch casing diameter

	r (feet)	R (feet)	L (feet)	T_o (seconds)
NW1-09	0.0417	0.167	88	232
NW2-09	0.0417	0.167	58	45
NW4-09	0.0417	0.167	48	30
JMP-09	0.0417	0.167	42	22.5

Hydraulic Conductivity values (feet/second)

NW1-09	2.67E-07	ft/sec
NW2-09	1.95E-06	ft/sec
NW4-09	3.42E-06	ft/sec
JMP-09	5.09E-06	ft/sec

Hydraulic Conductivity values (centimeters/second)

NW1-09	**8.13E-06**	**cm/sec**
NW2-09	**5.94E-05**	**cm/sec**
NW4-09	**1.04E-04**	**cm/sec**
JMP-09	**1.55E-04**	**cm/sec**

Appendix A Hvorslev Method slug test calculations.

Hvorslev Equation for slug test:
$K = r^2 \ln (L/R) / 2LT_o$

K = hydraulic conductivity
r = radius of well casing
R = radius of well screen
L = length of well screen
T_o = time it takes for the water level to fall to 37% of the initial change

Assumptions: Specified screen length, screen diameter = 1 inch

	r (feet)	R (feet)	L (feet)	T_o (seconds)
NW1-09	0.0417	0.167	88	232
NW2-09	0.0417	0.167	58	45
NW4-09	0.0417	0.167	48	30
JMP-09	0.0417	0.167	42	22.5

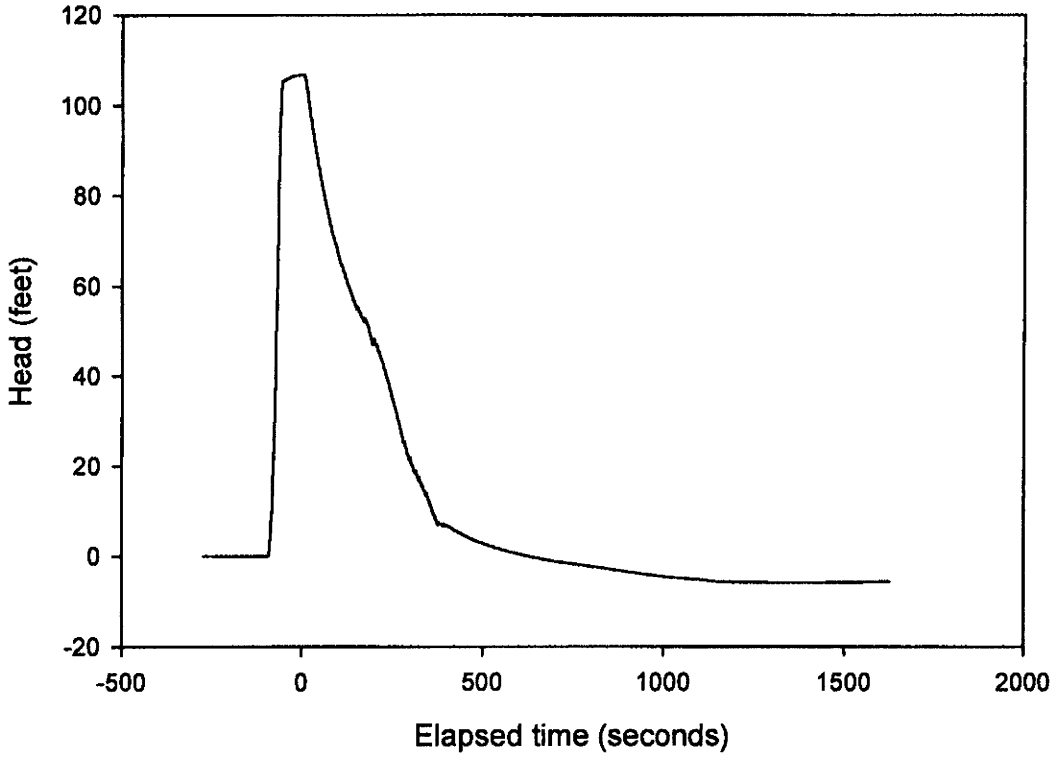
Hydraulic Conductivity values (feet/second)

