Oil & Natural Gas Technology

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Quarterly Report

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Water-related Issues Affecting Conventional Oil and Gas Recovery and Potential Oil-Shale Development in the Uinta Basin, Utah

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Office of Fossil Energy

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EXECUTIVE SUMMARY

Various data collection activities for all areas of the Utah Geological Survey's (UGS) Uinta Basin water project are nearly complete. The focus will now shift towards synthesizing all the collected data, creating a wide variety of maps and figures, and forming preliminary conclusions. The main research tasks are all on schedule and should provide valuable insights into the water disposal issues facing the Uinta Basin.

Data collection associated with Task 2 is now complete. The water chemistry database has over 2500 unique analyses from over 1400 wells. These data are invaluable as "ground truth" to aid in the mapping of aquifer salinity throughout the basin. In addition, the Task 2 team leader has picked the base of the moderately saline aquifer in all 258 selected wells, using digitized geophysical logs to calculate down-hole salinities. With the data collection complete, the team will focus on creating maps and regional cross sections during the next quarter.

The Task 3 team has analyzed the Birds Nest zone in over 250 wells and has mapped the aquifer's areal extent in central Uintah County. This first-of-its-kind map will greatly aid in determining potential Birds Nest aquifer saline water disposal areas. The Principal Investigator (PI) has also finished examining core containing the Birds Nest zone, which provides crucial ground truth to interpret the geophysical logs from wells lacking core. During the next quarter, the team plans to continue mapping various aspects of the Birds Nest aquifer, including detailed isopach maps for each zone.

PROGRESS, RESULTS, AND DISCUSSION

Task 1.0: Project Management Plan

During the month of January, the PI wrote and submitted the project's ninth quarterly report for the period October through December 2010. This report was subsequently sent via email to all interested parties and posted on the UGS project Web site.

Task 2.0: Moderately Saline Aquifer Study

One of the most important steps in accomplishing the goals of Task 2 was to collect as many water chemistry analyses as possible from wells in the Uinta Basin. Through March 2011, the team collected 2555 individual water analyses from 1407 different wells (figure 1). This information has been collected from a variety of sources including oil and gas operators (729 analyses), Utah Division of Oil, Gas, and Mining (DOGM) well files (404 analyses), UGS databases (1251 analyses), U.S. Geological Survey databases (103 analyses), and other publications (68 analyses). About 70 additional water chemistry analyses were recently received and will be added to the database in the next quarter.

A significant Task 2 milestone was reached in March; the Task 2 team leader finished picking the stratigraphic location of the base of the moderately saline aquifer (BMSA) in all 258 selected wells (figure 2). This process was made much easier thanks to the donation of 70% of the needed digital geophysical log files (LAS files) (figure 2). In fact, 26 companies donated LAS files from a total of 697 wells (table 1; many companies donated more LAS files than requested). The geophysical logs from the remaining 30% of selected wells were either digitized in-house (14 wells) or purchased

Table 1. *Number of donated LAS files by company.*

Company	# of LAS files
Questar	317
Newfield	102
Enduring	75
Anadarko	52
El Paso	24
Wind River	22
Bill Barrett	18
EOG	17
Berry	15
Gasco	15
Rosewood	7
FIML	6
Devon	5
Mustang Fuel	4
Whiting Petroleum	3
Forest	3
Flying J	2
Royale	2
Anschutz	1
Bayless	1
Pendragon	1
BT Operating	1
JW Operating	1
Elk Resources	1
McElvain	1
Summit Operating	1
Sub-total	697
Digitized by UGS	14
Purchased	66
Total	777

from a third party vendor (66 wells).

With the log interpretations complete, the next step will be to draft a map showing the depth to the BMSA throughout the Uinta Basin. The mapping effort will incorporate the collected water chemistry data with the interpreted geophysical logs to construct the most accurate map possible. A draft map should be completed by the end of the next quarter.

In order to add a third dimension to the mapping effort, wells were selected for the construction of five regional cross sections, two north-south sections and three east-west sections (figure 1). These cross sections will highlight the general geology, water-bearing formations, formations that act as seals, and the level of the BMSA.

An Access database has been populated with all the incoming data, facilitating its manipulation and retrieval. The database will continue to be updated as new data are acquired from operators or generated by project researchers.

