EPWM - 002

GENERAL CORRESPONDENCE

2008-2010

RO, NF Desalination Technology for Coal-Bed Methane Produced Water, Treatment, Rangeland Rehabilitation

Allan Sattler, Susan Altman, Malynda Cappelle*, Randy Everett, Bill Holub, Buddy Anderson,
Sandia National Laboratories

Bob Wirtanen, Monica Johnson, Gwen Frost, Rebekah Miller, Others
ConocoPhillips, San Juan Business Unit

Rick Arnold, New Mexico State U. Ag. Sciences Center, Farmington
Frank McDonald, Best Environmental Sciences and Technologies, Farmington

* Now at University of Texas, El Paso

NNSA

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories

Overview of ConocoPhillips GBNG Well Pad Showing Wellhead, Separator, Produced Water Tank, Sandia Transportainer, and Tanks (to Right of Wellhead)

Generator , Transportainer and Treated, Untreated Water, and Concentrate Tanks on ConocoPhillips CBM Well Pad

Summary of Reverse Osmosis Performance

Dissolved Constituents Removal

Analyte	Units	Untreated	RO Perm
Turbidity	NTU	8.3	0.23
pH	su	7.6	6.0
Conductivity (@ 25°C)		19800	1222
TOC	mg/L	21.3	5.7
SAR (calculated)		265	15
Alkalinity, as HCO_3	mg/L	8048	58
TDS (@180 °C)	mg/L	12625	1168
Chloride		2833	834
Barium	mg/L	30	0.3
Calcium	mg/L	14.4	0.3
Iron	mg/L	1.2	0.4
Magnesium	mg/L	9.2	0.1
Potassium	mg/L	25.6	0.3
Sodium	mg/L	4897	32

Sandia National Laboratories

NMSU Agricultural Science Center, Farmington
Watering Equipment on Pad of CP SAN JUAN 32-8 #237A Well

Soil Sample Results – Major Ions, Organics (worst case scenario – untreated land section)

Analyte	Units	9/12/08	10/15/08	10/30/08	11/12/08	No water (avg)
pH	su	9.17	8.61	9.34	9.26	7.6
TDS (@180 °C)	mg/L	170	388	640	480	329
Chloride	**mg/L**	**12.7**	**101**	**163**	**91**	**24.1**
Calcium	mg/L	100	43.1	35.6	84	59.7
Magnesium	mg/L	4.88	1.78	0.968	2.44	3.3
Sodium	mg/L	15.2	77.5	226	92.1	3.6
SAR (calc)	**ratio**	**3.100**	**3.140**	**10.187**	**2.699**	**0.3**
TOC	%C	0.56	0.82	0.47	1	0.7
PAH, VOCs	ug/kg	ND	ND	ND	ND	ND

- **Soil sampled as deep as possible w/o penetrating rock**
- **Soil Chloride level increased by ~70 mg/L (with 2-in addition of untreated water w/ 3000 mg/L Cl)**
- **PAH, Purgeable VOCs: non-detect in all samples & no build-up**

Sandia National Laboratories

Inadvertent “Blended” Patch:

Low TDS not Entire Story, Blended better than Treated,Untreated
(blended area saw significant improvement to grasses)

Use Nanofiltration for Water Reuse and Reduction of Scaling in Cooling Water Tower

Pilot operations to evaluate use of NANOFILTRATION FOR REUSE

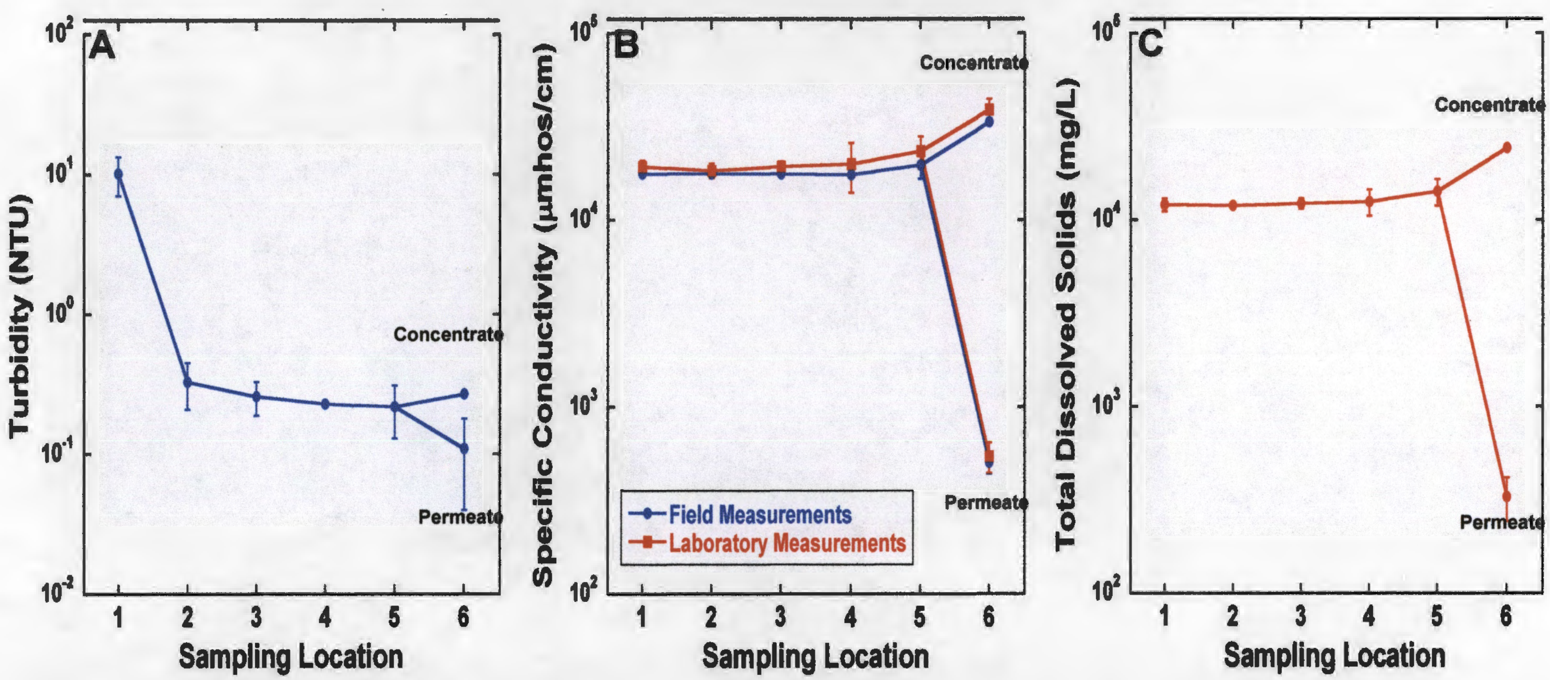
CBM Produced Water Site

Cooling Water Tower
600-1800 gpm

- High rejection rate for divalent ions
- Capable of decreasing total dissolve solids significantly
- Generally less prone to fouling than reverse osmosis membranes
- Operate at lower applied pressures and thus save energy and cost than reverse osmosis membranes

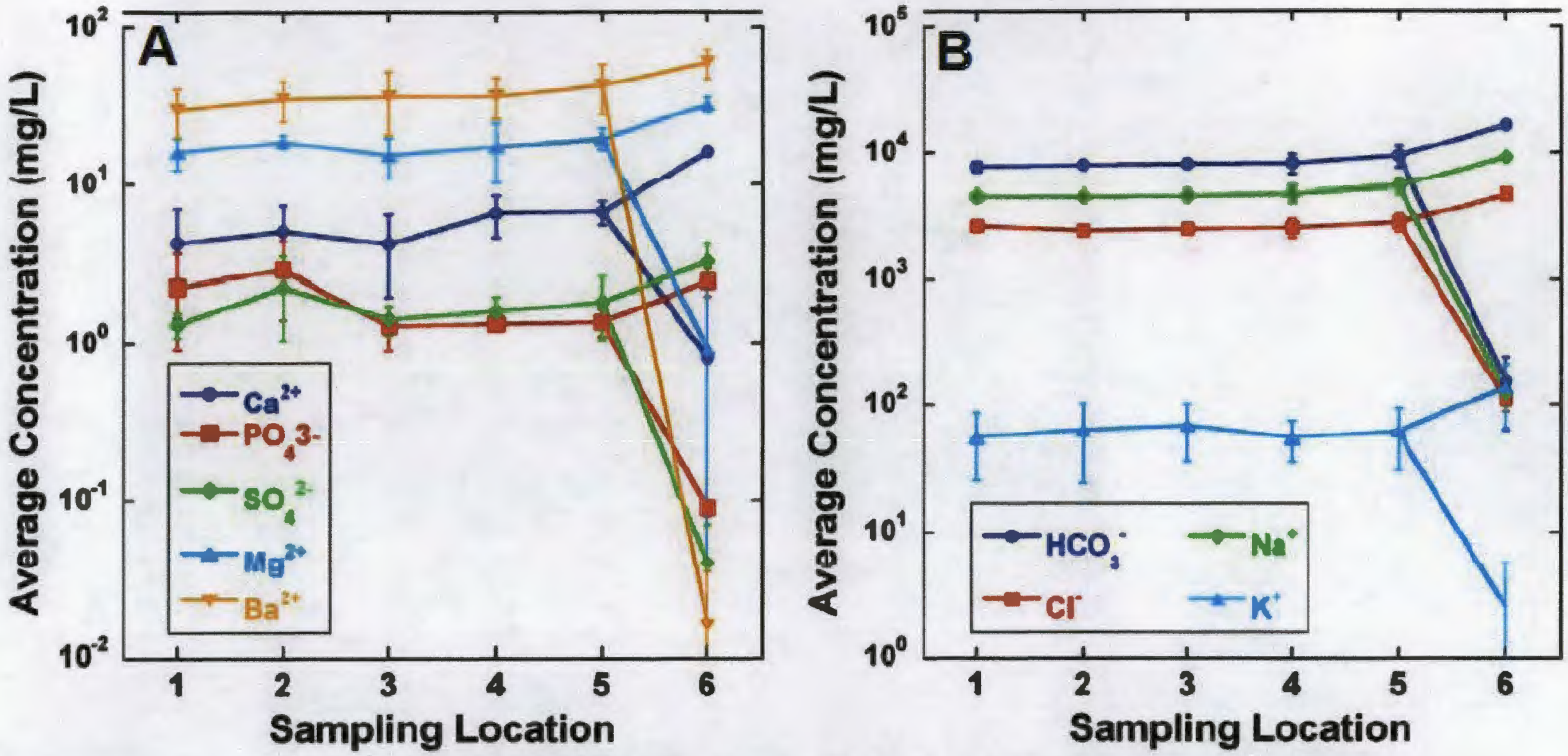
Sandia National Laboratories

Nanofiltration System Removed Over 90% of Dissolved Solids from Coal Bed Methane Produced Water



Average measured turbidity (A), specific conductivity (B), and total dissolved solids (TDS) (C). Error bars indicte ± 1 standard deviation of the measurements. [Sampling Location 1 = Raw Produced Water, 2 = GAC effluent, 3 = UF effluent, 4 = NF make-up water, 5 = NF feed water, 6 = NF concentrate and Permeate (Figure 18)].

Sandia National Laboratories



Average measured concentrations of divalent ions (A) and monovalent ions (B). Error bars indicate ± 1 standard deviation of the measurements. [Sampling locations: 1 = Raw Produced Water, 2 = GAC effluent, 3 = UF effluent, 4 = NF make-up water, 5 = NF feed water, 6 = NF concentrate and permeate.]

Sandia National Laboratories

Very Recent Challenges of Filtering Coal Bed Methane Produced Water

(An Ugly Summer)

- Parafilms in water
- Biological growth
- Filming agents
- Iron flocs
- Coal fines
- Cleaning of pump

Photo taken on 7/8/09 Pilot Produced Water Storage Tank

Sandia National Laboratories

A Salt Water Disposal Facility
(and Surrounding Acreage)
Produce Frac Water

Sandia National Laboratories

SWD Analysis

Parameter/Date Collected	10/07/2009	10/15/2009	10/22/2009
pH	8.03	8.04	7.83
Specific Conductivity (µmhos/cm)	15,200	15,800	14,000
TDS (mg/L)	10,380	9,870	8,130
SAR	150	134	137
Bicarbonate as $CaCO_3$ (mg/L)	4,300	4,180	3,980
Carbonate as $CaCO_3$ (mg/L)	<0.1	<0.1	<0.1
Hydroxide as $CaCO_3$ (mg/L)	<0.1	<0.1	<0.1
Nitrate (mg/L)	0.243	0.081	0.334
Nitrite (mg/L)	0.014	1.80	---
Chloride (mg/L)	3,620	3,450	2,330

SWD Analysis, Continued

Fluoride (mg/L)	2.19	0.309	<0.01
Phosphate (mg/L)	2.57	0.633	---
Sulfate (mg/L)	105	86.7	253.00
Iron (mg/L)	0.068	0.425	0.405
Calcium (mg/L)	25.6	12.4	9.7
Magnesium (mg/L)	15.7	27.4	17.3
Potassium (mg/L)	84.4	49.5	30.1
Sodium (mg/L)	3,910	3,700	3,070
Boron (mg/L)	5.72	1.75	3.28
Barium (mg/L)	29.0	16.5	12.9
Silica (mg/L)	22.8	17.2	---
TOC (mg/L)	110	45	---
DOC (mg/L)	76	52	---

§ - Field Measurement

SAR – Sodium Adsorption Ratio = $\frac{[Na^+]}{\sqrt{([Ca^{2+}]+[Mg^{2+}])/2}}$

TOC – Total Organic Carbon

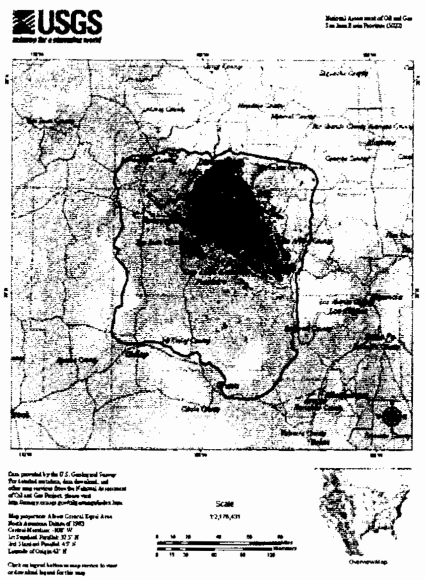
DOC – Dissolved Organic Carbon

Sandia National Laboratories

Recreation Hall, Sauna, Hot Showers and Club Room

Sandia National Laboratories

Using Coal Bed Methane Produced Water for Establishment of native and Non-Native grasses in the Oil and Gas Producing Basin of Northwest New Mexico, 2003-2006



BY: Richard N. Arnold

College Professor of Weed Science

New Mexico State University

Agricultural Science Center

January 3, 2007

Notice to Users of this Report

This report has been prepared as an aid to the Agricultural Science Center Staff in analyzing the results of the various research during the past year and for recording pertinent data for future reference. This is not a formal Agricultural Experiment Station Report of research results.

Information in this report represents results from only one year's research. The reader is cautioned against drawing conclusions or making recommendations as a result of data in the report. In many instances, data in this report represents only one of several years of research results that will constitute the final formal report. It should be pointed out, however, that staff members have made every effort to check accuracy of the data presented.

This report was not as a formal release; therefore, none of the data or information herein is authorized for release or publication without the written approval of the New Mexico Agricultural Experiment Station.

Mention of a proprietary pesticide does not imply registration under FIFRA as amended or endorsement by New Mexico State University.

Project Number 900393: Funds Provided by Several Oil and Gas Producers in the San Juan Oil and Gas Producing Basin and in Cooperation with the San Juan Cattle Growers Association of San Juan County and Bureau of Land Management Farmington Field Office, 2003-2006

Using Coal Bed Methane Produced Water from Well-Sites for Native and Non-Native Grass Stand Establishment.

Objectives

- Select several native or non-native cool and warm season cultivar's that are adapted to the intermountain regions of northwest New Mexico.
- Applying coal bed methane produced water varying in Total Dissolved Salts, to native and non-native grasses for stand establishment.

Material and methods

Research plots were established in August, 2003, April 2004 and 2005, to look at possible coal bed methane produced water for native and non-native grass establishment. Table 1 indicates the location, date of planting and year's research plots were evaluated.

Table 1. Location, date of planting and year research plots were evaluated.

Location	Date of Planting	Years Evaluated
William Production Rosa 159A	August 6, 2003	3
BP Americas K5M[a]	August 6, 2003	1
Conoco/Phillips 242A	April 21, 2004	2
Conoco/Phillips 207A	April 10, 2005	1
Williams Production 224	April 19, 2005	1

[a] BP Americas K5M was only rated on July 29, 2004 due to no grass established in 2005.

Research plots were planted with a cone seeder with six, ten in rows 25 ft long. The experimental design was a randomized complete block with four replications for all sites. Table 3 gives the names of the variety or cultivar planted at all five sites. A soil sample was taken from all sites at a depth from 0 to 12 inch before and after produced water was applied to determine pH, electrical conductivity (EC), calcium, magnesium, sodium, texture, and sodium adsorption ratio (SAR). Table 4 shows the results of soil samples before and after produced water application. EC describes the amount of electrical current conducted by a saturated soil extract at a fixed temperature. The more salts in solution, the greater the EC reading and the greater the toxicity to plants. This test does not distinguish between salt types; units of measure are usually in decisiemens per meter (dS/m). SAR describes the ratio of sodium relative to calcium and magnesium, to cations that moderate the adverse effects of sodium. The greater the SAR value, the more sodium relative to calcium and magnesium, the greater the toxicity. A 400-barrel tank (holds approximately 16,800 gallons) was supplied and put on each well site. Produced water was then pumped through a 3 in irrigation pipe consisting of a line spacing of 50 ft and a sprinkler spacing of 30 ft. Rainbird 25 ASFP-TNT sprinkler heads with 11/64 nozzles were used. Table 2 gives the location, date, and amount and total amount of produced water applied from 2003 to 2005.

Table 2. Location, date, and total amount of produced water applied, 2003 to 2005.

Location	Date produced water was applied	Amount of produced water applied at each application	Total amount of produced was applied at each location in inches and gallons
William Production Rosa 159A	August 13 and 19, September 17 and 23, 2003	1.12 inch	4.5 inches, or 26,880 gallons
BP Americas K5M[a]	August 12 and 21, September 16, 2003	2.8 inch	8.4 inches, or 50,400 gallons
Conoco/Phillips 242A	April 28, May 10 and 18, 2004	2.8 inch	8.4 inches or 50, 400 gallons
Conoco/Phillips 207A	May 12, 19, and 25, 2005	2.8, 1.4, and 1.4 inches	5.2 inches or 33,600 gallons
Williams Production 224	April 18, May 11 and 18, 2005	2.8, 1.4, and 1.4 inches	5.2 inches or 33,600 gallons

Water samples were taken during each application and sent to EnviroTech Labs for analysis. Table 5 gives the water analysis for Williams Production (WP) Rosa 159A and BP British Petroleum Americas (BP) Florence K5M and Conoco/Phillips 242A and 207A and Williams Production (WP) 224. Evaluation of research plots for stand establishment of WP Rosa 159A and 224, BP Americas Florence K5M, and Conoco/Phillips 242A, 207A are given in Table 7.

Results and discussion

Rainfall Averages: Cumulative rainfall was taken from Ignacio, Colorado at approximately 2.1 miles NNE from the Community Collaborative Rain, Hail and Snow Network (CoCo-RaHS) observation site. From August 1 to December 2003 approximately 2.8 in of moistured was measured. In 2004, 2005 and 2006 approximately 10.9, 16.8 and 13.4 inch of moisture was measured. Average moisture accumulation from 2004 to 2006 was 13.7 inch, respectively.

Soil Tests: Before and after soil test results are given in Table 4. Soil tests for pH, taken before produced water applications on all five sites averaged 7.2 and after produced water application of 7.5. Soil samples taken on BP Americas Florence K5M and WP 224, after 8.4 and 5.2 inch of produced water applied, averaging approximately 6432 and 9973 mg/L (milligrams per liter) in total dissolved salts (TDS), 86 and 142 in SAR, and 14.1 and 17.7 in EC dS/M values, (Table 6) and had the greatest increase in EC and SAR of 4.3 and 3.5 dS/m and 11.0 and 13, Table 4. Usually an EC in dS/m above 15 from a soil salinity test is unsuitable for most crops and where a severe decrease in forage production occurs. For example crested wheatgrass, western wheatgrass, slender wheatgrass, Canadian and Russian wild ryegrass, and intermediate wheatgrass, are moderate to tolerant at EC levels ranging from 10 to 15 dS/m. All five locations showed after soil EC levels in dS/m, below 6 after produced water was applied. An SAR value evaluates the sodium content of the soil. A value of 15 or greater indicates an excess of sodium will be adsorbed by the soil clay particles. Excess sodium can cause soil to be hard and cloddy when dry, to crust badly, and take water very slowly. The after soil SAR values of all sites were below 12, after produced water was applied, except for WP 224. Except for the after soil SAR value of 19.6 for WP 224, the after soil EC and SAR values for WP Rosa 159, BP Americas K5M, Conoco/Phillips 242A and 207A were under the described values for restricting forage production for most of these grasses planted Table 4.

