Oil & Natural Gas Technology

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Quarterly Report

July 2010 to September 2010

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

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National Energy Technology Laboratory

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Office of Fossil Energy

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EXECUTIVE SUMMARY

During the month of July, the Utah Geological Survey (UGS) completed the required continuation application and presented to National Energy Technology Laboratory (NETL) staff the results of the first half of their Uinta Basin water project. As a result, permission was granted to UGS to carry the project into Budget Period 3. In addition to these project management activities, the fourth quarter of Budget Period 2 was dominated by Birds Nest aquifer-related fieldwork and salinity calculations from geophysical logs related to Task 2. Furthermore, two abstracts were submitted, one to the 30th Oil Shale Symposium outlining the geologic characteristics of the Birds Nest, and one to the 2011 American Association of Petroleum Geologists (AAPG) Annual Meeting detailing preliminary project results.

Water chemistry data, sought to aid with the goals of Task 2, keep trickling in, with analyses received for over 1300 wells. These data will be invaluable as "ground truth" to aid in the mapping of aquifer salinity throughout the basin, scheduled to begin in Budget Period 3. In addition, several oil and gas operators have donated digitized log data from over 640 wells. These files will save large amounts of in-house digitizing time and provide the data needed to calculate the base of the moderately saline aquifer in selected wells.

The Principal Investigator (PI) spent many days in the field performing reconnaissance investigation of sites for potential measured sections through the saline zone within the upper Green River Formation. Locations will highlight the gradual disappearance of large saline nodules from the northern, deeper part of the lake, to the southern margin. The PI also toured two gilsonite mines in order to gain a better understanding of how groundwater might interact with these veins. The gilsonite veins were observed to act as barriers in some locations, and conduits for water flow in others, depending on the type and thickness of the gilsonite.

The Task 4 team leader received water chemistry results from the third round (spring 2010) of water sampling in the eastern Uinta Basin. These results were compared to earlier data in order to evaluate potential seasonal changes. The fourth round of sampling will commence in October 2010.

PROGRESS, RESULTS, AND DISCUSSION

Task 1.0: Project Management Plan

During the month of July, the PI wrote and submitted the project's seventh quarterly report for the period April through June 2010. This report was subsequently sent via email to all interested parties and posted on the UGS project Web site. The Project Summary was also updated and posted to the project's Web site. Furthermore, the PI completed a continuation application and presented the project's progress to the NETL project officer and other NETL staff. NETL permission was then granted to proceed with research into the third budget year.

Task 2.0: Moderately Saline Aquifer Study

One of the most important steps in accomplishing the goals of Task 2 is to collect as many water chemistry analyses as possible from wells in the Uinta Basin. Through September 2010, the team has collected 2324 individual water analyses from 1326 different wells (figure 1). This information has been collected from a variety of sources including oil and gas operators (720 analyses), Utah Division of Oil, Gas, and Mining (DOGM) well files (181 analyses), UGS databases (1247 analyses), U.S. Geological Survey databases

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

Company	# of LAS files
Questar	319
Newfield	86
Enduring	75
Anadarko	50
El Paso	20
Bill Barrett	15
Berry	15
EOG	15
Gasco	7
Rosewood	7
Wind River	6
Devon	5
FIML	4
Mustang Fuel	4
Whiting Petroleum	3
Forest	2
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
Total	645

(105 analyses), and other publications (71 analyses). Another large group of water chemistry analyses were collected from DOGM underground injection well files in September and will be added to the database in the next quarter.

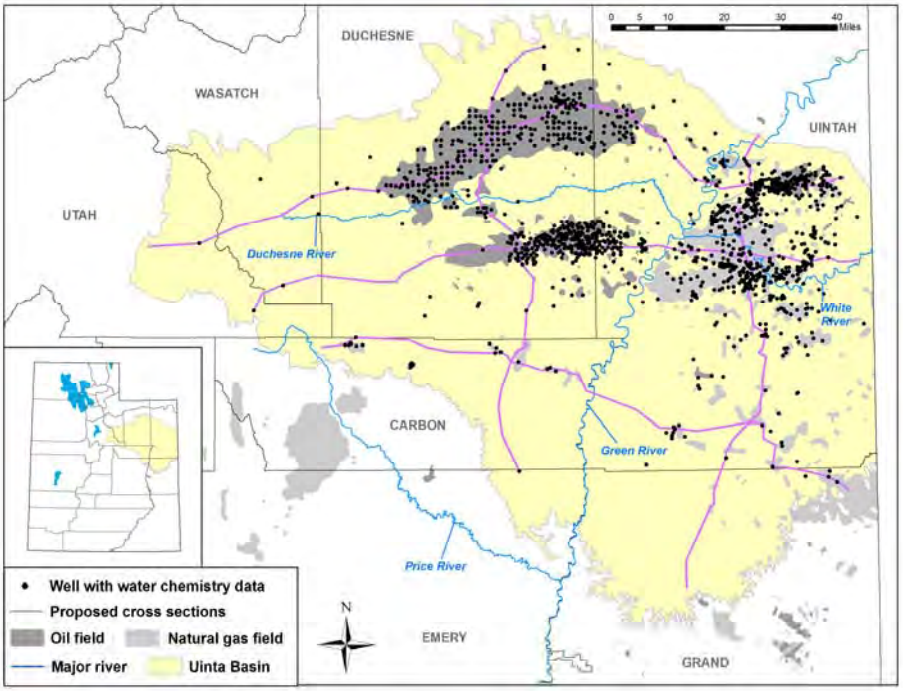

Figure 1. *Location of wells in the Uinta Basin with available water chemistry data.*