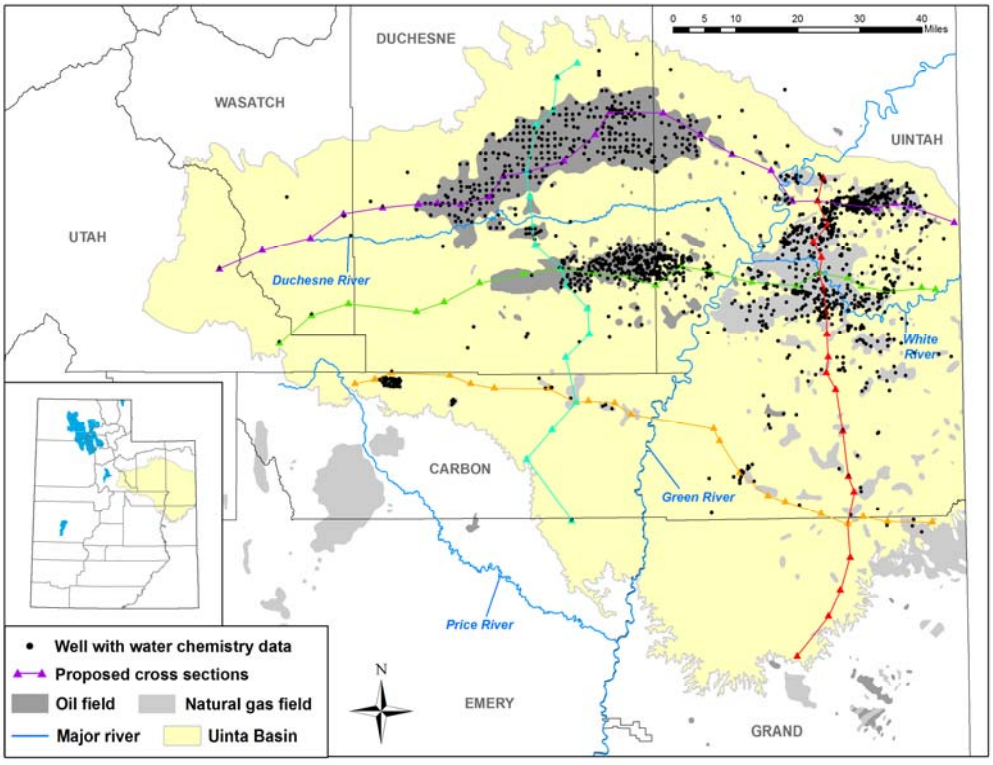

Figure 1. *Location of wells in the Uinta Basin with available water chemistry data.*

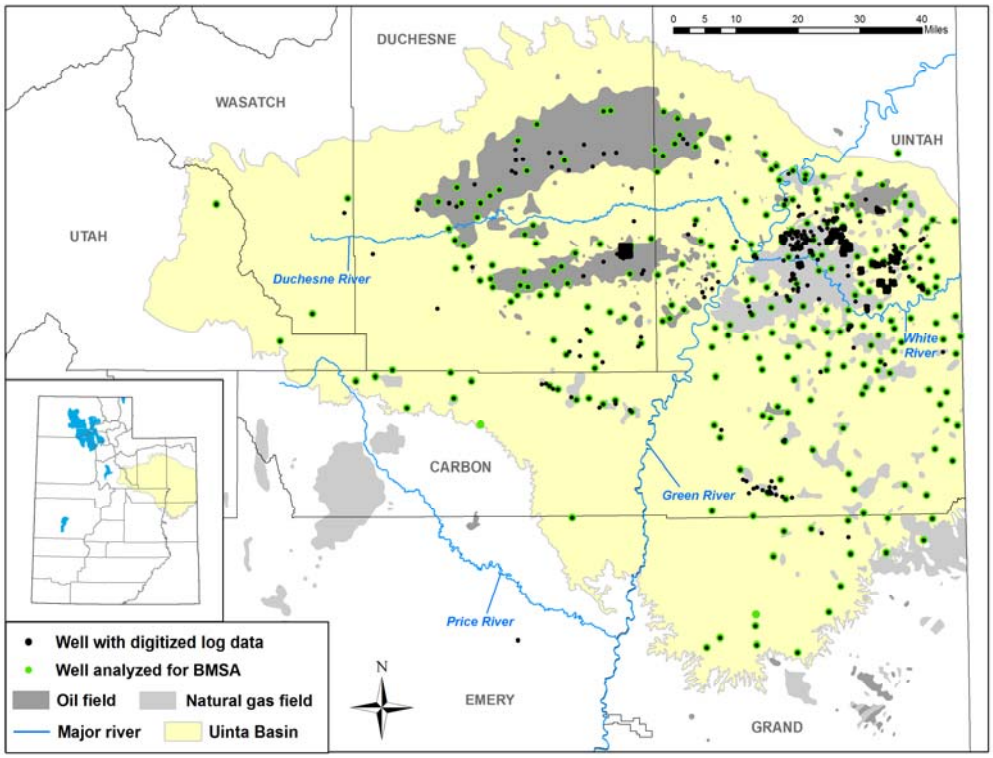

Figure 2. *Location of wells in the Uinta Basin with donated digital geophysical logs and wells evaluated for the base of the moderately saline aquifer.*

Task 3.0: Geologic Examination of the Birds Nest Aquifer

The Task 3 team evaluated geophysical logs from 237 wells in order to map the areal extent of the Birds Nest aquifer with potential for large-scale saline water disposal. This oval-shaped area, representing the depocenter of Eocene Lake Unita, is defined by the presence of large saline mineral nodules and thin beds recorded on geophysical logs as spikes to low density in two distinct zones (figure 3).

As ancient Lake Uinta began to recede, its waters became hyper-saline, depositing large saline nodules and thin saline mineral beds, ~100 feet thick, forming the more extensive and thicker lower Birds Nest zone (figure 4, 5, and 6). An influx of fresh water, represented by volcaniclastic debris flows recorded in rocks on the east side of the basin (Horsebench Sandstone), decreased the lake's salinity for a period of time, greatly reducing saline mineral deposition (figure 5). However, as the lake continued to shrink, it once again returned to its hyper-saline state, depositing a less extensive, ~40-foot thick, upper Birds Nest zone centered farther to the west than the lower zone (figure 4). The isopach map displayed in figure 7 represents the thickness of the Birds Nest as picked from the base of the lower zone to the top of the upper zone. The Task 3 team is currently creating independent isopach maps for both the upper and lower zones, which will be included in the next quarterly report.

The examination of bulk density logs for evidence of large saline nodules shows a very distinct boundary around the ancient lake's depocenter (figure 3). However, as evident from core and outcrop descriptions south of this area (and closer to the lake's shallower margin), the large nodules of the Birds Nest zone transition into a zone of small saline mineral crystals not recognized by the bulk density log (figure 6). There is evidence of saline mineral dissolution within these small saline crystals; however, this area lacks the large amounts of open space seen in areas to the north and thus has little potential for saline water disposal. Given that these deposits represent an ancient lake basin, it is assumed that a continuous

concentric zone of smaller saline mineral crystals also exists to the north and west of the ancient depocenter, but this can not be confirmed due to lack of core.