Water Analysis: Individual water analyses are given in Table 5 and averages are given in Table 6. Water analyses were conducted by EnviroTech Labs, Farmington, New Mexico. WP Rosa 159 had approximately 4.5 inch of produced water averaging approximately 8061 mg/L TDS, 97 SAR and an EC of 16.8 Table 6. BP Americas and Conoco/Phillips 242A and Conoco/Phillips 207A and WP 224 had approximately 8.4 and 5.2 inch of produced water averaging 6432, 3838, 4384 and 9973 mg/L TDS, 86, 69, 127 and 142 SAR and EC of 14.1, 6.8, 6.9 and 17.7. Usually if the irrigation water EC values in dS/m are over 3 except for tolerant crops (usually 8 to 12) and SAR values are above 26 (values below 10 acceptable for production) that water is unsuitable for production. The most influential water quality guideline on crop productivity is the salinity hazard as measured by EC. The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water available to plants, even though a field may appear wet. Water sources with an EC value of approximately 1.0 dS/m contains approximately 2,000 lbs of salt for every acre foot of water applied. With this in mind approximately 6.3, 9.8, 4.7, 2.9, and 7.6 tons of salt were applied to WP Rosa 159A, BP Americas Florence K5M and Conoco/Phillips 242A, Conoco/Phillips 207A and WP 224, respectively. While EC is an assessment of all soluble salts in a sample, sodium hazard is defined separately because of its specific detrimental effects on soil physical properties. With higher SAR (usually above 15) values the soil becomes more dispersed, will readily crust and have water infiltration and permeability problems. However, many factors including soil texture, organic matter, crop type, climate, irrigation system, and management impact how sodium in the irrigation water affects soils. With the relative small amount of produced water containing high EC and SAR values, it is hoped that most of the salt tolerant native and non-native grasses planted in these studies will survive and become established productive grasses, on the these disturbed locations.

Stand Establishment: Averaged stand establishment of native and non native grasses is given in Table 7. Three year average for stand establishment on WP Rosa 159A showed Chief Intermediate, Luna Pubescent, Hy Crest Crested, and San Luis Slender Wheatgrasses, VNS Canada Wild, and Bozoisky Russian Wild Ryegrasses, averaged from 2.7 to 2.4. BP Americas Florence K5M indicated that Arriba Western Wheatgrass, VNS Bottlebrush Squirreltail, Paloma Indian Ricegrass, Anatone Bluebunch Wheatgrass, Four-Wing Saltbush, Covar Sheep Fescue, and VNS Needle and Threadgrass had a rating of 1.5 for stand establishment one year after produced water application. BP Americas Florence k5M was not rated the second year due to no grass present. Excellent stand establishment for Arriba Western, Hy Crest Crested, Critana Thickspike, Anatone Bluebunch, San Luis Slender Wheatgrasses, VNS Canada Wild Ryegrass, and VNS Bottlebrush Squirreltail, these all averaged above 4.3 for stand establishment two year after produced water was applied to Conoco/Phillips 242A, Table 7. Conoco/Phillips 207A showed that Arriba Western Wheatgrass, Hy Crest Crested Wheatgrass, VNS Canada Wild ryegrass, Bozoisky Russian Wild Ryegrass, Critana Thickspike Wheatgrass, Anatone Bluebunch Wheatgrass, and San Luis Slender Wheatgrass averaged 3.0 or better approximately 15 months year after planting Table 7. Only Bozoisky Russian Wild Ryegrass and VNS Russian Wild Ryegrass had a rating of 2.5 for grass establishment on WP 224 approximately 15 months after planting Table 7.

Table 3. Names of cultivars or varieties planted at each site 2003 to 2005.

Variety or Cultivar	Seeding Rate (lb/pls/A[a])
Arriba Western Wheatgrass	8.0
Chief Intermediate Wheatgrass	10.0
Luna Pubescent Wheatgrass	10.0
Hy Crest Crested Wheatgrass	5.0
VNS[b] Canada Wild Ryegrass	7.0
Bozoisky Russian Wild Ryegrass	5.0
Critana Thickspike Wheatgrass	6.0
VNS[b] Bottlebrush Squirreltail	8.0
Redondo Arizona Fescue	3.0
Paloma Indian Ricegrass	6.0
Anatone Bluebunch Wheatgrass	9.0
VNS[b] Junegrass	4.0
Four-Wing Saltbush	2.0
Covar Sheep Fescue	2.0
San Luis Slender Wheatgrass	6.0
VNS[b] Needle and Threadgrass	8.0

[a] pls = pure live seed
[b] VNS = variety or cultivar not stated

Table 4. Soil sample results before and after produced water application on WP Rosa 159A and BP Americas Florence K5M, 2003, Conoco/Phillips 242A, 2004, Conoco/Phillips 207A, and WP 224, 2005

Well Site[a]	pH	EC (dS/m)	Ca (ppm)	Mg (ppm)	Na (ppm)	SAR	Texture
WP Rosa 159A (before)	7.32	3.4	912	67	533	7.3	loam
WP Rosa 159A (after)	7.53	5.1	341	80	725	9.2	loam
BP Americas Florence K5M (before)	6.95	1.7	253	42	36.3	0.6	loamy sand
BP Americas Florence K5M (after)	6.92	6.0	346	75	917	11.6	loamy sand
Conoco/Phillips 242A (before)	7.67	3.4	324	75	422	5.5	Loam
Conoco/Phillips 242A (after)	7.76	3.6	282	61	526	7.4	Loam
Conoco/Phillips 207A (before)	7.13	1.0	100	21	102	2.4	Sandy clay loam
Conoco/Phillips 207A (after)	7.39	1.2	84	16	180	4.7	Sandy clay loam
WP 224 (before)	7.29	0.9	39	6	167	6.6	Sandy clay loam
WP 224 (after)	7.65	4.4	97	19	809	19.6	Sandy clay loam

[a] Before means sample taken before produced water application and after means soil samples taken after last produced water application.

Table 5. Produced water analysis for WP Rosa 159A and BP Americas Florence K5M, 2003, Conoco/Phillips 242A, 2004, Conoco/Phillips 207A and WP 224, 2005.

Location	Application date	pH	TDS (mg/L)	SAR	EC (dS/m
WP Rosa 159A	9-19-03	8.5	5440	71	16.1
WP Rosa 159A	9-17-03	8.0	10682	122	17.4
BP Americas Florence K5M	8-12-03	8.3	4190	51	11.1
BP Americas Florence K5M	8-20-03	8.4	6980	105	17.6
BP Americas Florence K5M	9-16-03	8.1	8126	101	13.6
Conoco/Phillips 242A	4-30-04	8.1	3640	67	6.3
Conoco/Phillips 242A	5-19-04	8.5	4020	76	7.1
Conoco/Phillips 242A	5-23-04	8.1	3850	65	7.0
Conoco/Phillips 207A	5-12-05	8.7	2464	51	3.7
Conoco/Phillips 207A	5-19-05	9.8	6030	250	9.5
Conoco/Phillips 207A	5-25-05	9.6	4660	80	7.5
WP 224	4-18-25	6.4	16410	23	30.1
WP 224	5-11-05	7.7	6130	54	11.0
WP 224	5-18-05	7.4	7380	65	11.9

Table 6. Produced water analysis averages for WP Rosa 159A and BP Americas Florence K5M, 2003, Conoco/Phillips 242A, 2004, Conoco/Phillips 207A and WP 224, 2005.

Location	pH	TDS (mg/L)	SAR	EC (dS/m)
	Averages			
WP Rosa 159A	8.3	8061	97	16.8
BP Americas Florence K5M	8.3	6432	86	14.1
Conoco/Phillips 242A	8.2	3838	69	6.8
Conoco/Phillips 207A	9.4	4384	127	6.9
WP 224	7.2	9973	142	17.7

Table 7. Averaged stand establishment of native and non-native grasses approximately three, two and one year after planting on WP Rosa 159A on BP Americas Florence K5M, 2004, Conoco/Phillips 242A, 2005, Conoco/Phillips 207A, and WP 224, 2006.

		Stand establishment[b]				
Cultivar[a]	lbs/pls/A	WP Rosa 159A[c]	BP Americas Florence K5M[d]	Conoco /Phillips 242A[e]	Conoco /Phillips 207A[f]	WP 224[f]
Arriba Western Wheatgrass	8.0	1.8	1.5	4.8	3.1	1.5
Chief Intermediate Wheatgrass	10.0	2.6	1.4	2.8	1.5	1.0
Luna Pubescent Wheatgrass	10.0	2.6	1.3	2.8	1.6	1.0
Hy Crest Crested Wheatgrass	5.0	2.8	1.3	4.5	3.6	2.0
VNS Canada Wild Ryegrass	7.0	2.5	1.1	6.5	3.9	2.5
Bozoisky Russian Wild Ryegrass	5.0	2.7	1.1	2.9	5.3	2.5
Critana Thickspike Wheatgrass	6.0	2.0	1.3	6.5	4.3	1.5
VNS Bottlebrush Squirreltail	8.0	1.3	1.5	6.0	2.9	2.0
Redondo Arizona Fescue	3.0	1.0	1.3	2.4	1	1.0
Paloma Indian Ricegrass	6.0	1.9	1.5	1.6	1.5	2.0
Anatone Bluebunch Wheatgrass	9.0	1.8	1.5	5.5	4.5	1.0
VNS Junegrass	4.0	1.5	1.3	1.1	1.0	1.0
Four-Wing Saltbush	2.0	1.0	1.5	1.3	1.0	1.0
Covar Sheep Fescue	2.0	2.6	1.5	1.6	1.0	1.0
San Luis Slender Wheatgrass	6.0	2.0	1.0	6.5	3.0	2.0
VNS Needle and Threadgrass	8.0	2.0	1.5	4.1	2.8	2.0

[a] VNS equal variety or cultivar not stated.
[b] Rated on a scale from one to nine with one being no stand establishment and nine being 100 percent established.
[c] Three year average stand establishment rating on October 26, 2004 and July 28, 2005, and July 26, 2006.
[d] Location was only rated once on October 26, 2004, no grass survival in 2005.
[e] Two year average stand establishment rating on July 29, 2005 and July 26, 2006.
[f] Locations rated on July 26, 2006.

Appendices

Photos of Coal Bed Methane Produced Water for Stand Establishment of Selected Native and Non-Native Grasses in the San Juan Oil and Gas Producing Basin, 2003-2006

Planting of native and non-native seed on coal bed methane produced well site

Williams Production Rosa 159A showing 400 barrel tank and pump

BP Americas Florence K5M showing produced water application

Conoco/Phillips 242A after application of produced water

Williams Production Rosa 159A Arriba Western Wheatgrass

Williams Production Rosa 159A San Luis Slender wheatgrass

Williams Production Rosa 159A Bottlebrush Squirreltail

Williams Production Rosa 159A Hy Crest Crested Wheatgrass

Conoco/Phillips 242A Anatone Bluebunch Wheatgrass

Conoco/Phillips 242A Arriba Western Wheatgrass

**Conoco/Phillips 242A
Bottlebrush Squirreltail**

**Conoco/Phillips 242A Canada
Wild Ryegrass**

**Conoco/Phillips 242A Critana
Thickspike Wheatgrass**

**Conoco/Phillips Hy Crest Crested
Wheatgrass**

**Conoco/Phillips 242A San Luis
Slender Wheatgrass**

**Conoco/Phillips 207A Anatone
Bluebunch Wheatgrass**

Conoco/Phillips 207A Bozoisky
Russian Wild Ryegrass

Conoco/Phillips 207A Canada
Wild Ryegrass

Conoco/Phillips 207A Critana
Thickspike Wheatgrass

Conoco/Phillips 207A Hy Crest
Crested Wheatgrass

Conoco/Phillips 207A San Luis
Slender Wheatgrass

Conoco/Phillips 207A Arriba
Western Wheatgrass

Acknowledgements

The author wishes to express his appreciation to the following individuals and/or oil and gas industries for there financial support and/or assistance during the course of this research, Bureau of Land Management Farmington Field Office, Mr. Steve Henke, Mr. Ray Sanchez, Mr. Dale Wirth, Mr. Dave Mankiewicz, Mr. Mark Kelly, Mr. Bill Papich, Mr. Daniel Sandoval, and Mr. Jeff Tafoya, El Paso Field Services, Mr. Ron Sipe and Mr. Joe Velasquez, BP Americas, Mrs. Brittany Benko, Mr. Jerry Huwe, and Mr. Ted Black, Williams Production, Mr. Stergie Katirgis and Mr. Mark Lepich, Burlington Resources, Mr. Chuck Smith and Mr. Terry Lowe, Pure Resources, Mr. Jeff Pickett and Mr. Mike Phillips, XTO Energy, Mr. Del Craddock and Mr. Terry Matthews, Conoco/Phillips, Mr. Bob Wirtanen, San Juan Cattle Growers Association, and New Mexico State University Agricultural Science Center, Mr. Daniel Smeal.

Jones, Brad A., EMNRD

From: Cappelle, Malynda A [macappe@sandia.gov]
Sent: Tuesday, November 18, 2008 4:03 PM
To: 'Kay.K.Bjornen@conocophillips.com'; 'Smith, Cindy L'; 'Johnson, Monica'; 'Miller, Rebekah E.'; 'Wirtanen, Bob A'; 'gwendolynne.frost@conocophillips.com'; 'Brett.L.Adams@conocophillips.com'; 'Frank McDonald'; 'Rick Arnold'; 'joelbrow@nmsu.edu'; 'albierle@yahoo.com'; Henne, Lisa J. (LANL); DeGreeff, Jenniffer Leigh; Johnston, Mariann R. (LANL); Sullivan, Enid J. (LANL); Jones, Brad A., EMNRD; 'Dale_Wirth@nm.blm.gov'; Powell, Brandon, EMNRD; Powell, Brandon, EMNRD
Cc: Rigali, Mark J; Borns, David J; Merson, John A; Everett, Randy L; Holub Jr, William E
Subject: 2007 Sandia-ConocoPhillips-BEST Desalination Report
Attachments: CBNG Pilot Report SAND2008-4824 (revO 092608)-small.pdf

Hello,

I am attaching the report that covers 2007 operations at the ConocoPhillips well pad in the Four Corners area of New Mexico. I am sending to a large distribution, but am sure that I have mistakenly left someone off of the list. Please feel free to forward as you need. If you would prefer a printed copy, please let me know your address and I will gladly send you a copy.
I would like to thank everyone who helped get this work going and has provided support throughout the project, especially to ConocoPhillips. We at Sandia cannot express our appreciation enough for the collaboration of ConocoPhillips San Juan Business Unit on this venture. Also, without the efforts and support from Frank McDonald (Biosphere Environmental Sciences & Technology), Rick Arnold (New Mexico State University's Agricultural Science Center at Farmington), and our various funding sources (New Mexico Small Business Assistance program, Department of Energy, US Bureau of Land Management), this project could not have experienced the success we had this year.

We will be putting together a report for the 2008 pilot operations and hope to have it out by early spring 2009. We are looking forward to the future research and further collaborations with ConocoPhillips, Biosphere Environmental Sciences & Technology, New Mexico State University's Agricultural Science Center at Farmington, the New Mexico Oil & Gas Conservation Division, the New Mexico Bureau of Land Management office, and Los Alamos Laboratories.

Please let us know if you have any questions.

Warmest Regards,

Malynda Cappelle
macappe@sandia.gov
Sandia National Laboratories, 6316
P.O. Box 5800, MS 0754
Albuquerque, NM 87185-0754

Phone: (505) 844-1288
Fax: (505) 844-7354

SANDIA REPORT
SAND2008-4824
Unlimited Release
Printed August 2008

Coal Bed Natural Gas Produced Water Preliminary Pilot Plant Operation and Results

ConocoPhillips San Juan 32-8 Unit #237A Well Site

Malynda Cappelle, Randy Everett, William Holub, Richard Kottenstette, Allan Sattler (Sandia National Laboratories)

and

ConocoPhillips, San Juan Business Unit

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Sandia National Laboratories

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Available to DOE and DOE contractors from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865)576-8401
Facsimile: (865)576-5728
E-Mail: reports@adonis.osti.gov
Online ordering: http://www.osti.gov/bridge

Available to the public from
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Rd
Springfield, VA 22161

Telephone: (800)553-6847
Facsimile: (703)605-6900
E-Mail: orders@ntis.fedworld.gov
Online order: http://www.ntis.gov/help/ordermethods.asp?loc=7-4-0#online

SANDIA REPORT
SAND2008-4824
Unlimited Release
Printed August 2008

Coal Bed Natural Gas Produced Water Preliminary Pilot Plant Operation and Results

ConocoPhillips San Juan 32-8 Unit #237A Well Site

Malynda Cappelle, Randy Everett, William Holub, Richard Kottenstette, Allan Sattler (Sandia National Laboratories)

and

ConocoPhillips, San Juan Business Unit

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Approved for public release; further dissemination unlimited.

Sandia National Laboratories

Acknowledgements

This project gratefully the following acknowledges the following sponsors:

- The US Department of Energy-sponsored Natural Gas and Oil Technology Partnership managed through the National Energy Technology Laboratory
- The US Department Energy-sponsored Southwest Regional Partnership for Carbon Sequestration managed through the National Energy Technology Laboratory
- The Sandia National Laboratories' Desalination Program
- The Sandia National Laboratories' New Mexico Small Business Assistance Program
- The U S Bureau of Land Management Farmington, New Mexico District Office

We gratefully acknowledge the partnership of the ConocoPhillips San Juan Business Unit, especially Bob Wirtanen, Monica Johnson, Rebekah Miller, and Jimmy Bowman. ConocoPhillips provided extensive site-work, an electrical generator, access to the coal bed derived water and further safety provisions and training. Their professional staff and operators provided essential support to this project which could not have been completed without their professional and timely assistance.

Also this project would not have been possible without the generous collaboration of :

- Frank McDonald, Biosphere Environmental Sciences and Technologies,
- Professor Rick Arnold of the New Mexico State University Agricultural Sciences Center at Farmington.

The continuing support of David Borns, Mark Rigali, and John Merson at Sandia National Laboratories, as well as the continuing interest of and association with the U. S. Bureau of Land Management, Farmington, and with the New Mexico Oil Conservation Division, Santa Fe and Aztec, in this endeavor is gratefully acknowledged.

Sandia is a multiprogramming laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Table of Contents

Page

1. Introduction **9**

1.1. Produced Water Background *9*

1.2. San Juan Basin Wells *9*

2. Objectives of the CBNG Produced Water Pilot Test **11**

3. Description of Pilot Test **13**

3.1. Site Description *13*

3.2. Pilot Plant Description *15*
3.2.1. Pilot Test Design 15
3.2.2. Pilot Equipment and Treatment Equipment 15
3.2.3. Treatment Process – Ultrafiltration and Reverse Osmosis 18

3.3. Water Quality *19*

3.4. Sampling Plan *20*

4. Test Results **23**

4.1. Operations *23*

4.2. System Performance *23*
4.2.1. Cyclone Filters & Settling Tanks 23
4.2.2. Ultrafiltration System 23
4.2.3. Reverse Osmosis System 25

4.3. Land Application of Water by NMSU/USDA *27*

5. Discussion and Conclusions **29**

5.1. Water Treatment Cost Estimates *29*

5.2. Future Work *29*
5.2.1. Experimental Plan – CBNG Produced Water Desalination Pilot, Phase 2 29
5.2.2. Desalination at a Salt Water Disposal (SWD) Site 30

6. References **31**

Appendices **33**

Appendix B – Water Chemistry Measurements **37**

Appendix C – Particulate Analysis **44**

Appendix D – Water Meter Data **45**

Figures

Page

Figure 1-1. Overview Map of San Juan Basin, Colorado/New Mexico (source: EIA, 2004) 10
Figure 3-1. CBNG Produced Water Pilot Plant Location (PG Environmental, 2008) 13
Figure 3-2. Pilot Site Diagram 14
Figure 3-3. CBNG Well Site and Pilot Equipment 14
Figure 3-4. Generator, Transportainer and Treated, Untreated Water, and Concentrate Tanks on ConocoPhillips CBNG Well Pad 15
Figure 3-5. Pilot Flow Diagram 17
Figures 3-6 (a-d). Pilot Equipment Pictures 18
Figure 4-1. Reverse Osmosis Optimized Flow Rates and Mass Balance (on TDS) 23
Figure 4.2. Conductivity Measurements – RO Streams 25
Figure 4-3. Turbidity Removal – Reverse Osmosis System 26
Figure 4-4. Turbidity Reduction – UF and RO systems 27
Figure 4-5. Land Application of Untreated Produced Water 28
Figure 5-1. Water Treatment Pilot Equipment Flow Diagram 30
Figure C-1. Spectrex Particulate Analysis 44
Figure D-1. Totalized Water Meter Data 45
Figure D-2. Flow Meter Data 45

Tables

Page

Table 3-1. CBNG Produced Water Composition 19
Table 3-2. Produced Water Organic Composition 20
Table 3-3. Water Quality Sampling Plan 21
Table 4-1. UF Performance Summary 24
Table 4-2. UF Field Data 24
Table 4-3. Summary of RO Performance – Laboratory Analyses 26
Table A-1. Summary of Field Activities and Notes 34
Table B-1. Field Test Results 37
Table B-2. Log sheet Data: Flow Rate and Conductivity Measurements 40
Table B-3. Log sheet Data: Pressure and Temperature Measurements 42

Acronyms and Abbreviations

AA	atomic absorption
BBL	US barrel, defined as 42 gallons
CBNG	coal bed natural gas
COP	ConocoPhillips
BPD	barrels per day
B.E.S.T.	Biosphere Sciences and Technologies
EIA	Energy Information Agency
gpm	gallons per minute
ICP, ICP-MS	inductively coupled plasma mass spectrometer
kwh	kilowatt hour
Mcf/d	1000 cubic feet per day
mg/L	milligrams per liter
µm	micrometer or micron
µg/L	micrograms per liter
µS/cm	micro Siemens per centimeter (conductivity)
NMOCD	New Mexico Oil Conservation Division
NTU	nephelometric turbidity units
O&M	operations and maintenance
ppb	parts per billion
psi	pounds per square inch
PVC	polyvinyl chloride
RO	reverse osmosis
SNL	Sandia National Laboratories
SWD	salt water disposal facility
TOC	total organic carbon
TDS	total dissolved solids
TFC	thin film composite
TSS	total suspended solids
USBLM	U. S. Bureau of Land Management
USEPA	U.S. Environmental Protection Agency
USDA	U.S. Department of Agriculture

1. Introduction

1.1. Produced Water Background

Coal Bed Natural Gas (CBNG) accounted for over 10 percent of natural gas production in the U.S. in 2004 (EPA, 2008). Spurred by increased energy needs, environmental emission considerations, advantages of natural gas, and technology advances in exploration and production, CBNG production could easily double in the next 8-10 years, accounting for up to 20% of our total natural gas production. CBNG operators face increasing environmental problems and expense in hauling off and disposing of produced water (from $1-$5+/ barrel in the San Juan Basin) which has the potential of severely restricting the flow of natural gas. The aggregate water volumes from these gas wells, and the disposal and attendant environmental problems posed, are unprecedented. Operators relate that the problem of handling produced CBNG water is very urgent.