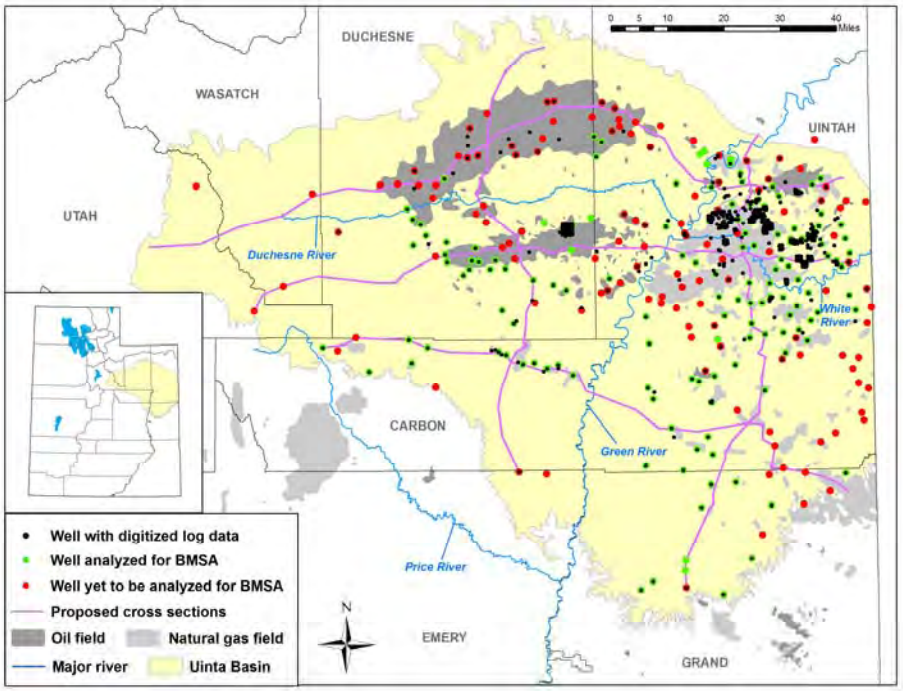

Figure 2. *Location of wells in the Uinta Basin with donated digitized geophysical logs and wells already and yet-to-be evaluated for the base of the*

For those areas where water chemistry data are lacking, work continues on determining the base of the moderately saline aquifer (BMSA) using geophysical logs. The Task 2 team leader has selected 271 wells spaced throughout the Uinta Basin for log interpretation. As of September 2010, the BMSA has been picked in 130 of the 271 wells (figure 2). To expedite this process, UGS has requested donations of the digital log files (LAS files) of these particular wells to aid in the picking of the BMSA. Through September 2010, UGS has received about 70% of the LAS files on the selected well list, and overall has obtained 645 digital log files from 26 different companies (table 1; many companies donated more LAS files than requested). For the remaining 30% of selected wells, digital log files will need to be purchased from a third party vendor. The original plan was to digitize all necessary logs in-house, but this has proven to be too time consuming and a waste of project funds. More details on the purchase of these LAS files will be available in the next quarterly report.

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.

Task 3.0: Geologic Examination of the Birds Nest Aquifer

The PI spent time in the field this past quarter looking at the Birds Nest aquifer in outcrop at three different locals on the eastern side of the Uinta Basin. The northernmost location, along Evacuation Creek near the White River, displays abundant large saline nodule cavities in a zone nearly 100 feet thick (figure 3 and 4). This closely matches observations made from the nearby P-4 core, south of the outcrop location. Farther to the south, near Long Draw, outcrop examinations reveal abundant small saline crystals, but very few large saline nodule cavities (figure 3). These observations match closely the saline deposits displayed in the nearby CRU-1 core. The southernmost outcrop location, near Bitter Creek, again displays significant saline mineral deposition in the form of small disseminated crystals and fracture fill, but no large saline nodule cavities were observed at this location (figure 3 and 5). These observations match the saline minerals displayed in the nearby SUB 12 and Suicide Canyon 1 cores.

The outcrop examinations confirm the PI's observations made from core and geophysical logs showing that large saline nodules disappear to the south, indicating a more shallow-water environment at the time of deposition. The next step will be to create detailed measured sections at these locations in order to quantify the above reconnaissance observations. The Task 3 team will also examine outcrops farther to the west on the southern side of the basin.

In August, the PI visited with the mine manager of American Gilsonite and was given a tour of two different gilsonite mines/veins. The purpose of the visit was to see how gilsonite veins might affect groundwater flow, including whether or not water could use the vein as a vertical conduit. The first mine was in the Bonanza vein – about 3 feet wide in this area – where the working face was about 630 feet deep and within the Uinta Formation (figure 3). The gilsonite in this mine was highly fractured and very friable (figure 6a). There was significant water infiltration from the wall rock (Uinta sands) in the mined-out sections, but also significant water draining through the vein itself (no photography was allowed in the mines). This highly fractured gilsonite vein seemed to create a vertical pathway for water flow. The second mine toured was in the Independent vein – again about 3 feet thick – where the working face was about 230 feet deep within the Uinta Formation (figure 3). The gilsonite in this mine is referred to as "select" and was much more solid and less fractured (figure 6b). This mine was significantly drier than the first, with only a small amount of water infiltrating from the wall rock in the mined-out areas. No water was observed within the vein itself suggesting that "select" ore could act as a significant barrier to lateral groundwater flow, and the tight contact with the wall rock is unlikely to allow for vertical movement of water. In conclusion, the type of gilsonite (fractured or solid) in the vein, as well as the vein thickness, will play a major role in whether the vein acts as a barrier to groundwater flow or a vertical and horizontal conduit.

In addition to the underground gilsonite mines, the PI visited a surface location where the mined-out Cowboy gilsonite vein intersects the Birds Nest aquifer near Cowboy Canyon (figure 3 and 7a). The nahcolite within the large saline nodules in the wall rock of the vein had been replaced with gilsonite

(figure 7b). Most likely, the nahcolite was dissolved away before the emplacement of the gilsonite. The intruding gilsonite then filled the cavities, eliminating the macroporosity near the vein available for groundwater movement and storage. Also observed at this vein was gilsonite intruding small vertical fractures in the rock parallel to the main vein (figure 7c). This grouting effect could have reduced available permeability near the vein/rock interface.