As stated above, the area shown in figure 3 represents where large saline nodules exist in one or two zones; however, other limitations exist as to where saline water disposal could take place. First, produced water can only be disposed into an aquifer that currently has water with greater than 10,000 ppm of total dissolved solids (TDS). Water chemistry analyses from the Birds Nest aquifer reveal a distinct southwest-northeast trending line, north of which the Birds Nest water is greater than 10,000 ppm TDS, and south of which the water is less than 10,000 ppm TDS (figure 3). Therefore, no produced water disposal can take place south of this line. With beds dipping to the northwest, it is thought that the southern area of the Birds Nest aquifer has essentially been flushed clean of saline minerals, but north of the 10,000 ppm TDS line, active dissolution is still taking place. Second, the Birds Nest aquifer is only present where saline mineral dissolution has already taken place, creating the needed porosity and permeability for water transmission. North of the 10,000 ppm TDS line, there is evidence that pods of no dissolution still exist, as seen in the Utah State 1 core; while these areas are poorly defined, they could have significant impacts on the overall potential areas suitable for water disposal.

The Task 3 team also created an isopach map showing the thickness of the "interburden" between the base of the Birds Nest aquifer and the top of the economic oil shale deposits, picked at the top of the Big 3 oil shale beds (figure 8, see also figure 4, 5, and 6 for lithologic logs). There is concern that large volumes of water disposed within the Birds Nest zone could impact future potential oil shale development. The thicker the interburden, which is made up of impermeable lean oil shale, the less likely water could travel vertically down to the rich oil shale beds. However, fractures or possibly gilsonite veins could act as vertical conduits for water flow between these two otherwise hydraulically-isolated zones. Current oil shale development is concentrated close to the oil shale outcrop areas, southeast and up-dip of current Birds Nest water disposal. However, future underground mining or in-situ oil shale development could be located closer to the basin's paleo-depocenter, near current disposal activities. Underground mining efforts would most likely focus on the Mahogany zone, ~230 feet below the Big 3 oil shale beds. The next quarterly report will include an isopach map of the "interburden" between the base of the Birds Nest zone and the top of the Mahogany zone.

In addition to the mapping efforts of the past quarter, the Task 3 team leader traveled to the USGS Core Center in Denver, CO to describe the five additional cores containing the Birds Nest aquifer (P-3, X-13, 14X-34, 14-36, and Red Wash 1). Only two wells from the 22 total remain undescribed; Skyline 16, which will be described in early May 2011, and the DP core, which will not be examined due to its very close proximity to the X-13 core and its lack of availability. The Task 3 team is in the process of creating individual core logs for each well which will include sediment descriptions, available geophysical logs, available Fischer assay oil yield data, and lithologic units (named formations, oil shale zones, etc.). These descriptions act as critical ground truth for geophysical log data from wells lacking core.

Task 4.0: Baseline Water Quality and Quantity GIS Database

No work on this task was performed during this quarter. The final round of water sampling will take place in May and June 2011.

Task 5.0: Integration of Analysis of Produced Water from Simulated In-situ Oil Shale Extraction Technologies

Researchers in the Department of Chemical Engineering at the University of Utah have completed laboratory experiments simulating in-situ oil shale extraction with two overall objectives in mind: (1) determine the presence and species of dissolved organics in the water phase post-pyrolysis, and (2) determine the effect of the presence of water on retorting and its products. Several experiments were conducted including water-soaked pyrolysis experiments on powdered and whole-rock samples, hydrous pyrolysis experiments at different temperatures, and analysis of water-phase products from non-hydrous pyrolysis experiments. Preliminary results indicate that very little water is released during the retorting of Utah oil shale, thus reducing the potential for large volumes of water needing disposal during

commercial-scale in-situ retorting. Also, in the laboratory experiments, any water that was produced contained only very low to non-detectable amounts of organic components, reducing the likelihood of severe aquifer contamination.

A detailed report is currently being prepared by Dr. Milind Deo and his graduate students and a summary of this report will be included in the next quarterly report.