Unlike some older established oil fields, CBNG fields like the San Juan and Raton Basins generally have relatively little infrastructure, especially when compared to other fields where complete gathering systems exist. In these relatively newer CBNG areas, desalination treatment of produced water may have to be done on a well pad by well pad basis, or by gathering the produced CBNG water from two or three adjacent pads. Therefore, more compact units may be more appropriate than larger desalination units.

CBNG produced water has a fairly consistent chemical signature, in that it has moderate to high levels of dissolved solids. The main dissolved constituent found in CBNG produced waters is bicarbonate, as well as higher levels of chloride and sodium. As described by Van Voast (2003), there is very little calcium or magnesium present in coal bed methane produced waters, which can be explained by the high bicarbonate levels; higher levels of bicarbonate lead to lowered solubility of calcium and magnesium.

1.2. San Juan Basin Wells

The San Juan Basin covers an area of about 7,500 square miles across the Colorado/New Mexico state line in the Four Corners region. Figure 1-1 (modified from EIA, 2004) shows the oil and gas mines in the region.

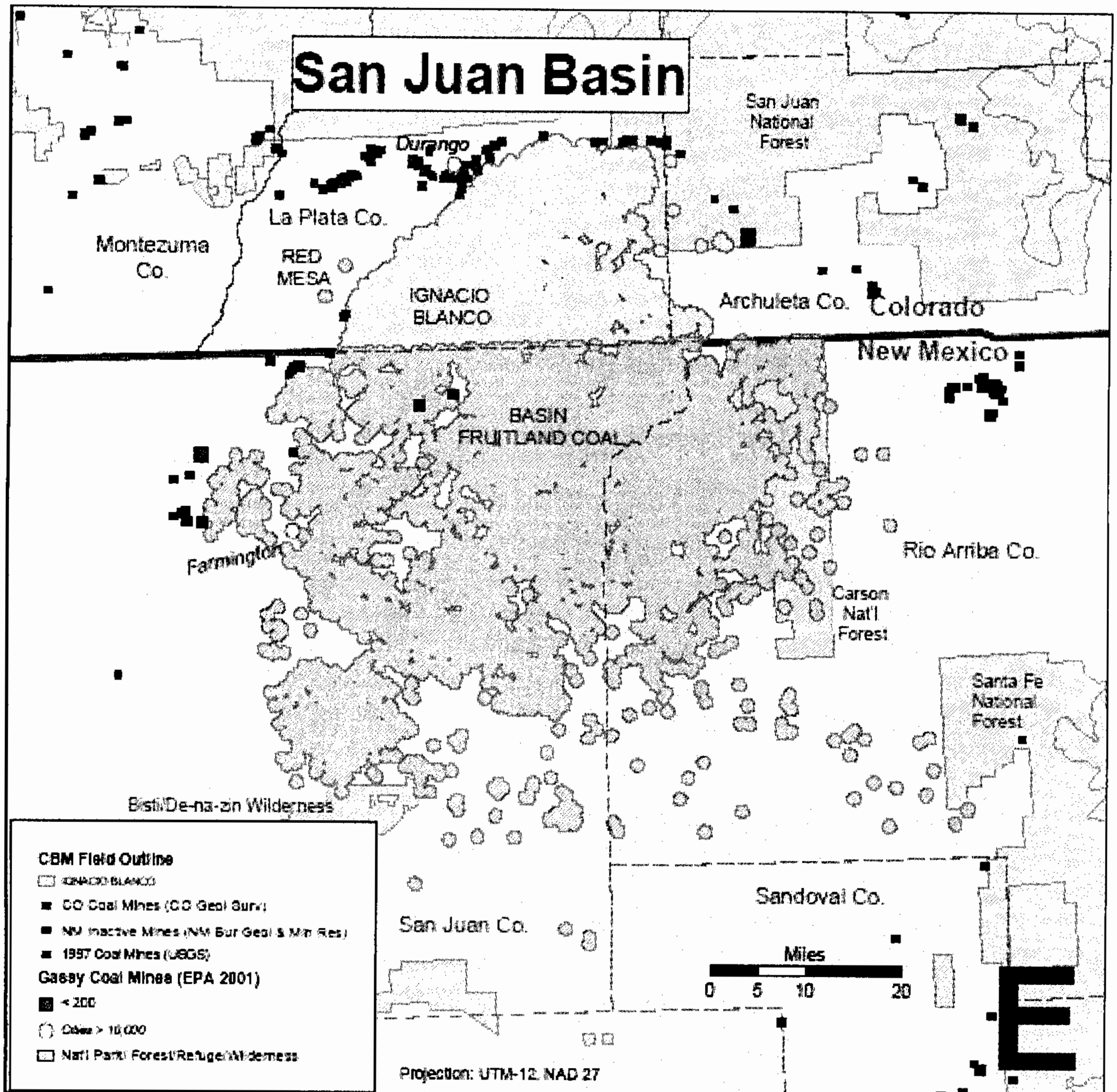


Figure 1-1. Overview Map of San Juan Basin, Colorado/New Mexico (source: EIA, 2004)

2. Objectives of the CBNG Produced Water Pilot Test

In this project, the produced water from CBNG wells was reclaimed (desalinated) and used for a short term rangeland improvement study. Some of the grasses near the pad of the ConocoPhillips San Juan San Juan 32-8 UNIT #237A well site were watered with treated and untreated water. The technology applied to bring CBNG produced water to a suitable standard for rangeland and riparian improvement depends both on the TDS and organic content of the particular CBNG produced water.

The technical challenge with respect to water treatment is to pre-treat the water for organic and other contaminants that will cause membrane fouling or scaling, as well as to remove coal fines prior to desalination. Membrane fouling and scaling can cause significant pressure increases and increase the amount of chemical cleaning required. The organic content of the produced water is designed to be lowered by membrane filtration. The pilot equipment was designed to remove coal fines by cyclone/centrifuge separators and a settling tank. After the pretreatment the salt content was lowered by reverse osmosis.

3. Description of Pilot Test

3.1. Site Description

The pilot location is on the ConocoPhillips San Juan 32-8 UNIT #237A well site, which is located 500 ft off NM 511. The closest town is Bloomfield, NM and the site is approximately 11 miles past Navajo Dam. Figure 3-1 shows the approximate location of the pilot operation.

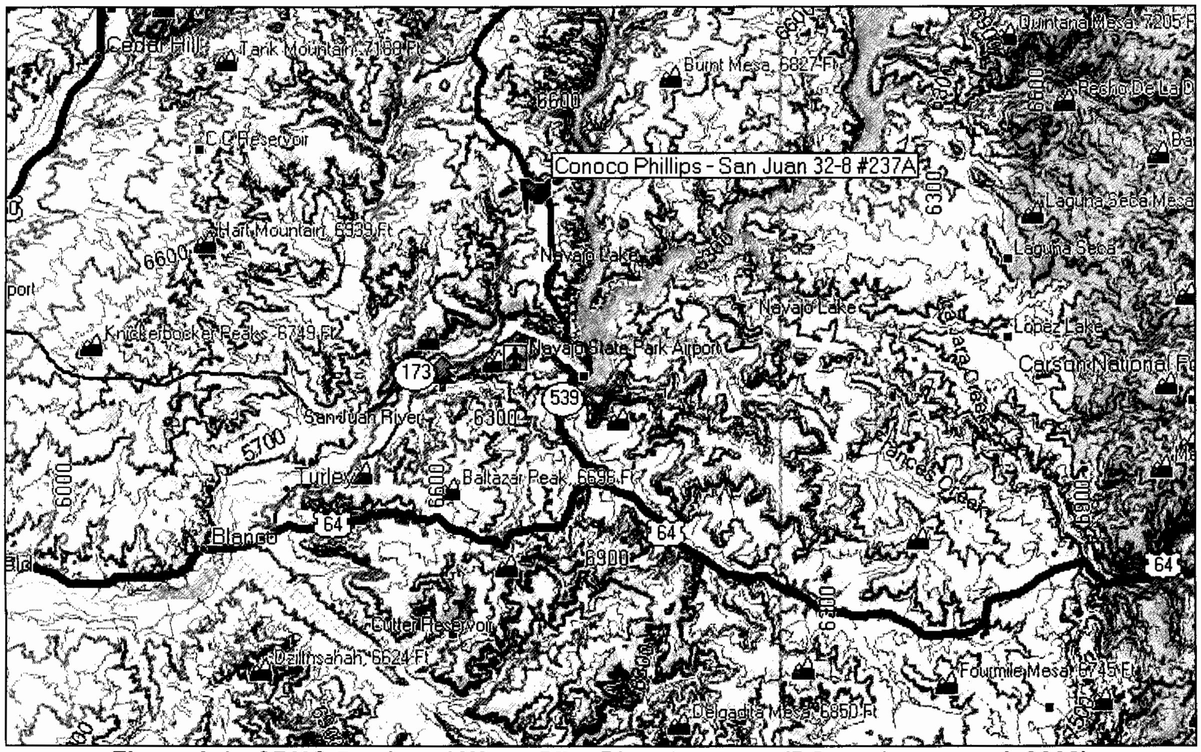


Figure 3-1. CBNG Produced Water Pilot Plant Location (PG Environmental, 2008)

Produced water from a single ConocoPhillips CBNG well is being utilized for this treatment pilot program. Natural gas and produced water are pumped from the Fruitland coal formation between 3,183 feet and 3,385 feet below the ground surface using a reciprocating piston pump. This mixture is sent to a gas-water separator, with the produced water going to a temporary storage tank. The water is normally drained from the storage tank and trucked away and is reinjected into the formation. The current gas production at this site is 220 Mcf/d. Water production from this well was approximately 15 to 37 BPD. Figure 3-2 shows the layout of the well site.

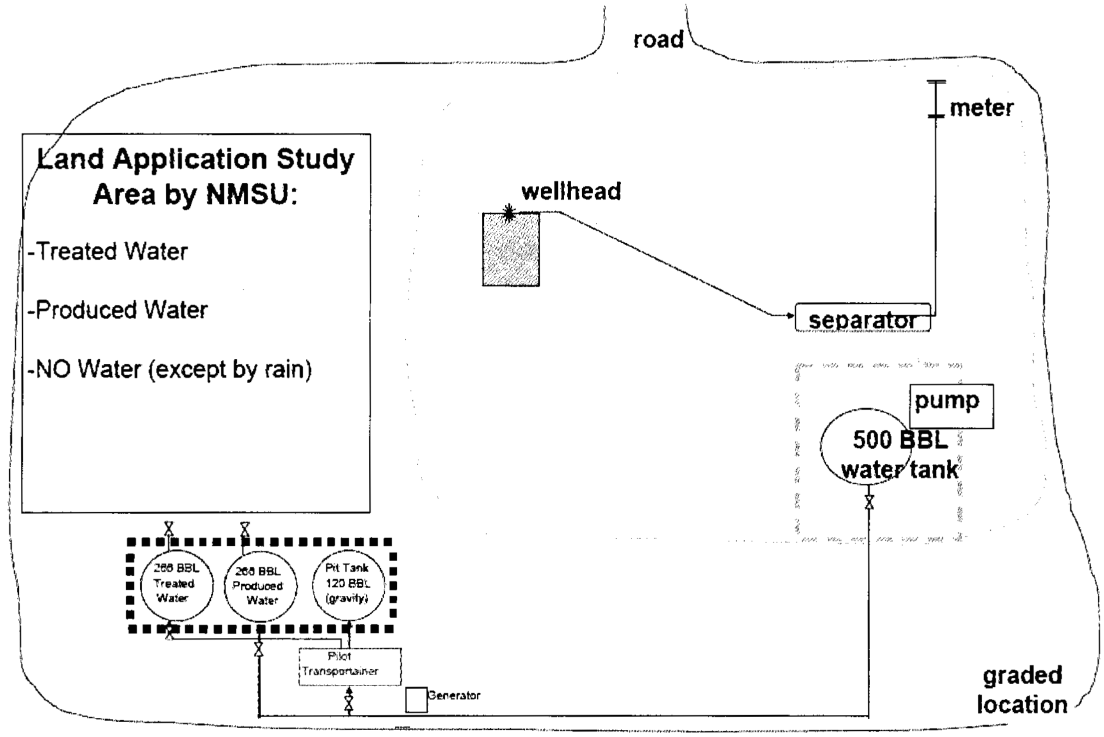


Figure 3-2. Pilot Site Diagram

Sandia pilot equipment is located on the ConocoPhillips well site and is located inside a 20-ft transportainer, owned by Sandia. The site has no electricity, which required the pilot equipment to be powered by a leased diesel generator for the duration of the pilot. ConocoPhillips provided produced water, site security, storage tanks, safety training and berming of critical areas. B.E.S.T. provided pilot operation and sampling. Figures 3-3 and 3-4 show the Sandia pilot equipment and the pilot site.

Figure 3-3. CBNG Well Site and Pilot Equipment

Figure 3-4. Generator, Transportainer and Treated, Untreated Water, and Concentrate Tanks on ConocoPhillips CBNG Well Pad

3.2. Pilot Plant Description

3.2.1. Pilot Test Design

ConocoPhillips provided raw (untreated) produced water to the Sandia pilot operation. This water was stored in the 500-BBL storage tank prior to being delivered the pilot. This water may have traces of constituents from the coal formation and/or from the mining process. The work, from 2/8/07-11/29/07, focused on testing a particulate removal system, along with membrane processes to produce water suitable for rangeland and riparian improvement.

3.2.2. Pilot Equipment and Treatment Equipment

The CBNG produced water pilot system is made up of the following modular components:

1. Raw water makeup system and water storage (ConocoPhillips equipment)
    a. 500-BBL produced water storage tank
    b. Piping to/from pilot equipment
    c. 266-BBL treated water storage tank
    d. 266-BBL raw produced water storage tank
    e. 120-BBL pit tank (for storage of pilot concentrate stream)
    f. Heat tape on water lines
    g. Berming of grasses and desalination equipment

2. Sandia Pilot Equipment
    a. Large Particulate Removal (settling tank, cyclone separators) to remove coal fines and other particulate matter that is 10-20 microns (μm) or larger
    b. Ultrafiltration to remove finer suspended matter, down to 0.01 μm (molecular weight cut-off of 20K-50K Daltons)
    c. Reverse Osmosis to remove dissolved matter (and remaining suspended matter)
    d. Data logging and controls system
    e. Pumps, tanks, filters, and treatment chemicals

3. Land Application Area, (3) 4000 ft^2 areas
    a. ~1/3 Natural Area, No additional water added
    b. 1/3 Natural Area, Untreated produced water application
    c. 1/3 Natural Area, Treated produced water application (TDS < 1,000 mg/L)

Figure 3-5 shows the flow diagram of the pilot equipment and Figures 3-6 a-d show the pieces of equipment themselves. Raw produced water from the 500-BBL storage tank was pumped into the pilot's settling tank (T-100). This tank has level control equipment installed to protect from over/under-filling. Water from T-100 was pumped through cyclone filters to remove larger suspended particles (designed for removal of 10-20 μm particles) and sent to the UF feed tank (T-200). Water from T-200 was fed to the 5-μm pre-filter, then through the UF itself to the RO feed tank (T-300). The final step is for the water to be pumped through the RO pre-filter and the RO itself to the permeate storage tank (T-400). T-400 was pumped to the ConocoPhillips treated water storage tank as it is filled (approximately every 35 gallons).