It is still unclear how these general observations relate to specific conditions found in areas deeper in the basin, where active/proposed saline water disposal wells are located, but it does give an idea of how gilsonite veins could influence groundwater flow, either acting as barriers or conduits depending on the physical characteristics of the vein. Future studies might seek ways to determine gilsonite composition and thickness near, or within, disposal sites.

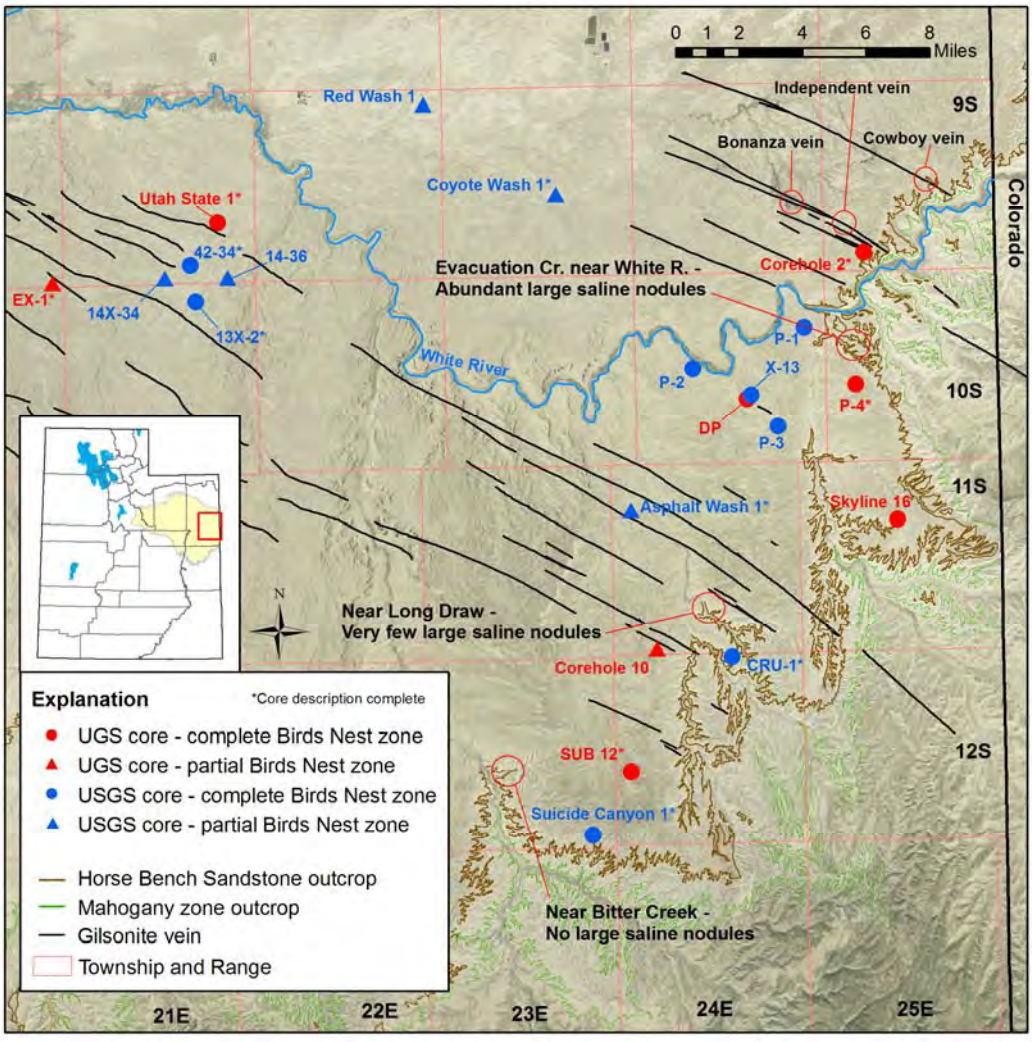

Figure 3. *Location of 21 wells in Uintah County with core that captured all or part of the Birds Nest aquifer. The cores are housed either at the Utah Core Research Center in Salt Lake City, UT, or at the USGS Core Research Center in Denver, CO.*

Figure 4. *Saline nodule cavities along Evacuation Creek, eastern Uinta Basin, Utah.*