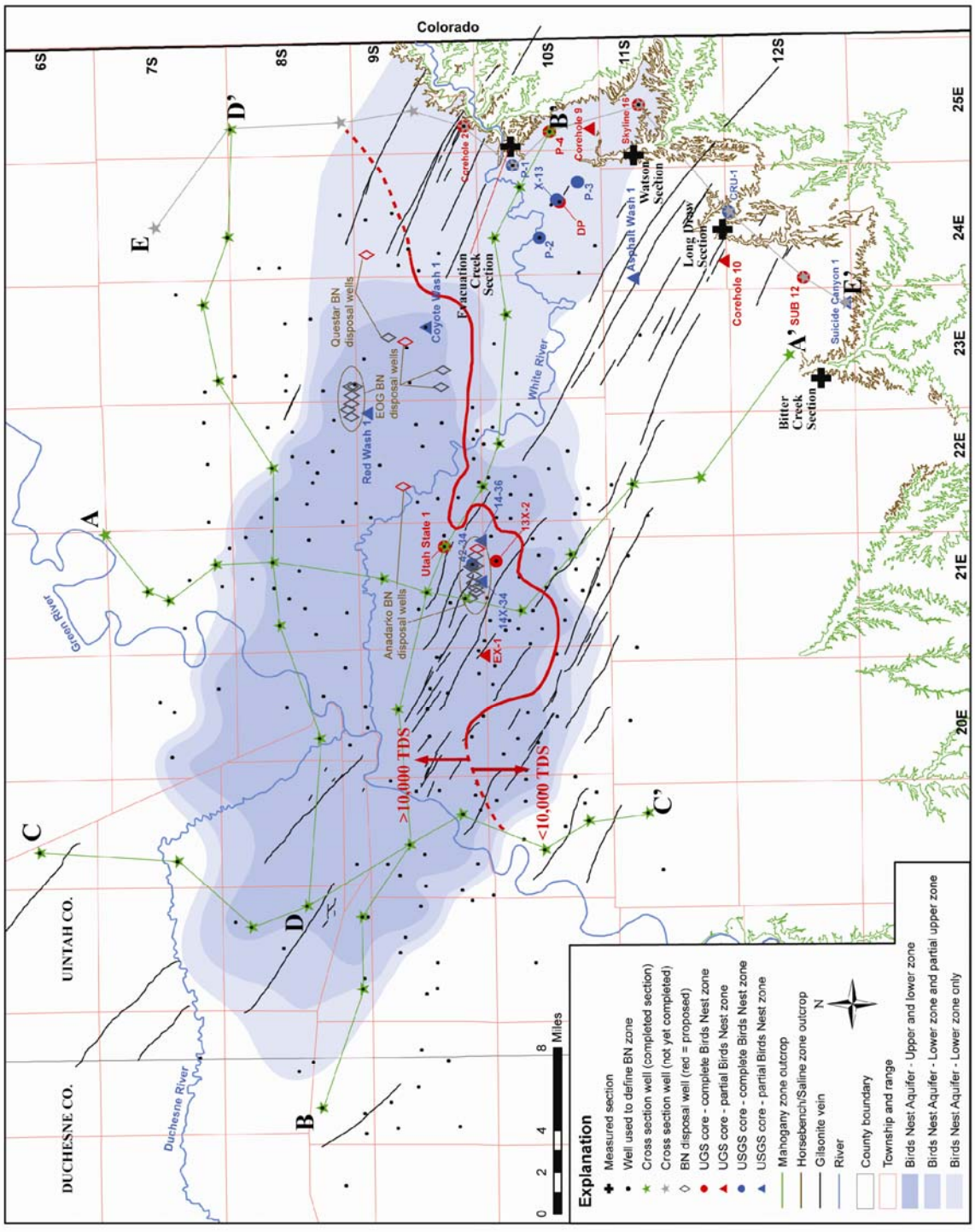

Figure 3. *Areal extent of the Birds Nest aquifer with potential for saline water disposal (location of large saline nodules or beds) as determined using geophysical logs. Dark blue represents the area where both an upper and lower Birds Nest zone exist, medium blue represents an area with the lower zone but only a partial upper zone, and the lightest blue represents an area where only the lower zone exists. Four cross sections have been constructed to illustrate the aquifer's spatial and stratigraphic extent (A-A' and B-B' are available on the 2010 AAPG poster, C-C' and D-D' are available on the 2011 AAPG poster, and E-E' has yet to be constructed).*

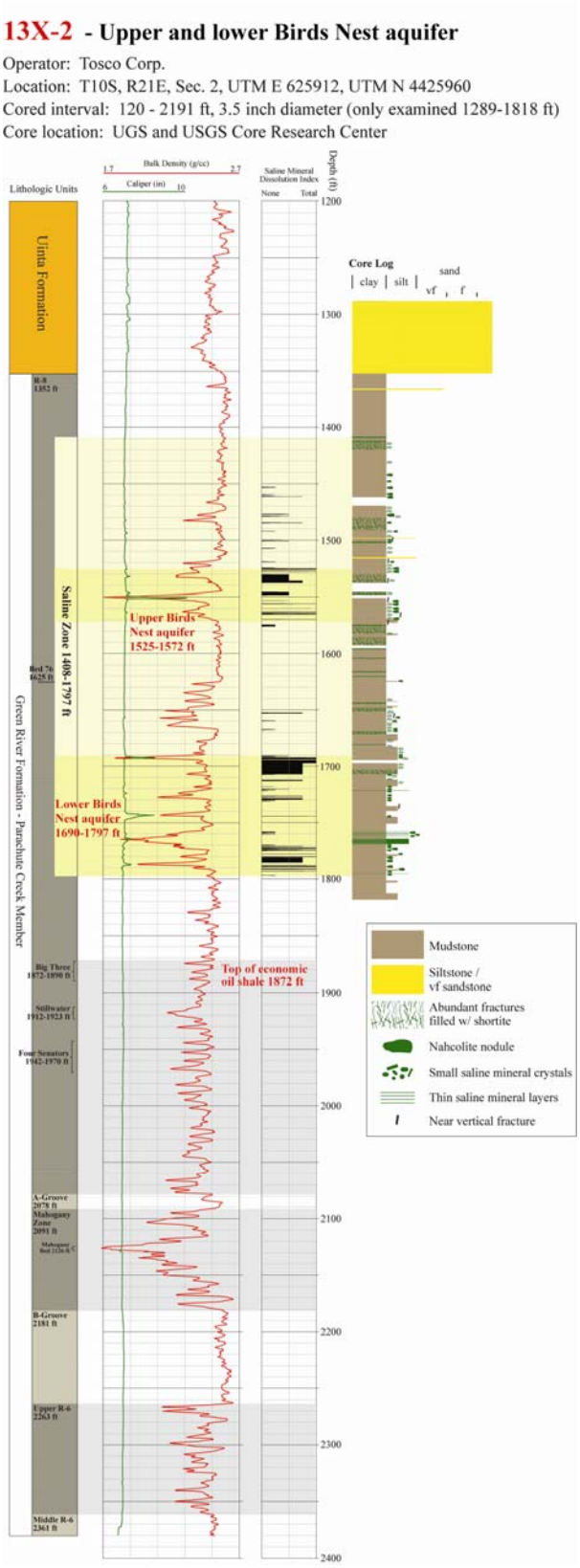

Figure 4. *Core log for the 13X-2 well (location noted on figure 3) showing the upper and lower Birds Nest zone typical of wells in this area. Note that the Birds Nest aquifer lies within a thicker sequence of saline minerals mostly too small to be recognized on the bulk density log.*