NW1-09	2.67E-07	ft/sec
NW2-09	1.95E-06	ft/sec
NW4-09	3.42E-06	ft/sec
JMP-09	5.09E-06	ft/sec

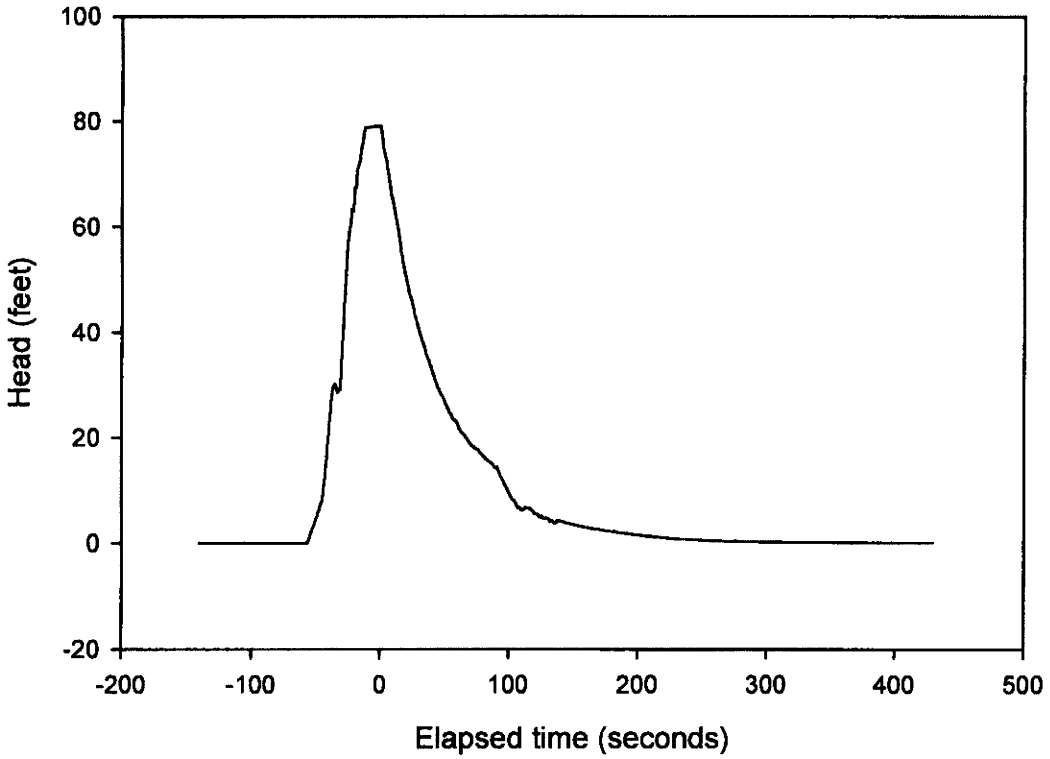
Hydraulic Conductivity values (centimeters/second)

NW1-09	**8.13E-06**	**cm/sec**
NW2-09	**5.94E-05**	**cm/sec**
NW4-09	**1.04E-04**	**cm/sec**
JMP-09	**1.55E-04**	**cm/sec**