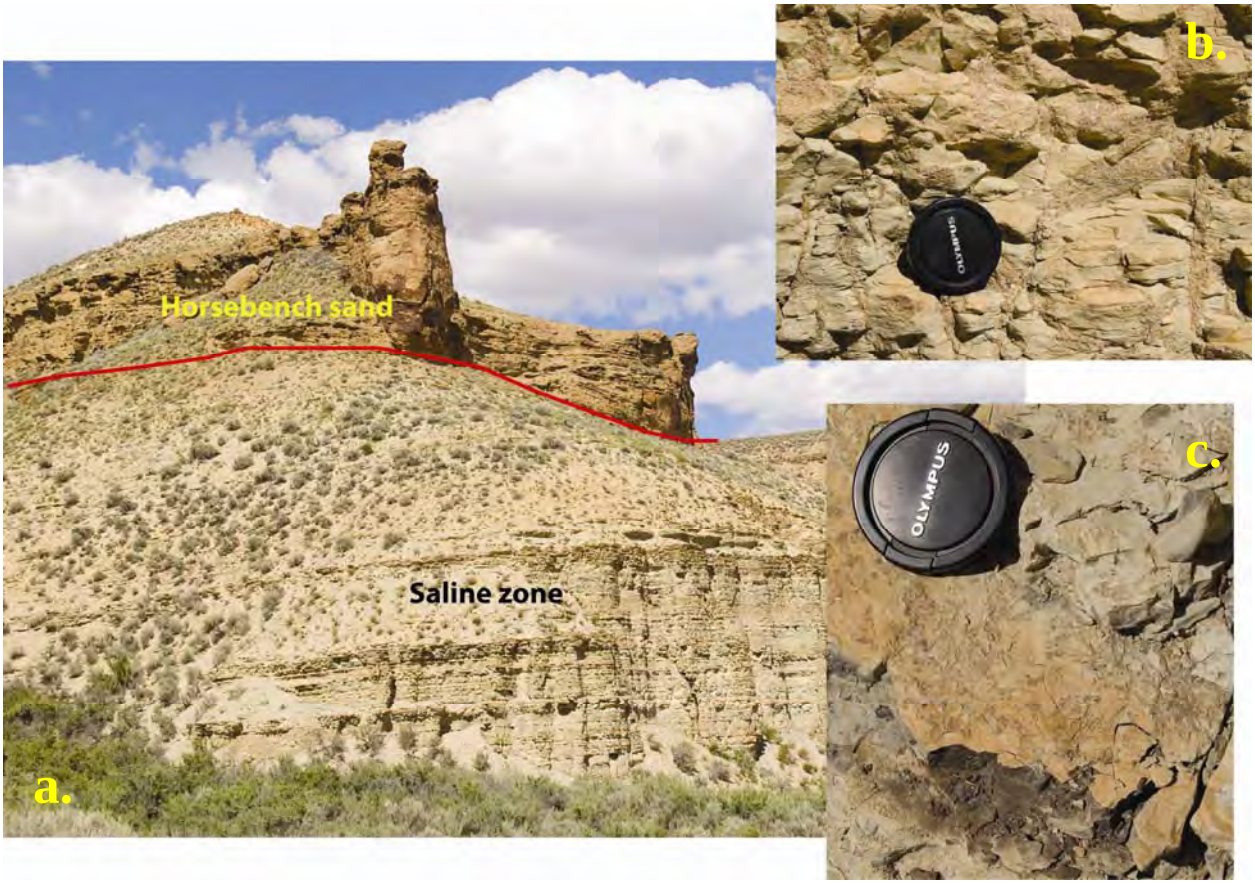

Figure 5. *a. Outcrop of the saline zone near Bitter Creek, southeastern Uinta Basin, Utah. b. Shortite fracture fill displayed in outcrop near Bitter Creek. c. Small disseminated saline mineral crystals displayed in outcrop near Bitter Creek.*

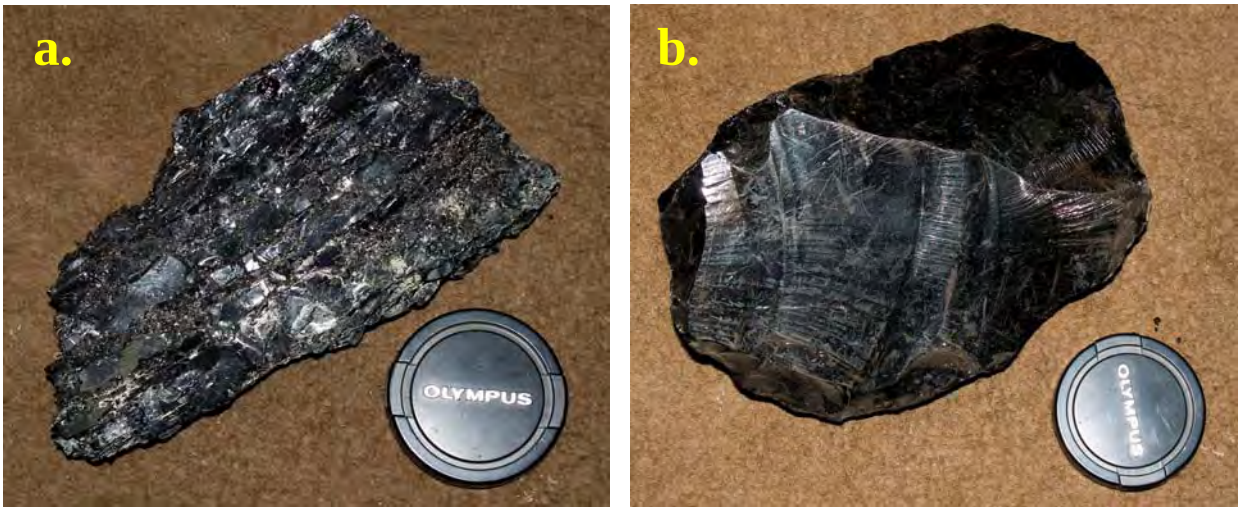

Figure 6. *a. Highly fractured gilsonite. b. Solid "select" gilsonite.*

Figure 7. *a. Mined-out Cowboy gilsonite vein. b. Gilsonite within a dissolved saline mineral cavity; notice the blade-like shape of the replaced nahcolite crystals. c. Gilsonite in vertical fracture.*

Task 4.0: Baseline Water Quality and Quantity GIS Database

During May and June 2010, 17 water samples were collected from several water wells and surface-water sites. Thirteen of the samples were from repeat visits to sites previously sampled in 2009, and four were from new sample sites (table 2, figure 8). Three wells that were sampled during 2009 were no longer accessible and/or functioning wells. The four new sample sites include two USGS monitoring wells that were drilled during the 1970s, one spring, and one sample from the Green River.

Total-dissolved-solids concentrations for spring 2010 samples range from 172 to 2708 mg/L and nitrate concentrations range from <0.1 to 12.7 mg/L (figures 9 and 10). Ten samples had at least one detectable volatile organic compound, but below maximum contaminant levels (MCL). Most samples had levels of boron above the detection level, but below the MCL. The Utah Division of Water Quality's criterion for maximum boron concentration is 0.75 mg/L for Class 4 "Beneficial Use Designation" for the Green River emptying into Flaming Gorge. Figure 11 shows boron concentration for different seasons sampled from 2009-2010. Samples from four sites exceed the 0.75 mg/L criterion for boron for Class 4 Beneficial Use. The source of boron is likely from dissolution of saline minerals in the Green River Formation. For all graphs, points that plot on the x-axis have concentrations below the detection level.