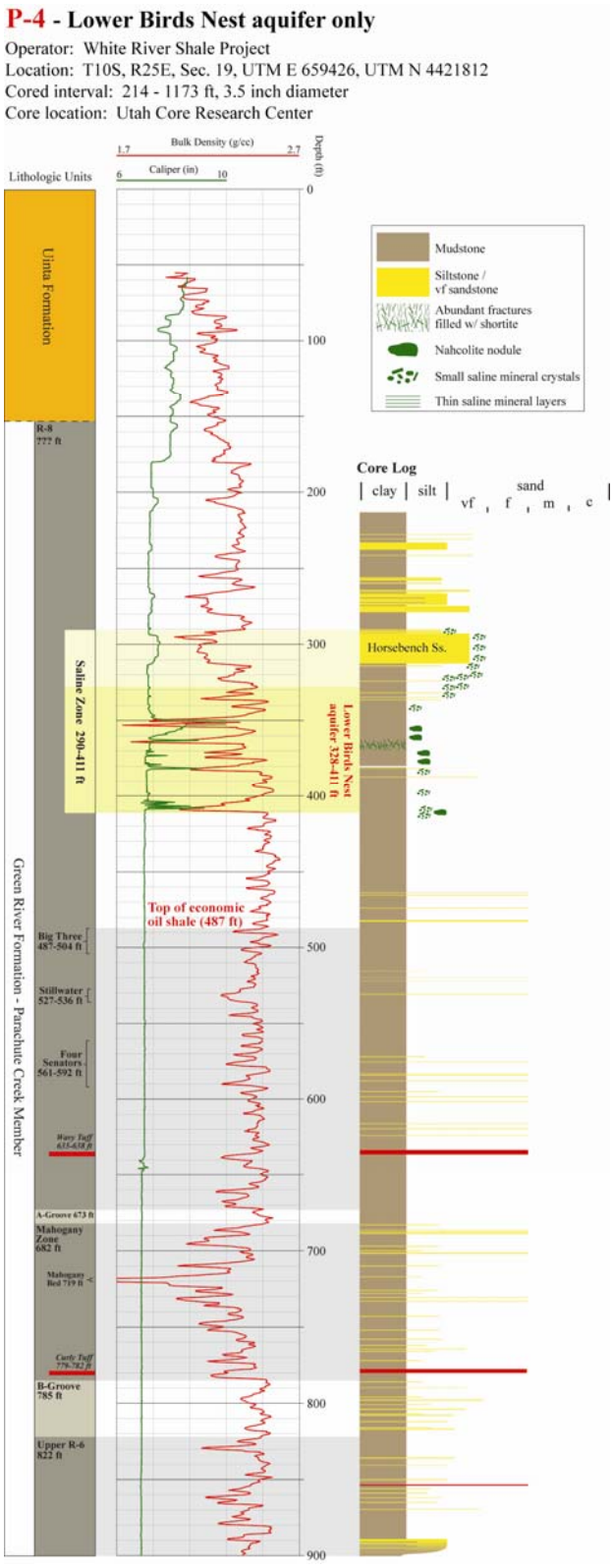

Figure 5. *Core log for the P-4 well (location noted on figure 3) showing only the lower Birds Nest zone. An influx of fresh water represented by volcaniclastic debris flows (e.g., Horsebench Sandstone) created a localized freshening of the lake, shutting off saline mineral deposition.*