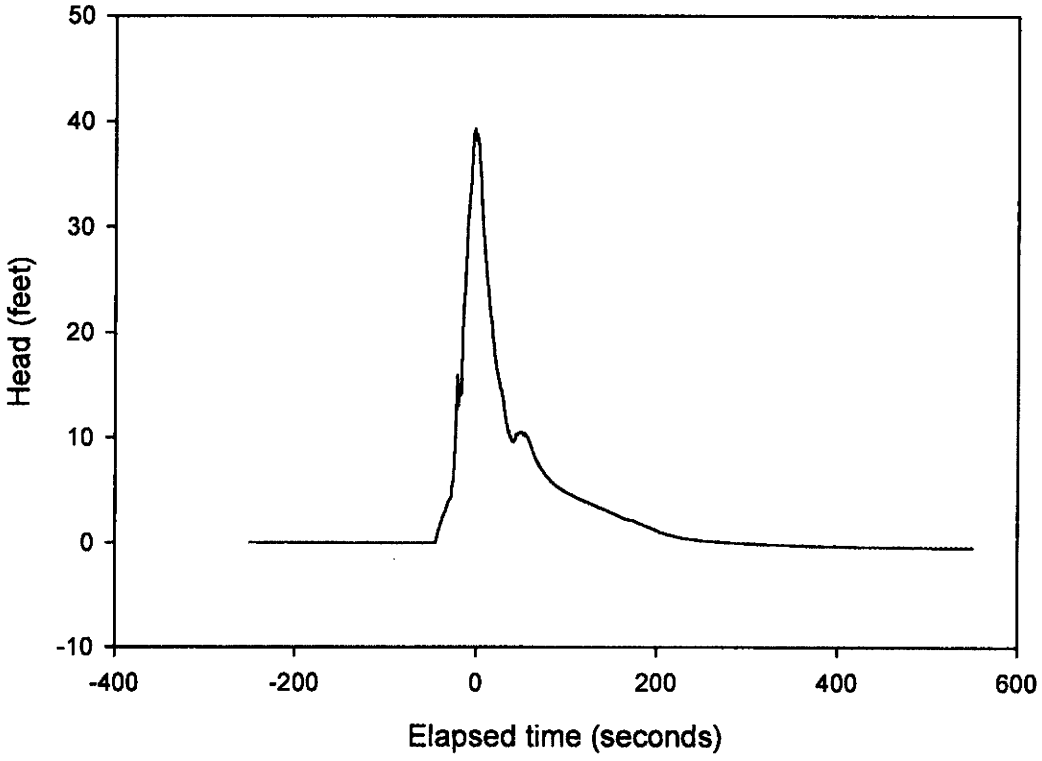
NW1-09 Slug Test



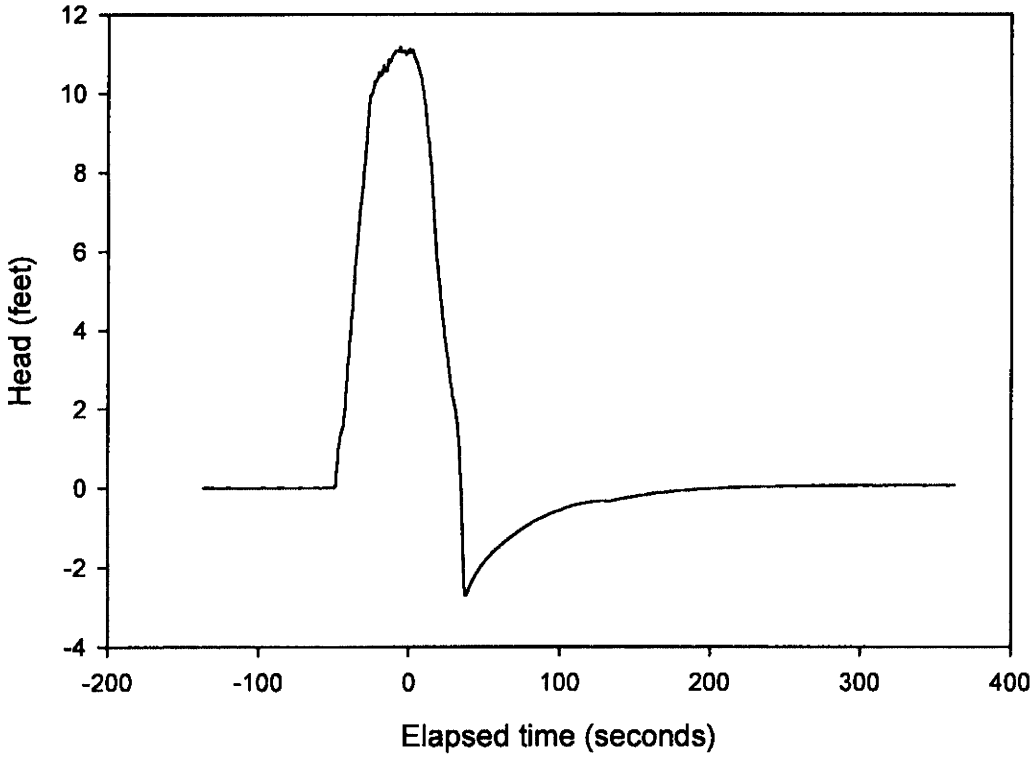
NW2-09 Slug Test