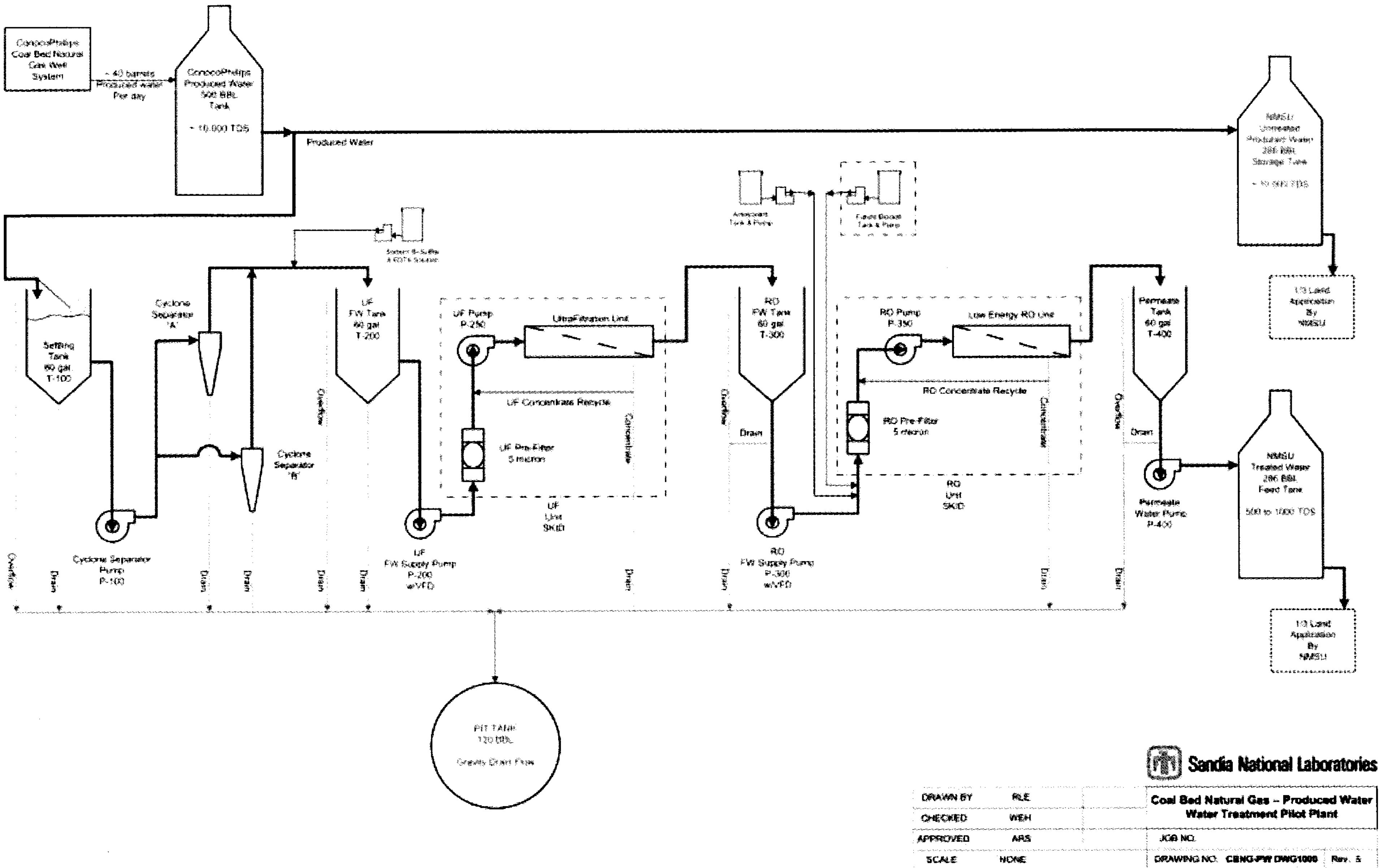


Figure 3-5. Pilot Flow Diagram

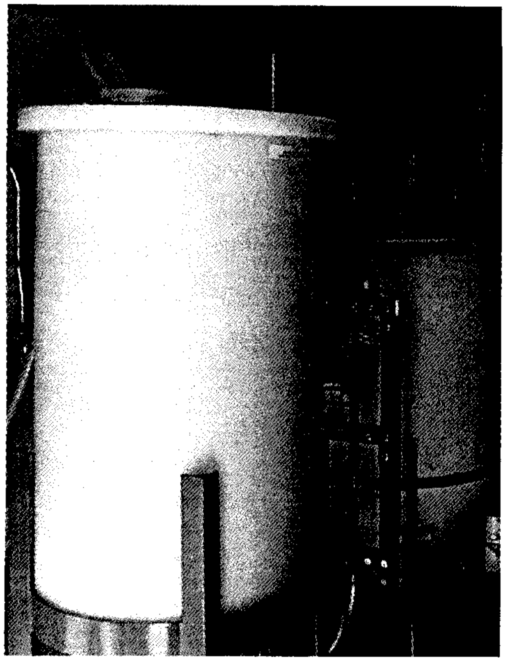


Figure 3-6a. T-100, Cyclone Filters, T-200

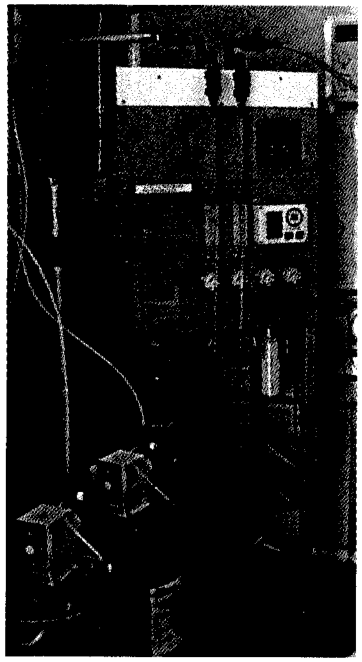


Figure 3-6b. Chemical Feed Tanks, UF System

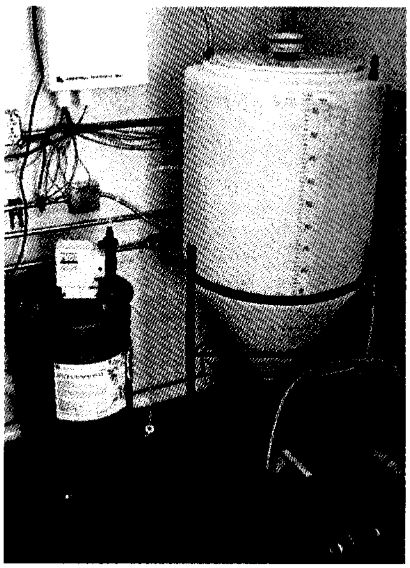


Figure 3-6c. Chemical Feed Tank, T-300

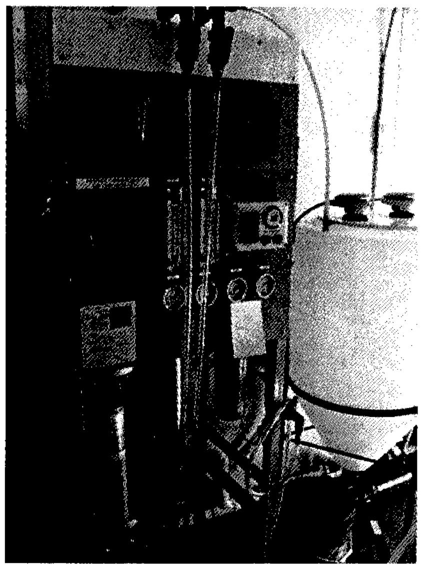


Figure 3-6d. RO System, T-400

Figures 3-6 (a-d). Pilot Equipment Pictures

3.2.3. Treatment Process – Ultrafiltration and Reverse Osmosis

Ultrafiltration (UF) is a membrane process that separates particulate matter from water based on membrane pore size. The GE M-Series spiral wound UF membrane used in this pilot are characterized by a pore size of 0.01 μm with an approximate molecular weight cut-off of 20K-50K Daltons. Since the membrane is spiral wound, it is not able to be backwashed. The system was operated at a pressure of 160 psi.

Reverse Osmosis is a membrane process that removes dissolved species by overcoming the osmotic pressure of the feed stream with enough excess pressure to create a permeate stream. This occurs via diffusion, but the majority of all suspended and colloidal species remaining in the feed stream will also be removed (e.g. TOC, iron, etc.). The osmotic pressure of the feed water in this case is approximately 150 psi, which means more than 150 psi is required to produce permeate from the RO membrane. The more pressure applied, the more water (and better quality) is produced. The GE AG4040 membranes used in this pilot operation were thin film composite (TFC) membranes that are designed for low energy (low pressure) brackish water desalination. The system was operated at a pressure of 270 psi.

3.3. Water Quality

Average produced water quality experienced during this pilot (February-December 2007) is presented in Tables 3-1 and 3-2. The water is brackish, with an average TDS (as calculated by summing of dissolved species present in water) of 14,500 mg/L. The TDS (gravimetric, at 180 °C) is 10,700 mg/L on average. It is important to note that historical calculations for TDS and many publications would cite the TDS differently. The method used to measure TDS is to evaporate the water and weigh the solids leftover, causing about 50% of the bicarbonate to off gas. Therefore, it is not counted. Many laboratories will reduce the calculated TDS if they sum all of the dissolved species by subtracting about 50% of the bicarbonate. For desalination operations, it is most correct to sum up all dissolved species for membrane design, but both forms are shown here for completeness.

Table 3-1. CBNG Produced Water Composition

Analyte	Units	Avg Value
Specific Conductance	µS/cm	17,300
Total Dissolved Solids (@ 180 °C)	mg/L	10,700
TDS (sum of all dissolved species)	mg/L	14,500
pH	units	7.91
Temperature	°C	16.2
Specific Gravity		1.00
Dissolved Oxygen	mg/L	5.30
Total Suspended Solids	mg/L	150
Anions		
Chloride	mg/L	2,087
Fluoride	mg/L	0.724
Nitrate, as N	mg/L	0.775
OrthoPhosphate, as P	mg/L	12.8
Total Phosphorous, as P	mg/L	13.0
Sulfate	mg/L	2.78
Silica	mg/L	9.88
Alkalinity		
Total, as $CaCO_3$	mg/L	6,380
Bicarbonate, as HCO_3	mg/L	7,790
Carbonate, as CO_3	mg/L	ND
Cations		
Hardness, as $CaCO_3$	mg/L	80.0
Aluminum	mg/L	<0.1
Arsenic	mg/L	<0.01
Boron	mg/L	2.65
Barium	mg/L	28.1
Copper	mg/L	<0.1
Calcium	mg/L	27.3
Iron	mg/L	0.405
Magnesium	mg/L	5.86
Manganese	mg/L	<0.1
Potassium	mg/L	22.8
Selenium	mg/L	ND
Sodium	mg/L	4,520

Table 3-2. Produced Water Organic Composition

Analyte	Units	Avg Value
Purgeable VOCs		
Benzene	µg/L	1.00
Ethylbenzene	µg/L	1.15
o-Xylene	µg/L	1.90
p/m-Xylenes	µg/L	6.90
Toluene	µg/L	39.0
Total BTEX	µg/L	50.0
Gasoline Range Organics	mg/L	ND
Diesel Range Organics	mg/L	ND
TOC	mg/L	17.7
Total Recoverable Petroleum Hydrocarbons	mg/L	ND
N-Hexane Extractable Material	mg/L	2.0

Similar to other CBNG produced waters, the main dissolved constituents are chloride, bicarbonate, and sodium. The elevated bicarbonate leads to significantly lowered calcium and magnesium solubility. Thus, this water, like most CBNG water, has extremely low calcium and magnesium content. CBNG produced waters are different from oil and gas produced waters in that they have minimal dissolved or emulsified organic constituents. The methanogenic microbes present in the formations anaerobically produce mostly methane and reduce sulfur to a sulfide. This accounts for low sulfate content in the water as well. Although tests indicated that a small amount of VOCs were present in the water, it is unclear whether they were significant since the number of samples were small. This may be an indication of contamination during sampling or storage in the 500 BBL tank. This will be investigated during the next phase of the project.

3.4. Sampling Plan

A rigorous sampling plan was not created for this pilot operation. The raw (untreated) water was analyzed three times, the RO system twice, and the UF system once. Table 3-3 summarizes the analyses and methods performed by contract laboratories.

Table 3-3. Water Quality Sampling Plan

Parameter	Stream Sampled	Method Used (Envirotech[1])	Method Used (Assaigai)
Specific Conductance	Raw, UF (F,C,P), RO-all	EPA 600/4-79/020	EPA 120.1
Total Dissolved Solids (@ 180 °C)	Raw, UF (F,C,P), RO-all	EPA 600/4-79/020	EPA 160.1
TDS (summation of all dissolved species)	Raw, UF (F,C,P), RO-all	N/A	
pH	Raw, UF (F,C,P), RO-all	EPA 600/4-79/020	EPA 150.1
Temperature	Raw, UF (F,C,P), RO-all	EPA 600/4-79/020	Not analyzed
Specific Gravity	Raw, UF (F,C,P), RO-all	EPA 600/4-79/020	Not analyzed
Dissolved Oxygen	Raw, UF (F,C,P), RO-all	EPA 600/4-79/020	Not analyzed
Total Suspended Solids	Raw, UF (F, P), RO (all)	EPA 600/4-79/020	Not analyzed
Anions			
Chloride	Raw, RO (all)	EPA 600/4-79/020	EPA 300.0 (IC)
Fluoride	Raw, RO (all)	EPA 600/4-79/020	Not analyzed
Nitrate, as N	Raw, RO (all)	EPA 600/4-79/020	Not analyzed
OrthoPhosphate, as P	Raw, RO (all)	EPA 600/4-79/020	EPA 300.0 (IC)
Total Phosphorous, as P	Raw, RO (all)	EPA 600/4-79/020	SM 4500-P-B, D
Sulfate	Raw, RO (all)	EPA 600/4-79/020	EPA 300.0 (IC)
Silica	Raw, RO (all)	EPA 6010B	EPA 200.7 (ICP)
Alkalinity			
Total, as $CaCO_3$	Raw, RO (all)	EPA 600/4-79/020	Not analyzed
Bicarbonate, as HCO_3	Raw, RO (all)	EPA 600/4-79/020	EPA 310.1 (titration)
Carbonate, as CO_3	Raw, RO (all)	EPA 600/4-79/020	EPA 310.1 (titration)
Cations			
Hardness, as $CaCO_3$	Raw, RO (all)	EPA 600/4-79/020	SM 2340B (titration)
Aluminum	Raw, RO (all)	EPA 6010B	Not analyzed
Arsenic	Raw, RO (all)	EPA 6010B	EPA 200.8 (ICP-MS)
Boron	Raw, RO (all)	EPA 6010B	Not analyzed
Barium	Raw, RO (all)	EPA 600/4-79/020	Not analyzed
Copper	Raw, RO (all)	EPA 6010B	Not analyzed
Calcium	Raw, RO (all)	EPA 600/4-79/020	EPA 200.7 (ICP)
Iron	Raw, RO (all)	EPA 600/4-79/020	EPA 200.7 (ICP)
Magnesium	Raw, RO (all)	EPA 600/4-79/020	EPA 200.7 (ICP)
Manganese	Raw, RO (all)	EPA 6010B	Not analyzed
Potassium	Raw, RO (all)	EPA 600/4-79/020	EPA 200.7 (ICP)
Selenium	Raw, RO (all)	EPA 6010B	Not analyzed
Sodium	Raw, RO (all)	EPA 600/4-79/020	EPA 200.7 (ICP)
Purgeable VOCs		EPA 600/4-79/020	Not analyzed
Benzene	Raw, UF (F, P)	EPA 8021, 8260	EPA 8021B
Ethylbenzene	Raw, UF (F, P)	EPA 8021, 8260	EPA 8021B
o-Xylene	Raw, UF (F, P)	EPA 8021, 8260	EPA 8021B
p/m-Xylenes	Raw, UF (F, P)	EPA 8021, 8260	EPA 8021B
Toluene	Raw, UF (F, P)	EPA 8021, 8260	EPA 8021B
Total BTEX	Raw, UF (F, P)	EPA 8021, 8260	Not analyzed
Gasoline Range Organics	Raw, UF (F, P)	EPA 8015B	EPA 8015B
Diesel Range Organics	Raw, UF (F, P)	EPA 8015B	EPA 8015B
Total Organic Carbon	Raw, UF (F, P)	EPA 9060	EPA 9060
Total Recoverable Petroleum Hydrocarbons	Raw, UF (F, P)	EPA 8015B, 418.1	Not analyzed
N-Hexane Extractable Material	Raw, UF (F, P)	EPA 1664a	Not analyzed

[1]Envirotech used EPA Methods for Chemical Analysis of Water

4. Test Results

4.1. Operations

The pilot started producing water on 10/1/07 without the UF system in operation and a 5 μm cartridge filter was installed. Because we noted that iron, turbidity and suspended solids levels after the 5 μm filter were higher than the RO manufacturer's specifications the filter was replaced with a 0.38 μm filter on 10/17/07.

During the commissioning of the pilot equipment, flow rates were optimized to maintain flow while minimizing on/off cycles of pumps and maintaining proper levels in the various tanks. Figure 4-1 summarizes the optimized flow rates and associated TDS and pH levels in each of the streams on 11/28/07 (these flow rates were utilized from 10/10/07 until the end of the pilot).

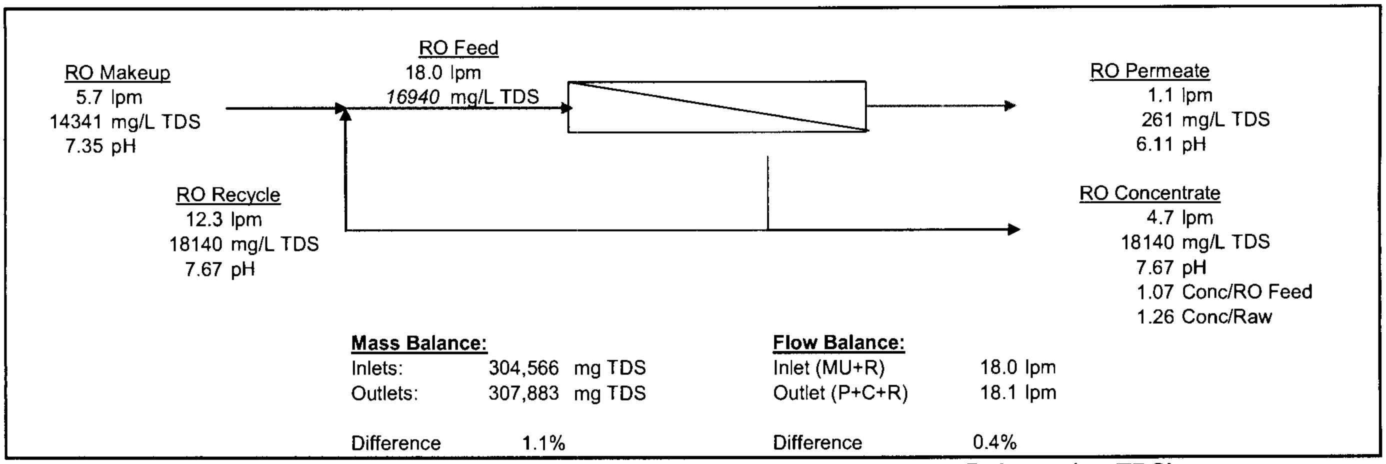


Figure 4-1. Reverse Osmosis Optimized Flow Rates and Mass Balance (on TDS)

The UF system was put into operation on 11/15/07. At that time, the pre-filter for the reverse osmosis system was changed back to a 1 μm size to minimize the pressure drop.

4.2. System Performance

4.2.1. Cyclone Filters & Settling Tanks

The original design utilized a settling tank and cyclone filters for the anticipated need for to remove coal fines and other particulate matter greater than 10-20 μm in size. It became apparent during this test that there were very few coal fines or other particulate matter greater than 10-20 μm present. The cyclone filters were causing difficulties with flow balancing in the entire system and were removed on 11/13/07. Some particulate matter did settle in low flow areas such as tubing to pressure gauges. Since the pilot was not run for a long duration, it is unclear if any particulates caused problems within the membrane systems (UF and RO).

4.2.2. Ultrafiltration System

The UF system was placed in operation on 11/14/07 and ran for a total of four days. During phase 2, an extended period of operation is expected. The electronic datalogging equipment (flow metering) was not calibrated for the UF system so all flow data presented here are from the rotameters installed on the UF system. During operation only one sample was analyzed for organics on the UF streams; salt content was not analyzed since dissolved constituents are not removed with UF. Table 4-1 summarizes the single sample's analyses. Gasoline and diesel range organics, as well as total recoverable petroleum hydrocarbon data are not presented; all streams had non-detectable values.

Table 4-1. UF Performance Summary

	Units	Raw	UF Permeate	Removal Efficiency
Specific Conductance (@ 25°C)	μS/cm	16,500	16,400	N/A
Total Dissolved Solids (@ 180°C)	mg/L	12,200	11,800	N/A
TDS (calculation)	mg/L	14,953	14,341	N/A
pH	Units	7.35	7.58	N/A
Specific Gravity		1.0078	1.008	N/A
Dissolved Oxygen	mg/L	5.7	6	N/A
Total Suspended Solids	mg/L	150	150	0%
Benzene	μg/L	1.1	0.9	18%
Ethylbenzene	μg/L	0.5	0.6	0%
o-Xylene	μg/L	1.5	1.4	7%
p/m-Xylenes	μg/L	4	3.3	18%
Toluene	μg/L	83	53.4	36%
TOC	mg/L	30	30	0%
N-Hexane Extractable Material	mg/L	4	8	0%

This data would suggest that the UF may not have not have performed well or performed inconsistently since TSS did not seem to be removed. However, it should be noted that all equipment was operated with sub-optimal conditions. Equipment was not operated continuously and in many cases was stagnant for multiple days. In addition, the design of the UF membrane (spiral wound) is such that is not able to be backwashed. A full scale system may be better served by an outside-inside UF system that can be backwashed on a regular frequency to minimize fouling by suspended solids. Finally, UF membranes will not remove any dissolved organic species, which may explain the low TOC removal.

Field data obtained during UF operation however, would suggest that the UF removed a considerable amount of turbidity from the feed water. This improved the water quality sent to the RO system. Table 4-2 summarizes the field data obtained during the UF operation. Turbidity was decreased by at least 68%. The variation of removal efficiency was likely affected by the intermittent operation of the system.

Table 4-2. UF Field Data

	Parameter	Units	Inlet	Concentrate	Permeate
11/14/2007	Conductivity	μS/cm	17,840	17,930	17,940
	Temperature	C	16.5	17.1	17.4
	pH	units	7.4	7.4	7.4
	Turbidity	NTU	12.1	10.5	0.2
	Iron	mg/L	3.04	2.95	2.31
11/16/2007	Conductivity	μS/cm	17,900	18,010	18,100
	Temperature	C	14.2	14.8	14.4
	pH	units			
	Turbidity	NTU	17.9	16.3	1.08
	Iron	mg/L			
11/26/2007	Conductivity	μS/cm	18,010	18,180	18,130
	Temperature	C	11.1	10.3	10.5
	pH	units			
	Turbidity	NTU	8.57	11.5	2.94
	Iron	mg/L			
11/28/2007	Turbidity	NTU	15.6	18.4	4.91

4.2.3. Reverse Osmosis System

As previously described, the RO system was operated without the UF system until 11/14/07. In addition, the system was operated intermittently and without a permeate flush or preservation during periods of inactivity. While these conditions are sub-optimal, they are good for testing the worst-case operational limits of the RO system itself.

Initially, the RO system was operated with a 5 µm pre-filter to remove particulate matter from the influent water. After some field data was gathered indicating higher than expected iron levels and turbidity levels above the RO membrane manufacturer's suggested levels, the pre-filter was changed to a 0.38 µm pre-filter anticipating it would greatly improve protection of RO membrane. Once the UF was in operation, a 1 µm pre-filter was installed. The filter was changed out a total of eight times.

Most species present in the feed water were removed by 98% or better by the reverse osmosis system. Some species such as TSS, silica, and sulfate, were removed to a lesser degree. It should be noted that only two sets of data were analyzed for the full suite of constituents. Of these, only one is a more accurate representation of the pilot operation as designed (UF & RO in operation). Removal results were all higher (more species removed) on the 10/9/07 sample. During phase 2 we anticipate gathering more data to better quantify system performance. Table 5 summarizes the data obtained from laboratory testing. Figure 4.2 shows the desalination efficiency of the reverse osmosis system by way of conductivity measurements.