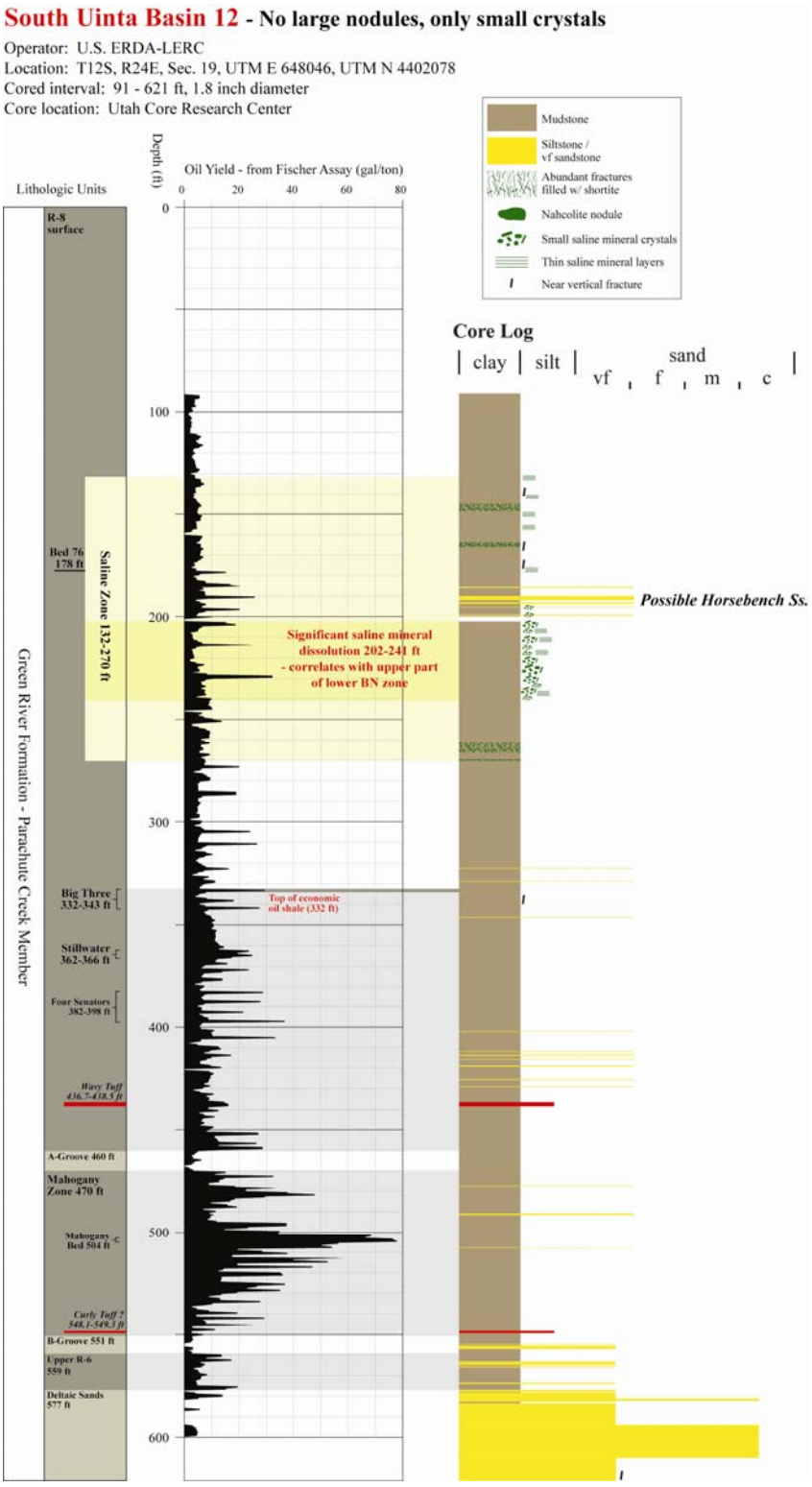

Figure 6. *Core log for the SUB 12 well (location noted on figure 3) showing the thinner sequence of small saline mineral crystals, roughly correlated with the lower Birds Nest zone, found in the southern portion of the basin.*

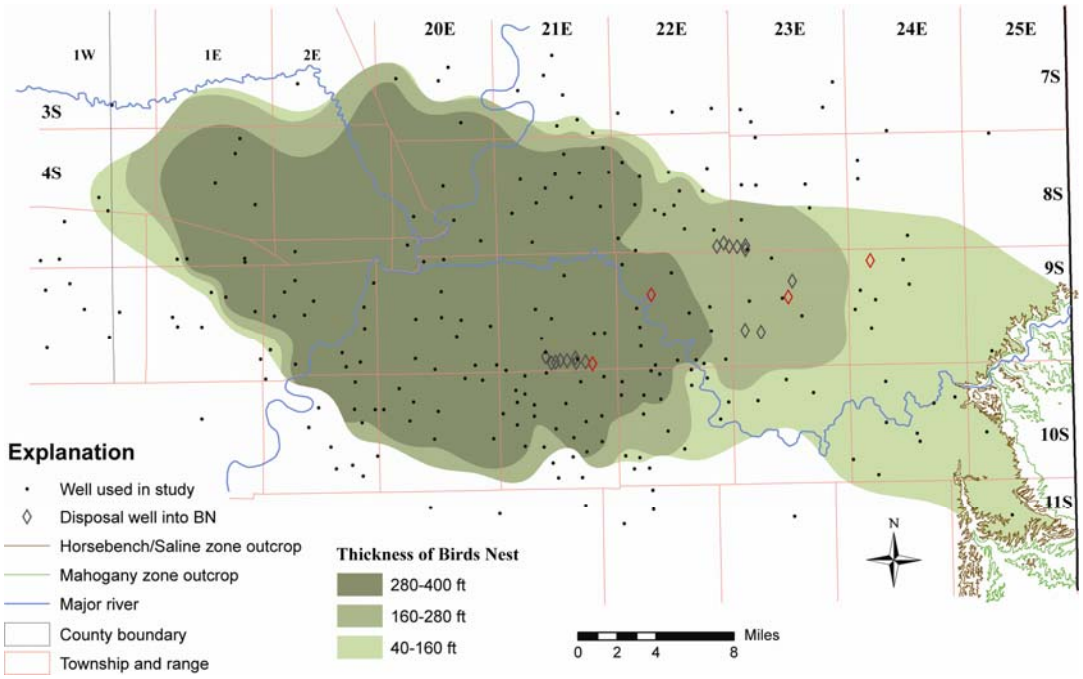

Figure 7. *The Birds Nest aquifer isopach displayed on this map is measured from the base of the lower zone to the top of the upper zone (if present). Where both zones exist, the thickness ranges up to 400 feet; however, where only the lower zone is present (mainly to the east), the thickness drops to between 40 and 100 ft. This map only records where large saline mineral nodules/beds are present based on geophysical logs and core descriptions; the dissolution of such nodules creates the space for potential larg- scale water disposal.*

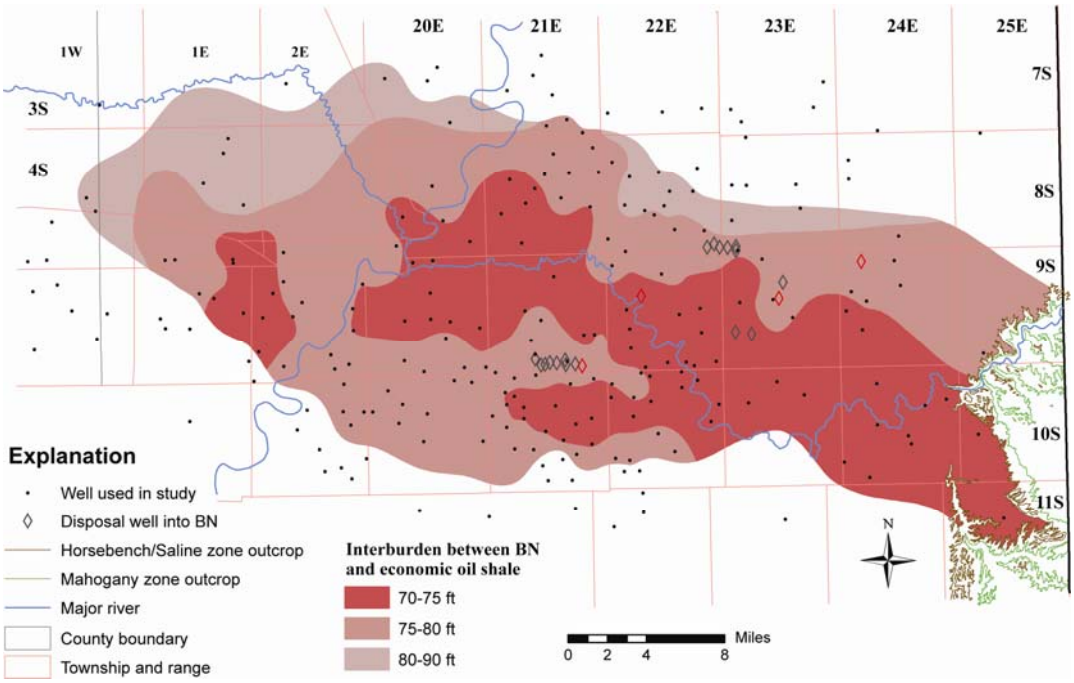

Figure 8. *Interburden from the base of the Birds Nest aquifer (between 70 and 90 ft) to the top of economic oil shale, picked at the top of the Big 3 oil shale beds. Saline water disposal could impact development of the underlying oil shale if vertical migration of water occurs via fractures or joints.*