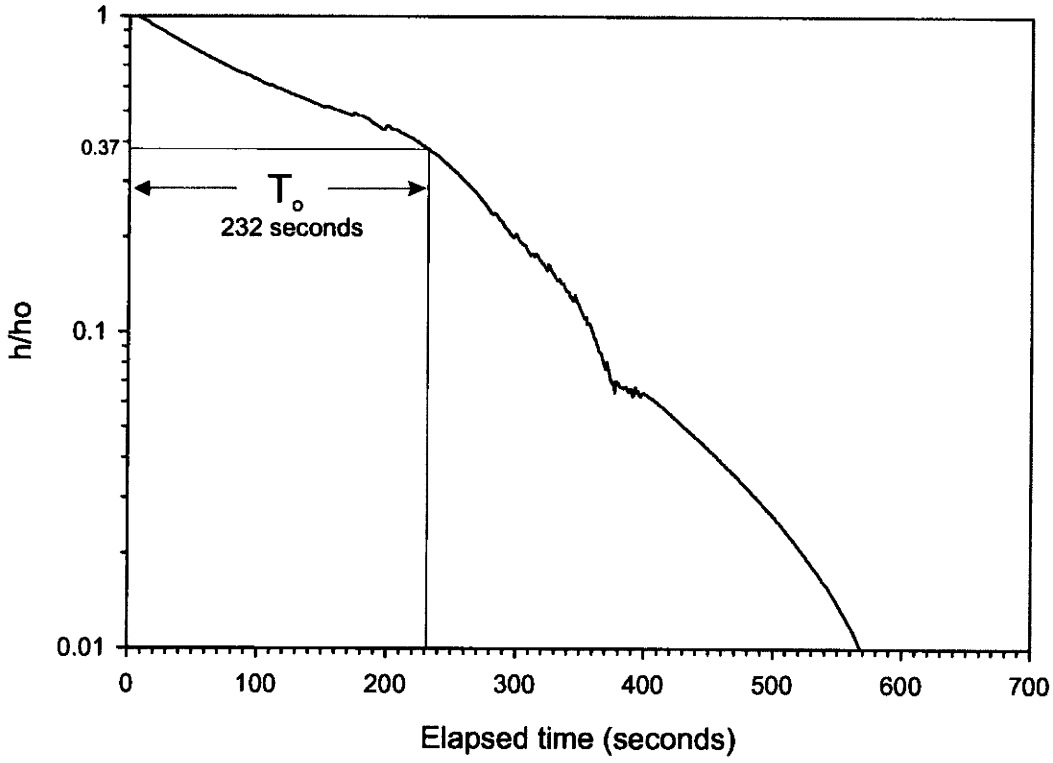
NW4-09 Slug Test



JMP-09 Slug Test



NW1-09 Hvorslev h/ho plot



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