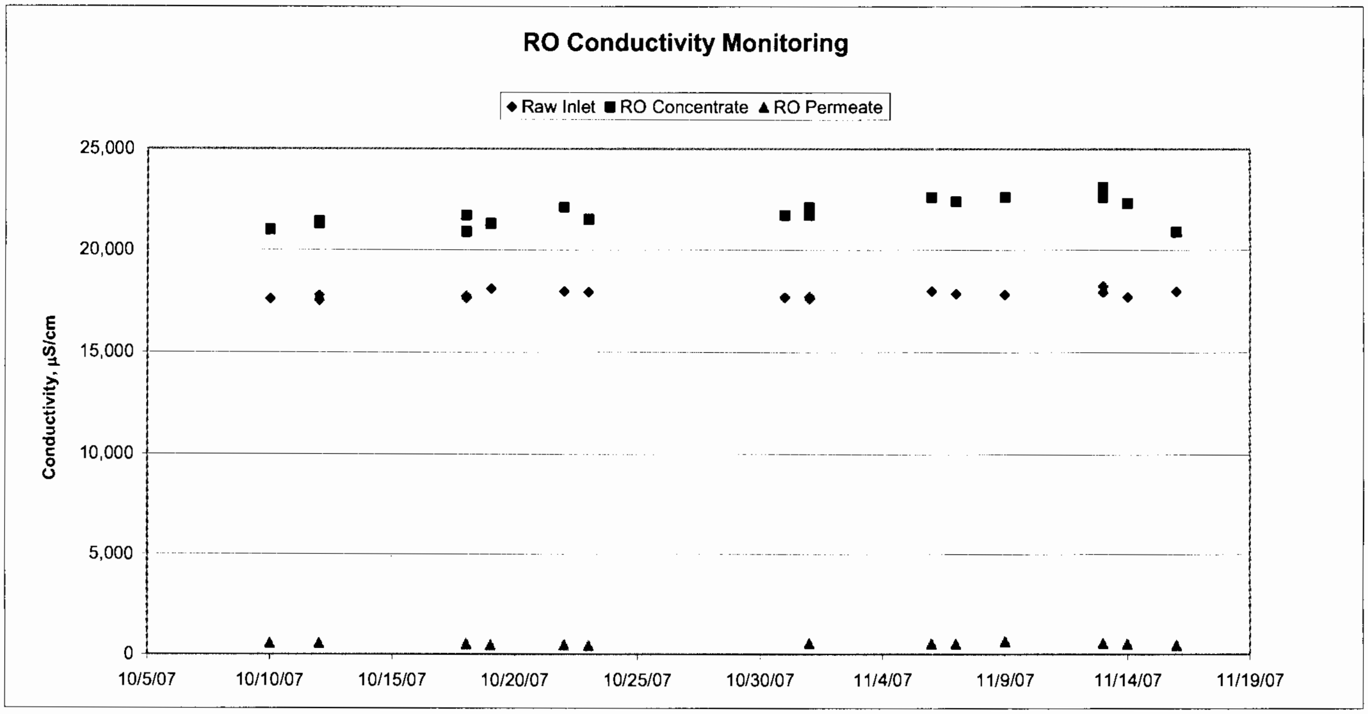


Figure 4.2. Conductivity Measurements – RO Streams

From mass balance calculations performed for each of the monitored constituents in the water streams, it appears that some scaling (Ca, SiO_2, SO_4) and some fouling (organic, TSS) occurred within the RO membrane. Since the RO feed pump could not attain pressures higher than approximately 275 psi, increased net driving pressure and/or decreased normalized permeate flux would not be observed. Also, the pilot operation's run was not long enough in duration to observe flux decline.

The RO system as installed at the pilot operated at a 6-8% efficiency across the single membrane stage (2 membranes in parallel) and 20-25% system efficiency (accounts for concentrate recycle). A full scale system would have more membrane surface area to attain higher efficiencies.

Table 4-3. Summary of RO Performance – Laboratory Analyses

	RO Concentration Factor (Conc/Raw)		RO Removal Eff	
Analyte	10/9/07	11/28/07	10/9/07	11/28/07
Specific Conductance (@ 25°C)	1.14	1.18	98%	98%
Total Dissolved Solids (@ 180°C)	1.11	1.22	98%	98%
TDS (calculation)	1.20	1.26	98%	98%
Total Suspended Solids	0.67	1.07	27%	53%
Chloride	1.06	1.48	98%	97%
Sulfate	1.00	0.67	100%	44%
Silica	1.10	0.76	97%	88%
Total	1.26	1.23	98%	99%
Bicarbonate	1.26	1.23	98%	99%
Hardness, as $CaCO_3$	0.80	0.93	100%	99%
Calcium	0.80	1.15	100%	98%
Iron	3.96	1.68	96%	74%
Magnesium		0.21		100%
Potassium	0.90	1.26	100%	99%
Sodium	1.19	1.09	98%	98%

There were two sets of field analyses where UF and RO systems were in operation. From this data one can observe a marked improvement in turbidity removal when the UF is operational. Figures 4-2 & 4-3 show the turbidity removal with and without the UF system. Appendix B contains all field and analytical data for the pilot operations.

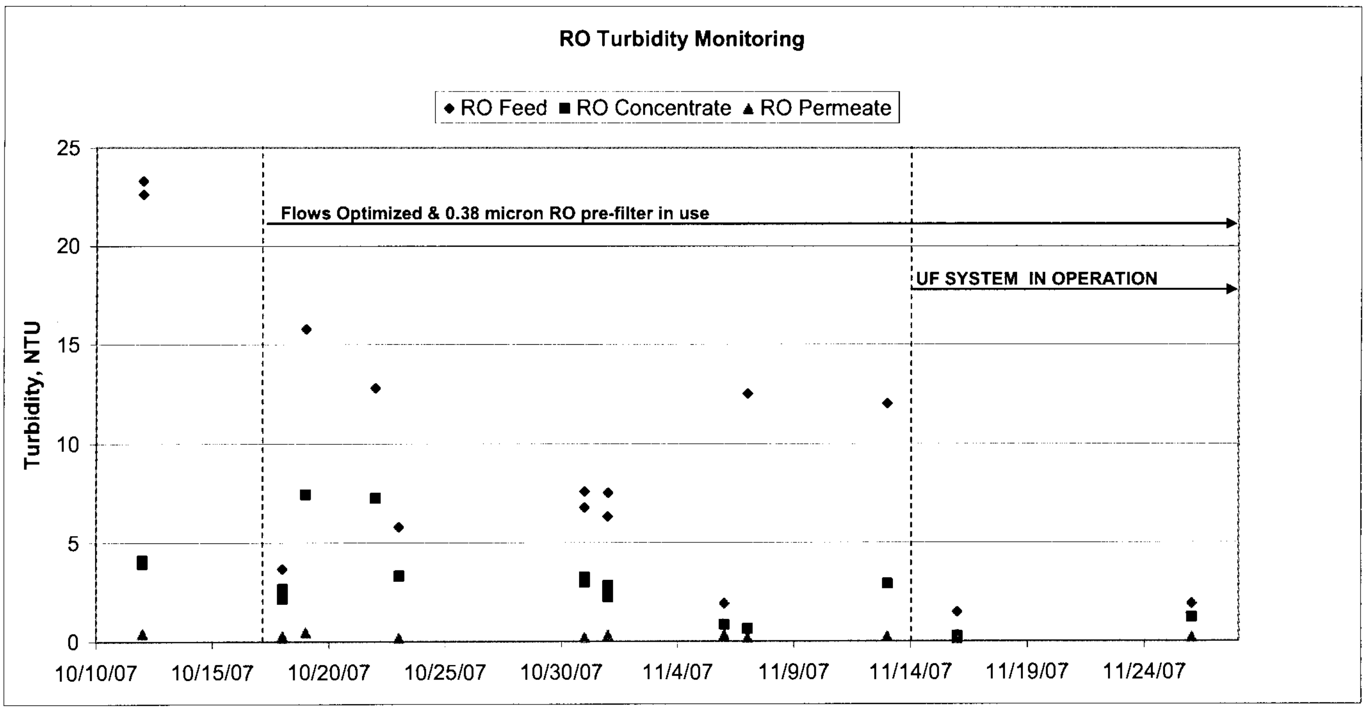


Figure 4-3. Turbidity Removal – Reverse Osmosis System

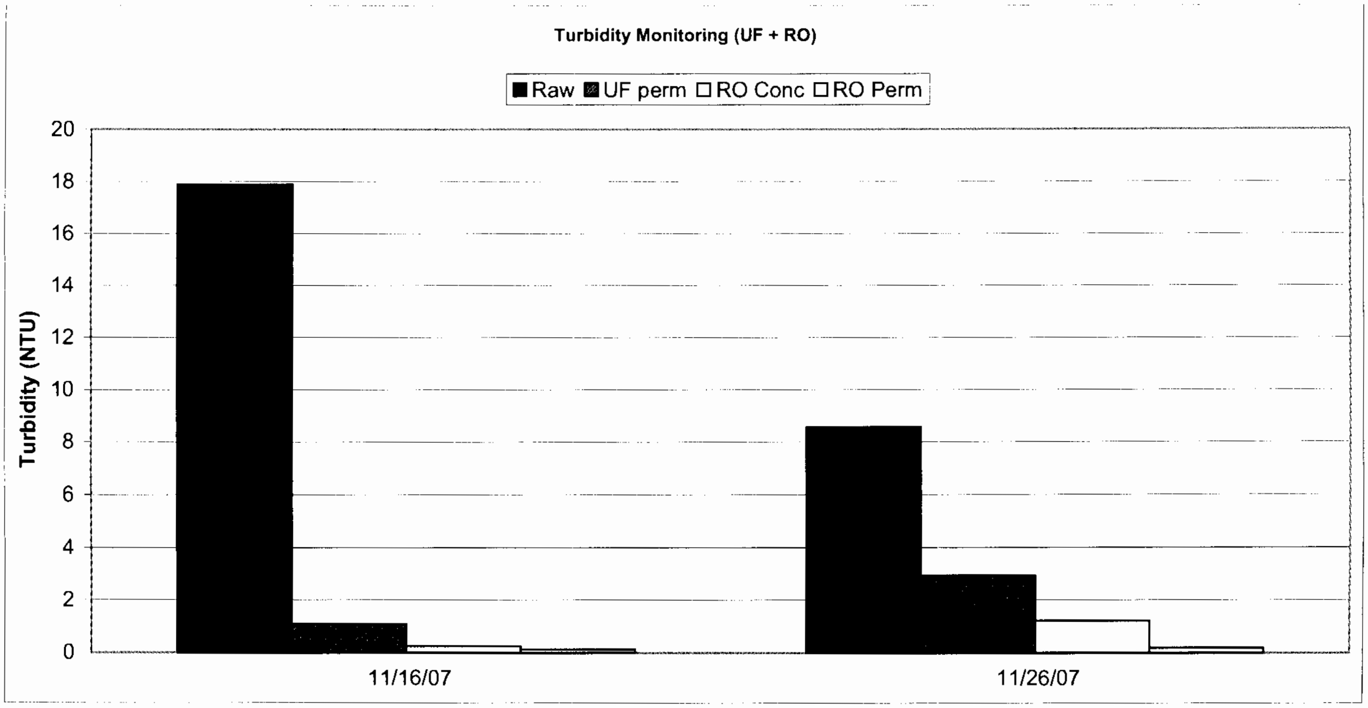


Figure 4-4. Turbidity Reduction – UF and RO systems

4.3. Land Application of Water by NMSU/USDA

Rangelands in the San Juan Basin of New Mexico are a potentially large reservoir for carbon, both in terms of available oil and gas and in terms of a potential for carbon sequestration. In addition, the rangelands have an ecological value of providing food, fiber, and opportunities for recreation, wildlife habitat, and sustainable watersheds. However, land degradation associated with historical and current land use and management has threatened the stability of these landscapes. The barriers to achieving their potential lie primarily in the limited growing conditions (erratic precipitation) and reduced capacity for recovery (historical damage and ongoing disturbance). Increasing carbon storage while maintaining or increasing the value of other ecosystem services in arid rangelands requires a strategic approach to reestablish watershed functions. Stabilizing arid landscapes requires both enhancing existing vegetation and reintroducing woody plant species along riparian areas as well as reestablishing native grasses and shrubs in upland areas. The limiting factor in both cases is water availability, primarily with respect to the distribution in time and space.

A reliable source of water of sufficient quality for agricultural irrigation could provide the necessary base for the reestablishment of native vegetation with a host of environmental benefits. The technical challenges include: 1) selecting appropriate species for revegetation, 2) distribution and application of water to enhance germination and 3) protection of establishing from grazing (native and domestic grazers). Information to select appropriate species and guide resource allocation for restoration is critical for the cost: benefit analysis. These decisions must be guided by existing and potential soil, vegetation and landscape conditions. NMSU and the USDA are currently characterizing (soils, vegetation, geomorphology, ecological site descriptions) the La Manga Canyon watershed to provide this information. In addition to current conditions, we are constructing chronosequences of soil and vegetation change and building predictive models of landscape scale potential. This information will be used to stabilize the landscape using the appropriate species at critical sites.

Approximately 1.81 inches of produced water and 0.68 inches of treated water were applied to ConocoPhillips San Juan 32-8 UNIT #237A well site. The dates were October 24 and November 23 for produced water application and November 23 for treated water application. Figure 4-4 shows irrigation performed on 10/24/07. Below is a summary of all activities performed by the USDA and NMSU.

1. Took soil samples from both non-treated and treated area before water was applied. Dates are 10-24-07 and 11-23-07 for non-treated and treated produced water.
2. Applied non-treated produced water on 10-24-07 and 11-23-07. Treated area was approximately 4500 square feet with approximately 60 barrels of non-treated produced water applied at each date for a total of 120 barrels.
3. Applied treated water on 11-23-07. Treated area was approximately 4500 square feet with approximately 45 barrels of treated water applied.

Figure 4-5. Land Application of Untreated Produced Water

5. Discussion and Conclusions

The Fall 2007 CBNG produced water desalination pilot effectively demonstrated a proof of concept for low energy reverse osmosis treatment of the water. There were variations in the influent water quality (TOC, organics, turbidity, iron) throughout the pilot operation. More samples would be required for a full quantification of the results. However, using a single reverse osmosis membrane in sub-optimal conditions (high fouling-tendency, single membrane, and most of the time without the benefit of an ultra filtration membrane), good quality water was produced for the rangeland/riparian improvement study.

5.1. Water Treatment Cost Estimates

Understanding the energy consumption for membrane processes is critical to understanding the maintenance and operations (M&O) budget. It is feasible to scale up from our pilot to a full scale operation, even though there are many factors that are totally different. For example, unlike the pilot, a full scale system would be equipped with high efficiency pumps. In addition, there are many design changes and operational modes that could be employed at full scale that are not attainable in this size of a pilot (e.g. more membranes, energy recovery).

Using data from the Desalting Handbook for Planners (2003, Bureau of Reclamation), electrical consumption is estimated to be at least 2.25 kwh/m^3 (0.36 kwh/BBL) of permeate. Extrapolating using the standard reverse osmosis curve from figure 7-8 in the handbook, to 14,000 mg/L TDS, the number is more like 2.75-3.00 kwh/m^3 (0.43-0.48 kwh/BBL) of permeate. Using the data in figure 7-9, it is estimated that 600-625 psi would be required for 14,000 mg/L TDS removal using standard reverse osmosis systems. Both estimates assume 75% recovery. Generally speaking, approximately 30% of a desalination facility's cost will be in the pressure required to pump water.

5.2. Future Work

5.2.1. Experimental Plan – CBNG Produced Water Desalination Pilot, Phase 2

It is anticipated that a "Phase 2" pilot will be conducted during 2008. This pilot will build on lessons learned from the "Phase 1" operations summarized in this report. The plan is to test the efficacy of using nanofiltration membranes. The pilot itself will actually expand the 2007 pilot operations and use reverse osmosis membranes for lower pressure operations, and it will retain the ultrafiltration skid for particulate and suspended organics removal. Sandia pilot equipment will be located on the same ConocoPhillips well site used for the 2007 pilot demonstrations.

As in the first pilot, the Phase 2 pilot will again demonstrate low pressure/low energy desalination of CBNG produced water. The treated water, raw produced water, and natural rainfall will, as in the first pilot, be applied to separate sections of native grasses in order to study the effects for rangeland and riparian repair by NMSU and the USDA. This phase of the pilot operation will produce 1-2 gpm of permeate with a TDS less than 1000 mg/L (most likely below 530 mg/L). Professor Rick Arnold, from NMSU's Agricultural Science Center at Farmington, has indicated that the lack of troublesome dissolved species (Na, Ca, Mg) combined with a low TDS (less than 1000 mg/L) should provide good quality water for rangeland and riparian studies.

The proposed pilot operation flow diagram is summarized in Figure 5-1. Raw CBNG produced water will be sent to an ultrafiltration system (UF), which will remove most of the particulate matter and larger molecular weight organic matter. The UF filtrate will be dosed with an antiscalant (for scale protection) and fed directly to a reverse osmosis system (RO). The RO is comprised of three membranes in series and will require approximately 330 psi of pressure for desalination. The RO can also be operated with only two membranes for lower feed pressure and lower permeate production with similar water quality in the permeate stream. Finally, the potential for nanofiltration (NF) with the produced water may be tested towards the end of the pilot operation by changing out RO membranes for NF membranes.

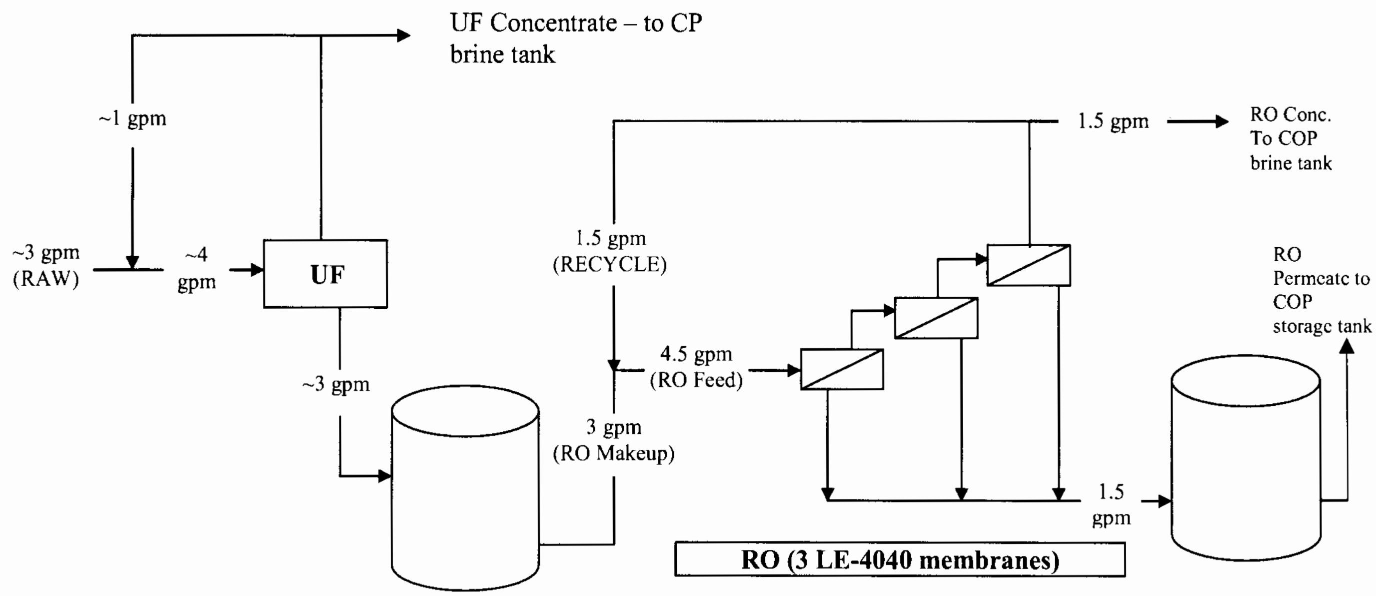


Figure 5-1. Water Treatment Pilot Equipment Flow Diagram

5.2.2. Desalination at a Salt Water Disposal (SWD) Site

For 2009 and beyond, additional pilot operations utilizing desalination and other treatment technologies at a ConocoPhillips SWD is envisioned. This would be on a larger scale than the current pilot operations described in this report and the challenges would be greater. Water at a SWD will have more dissolved and emulsified organic constituents, as well as other contaminants that will require other modes of treatment (e.g. iron). This may require more elaborate pretreatment processes.

Permitting requirements for the alternative use of water on a larger scale must also be factored into pilot operation plans. The use of treated water for impaired riparian area improvement and revegetation of disturbed areas may require some hauling of the processed water.

6. References

Ayers, R. S., and D. W. Westcott. 1985. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29, Rev. 1, U.N. Rome.

BoR 2003, "Desalting Handbook for Planners, 3rd Edition", Bureau of Reclamation, July 2003.

EPA 2008, "Current National Recommended Water Quality Criteria", http://www.epa.gov/waterscience/criteria/wqcriteria.html

EPA 2008, "Effluent Limitation Guidelines", EPA 821-F-08-001. http://www.epa.gov/guide/304m/2008/cbm-icr-200801.html

PG Environmental, LLC. 2008. Final Site Visit Report: Sandia National Laboratories (SNL) Pilot Treatment Plant and New Mexico State University (NMSU) Land Application Study ConocoPhillips Well Pad (San Juan 32-8 Unit #237A Well Site) West of Navajo Lake, NM (San Juan Basin) - [DCN 05270A1]. http://www.regulations.gov/fdmspublic/component/main?main=DocumentDetail&o=09000064803c3e9b

Van Voast, W. Geochemical signature of formation waters associated with coal bed methane. *AAPG Bulletin.* **87** (4) 667–676.

Xu, Pei, J.E. Drewes, Heil, D. 2008. Beneficial use of co-produced water through membrane treatment: technical-economic assessment, *Desalination.* **225:** 139–155.