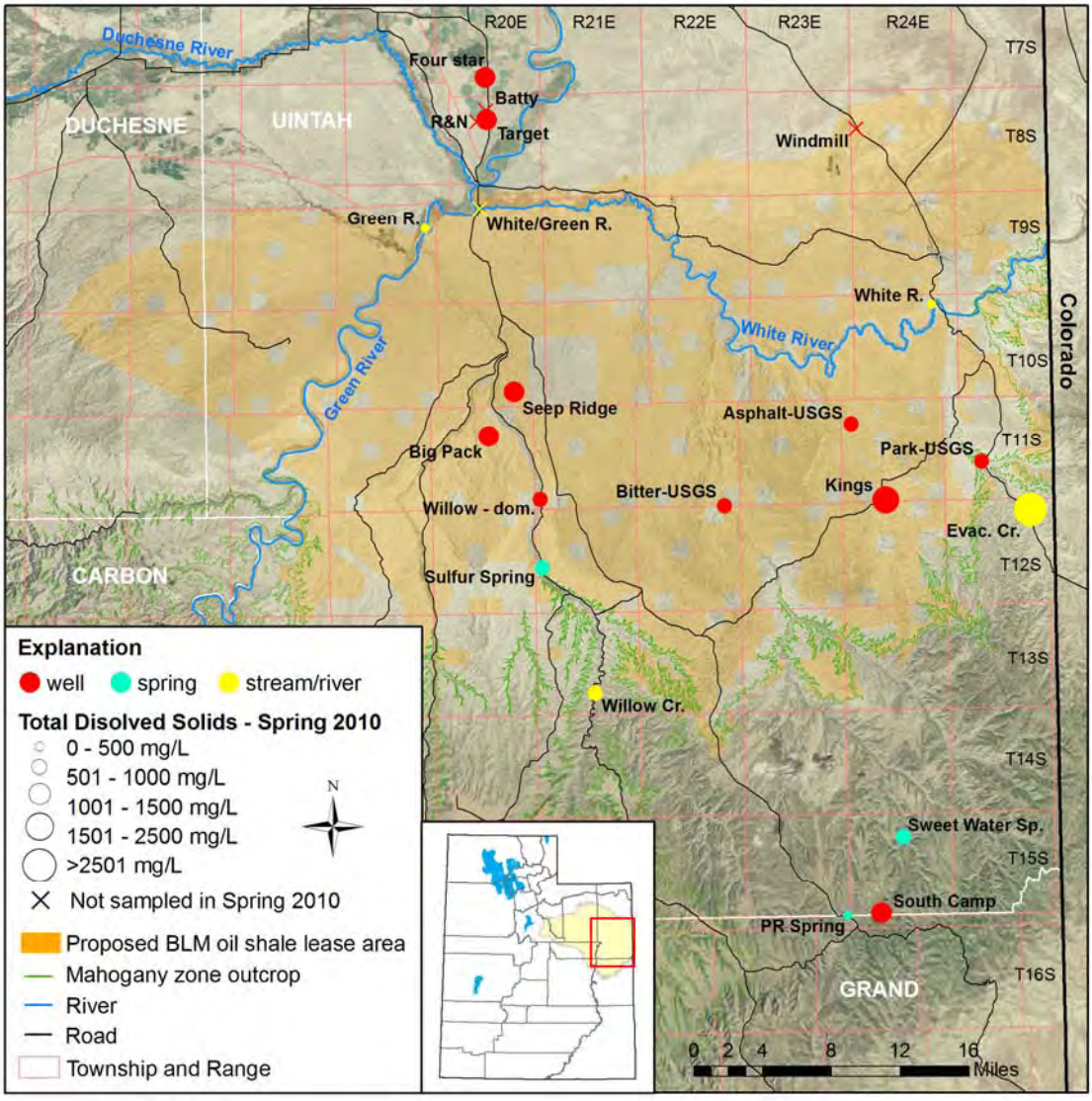

Figure 8. *Sampling sites related to Task 4, with TDS data from spring 2010 samples.*

Table 2. *Overview of water sampling sites.*

Well ID	Depth (ft)	Level (ft)	NO_3 (mg/L)			TDS (mg/L)			Boron (µg/L)			Formation
			Summer 2009	Fall 2009	Spring 2010	Summer 2009	Fall 2009	Spring 2010	Summer 2009	Fall 2009	Spring 2010	
Park-USGS	193+	flowing	<0.1	<0.1	<0.1	796	854	786	442	414	398	Green River
Big Pack	6900	flowing	<0.1	<0.1	<0.1	1298	1308	1320	2760	3010	3170	Wasatch
Willow – dom.	711	flowing	<0.1	<0.1	<0.1	936	956	924	321	294	295	Green River?
Willow Creek	surface	surface	<0.1	<0.1	0.1	562	648	506	na	74	41	Alluvial
Sulfur Spring	spring	flowing	<0.1	<0.1	<0.1	578	584	586	159	135	133	Green River?
Evacuation Cr.	surface	surface	<0.1	<0.1	<0.1	2832	2724	2708	236	182	145	Alluvial
4-star	172	70	12.6	13.5	12.7	1260	1280	1332	576	672	653	Alluvial
Kings[1]	?	67?	9.5	--	8.2	2114	--	1988	5620	--	6020	?
Windmill[4]	1382+?	flowing?	<0.1	<0.1	--	2394	2236	--	3030	na	--	Green River?
Target[2]	53	23	10.0	--	8.5	1442	--	1496	324	--	315	Alluvial
R&N[5]	60 & 80	23 & 49	7.7	7.7	--	1016	978	--	na	399	--	Alluvial
Batty[2,6]	83	28	18.8	--	--	1908	--	--	482	--	--	Alluvial
Seep Ridge	>2510	flowing	<0.1	<0.1	<0.1	3056	1462	1486	2510	1750	1360	Green River
PR Spring[1]	spring	flowing	0.4	--	0.6	420	--	356	<30	--	<30	Green River?
South camp[3]	98	61	--	5.8	<0.1	--	1204	1352	--	32	<30	Green River?
White River[3]	surface	surface	--	<0.1	<0.1	--	400	300	--	99	37	Alluvial
White/Green R.[3,7]	surface	surface	--	<0.1	--	--	412	--	--	165	--	Alluvial
Green River[8]	surface	surface	--	--	<0.1	--	--	172	--	--	89	Alluvial
Sweet Water Spr.[8]	spring	flowing	--	--	0.6	--	--	994	--	--	34	?
Bitter Cr –USGS[8]	1497	?	--	--	<0.1	--	--	950	--	--	253	Green River
Asphalt 1–USGS[8]	2650	?	--	--	<0.1	--	--	1012	--	--	202	Green River