Task 6.0: Technology Transfer

- The PI and other team members attended the quarterly Uinta Basin Oil and Gas Collaborative Group meeting in Vernal, UT on January 13, 2011 and discussed the project with interested attendees.
- The UGS hosted a Year-2 Review meeting in Vernal, Utah in the beginning of January. Roughly 35 individuals from local oil and gas companies, government agencies, and academia attended the meeting either in person or via teleconference. After a brief introduction by the PI, each Task Leader presented an update on the work accomplished to-date, and what they hope to accomplish in the final year of the project. The meeting was well received and many individuals provided excellent feedback and encouragement. The presentations for each task have been posted to the UGS project Web site.
- The PI submitted an abstract to the Rocky Mountain Section - American Association of Petroleum Geologist (RMS-AAPG) meeting which will be held in Cheyenne, WY in June 2011. The abstract was accepted and the PI will present a poster detailing research performed on the Birds Nest aquifer. The abstract is available on the UGS project Web site.
- The Task 4 team leader submitted an abstract to the Rocky Mountain Section – Geological Society of America (RMS-GSA) meeting to be held in Logan, UT in May 2011. The abstract was accepted and a presentation will be made on the progress of the Uinta Basin seasonal water sampling portion of the project. The abstract is available on the UGS project Web site.
- The project Web site (http://geology.utah.gov/emp/UBwater_study) was updated with new quarterly reports, abstracts, and presentations prepared by project team members.

CONCLUSION

The data collection phase of the project is nearly complete. The Task 2 team has collected thousands of down-hole water chemistry analyses and hundreds of digitized log files to aid in picking the base of the moderately saline aquifer; the Task 3 team has analyzed over 250 wells containing the Birds Nest aquifer and has begun mapping the aquifer's areal extent and thickness; and the Task 4 team has only one more sampling round in central Uintah County as part of a biannual sampling plan to develop baseline water quality data for the area. During the next quarter, the project team will continue to analyze collected data and synthesize results.

COST STATUS

Significant time was dedicated to the project this quarter, more than originally budgeted, bringing the overall actual budget within 99.2% of the projected budget (figure 10). Also, the purchase of digital log files this quarter helped bring the budget close to projected totals. Costs are projected to stay near budgeted totals for the remainder of the project.

Table 2. *Project costing profile for Budget Period 3 (second quarter).*

	Jan 2011		Feb 2011		Mar 2011	
	Plan	Actual	Plan	Actual	Plan	Actual
UGS-personnel	$3,848	$8,391	$4,944	$9,555	$7,491	$3,362
Travel Expenses[1]		$445		$773		$1,272
Water Chemistry		$4,012		$544		
Miscellaneous[2]		$11,470		$3,000		$275
SUBTOTALS	$3,848	$24,318	$4,944	$13,872	$7,491	$4,909
UGS OVERHEAD (32.40%)	$1,247	$7,879	$1,602	$4,494	$2,427	$1,591
SUBCONTRACTS						
P. Anderson[3]	$6,777	$7,860	$6,777	$0	$6,777	$12,720
GRAND TOTALS	$11,872	$40,057	$13,323	$18,366	$16,695	$19,220

[1]January – AAPG 2011 registration; February – plane ticket for AAPG 2011, trip to Vernal, UT, booth rental for RMS-AAPG 2011; March – Core description in Denver, CO
[2]January – purchase of digital log files, poster lamination; February – purchase of digital log files; March – purchase of digital log files
[3]March billing includes February