Appendices

Appendix A – CBNG Produced Water Pilot Plant Logs
Appendix B – Water Chemistry Measurements
Appendix C – Particulate Analysis
Appendix D – Water Meter Data

Appendix A – CBNG Produced Water Pilot Plant Logs

Table A-1. Summary of Field Activities and Notes

Event Date or Trip	Specific Date	Description of Work Performed
02/08/07		PW Sample from 500BBL Tank to Assaigai
03/07/07 – 03/08/07		Initial trip w/Team to Western Environmental Management in Carlsbad
3/16/07		1st meeting with SNL Electrical Engineer
03/28/07 – 03/29/07		ConocoPhillips HSE Training & Site Visit
04/20/07		1st SNL-COP-BEST Meeting in Farmington 30th St. Office
05/15/07		B&D To Finish on Transportainer
05/21/07		Cancelled Transportainer Pickup– Electrical Systems must be inspected and Electrical TWD's in place.
08/01/07		Transportainer picked up
08/16/07		Transportainer delivered to site
08/27/07		Electrical Safety Document approved
09/05/07 – 09/07/07		
	090/5/07	Transported equipment with rental Truck
	09/06/07	Installation of Water Treatment Equipment
	09/07/07	Installation of Water Treatment Equipment
09/11/07 – 09/14/07		
	09/11/07	Installation of Process Piping & Data Acquisition System
	09/12/07	Installation of Process Piping & DAS Generator being installed by COP, Initial Electrical Tests Roust-About crew working on grass field berms, Pilot inspection by COP
	09/13/07	Electrical Troubleshooting by COP Final install of main equipment Starting to hydro-test system Continued work on DAS & Controls
	09/14/07	Electrical and system troubleshooting Repair of leaks DAS & Controls
09/17/07 – 09/21/07		
	09/17/07	Ji working on DAS & Controls
	09/18/07	Ji working on DAS & Controls
	09/19/07	DAS Tank & Pump Hydro test Change out membranes On UF & RO Units UF switched AK for MW series cartridges. RO switched AK-LE for the AG series cartridges. UF Unit could not be put in service. The existing housing end caps will not accept the MW membrane cartridges. MW cartridge has female ends. Ordered adapters.
	09/20/07	Programming DAS Startup on equipment motors, pumps, tank check leaks Pressures and flows
	09/21/07	Check and calibrate Echo Switches
09/27/07 – 09/28/07		
	09/27/07	Replace pressure switches Installed new adapters for UF Unit to accept M-Series Membranes

Event Date or Trip	Specific Date	Description of Work Performed
		UF Unit could not be in service. The existing housing is not long enough. No one indicated that the MW Series membranes also needed longer housing to hold cartridge. New housing on order. 30 day lead time from factory Repair T-300 Leak Finish checking Echo Switches Seal holes in transportainer
	09/28/07	Bypass & equalizing line between T-200 & T-300 Found leak on one of the RO end caps. Found manufacturing defect in housing where O-ring seals. Replaced the housing with the one short housing from the UF Unit. ½" piping inside T-100 to diffuse water splash, eliminates cavitations at low tank level. Found roof leaking from recent rains. Will purchase roof coat to seal screw holes in roof.
10/01/07 – 10/03/07		
	10/01/07	System Startup Calibration of DAS components Main PW 500BBL Tank is operating at 10'. Jimmy Bowman to reset. Only getting 2.5 to 3.0 gpm to the inlet of T-100. As per WEM: Both E4 and LE-E4 units, the TOMCO pump must operate with a total of 5 gpm through pump. Total flow equals, concentrate flow out + recycle flow + permeate flow out. Maximum pressure outputs from TOMCO pumps UF 130 psi + suction pressure RO 245 psi + suction pressure Primary pressure to RO operating at 270psi yielding Permeate output around 0.3 gpm. Set Auto-Flush Timers for manual operation with 10 to 15 minute flush at system startup, 2 to 3 hours of continuous operation and final just before unit shutdown. System is not designed to use permeate for flush. Auto flush timer just increases flow through membrane.
	10/02/07	System Startup Calibration of DAS Analytical Testing
10/8/07 – 10/12/07		
	10/08/07	Operating RO DAS
	10/09/07	Operating RO DAS Set of samples taken for Envirotech
	10/10/07	Operating RO ES&H Walk Through with SNL safety personnel
	10/11/07	Operate RO Recalibrate T-200 Cleanup inside of Transportainer Tour with SNL & COP Managers

Event Date or Trip	Specific Date	Description of Work Performed
		Notes from B.E.S.T. We need to test for Barium & Lead. COP has PW chemical concentration re-injection limits. What are those limits? COP had to send SWD pre-filters to hazardous waste facility. Also Frank recommended when we present our data to use some graphical plots.
	10/12/07	Operate RO Seal holes top of Transportainer
10/17/07 – 10/19/07		
	10/17/07	RO Operation RO Performance Testing and Analysis with SNL project engineer
	10/18/07	RO Operation Training DAS-PC Interface
	10/19/07	500BBL PW Tank level re-adjusted to 15 feet we can now get ~ 5 gpm flow to T-100; tank does not run dry now. With this extra flow Frank started filling the PW-Untreated NMSU 286BBL Tank. RO Operation
10/23/07		Tour with EPA, OCD, & BLM
10/24//07		1st addition of PW-Untreated by NMSU
10/31/07		RO Operation by Frank Filters clogging fast – Iron residuals high ~2 mg/L
11/01/07		RO Operation by Frank
11/13/07 – 11/15/07		
	11/13/07	Cyclone separators taken out of service.
	11/14/07	RO Operation Frank showed us the RO pre-filters. Filters have a lot of iron precipitate being removed. New Conductivity Sensors UF Rebuild – Used new longer membrane housing. UF still out of service – Found brass fittings (factory install) leaking. Fittings were cracked. Went to town to find fittings. ABB Drive
	11/15/07	Repair leak on UF Calibrate VFD UF startup. UF finally in service Operate UF & RO
11/27/07 – 11/29/07		
	11/27/07	2nd Watering by NMSU for PW-Untreated 1st Watering by NMSU for Treated PW
	11/28/07	Last Envirotech Sample Also took sample of PW for GAB Winterizing of Pilot
	11/29/07	Pilot shut down until Spring '08

Appendix B – Water Chemistry Measurements

Table B-1. Field Test Results

FIELD TEST RESULTS				UF			RO			
				Inlet	CONC	PERM	Makeup	FW	CONC	PERM
10/10/2007	17:25	Conductivity	µS/cm				17,600		21,000	572
10/10/2007	17:25	Temperature	C				22.2		25.5	25.5
10/10/2007	17:25	pH	units				7.54		7.6	6.34
10/10/2007	17:25	Turbidity	ntu							
10/10/2007	17:25	Iron	mg/L							
10/12/2007	9:30	Conductivity	µS/cm				17,770		21,400	560
10/12/2007	9:30	Temperature	C				16.9		18.1	18.1
10/12/2007	9:30	pH	units				7.5		7.7	6.3
10/12/2007	9:30	Turbidity	ntu				22.6		3.94	0.41
10/12/2007	9:30	Iron	mg/L							
10/12/2007	12:45	Conductivity	µS/cm				17,540		21,300	582
10/12/2007	12:45	Temperature	C				21.1		24.2	24.1
10/12/2007	12:45	pH	units				7.7		7.7	6.4
10/12/2007	12:45	Turbidity	ntu				23.3		4.1	0.4
10/12/2007	12:45	Iron	mg/L							
10/18/2007	10:00	Conductivity	µS/cm				17,640	17,830	20,900	494
10/18/2007	10:00	Temperature	C				15.3	15.2	18	17.4
10/18/2007	10:00	pH	units				7.3	7.5	7.5	6.2
10/18/2007	10:00	Turbidity	ntu				13.5	3.68	2.17	0.27
10/18/2007	10:00	Iron	mg/L				1.5	1.17	1.1	0.02
10/18/2007	10:00	Sulfite	mg/L				<20			
10/18/2007	14:30	Conductivity	µS/cm				17,720	17,910	21,700	519
10/18/2007	14:30	Temperature	C					12.9	16	16.1
10/18/2007	14:30	pH					7.8	7.8	7.8	6.3
10/18/2007	14:30	Turbidity	ntu				6.7	2.55	2.66	0.2
10/18/2007	14:30	Iron	mg/L				0.54	0.73	1.07	0
10/18/2007	14:30	Sulfite	mg/L				30			
10/19/2007		Conductivity	µS/cm				18,100	18,130	21,300	458
10/19/2007		Temperature	C				10.8	11	13.1	13
10/19/2007		pH	units				7.3	7.5	7.5	6.2
10/19/2007		Turbidity	ntu				19.6	15.8	7.47	0.46
10/19/2007		Iron	mg/L				1.31	1.24	1.13	0.01
10/19/2007		Sulfite	mg/L				<30			
10/22/2007		Conductivity	µS/cm				17,970	17,930	22,100	460
10/22/2007		Temperature	C				12.5	13.2	14.5	14.1
10/22/2007		pH	units				7.9	7.9	7.5	6.3
10/22/2007		Turbidity	ntu				20.3	12.8	7.28	
10/22/2007		Iron	mg/L				1.51	1.34	1.51	0.04
10/23/2007		Conductivity	µS/cm				17,930	17,810	21,500	424
10/23/2007		Temperature	C				12.5	13.3	15.5	15.1
10/23/2007		pH	units				7.5	7.5	7.5	6.3
10/23/2007		Turbidity	ntu				17.1	5.8	3.32	0.19
10/23/2007		Iron	mg/L				1.28	0.97	0.91	0.01
10/31/2007	10:00	Conductivity	µS/cm							
10/31/2007	10:00	Temperature	C							
10/31/2007	10:00	pH	units				7.5	7.5	7.5	6.2
10/31/2007	10:00	Turbidity	ntu				17.4	6.8	3	0.2

FIELD TEST RESULTS				UF			RO			
				Inlet	CONC	PERM	Makeup	FW	CONC	PERM
10/31/2007	10:00	Iron	mg/L				1.99	1.4	1.39	0
10/31/2007	14:30	Conductivity	µS/cm				17,670	17,540	21,700	
10/31/2007	14:30	Temperature	C				17.1	17.8	21.7	
10/31/2007	14:30	pH	units				7.4	7.3	7.5	
10/31/2007	14:30	Turbidity	ntu				15.2	7.6	3.25	
10/31/2007	14:30	Iron	mg/L				1.3	1.15	1.53	
11/1/2007	10:30	Conductivity	µS/cm				17,700	17,320	22,100	523
11/1/2007	10:30	Temperature	C				18.7	19.3	21	23.6
11/1/2007	10:30	pH	units				7.5	7.5	7.6	6.2
11/1/2007	10:30	Turbidity	ntu				13	7.53	2.82	0.3
11/1/2007	10:30	Iron	mg/L				1.74	1.36	1.25	0.01
11/1/2007	14:30	Conductivity	µS/cm				17,600	17,750	21,700	502
11/1/2007	14:30	Temperature	C				19.3	19.2	21.6	21.4
11/1/2007	14:30	pH	units				7.9	7.9	7.9	6
11/1/2007	14:30	Turbidity	ntu				20.3	6.34	2.26	0.31
11/1/2007	14:30	Iron	mg/L				2.67	1.7	1.51	0
11/6/2007		Conductivity	µS/cm				17,980	17,820	22,600	511
11/6/2007		Temperature	C				12.5	14.2	15.4	18.7
11/6/2007		pH	units				7.6	7.5	7.8	6.5
11/6/2007		Turbidity	ntu				13.9	1.89	0.84	0.33
11/6/2007		Iron	mg/L				1.56	1.33	1.28	0
11/7/2007		Conductivity	µS/cm				17,830	17,830	22,400	502
11/7/2007		Temperature	C				15.6	15.6	20.1	20
11/7/2007		pH	units				7.4	7.4	7.5	6.1
11/7/2007		Turbidity	ntu				17.5	12.5	0.64	0.19
11/7/2007		Iron	mg/L				1.83	1.83	1.29	0
11/9/2007		Conductivity	µS/cm				17,790	17,630	22,600	621
11/9/2007		Temperature	C				17.6	17.6	19.7	20
11/9/2007		pH	units				7.4	7.3	7.5	6.2
11/9/2007		Turbidity	ntu							
11/9/2007		Iron	mg/L							
11/13/2007	8:30	Conductivity	µS/cm				18,210	17,960	23,100	545
11/13/2007	8:30	Temperature	C				11.3	12.2	15.4	12.4
11/13/2007	8:30	pH	units				7.6	7.5		6.3
11/13/2007	10:45	Conductivity	µS/cm				17,920	17,700	22,600	529
11/13/2007	10:45	Temperature	C				16.7	17.5	19.3	20.2
11/13/2007	10:45	pH	units				7.4	7.3	7.4	6
11/13/2007	10:45	Turbidity	ntu				40.9	12	2.91	0.24
11/13/2007	10:45	Iron	mg/L				3.01	1.9	1.92	0.02
11/14/2007		Turbidity	ntu	20.3		1.53				
11/14/2007		Conductivity	µS/cm	17,840	17,930	17,940				
11/14/2007		Temperature	C	16.5	17.1	17.4				
11/14/2007		pH	units	7.4	7.4	7.4				
11/14/2007		Turbidity	ntu	12.1	10.5	0.2				
11/14/2007		Iron	mg/L	3.04	2.95	2.31				
11/16/2007		Conductivity	µS/cm	17,900	18,010	18,100	17,690		22,300	497
11/16/2007		Temperature	C	14.2	14.8	14.4	16.5		18.2	17.8
11/16/2007		pH	units				7.4		7.5	6.1
11/16/2007		Turbidity	ntu	17.9	16.3	1.08	1.48		0.26	0.13
11/16/2007		Iron	mg/L				1.48		1.39	0.05

FIELD TEST RESULTS				UF			RO			
				Inlet	**CONC**	**PERM**	**Makeup**	**FW**	**CONC**	**PERM**
11/26/2007		Conductivity	μS/cm	18,010	18,180	18,130	17,960		20,900	444
11/26/2007		Temperature	C	11.1	10.3	10.5	10.6		12.9	12.1
11/26/2007		pH	units				7.4		7.5	6.2
11/26/2007		Turbidity	ntu	8.57	11.5	2.94	1.91		1.22	0.2
11/26/2007		Iron	mg/L				1.42		1.22	0.03
11/28/2007		Turbidity	ntu	15.6	18.4	4.91				

Table B-2. Log sheet Data: Flow Rate and Conductivity Measurements

			Flow Rates - (gpm)				Conductivities - (μS/cm)			
Date	Time	Field Tests	Makeup Pre-Filter	CONC	REC	PERM	Makeup Pre-Filter	Makeup Post-Filter	CONC	PERM
10/8/07	9:30am		Data Acquisition System (DAS) not in service				18,650		21,800	400
10/8/07	1:14pm		DAS not in service				18,820		21,700	412
10/8/07	3:10pm		DAS not in service				18,780		21,700	406
10/9/07	morning		DAS not in service				14,910		17,210	374
10/9/07	11:00am		DAS not in service				14,300		16,630	355
10/10/07	morning	YES	DAS not in service				13,640		14,450	355
10/10/07	10:30am		DAS not in service				13,550		13,680	305
10/10/07	1:00pm		0.9	0.5	3	0.25	18,440		26,300	993
10/10/07	1:30		0.68	0.5	4	0.23	17,470		24,100	1013
10/10/07	2:00		1.23	1	3.5	0.27	17,590		22,100	766
10/10/07	3:30		1.74	1.5	3	0.3	17,540		20,900	583
10/10/07	4:00		2.22	2	2.5	0.31	17,620		20,100	510
10/10/07	4:30		1.53	1.25	3.25	0.3	17,620		21,700	541
10/10/07	5:25pm		1.53	1.25	3.25	0.29	17,600		21,000	572
10/11/07	9:45am		1.57	1.3	3.25	0.3	17,690		21,100	544
10/12/07	9:30am	YES	1.55	1.27	3.25	0.29	17,770		21,400	560
10/12/07	12:45pm	YES	1.55	1.27	3.25	0.29	17,540		21,300	582
10/17/07	10:30am		Changed Filter to 1.0 micron from 5 micron							
10/17/07	11:45am		1.45	1.08	3.25	0.31	17,910		21,700	519
10/17/07	1:45pm		1.53	1.25	3.25	0.27	17,820		21,200	524
10/17/07	2:00pm		Changed Filter to 0.38 micron							
10/17/07	2:30pm		1.53	1.19	3.25	0.29	17,865			
10/18/07	2:30pm	YES	1.6	1.31	3.25	0.28	17,640	17,830	20,900	494
10/19/07	9:25am	YES	1.5	1.2	3.25	0.26	18,100	18,130	21,300	458
10/19/07	9:45am		Changed Filter with 0.38 micron							
10/22/07	12:30pm	YES	1.43	1.07	3.25	0.29	17,970	17,930	22,100	460
10/22/07			Changed Filter with 0.38 micron							
10/23/07	11:00am	YES	1.64	1.26	3.25	0.33	17,930	17,810	21,500	424
10/24/07			NMSU Watering Field. Added ~ 214.5BBL of PW-Untreated on 4500 sq ft							
10/31/07	8:40am		Changed Filter with 0.38 micron							
10/31/07	9:10am	YES	1.64	1.27	3.25	0.41	17,970	17,790	22,600	469
10/31/07	11:15am		1.6	1.26	3.25	0.35	17,730	17,570	21,900	466
10/31/07	11:40am		Changed Filter with 0.38 micron							
10/31/07	2:30pm	YES	1.57	1.27	3.25	0.34	17,670	17,540	21,700	495
11/1/07	10:30am	YES	1.6	1.25	3.25	0.37	17,700	17320	22,100	523
11/1/07	11:40am		Changed Filter with 0.38 micron							
11/1/07	2:30pm	YES	1.53	1.24	3.25	0.33	17,600	17,750	21,700	502
11/6/07	11:30am		Changed Filter with 0.38 micron							
11/6/07	12:00PM	YES	1.53	1.18	3.25	0.39	17,980	17820	22,600	511
11/7/07	9:00am		Changed Filter with 0.38 micron							
11/7/07	10:00am	YES	1.53	1.17	3.25	0.38	17,830	17,520	22400	502
11/7/07	12:30pm		1.5	1.14	3.25	0.32	17,810	17,670	22,100	462
11/7/07	12:40pm		Changed Filter with 0.38 micron							
11/9/07	11:40am	YES	1.5	1.1	3.25	0.38	17,790	17,630	22,600	627
11/13/07	8:30am	YES	1.5	1.1	3.25	0.38	18,210	17,960	23,100	545
11/13/07	10:45am	YES	1.47	1.06	3.25	0.36	17,920	17,700	22,600	529

			Flow Rates - (gpm)				Conductivities - (μS/cm)			
Date	Time	Field Tests	Makeup Pre-Filter	CONC	REC	PERM	Makeup Pre-Filter	Makeup Post-Filter	CONC	PERM
11/14/07		UF Unit was put in service, in process of optimizing system. UF DAS not in Service Pre-Filter Status - UF @ 5 micron RO @ 1 micron								
UF Unit		YES	3	0.75	2	2.25	17,840		17,930	17,940
11/16/07										
UF Unit	9:30	YES	3	0.75	2	2.25	17,980		18,010	18,100
RO Unit	to 10:30	YES	1.57	1.26	3.25	0.35	17,680		22,300	497
11/19/07			No Tests!							
11/26/07										
UF Unit	9:00	YES	3	0.75	2	2.25	18,010		18,180	18,130
RO Unit	to 10:00	YES	1.5	1.25	3.25	0.24	17,960		20,900	444
11/28/07		System Shutdown and Winterized! NMSU Watering Fields, PW-Untreated 120BBL on 4500 sq ft and Treated-PW 45BBL on 4500 sq ft								

Table B-3. Log sheet Data: Pressure and Temperature Measurements

			Pressures - (psi)				Temperatures (degrees C)			
Date	Time	Field Tests	Makeup Pre-Filter	Makeup Post-Filter	RO Feed	RO Conc	Makeup Pre-Filter	Makeup Post-Filter	CONC	PERM
10/8/07	9:30am						14.6		15.5	19
10/8/07	1:14pm		32	32	270	268	18		19.2	19.4
10/8/07	3:10pm		32	32	270	268				
10/9/07	morning		32	32	270	268				
10/9/07	11:00am		32	32	270	268	19.6		19.1	19.1
10/10/07	morning	YES	33	33	270	270	18.8		19.1	19
10/10/07	10:30am		31	31	270	268	19.1		19.7	19.6
10/10/07	1:00pm		36	36	274	274				26.3
10/10/07	1:30		36	36	274	274	22.5		29.4	29
10/10/07	2:00		36	36	274	274	22.3		27.6	27.8
10/10/07	3:30		36	36	274	274	22.4		25.3	25.4
10/10/07	4:00		36	36	274	274	22.2		25	24.7
10/10/07	4:30		36	36	274	274	22.5		26.2	25.6
10/10/07	5:25pm		36	36	274	274	22.2		25.5	25.5
10/11/07	9:45am		33.5	32.5	269	269	17.4		20.3	20.3
10/12/07	9:30am	YES	33	31	268	267	16.9		18.1	18.1
10/12/07	12:45pm	YES	33	31	268	267	21.1		24.2	24.1
10/17/07	10:30am									
10/17/07	11:45am		32	32	270	268				
10/17/07	1:45pm		33	24	260	258				
10/17/07	2:00pm									
10/17/07	2:30pm		33	33	270	270				
10/18/07	2:30pm	YES	33	33	269	269				
10/19/07	9:25am	YES	31	26	265	262				
10/19/07	9:45am									
10/22/07	12:30pm	YES	26	19	255	250	12.5	13.2	14.5	14.1
10/22/07										
10/23/07	11:00am	YES	31.5	28.5	264	262	12.5	13.3	15.5	15.1
10/24/07										
10/31/07	8:40am									
10/31/07	9:10am	YES	32	32	268	267	13.8	15.3	16.6	16.3
10/31/07	11:15am		33	27	263	260	18.2	18.9	20.6	21
10/31/07	11:40am									
10/31/07	2:30pm	YES	34	30	266	266	19.1	19.8	21.7	22.3
11/1/07	10:30am	YES	33	30	266	264	18.7	19.3	21	23.6
11/1/07	11:40am									
11/1/07	2:30pm	YES	33	28	265	262	19.3	19.2	21.6	21.4
11/6/07	11:30am									
11/6/07	12:00PM	YES	33	32	269	266	12.5	14.2	15.4	18.7
11/7/07	9:00am									
11/7/07	10:00am	YES	33	31	266	265	15.6	17.3	20.1	20
11/7/07	12:30pm		33	23	260	258	16.7	17	19.3	19.9
11/7/07	12:40pm									
11/9/07	11:40am	YES	33	28	265	263	17	17.6	19.7	20
11/13/07	8:30am	YES	31	31	266	266	11.3	12.2	15.4	12.4
11/13/07	10:45am	YES	33	27	264	261	16.7	17.5	19.3	20.2
UF Unit		YES	29	29	163	160	16.5		17.1	17.4

			Pressures - (psi)				Temperatures (degrees C)			
Date	**Time**	**Field Tests**	**Makeup Pre-Filter**	**Makeup Post-Filter**	**RO Feed**	**RO Conc**	**Makeup Pre-Filter**	**Makeup Post-Filter**	**CONC**	**PERM**
11/16/07										
UF Unit	9:30	YES	29	29	162	161	14.2		14.8	14.4
RO Unit	to 10:30	YES	32	31	267	265	16.5		17.8	18.2
11/19/07										
11/26/07										
UF Unit	9:00	YES	28	28	161	160	11.1		10.3	10.5
RO Unit	to 10:00	YES	32	28	265	264	10.6		12.9	12.1

Appendix C – Particulate Analysis

Samples were obtained for the raw inlet, pre/post cyclone, and RO feed pre/post filter for particulate analysis by Spectrex. Results indicate that the majority of particulate matter was less than 10 microns, and most was 1 micron or less in size. There is some doubt as to whether proper sampling procedures were followed, and this test will be repeated at the next phase of the pilot.