[1]No access to site in fall 2009 due to weather conditions
[2]Not sampled in fall 2009 due to time constraints
[3]New sites sampled in fall 2009
[4]Well not operational in spring 2010
[5]Unable to sample in spring 2010
[6]Well no longer in use in spring 2010
[7]Not sampled in spring 2010
[8]New sites sampled in spring 2010

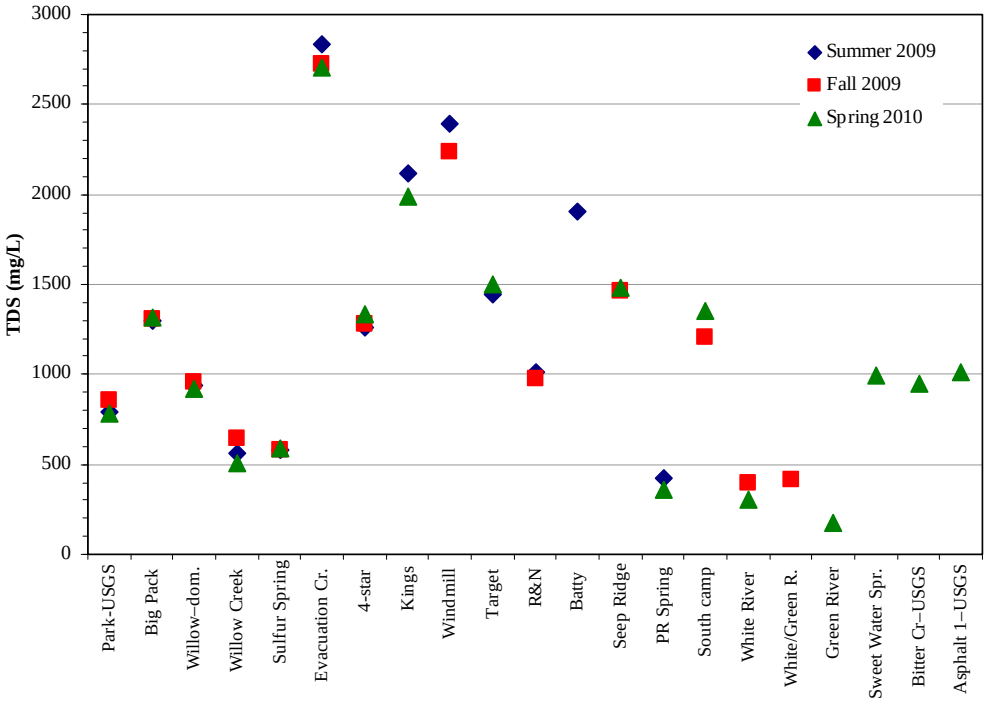

Figure 9. *Total dissolved solids concentrations from sites sampled as part of Task 4.*