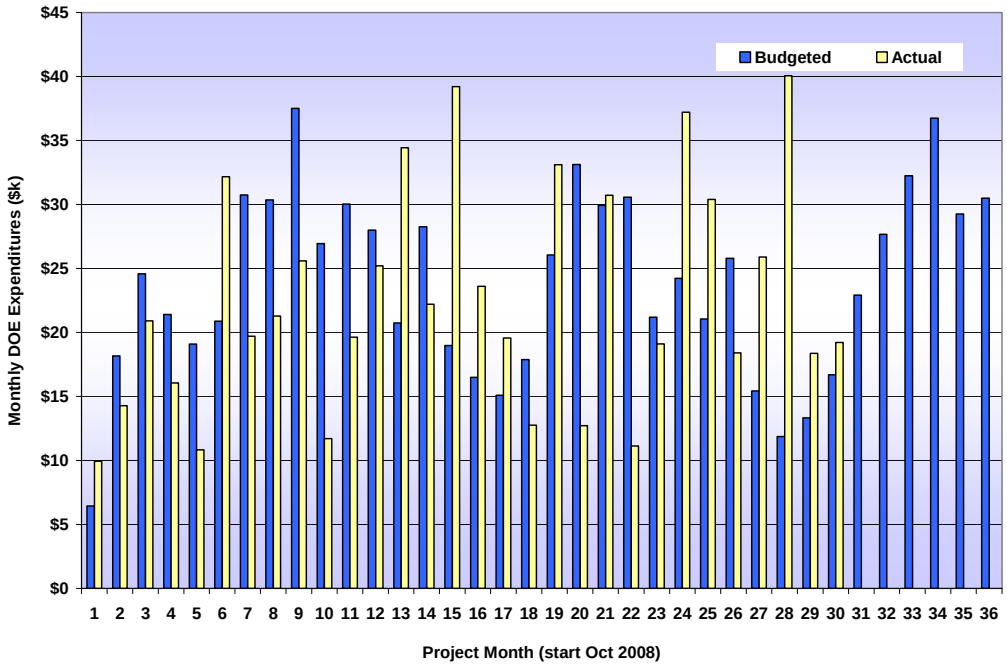

Figure 9. *Project costing profile.*

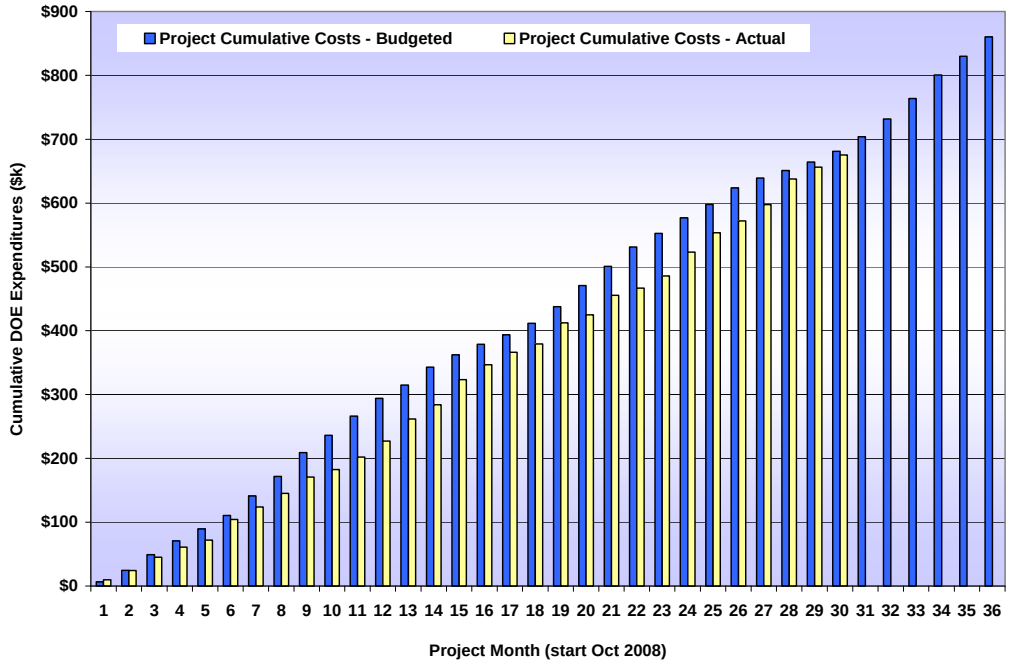

Figure 10. *Project cumulative costs.*

MILESTONE STATUS

Table 3. *Milestone log for Budget Period 3.*

	Title	Description	Related task or subtask	Completion Date	Update/comments
Milestone 3.1	Map the base of the moderately saline aquifer	Re-map the base of the moderately saline aquifer, including cross-sections, based on data collected during the previous two years	Subtask 2.2	3/31/2011	Currently have 2555 individual water analyses from 1407 wells; determined the BMSA using geophysical logs in all 258 wells, re-mapping will commence in the next quarter
Milestone 3.2	Creation of Birds Nest aquifer maps	Map the thickness, extent, and water chemistry of the Birds Nest aquifer	Subtask 3.5	6/30/2011	Preliminary maps are now completed
Milestone 3.3	Water quality and quantity analysis	Combine all collected water data and combine into a final report	Subtask 4.4	9/30/20011	One round of water sample collection remains (Spring 2011)
Milestone 3.4	Integration analysis	Model transfer of oil and water to adjacent aquifers and beyond	Task 5	6/30/2011	Researchers at the University of Utah have completed this part of the project and are in the process of preparing a final report

ACCOMPLISHMENTS

- Hosted a Year-2 Review meeting in Vernal, UT
    - ~35 attendees (both in-person and via teleconference)
- Completed interpretation of digital geophysical logs from 258 wells throughout the Uinta Basin, picking the BMSA in each well
- Completed detailed descriptions of all core containing the Birds Nest aquifer
- Completed preliminary maps displaying the areal extent and thickness of the Birds Nest aquifer

PROBLEMS OR DELAYS

None at this time

PRODUCTS AND TECHNOLOGY TRANSFER ACTIVITIES

- Completed ninth quarterly report
    - October 2010 through December 2010 – available on the UGS project Web site
- Updated project Web site
    - Posted various new reports, abstracts, and presentations prepared by project team members.
    - http://geology.utah.gov/emp/UBwater_study
- Attended the quarterly Uinta Basin Oil and Gas Collaborative Group meeting in Vernal, UT – January 13, 2011
    - Discussed project with interested attendees.
- Hosted Year-2 review meeting in Vernal, UT – convened January 13, 2011
    - Each Task Leader presented an overview of accomplishments to-date
    - Displayed maps, posters, and Birds Nest core
    - Attended by ~35 people from industry, government, and academia
    - Presentations are available on the UGS project Web site
- Abstract – RMS-AAPG Annual Meeting – Cheyenne, WY – June 26-29, 2011
    - An abstract was submitted and accepted to the 2011 RMS-AAPG Annual Meeting detailing research performed on the Birds Nest aquifer
    - The abstract is available on the UGS project Web site
- Abstract – RMS-GSA Annual Meeting – Logan, UT – May 18-20, 2011
    - An abstract was submitted and accepted to the 2011 RMS-GSA Annual Meeting detailing progress made on the seasonal water sampling in the eastern Uinta Basin (Task 4)
    - The abstract is available on the UGS project Web site
- The Task 2 Team leader has picked the BMSA in 258 selected wells throughout the Uinta Basin
- The PI completed descriptions of 20 cores (of 22) containing the Birds Nest aquifer
- The PI completed preliminary maps of the areal extent and thickness of the Birds Nest aquifer

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