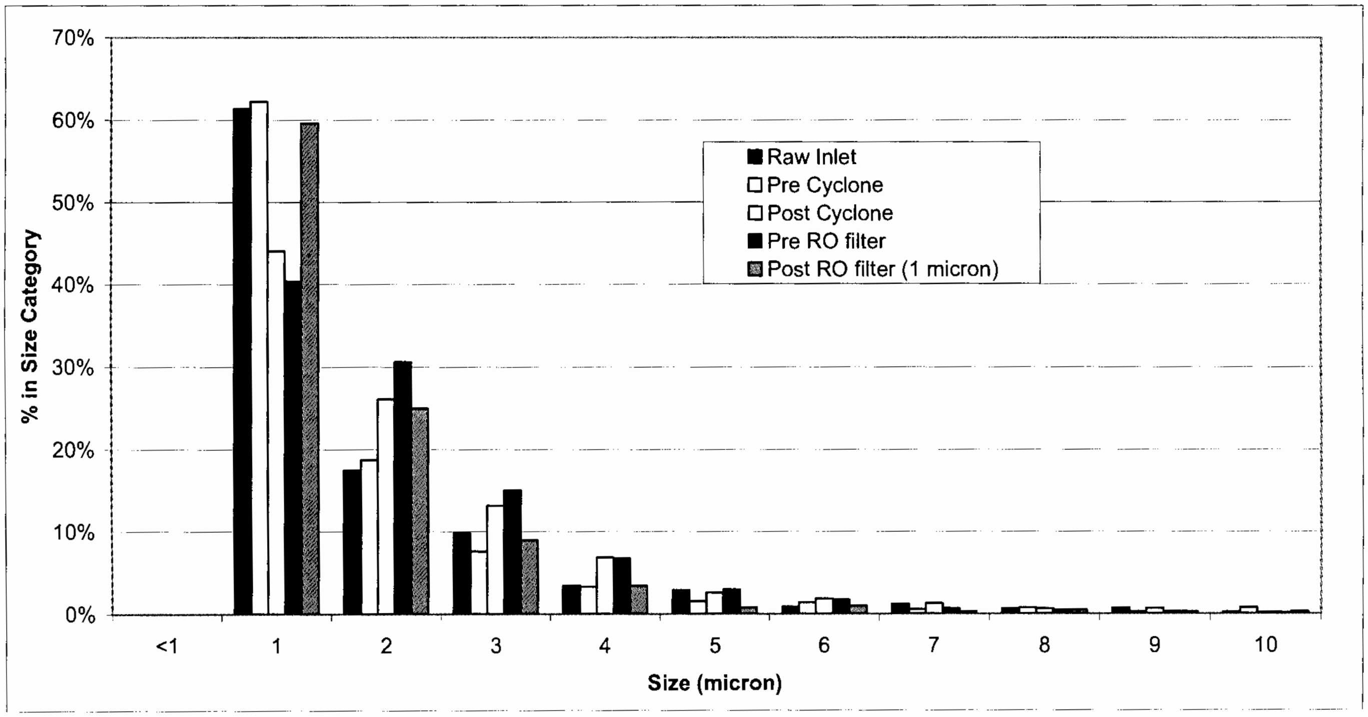


Figure C-1. Spectrex Particulate Analysis

Appendix D – Water Meter Data

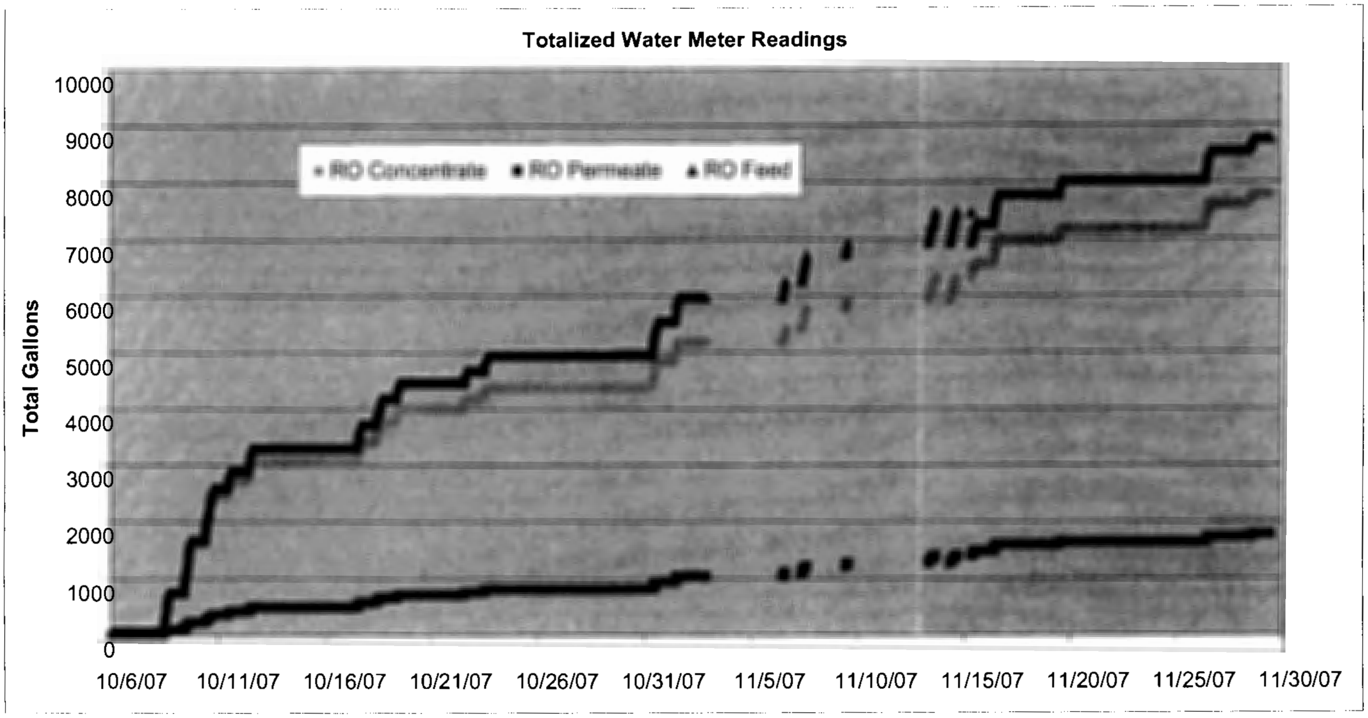


Figure D-1. Totalized Water Meter Data

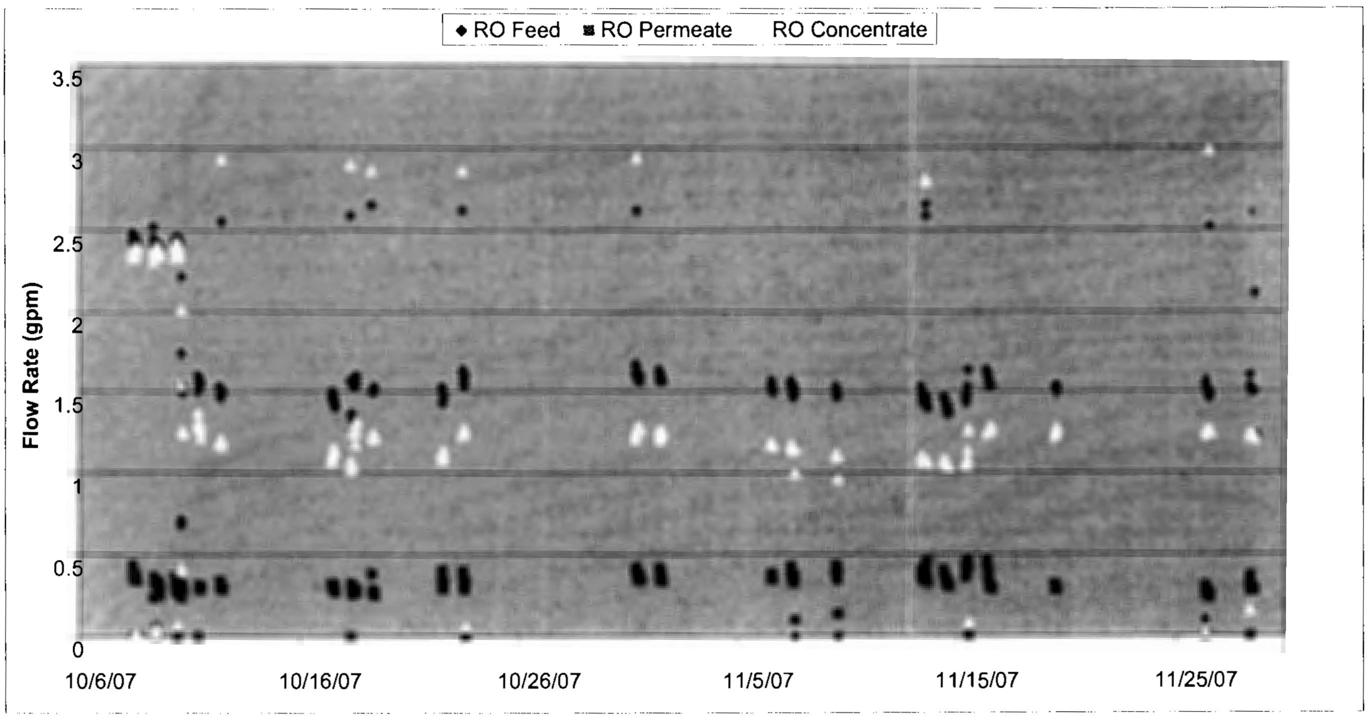


Figure D-2. Flow Meter Data

Distribution:

Bill Hocheiser, DOE/HQ
Peter Lagiovane, DOE/HQ
John Ford DOE Field Office, Carlsbad
Bob Wirtanen, ConocoPhillips, San Juan Business Unit
Monica Johnston, ConocoPhillips, San Juan Business Unit
Ryan Frost, ConocoPhillips, San Juan Business Unit
Thomas Cochrane, ConocoPhillips, San Juan Business Unit
Rebekah Miller, ConocoPhillips, San Juan Business Unit
Ayman Gazawi, ConocoPhillips, San Juan Business Unit
Kay Bjornen, ConocoPhillips, Ponca City, R & D
Frank McDonald, Biosphere Sciences and Technologies, LLC
Rick Arnold, NMSU, Farmington
Joel Brown, USDA, Jornada
Al Bierle, Western Environmental Management Corp., Ltd.
Carey Johnston, EPA HQ
Julianna Fessenden, LANL
Lisa Henne, LANL
Marianne Johnston, LANL
Enid Sullivan, LANL
Liangxiong Li, PRRC, NM Tech
Dale Wirth, BLM, Farmington
Jeff Tafoya, BLM, Farmington
John Matis, BLM, Santa Fe
Brandon Powell, NMOCD, Aztec
Wayne Price NMOCD, Santa Fe
Brad Jones, NMOCD, Santa Fe
Richard Benson, Applied Science Laboratories, Inc.
Ed Judkins

Sandia Internal:

1	MS 0735	J. Merson, 6310
1	MS 1104	Margie Tatro, 6200
1	MS 0706	D.J. Borns, 6312
1	MS 0706	A.R. Sattler, 6312
1	MS 1495	Jacqueline Kerby Moore 1495
1	MS 1033	Alma Giron, 1457
1	MS 0754	Patrick Brady, 6312
1	MS 0754	Thomas Mayer, 6316
1	MS 0892	Richard Kottenstette, 1716
1	MS 1108	M. Michael Hightower, 6332
1	MS 0754	Malynda Cappelle, 6316
1	MS 0754	Randy Everett, 6316
1	MS 0754	William Holub, 6316
1	MS 1104	Rush Robinett III, 6330
1	MS 0734	Bruce Kelley, 6327
1	MS 0754	Mark Rigali, 6316
1	MS 0735	Ray Finley, 6313
1	MS 0899	Tech Library, 9536 (electronic copy)

Jones, Brad A., EMNRD

From: Johnson, Monica [Monica.Johnson@conocophillips.com]
Sent: Monday, June 29, 2009 3:31 PM
To: Jones, Brad A., EMNRD; Chavez, Carl J, EMNRD
Cc: Powell, Brandon, EMNRD; Dale_Wirth@nm.blm.gov; Sattler, Allan R; Cappelle, Malynda A; Wirtanen, Bob A; Miller, Rebekah E.; Frank McDonald, B.E.S.T.; Rick Arnold; Dave_Mankiewicz@nm.blm.gov; barney_wegener@nm.blm.gov; Emerson, Warren; Frost, Gwendolynne
Subject: Produced Water Pilot Project Permit #EPWM-002 amendment request
Attachments: OCD pilot study letter amendment 6-29-09.pdf

Dear Mr. Jones and Mr. Chavez,

Please find attached an electronic letter requesting permission to amend permit #EPWM-002 for the San Juan 32-8 Unit #237A water pilot project.

Should you have any further questions, please let me know.

Thank you!

Monica D. Johnson
Sr. Environmental Scientist
ConocoPhillips Company
3401 East 30th Street
Farmington, NM 87402
Office: (505) 326-9829
Cell: (505) 320-9056
Direct Fax: (918) 662-1826
Office Fax: (505) 599-4005

ConocoPhillips

San Juan Business Unit
P.O. Box 4289
Farmington, NM 87402-4289
(505) 326-9700

Sent Via Email

June 29, 2009

Mr. Brad Jones and Mr. Carl Chavez
Environmental Bureau Engineers
New Mexico Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, NM 87505

RE: Produced Water Pilot Project Permit # EPWM - 002 for the San Juan 32-8 Unit #237A

Dear Mr. Jones and Mr. Chavez:

ConocoPhillips Company is requesting approval to apply treated produced water on portions of the San Juan 32-8 Unit #237A (T31N, R8W, Section 23, Unit I) location as part of a pilot project described below. The New Mexico Oil Conservation Division (NMOCD) previously granted permission to apply certain quantities of treated and untreated water to the subject location. This request is being resubmitted because the permit expires July 28, 2009, and we wish to continue and improve our water treatment train especially in pretreatment produced water. We propose to treat some of the grasses by a method described below. An important difference from our previously granted permits is that only treated/desalinated water would be applied to the ground. No application of untreated water on the soil is included in this request.

ConocoPhillips is seeking to find alternative use methods for produced water generated by the oil and gas industry. New Mexico State University's Agricultural Science Center, Farmington and the U. S. Department of Agriculture's Jornada Experimental Range, Las Cruces will water grasses on the subject well pad on a limited/spot basis. The watering is to accompany a pilot desalination operation constructed by Sandia National Laboratories on the same well pad. Use of the treated/ desalinated water is critical to this plan.

The complete details of our request were found in our letter and the attachment hand delivered during a meeting dated May 28, 2009. Subsequent to that letter, additional discussions about the permit application were held with Allan Sattler at your office. It was felt that an amendment to the original May 28, 2009 permit request would be appropriate.

Pilot operations would remain as in the original permit request, in that a study of ultrafiltration pre-treatment combined with reverse osmosis desalination will be used to treat produced water at the San Juan 32-8 Unit #237A well pad. The original permit requested elimination of analyses that had previously shown "non-detect" levels, as well as a decrease in the frequency of analysis. From the above mentioned discussions, however, the permit sampling types and frequency for complete laboratory analysis (NMAC 20.6.2.3103, Subsections A-C) are now amended as follows:

1. Due to the fact that pilot operations plan to water an area previously watered with untreated produced water, both the treated water and the soil will require analysis:
    a. The treated water (permeate) will be analyzed once per NMAC 20.6.2.3103, Subsections A-C.
    b. The soil where untreated produced water was previously added will be analyzed prior to watering and after each watering event, per NMAC 20.6.2.3103, Subsections A-C (estimated to be once per month).
    c. The soil where treated/desalinated produced water was previously added will be analyzed prior to watering and after the last watering event, per NMAC 20.6.2.3103, Subsections A-C.
    d. The area with no additional water ("mother nature") requires no additional testing.
2. If the treatment train is modified significantly (differing membrane configurations or types or significant additional pretreatment schemes), then the treated water and the soil plot where treated water will be applied will be tested as summarized above. Change of mechanical filters only is not considered a change in the treatment train.
3. All cartridge filters, UF membranes, and RO membranes will be disposed of in an approved landfill, as before. Prior to disposal, they will be tested according to NMAC 19.15.35.8.
4. Additional tests will be performed to assess the treatment effectiveness and impacts on the soil. However, this item is neither a part of the permit request nor a permit requirement. It is included for information only. (See comment in item 5 below.)
    a. Each of the water streams (untreated produced water, ultrafiltration filtrate, reverse osmosis feed, concentrate, and permeate/treated) will be analyzed as summarized originally in the permit application.
    b. Each of the soil plots where water has/was applied may be analyzed for anions and other constituents of interest as originally in the permit application.
5. Other methods of treatment may be evaluated during this year's efforts, such as nanofiltration, LANL-developed pre-treatment, etc. However, no treated water will be placed on any ground surface as a result of these operations. **This particular item and item 4. above are neither a part of the permit request nor a permit requirement.** Any available information from these two items will be included in the information sent to the NMOCD as a matter of course to help expand their produced water database.

If you should have additional questions or comments, you can reach me at 505-326-9829.

Sincerely,

Monica D. Johnson

Monica D. Johnson
Sr. Environmental Scientist

Attachment

Cc: Brandon Powell - NMOCD, Aztec
David Mankiewicz - Bureau of Land Management

Dale Wirth - Bureau of Land Management
Barney Wegener - Bureau of Land Management
Rebekah Miller - ConocoPhillips
Warren Emerson - ConocoPhillips
Gwen Frost - ConocoPhillips
Bob Wirtanen - ConocoPhillips
Frank McDonald - BEST
Rick Arnold - NMSU
Malynda Cappelle - Sandia National Labs, MS-1373
Allan Sattler - Sandia National Labs, MS-0706

ConocoPhillips

San Juan Business Unit
P.O. Box 4289
Farmington, NM 87402-4289
(505) 326-9700

Delivered in person

May 22, 2009

Mr. Brad Jones and Mr. Carl Chavez
Environmental Bureau Engineers
New Mexico Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, NM 87505

RE: Produced Water Pilot Project Permit # EPWM - 002 for the San Juan 32-8 Unit #237A

Dear Mr. Jones and Mr. Chavez:

ConocoPhillips Company is requesting approval to apply treated produced water on portions of the San Juan 32-8 Unit #237A (T31N, R8W, Section 23, Unit I) location as part of a pilot project described below. The New Mexico Oil Conservation Division (NMOCD) previously granted permission to apply certain quantities of treated and untreated water to the subject location. This request is being resubmitted because the permit expires July 28, 2009, and we wish to continue and improve our water treatment train especially in pretreatment produced water. We propose to treat some of the grasses by a method described below. An important difference from our previously granted permits is that only treated/desalinated water would be applied to the ground. No application of untreated water on the soil is included in this request.

ConocoPhillips is seeking to find alternative use methods for produced water generated by the oil and gas industry. New Mexico State University's Agricultural Science Center, Farmington and the U. S. Department of Agriculture's Jornada Experimental Range, Las Cruces will water grasses on the subject well pad on a limited/spot basis. The watering is to accompany a pilot desalination operation constructed by Sandia National Laboratories on the same well pad. Use of the treated/ desalinated water is critical to this plan.

The complete details of our request are found in the attachment and are summarized here along with the contents of the attachment, below.

- Elimination of the full set of VOCs and PAHs is requested, as they have all been at non-detect levels due to the prohibitive cost. Table 1 of the attachment (Page 1-2) shows the original matrix of required tests. Table 2 (Page 4) shows the analysis of the untreated water. Table 3-5 (Page5-7) show the soil analysis for the three plots where treated, untreated, and no water have been applied (natural rainfall only). **Soil analysis shows that the VOCs and PAHs have all been at non-detect levels.**
- A decreased frequency of testing is requested. There was minimal change with most analyses in the soil with applications of untreated water. Tests are suggested at the beginning of the pilot operation this year and at the end of the operation this year which would test all three plots of land and any treated water that is added to the land. Analyses that are critical to assessment of the desalination effectiveness (i.e., major anions, cations,

TOC, pH, alkalinity) will be tested on a daily basis by Sandia personnel. This provides continuous daily monitoring. Detail is provided on Table 5 (Page 8-9) and the accompanying text.