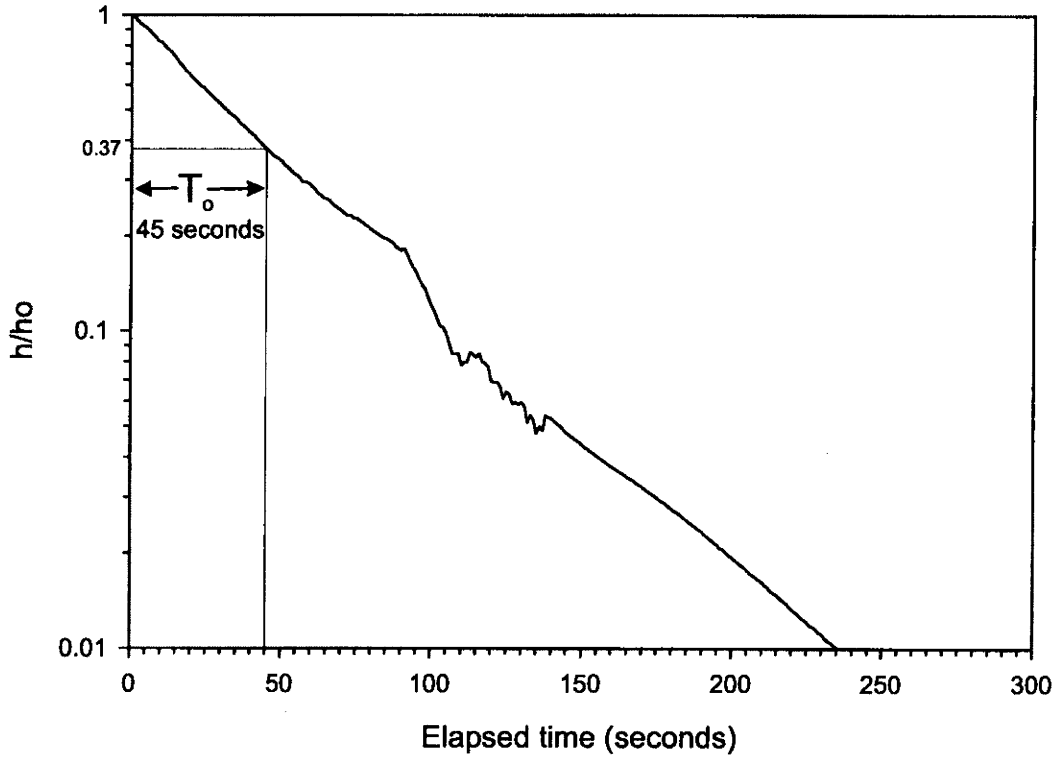
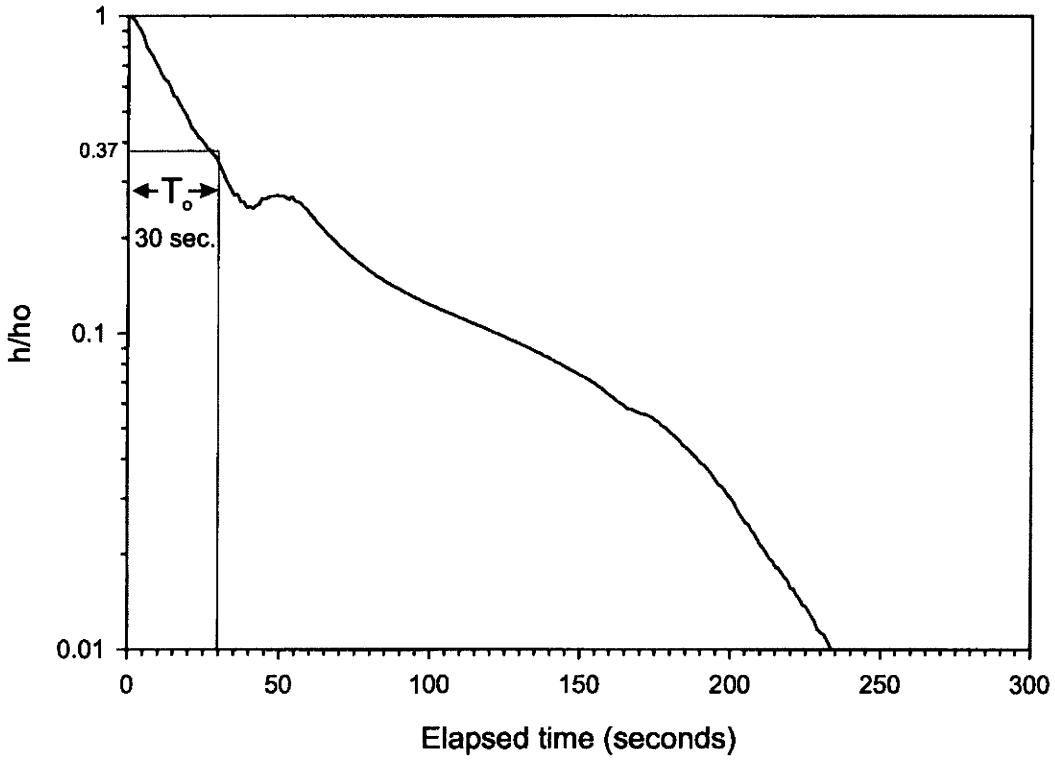


NW4-09 Hvorslev h/ho plot



JMP-09 Hvorslev h/ho plot