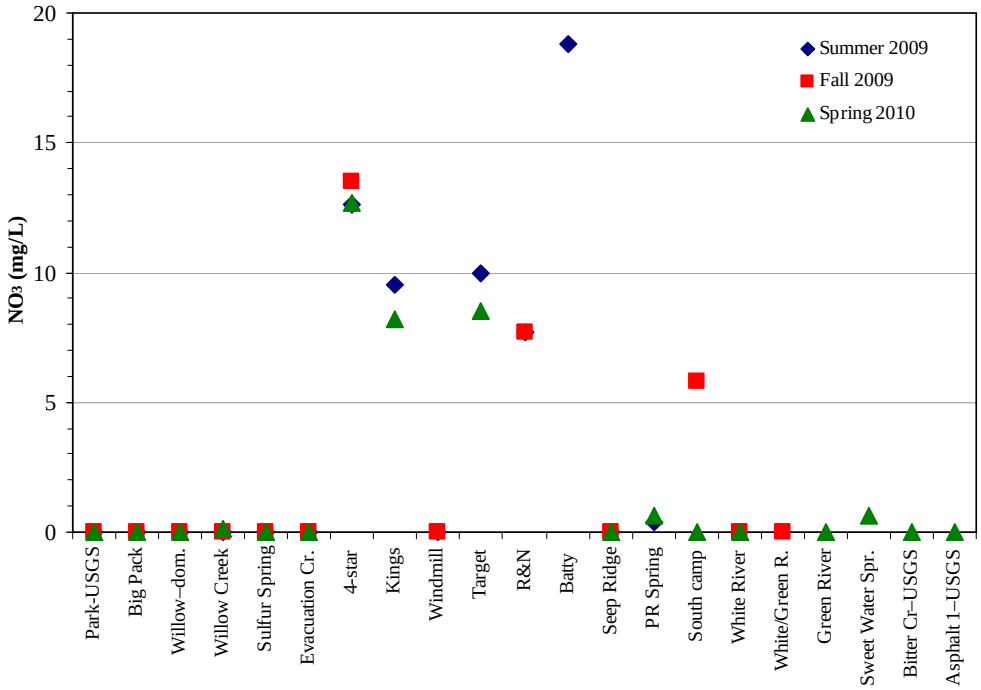

Figure 10. *Nitrate concentrations from sites sampled as part of Task 4.*

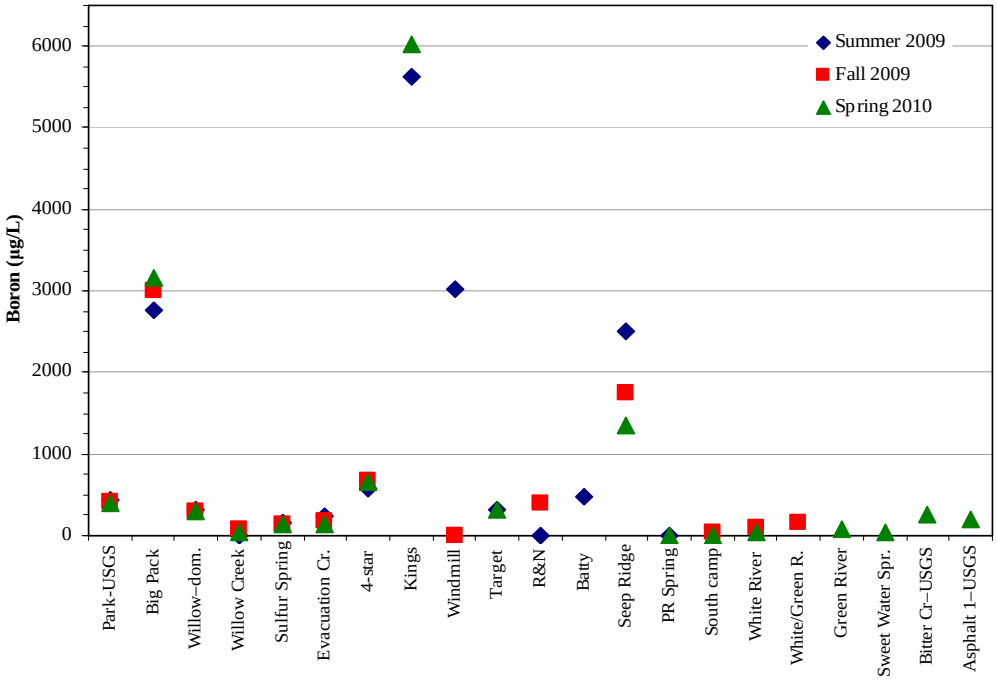

Figure 11. *Boron concentrations from sites sampled as part of Task 4.*

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

This task is scheduled for Budget Period 3.

Task 6.0: Technology Transfer

- The PI revised the Project Summary and posted the new version on the project Web site.
- The PI completed a continuation application and presented the results/progress of the project's first half to NETL staff. The PI was subsequentaly granted permission to carry the project into the third budget period.
- The PI submitted an abstract, which was accepted, to the 30th Oil Shale Symposium detailing research performed on the Birds Nest aquifer. The symposium was held at the Colorado School of Mines in October 2010.
- The PI submitted an abstract to the AAPG Annual Meeting, to be held in April 2011 in Houston, TX. The abstract details the progress made thus far on the mapping of the base of the moderately saline aquifer and the geologic characterization of the Birds Nest aquifer.
- 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

With the completion of Budget Period 2, this study is on schedule to achieve the goal of better understanding the aquifers in the Uinta Basin in order to help facilitate safe and efficient saline water disposal. The Task 2 team has collected hundreds 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 described 11 cores containing the Birds Nest aquifer and has compared them to several outcrop locations; and the Task 4 team has collected three sets of water samples from 21 sites in central Uintah County as part of a biannual sampling plan to develop baseline water quality in the area. Several more months of data collection and analysis are scheduled before the final interpretation and synthesis can begin in the latter half of year three.

COST STATUS

Lower costs in July were the result of the PI and other members of the project team working on other projects, while significant fieldwork in August and September helped keep costs near budget. As displayed in figure 13, the cumulative billing through the end of September 2010 is very close (91%) to budgeted costs.

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

	Jul 2010		Aug 2010		Sep 2010	
	Plan	Actual	Plan	Actual	Plan	Actual
UGS-personnel	$8,615	$3,039	$9,752	$9,154	$13,077	$8,136
Travel Expenses[1]			$1,136	$611	$106	$1,512
Water Chemistry	$9,359			$4,670		$3,038
Miscellaneous[2]		$350				$1,840
SUBTOTALS	$17,974	$3,389	$10,888	$14,435	$13,183	$14,526
UGS OVERHEAD (32.40%)	$5,824	$1,098	$3,528	$4,677	$4,271	$4,707
SUBCONTRACTS						
P. Anderson[3]	$6,777	$6,640	$6,777	$0	$6,777	$17,980
GRAND TOTALS	$30,574	$11,127	$21,193	$19,112	$24,232	$37,213

[1]August –Birds Nest fieldwork in the Uinta Basin; September – Water sampling in Uinta Basin, Birds Nest fieldwork in the Uinta Basin, registration and plane ticket to Denver for the 30th Oil Shale Symposium (Oct 18-20, 1020)
[2]July – AAPG Annual meeting booth rental; September – Slabbing of Birds Nest core, field supplies
[3]September billing includes August

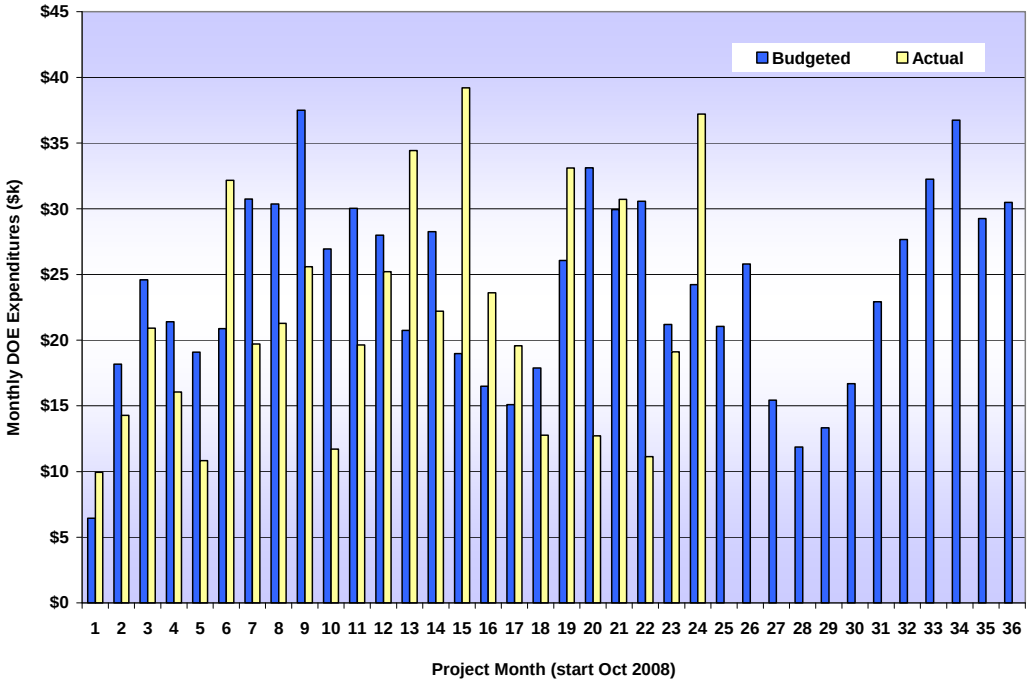

Figure 12. *Project costing profile.*

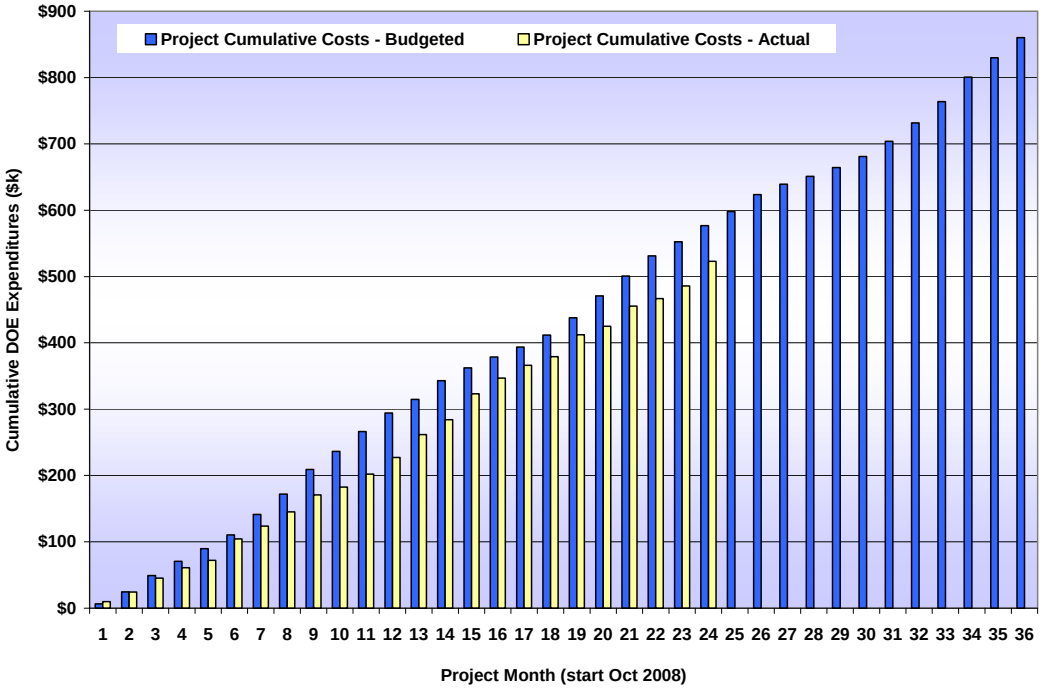

Figure 13. *Project cumulative costs.*

MILESTONE STATUS

Table 4. *Milestone log for Budget Period 2.*

	Title	Description	Related task or subtask	Completion Date	Update/comments
Milestone 2.1	Water chemistry data collection (part 2)	Collect the remaining required 1 well per township, adding additional data to areas of interest	Subtask 2.1	9/30/2010	Collected chemistry data from 1326 wells; currently analyzing well logs in areas where no chemistry data exist (130 of 271 wells completed)
Milestone 2.2	Create Birds Nest aquifer well database	Create a database with all collected data	Subtask 3.4	9/30/2010	Evaluated Birds Nest in 11 of 21 cores; started Birds Nest well database, initially focusing on wells with core, core examination will continue into the fall of 2010

ACCOMPLISHMENTS

- Submitted abstract to the 30th Oil Shale Symposium
- Submitted abstract to the 2011 AAPG Annual Meeting
- Successfully completed continuation application and presented progress to NETL staff
- Conducted Birds Nest aquifer-related fieldwork including touring gilsonite mines
- Completed the third round of water quality sampling and obtained chemistry data

PROBLEMS OR DELAYS

None at this time

PRODUCTS AND TECHNOLOGY TRANSFER ACTIVITIES

- Completed seventh quarterly report
  - April 2010 through June 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
- Completed continuation application and presented results/progress to NETL staff
  - UGS was granted permission to advance the project into the third budget period
- Abstract – 30th Oil Shale Symposium – Colorado School of Mines – Golden, CO – October 18-20, 2010
  - An abstract was submitted and accepted to the 30th Oil Shale Symposium
  - The presentation detailed the research done to date on the Birds Nest aquifer and how it relates to oil shale deposits
  - The abstract is available on the UGS project Web site
- Abstract – AAPG Annual Meeting – Houston, TX – April 11-13, 2011
  - An abstract was submitted to the 2011 AAPG Annual Meeting
  - The presentation will detail the project's overall progress on all tasks
  - The abstract is available on the UGS project Web site
- The PI participated in a AAPG field seminar – Lacustrine Basin Exploration – which focused on the modern Great Salt Lake Basin in Utah and the Eocene Green River Basin in Wyoming
  - Studying the lacustrine deposits in Wyoming provided insights into the deposition of similar sediments in the Uinta Basin, including saline deposits

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