- Permission is requested to add water, as before, to the two sections of land that were previously treated; the same plot that received treated water as before and the same section that received untreated water as before. In this instance, only treated water will be applied to **both** sections of the land. Again, no application of untreated water on the soil is envisioned in this request. The application of treated water on the soil plot that had previously had untreated water applied may well demonstrate the potential for using treated water to improve/remediate soil quality in areas where raw produced water spills did occur. Detail is provided in the text of Page 8.
- The text on Page 8 gives details of proposed improvements for water treatment.
- Other information relevant is also given in the attachment.

Each test plot will be approximately 50 feet by 80 feet. The water will be applied in a manner that will confine the water to the existing ConocoPhillips location. Earthen berms have been constructed and a limited amount of watering has already been accomplished.

Moreover, the numerous earlier procedures were done with approvals from the NMOCD and the BLM. Then comparable amounts of produced water, with TDS values between approximately 5,000 and 12,000 ppm, were placed on the soil to enhance grass growth. In virtually all those previously approved cases, as well as in the present operations, critical soil parameters, Sodium Adsorption Ratio, and Electrical Conductivity, remained below critical limits of 25 and 15 decisiemens respectively. These parameters along with any required analyses would continue to be carefully monitored in this work and made available to both the NMOCD and BLM.

Sincerely,

Monica D. Johnson

Monica D. Johnson
Sr. Environmental Scientist

Attachment

Cc: Brandon Powell - NMOCD, Aztec
David Mankiewicz - Bureau of Land Management
Dale Wirth - Bureau of Land Management
Barney Wegener - Bureau of Land Management
Rebekah Miller - ConocoPhillips
Warren Emerson - ConocoPhillips
Gwen Frost - ConocoPhillips
Bob Wirtanen - ConocoPhillips
Frank McDonald - BEST
Rick Arnold - NMSU
Malynda Cappelle - Sandia National Labs, MS-1373
Allan Sattler - Sandia National Labs, MS-0706

ATTACHMENT: PAST ANALYSIS SUMMARY AND PROPOSED ANALYSIS PLAN

2008 Sample Analysis Summary

To do all analyses requested and required by our previous OCD permit, it cost $1130 per sample ($5,650 per sampling event). Many of the constituents were consistently at non-detect levels and we suggest minimizing or eliminating those constituents from the required analyses. Table 1 describes all analyses obtained for water and soil samples during 2008 pilot operations.

Table 1. 2008 Sample Analysis Summary

	SOIL		WATER		
Analyte	**Det. Limit**	**Units**	**Det. Limit**	**Units**	**OCD permit req?**
Miscellaneous/Anion					
pH		su			Y
Conductivity (@ 25°C)		uS/cm			
TDS (@180 °C)		mg/L			Y
SAR (calculated)					
TOC	0.1	%C	1.0	mg/L	
Nitrate (as NO_3-N)	0.1	mg/L	0.1	mg/L	Y
Cyanide	0.01	mg/L	0.01	mg/L	Y
Fluoride	0.001	mg/L	0.001	mg/L	Y
Chloride		mg/L		mg/L	Y
Sulfate	0.1	mg/L	0.1	mg/L	Y
Total Alkalinity (as HCO_3)		mg/L		mg/L	
Bicarbonate Alkalinity (as HCO_3)		mg/L		mg/L	
Carbonate Alkalinity (as CO_3)		mg/L		mg/L	
OH Alkalinity (as OH)		mg/L		mg/L	
Radium, Uranium					
Uranium	0.7	mg/kg-dry	30	ug/L	Y
Ra-226 + Ra-228	0.8	pCi/g-dry	5.1	pCi/L	Y
Cation					
Arsenic	0.001	mg/kg	0.001	mg/L	Y
Aluminum	0.001	mg/kg	0.001	mg/L	Y
Barium	0.001	mg/kg	0.001	mg/L	Y
Boron	0.001	mg/kg	0.001	mg/L	Y
Cadmium	0.001	mg/kg	0.001	mg/L	Y
Calcium	0.001	mg/L	0.001	mg/L	
Chromium	0.001	mg/kg	0.001	mg/L	Y
Cobalt	0.001	mg/kg	0.001	mg/L	Y
Copper	0.001	mg/kg	0.001	mg/L	Y
Iron	0.001	mg/kg	0.001	mg/L	Y
Lead	0.001	mg/kg	0.001	mg/L	Y
Magnesium	0.001	mg/L	0.001	mg/L	
Manganese	0.001	mg/kg	0.001	mg/L	Y
Mercury	0.033	mg/kg	0.00020	mg/L	Y
Molybdenum	0.001	mg/kg	0.001	mg/L	Y
Nickel	0.001	mg/kg	0.001	mg/L	Y
Potassium	0.001	mg/kg	0.001	mg/L	
Selenium	0.001	mg/kg	0.001	mg/L	Y

	SOIL		WATER		
Analyte	**Det. Limit**	**Units**	**Det. Limit**	**Units**	**OCD permit req?**
Silver	0.001	mg/kg	0.001	mg/L	Y
Sodium	0.001	mg/L	0.001	mg/L	
Zinc	0.001	mg/kg	0.001	mg/L	Y
Purgeable VOCs:					
Benzene	1.0	μg/kg	1.0	μg/L	Y
Toluene	1.0	μg/kg	1.0	μg/L	Y
Ethylbenzene	1.0	μg/kg	1.0	μg/L	Y
Xylenes, total	1.0	μg/kg	1.0	μg/L	Y
Methyl tert-butyl ether (MTBE)	1.0	μg/kg	1.0	μg/L	
1,2,4-Trimethylbenzene	1.0	μg/kg	1.0	μg/L	
1,3,5-Trimethylbenzene	1.0	μg/kg	1.0	μg/L	
1,2-Dichloroethane (EDC)	1.0	μg/kg	1.0	μg/L	Y
1,2-Dibromoethane (EDB)	1.0	μg/kg	1.0	μg/L	Y
Napthalene	1.0	μg/kg	1.0	μg/L	
1-Methylnapthalene	2.0	μg/kg	2.0	μg/L	
2-Methylnapthalene	2.0	μg/kg	2.0	μg/L	
Bromobenzene	1.0	μg/kg	1.0	μg/L	
Bromochloromethane	1.0	μg/kg	1.0	μg/L	
Bromodichloromethane	1.0	μg/kg	1.0	μg/L	
Bromoform	1.0	μg/kg	1.0	μg/L	
Bromomethane	1.0	μg/kg	1.0	μg/L	
Carbon tetrachloride	1.0	μg/kg	1.0	μg/L	Y
Chlorobenzene	1.0	μg/kg	1.0	μg/L	
Chloroethane	2.0	μg/kg	2.0	μg/L	
Chloroform	1.0	μg/kg	1.0	μg/L	Y
Chloromethane	1.0	μg/kg	1.0	μg/L	
2-Chlorotoluene	1.0	μg/kg	1.0	μg/L	
4-Chlorotoluene	1.0	μg/kg	1.0	μg/L	
cis-1,2-Dichloroethene	1.0	μg/kg	1.0	μg/L	
cis-1,2-Dichloropropene	1.0	μg/kg	1.0	μg/L	
1,2-Dibromo-3-chloropropane	2.0	μg/kg	2.0	μg/L	
Cibroomchloromethane	1.0	μg/kg	1.0	μg/L	
Dibromoethane	2.0	μg/kg	2.0	μg/L	
1,2-Dichlorobenzene	1.0	μg/kg	1.0	μg/L	
1,3-Dichlorobenzene	1.0	μg/kg	1.0	μg/L	
1,4-Dichlorobenzene	1.0	μg/kg	1.0	μg/L	
Dichlorodifluoromethane	1.0	μg/kg	1.0	μg/L	
1,1-Dichloroethane	1.0	μg/kg	1.0	μg/L	Y
1,1-Dichloroethene (a.k.a. 1,1-DCE)	1.0	μg/kg	1.0	μg/L	Y
1,2-Dichloropropane	1.0	μg/kg	1.0	μg/L	
1,3-Dichloropropane	1.0	μg/kg	1.0	μg/L	
2,2-Dichloropropane	1.0	μg/kg	1.0	μg/L	
1,1-Dichloropropene	1.0	μg/kg	1.0	μg/L	
Hexachlorobutadiene	1.0	μg/kg	1.0	μg/L	
Isopropylbenzene	1.0	μg/kg	1.0	μg/L	
4-Isopropylbenzene	1.0	μg/kg	1.0	μg/L	
Methylene chloride	3.0	μg/kg	3.0	μg/L	Y
n-Butylbenzene	1.0	μg/kg	1.0	μg/L	

	SOIL		WATER		
Analyte	**Det. Limit**	**Units**	**Det. Limit**	**Units**	**OCD permit req?**
n-Propylbenzene	1.0	μg/kg	1.0	μg/L	
sec-Butylbenzene	1.0	μg/kg	1.0	μg/L	
Styrene	1.0	μg/kg	1.0	μg/L	
tert-Butylbenzene	1.0	μg/kg	1.0	μg/L	
Tetrachloroethene (PCE)	1.0	μg/kg	1.0	μg/L	Y
1,1,1,2-Tetrachloroethane	1.0	μg/kg	1.0	μg/L	
1,1,2,2-Tetrachloroethane	1.0	μg/kg	1.0	μg/L	Y
trans-1,2-Dichloroethane	1.0	μg/kg	1.0	μg/L	
trans-1,3-Dichloropropene	1.0	μg/kg	1.0	μg/L	
Trichloroethene (TCE)	1.0	μg/kg	1.0	μg/L	Y
Trichlorofluoromethane	1.0	μg/kg	1.0	μg/L	
1,2,3-Trichlorobenzene	1.0	μg/kg	1.0	μg/L	
1,2,4-Trichlorobenzene	1.0	μg/kg	1.0	μg/L	
1,1,1-Trichloroethane	1.0	μg/kg	1.0	μg/L	Y
1,1,2-Trichloroethane	1.0	μg/kg	1.0	μg/L	Y
1,2,3-Trichloropropane	2.0	μg/kg	2.0	μg/L	
Vinyl Chloride	2.0	μg/kg	2.0	μg/L	Y
Polychlorinated biphenyls (PCBs)	0.0	μg/kg	1.0-5.0*	μg/L	Y
benzo-a-pyrene	0.01	μg/kg	0.1	μg/L	Y
Phenols	0.2	μg/kg	2.5	μg/L	Y
PAHs (EPA 8310)					
Napthalene	0.3	μg/kg	2.0	μg/L	Y
1-Methylnapthalene	0.3	μg/kg	2.0	μg/L	Y
2-Methylnapthalene	0.3	μg/kg	2.0	μg/L	Y
Fluorene	0.03	μg/kg	0.8	μg/L	Y

*All PCB's detection limits are 1.0 μg/L, except for Arochlor 1221, which is 5.0 μg/L

Water Analysis Summary

At least one sample per week was taken on all water streams for a limited analysis at Sandia (major ions, alkalinity, TOC). At each water application, the RO permeate and untreated waters were sampled for all OCD-required analyses plus analyses useful for determination of treatment efficiencies. Treated water quality was typically less than 200 mg/L in salinity and most constituents were removed entirely by the reverse osmosis system.

Although only in operation for several hours, the ultrafiltration system appeared to make fairly good quality of water (significant turbidity and TOC removal attainable). A properly functioning ultrafiltration system will be required for full scale operation; the reverse osmosis membranes would need to be replaced too frequently to be cost effective otherwise.

Table 2. 2008 Water Analysis Summary

Analyte	Units	Untreated	RO Perm
Turbidity	NTU	8.3	0.23
pH	su	7.6	5.9
Conductivity (@ 25°C)		19800	203
TOC	mg/L	21.3	6.5
SAR (calculated)		265	13.7
Alkalinity, as HCO3	mg/L	8048	55.7
TDS (@180 °C)	mg/L	12625	131
Nitrate (as NO3-N)	mg/L	1.6	0.2
Chloride		2833	23.3
Phosphate	mg/L	13	0.1
Sulfate	mg/L	2.4	0.1
Barium	mg/L	30	0.4
Calcium	mg/L	14.4	0.4
Iron	mg/L	1.2	0.1
Magnesium	mg/L	9.2	0.1
Potassium	mg/L	25.6	0.4
Sodium	mg/L	4897	32.2

Significant fouling occurred on the membranes and a crude autopsy was performed to evaluate the cause. It appears that much of the fouling was caused by iron precipitate, organic constituents, and some phosphate and barium.

Soil Analysis Summaries

Soil samples were collected and analyzed after each water application. Approximately 60 bbl each of raw produced water and treated water was applied to separate 4,500 land sections four times during the 2008 pilot. There was a third section, dubbed "mother nature", which received no additional watering. This section was sampled three times.

As expected, there was an increase in the soil salinity in the section that received untreated/raw produced water. The treated section had a slight improvement in overall quality. Finally, there was variation in the mother nature section that is not understood. This variation in the control section makes comparisons to the other plots difficult at this time. Additional samples will be obtained and analyzed in 2009.

There was a section of land that happened to get a mixture of untreated and treated water due to piping arrangements and drainage from the irrigation pipes. This section thrived, which may be an indication that higher TDS waters are a better match for spot irrigation. As shown by NMSU and others, many grasses and plants can thrive on 1,000 mg/L TDS or higher.

Table 3. Untreated/Raw Water Application – Soil Analyses

Analyte	**Units**	**9/12/08**	**10/15/08**	**10/30/08**	**11/12/08**
Miscellaneous/Anion					
pH	su	9.17	8.61	9.34	9.26
Conductivity (25 °C)	uS/cm		553	1100	1040
TDS (@180 °C)	mg/L	170	388	640	480
SAR (calc)		3.100	3.140	10.187	2.699
TOC	%C	0.56	0.82	0.47	1
Nitrate (as NO3-N)	mg/L	15.3	<0.01	<0.01	7.55
Cyanide	mg/L	0.002	0.002	<0.01	0.010
Fluoride	mg/L	2.08	1.4	2.97	0.195
Chloride	mg/L	12.7	101	163	91
Sulfate	mg/L	5.2	4.98	5.13	3.2
Total Alkalinity (as HCO3)	mg/L	304	168	418	354
Radium, Uranium					
Uranium	mg/kg-dry	0.7	1	0.6	0.7
Ra-226 & Ra-228	pCi/g-dry	0.8	0.29	1.8	ND
Cation					
Calcium	mg/L	100	43.1	35.6	84
Magnesium	mg/L	4.88	1.78	0.968	2.44
Sodium	mg/L	15.2	77.5	226	92.1
Arsenic	mg/kg	0.076	0.088	0.088	0.044
Aluminum	mg/kg	321	40.4	202	183
Barium	mg/kg	27.9	26.6	21	12.4
Boron	mg/kg	ND	0.101	1.36	0.582
Cadmium	mg/kg	0.005	0.012	0.012	0.006
Chromium	mg/kg	0.181	0.286	0.186	0.167
Cobalt	mg/kg	0.155	0.004	0.147	0.116
Copper	mg/kg	0.220	0.54	0.248	0.154
Iron	mg/kg	303	7.68	209	176
Lead	mg/kg	0.358	0.437	0.429	0.311
Manganese	mg/kg	15.6	2.12	17.3	17.7
Mercury	mg/kg	0.036	ND	ND	ND
Molybdenum	mg/kg	0.004	0.008	0.01	0.004

Analyte	Units	9/12/08	10/15/08	10/30/08	11/12/08
Nickel	mg/kg	0.135	0.706	0.246	0.244
Potassium	mg/kg		2.57	0.793	0.788
Selenium	mg/kg	ND	ND	ND	ND
Silver	mg/kg	ND	ND	ND	ND
Zinc	mg/kg	0.783	0.486	0.821	0.51
Purgeable VOCs, PAHs, PCBs	mg/kg	ND	ND	ND	ND

Table 4. Treated Water Application – Soil Analyses

Analyte	Units	9/12/08	10/15/08	10/30/08	11/12/08
Miscellaneous/Anion					
pH	su	7.98	7.74	7.8	7.68
Conductivity (25 oC)	uS/cm			223	239
TDS (@180 oC)	mg/L	69	319	132	180
SAR (calc)		0.008	0.0004	0.497	0.078
TOC	%C	0.98	0.98	0.83	1
Nitrate (as NO3-N)	mg/L	5.41	2.01	<0.01	1.47
Cyanide	mg/L	<0.01	0.01	<0.01	0.010
Fluoride	mg/L	2.23	1.42	3.45	0.127
Chloride	mg/L	2.53	2.63	2.12	5.83
Sulfate	mg/L	2.6	0.861	0.986	1.52
Total Alkalinity (as HCO3)	mg/L	72	154	146	172
Radium, Uranium					
Uranium	mg/kg-dry	1	0.8	0.6	0.7
Ra-226 & Ra-228	pCi/g-dry	0.8	1	0.8	0.39
Cation					
Calcium	mg/L	45.6	56.4	40.6	52.4
Magnesium	mg/L	3.17	1.95	1.67	2.91
Sodium	mg/L	0.202	0.01	11.9	2.16
Arsenic	mg/kg	0.06	0.058	0.067	0.043
Aluminum	mg/kg	185	220	176	163
Barium	mg/kg	18.9	25.5	20	14.7
Boron	mg/kg	0.118	0.117	0.411	0.56
Cadmium	mg/kg	0.008	0.01	0.013	0.01
Chromium	mg/kg	0.133	0.352	0.144	0.147
Cobalt	mg/kg	0.108	0.015	0.178	0.119
Copper	mg/kg	0.189	0.307	0.204	0.156
Iron	mg/kg	152	25.9	152	168
Lead	mg/kg	0.353	0.399	0.43	0.305
Manganese	mg/kg	17.6	2.25	20.2	17.3
Mercury	mg/kg	0.033	ND	0.033	ND
Molybdenum	mg/kg	0.006	0.008	0.008	0.005
Nickel	mg/kg	0.044	0.493	0.22	0.234
Potassium	mg/kg		1.7	2.23	6.5
Selenium	mg/kg	ND	ND	ND	ND
Silver	mg/kg	ND	ND	0.018	ND
Zinc	mg/kg	0.494	0.453	0.72	0.59
Purgeable VOCs, PAHs, PCBs	mg/kg	ND	ND	ND	ND

Table 5. No Water Application (Mother Nature) – Soil Analyses

Analyte	Units	10/15/08	10/30/08	11/12/08
Miscellaneous/Anion				
pH	su	7.85	7.44	7.57
Conductivity (25 oC)	uS/cm		347	311
TDS (@180 oC)	mg/L	317	232	176
SAR (calc)		0.299	0.065	0.507
TOC	%C	1	0.52	0.58
Nitrate (as NO3-N)	mg/L	7.09	6.09	13.9
Cyanide	mg/L	0.008	0.001	<0.01
Fluoride	mg/L	1.55	2.83	0.101
Chloride	mg/L	2.29	26.5	23
Sulfate	mg/L	3.92	3.57	2.71
Total Alkalinity (as HCO3)	mg/L	153	157	159
Radium, Uranium				
Uranium	mg/kg-dry	0.8	0.8	0.5
Ra-226 & Ra-228	pCi/g-dry	0.207	0.8	0.29
Cation				
Calcium	mg/L	48	73.5	57.7
Magnesium	mg/L	3.2	2.83	4
Sodium	mg/L	7.94	2.1	0.9
Arsenic	mg/kg	0.051	0.077	0.064
Aluminum	mg/kg	193	274	202
Barium	mg/kg	24.8	20.5	14.2
Boron	mg/kg	0.107	1.03	0.66
Cadmium	mg/kg	0.009	0.025	0.017
Chromium	mg/kg	0.381	0.122	0.017
Cobalt	mg/kg	0.015	0.136	0.144
Copper	mg/kg	0.324	0.676	0.19
Iron	mg/kg	23.3	146	203
Lead	mg/kg	0.411	0.516	0.346
Manganese	mg/kg	2.58	6.86	19.5
Mercury	mg/kg	ND	0.057	ND
Molybdenum	mg/kg	0.004	0.004	0.004
Nickel	mg/kg	0.469	0.191	0.205
Potassium	mg/kg	0.762	0.895	0.905
Selenium	mg/kg	ND	0.019	ND
Silver	mg/kg	ND	ND	ND
Zinc	mg/kg	0.453	0.621	0.7
Purgeable VOCs, PAHs, PCBs	mg/kg	ND	ND	ND

2009 Proposed testing protocol & Analysis Plans

2009 pilot operations will continue at the same San Juan 32-8 Unit #237A well pad. Partners will continue to be ConocoPhillips, Biosphere Environmental Science & Technology (BEST), New Mexico State University (NMSU), and the United States Department of Agriculture (USDA).

This year's pilot will primarily focus on optimization of the ultrafiltration system (UF). A new unit is to be purchased, installed, and operated for at least one month. None of this UF-treated water will be applied to the land and will be disposed of according to normal ConocoPhillips processes.

Once the UF has been optimized, it will be paired with the existing desalination system for a final treatment. Two types of desalination membranes will be tested: nanofiltration and reverse osmosis. Nanofiltration membranes offer a lesser degree of desalination at significantly lower pressure. The only water that will be applied to the land will be the water that has passed through the UF and reverse osmosis systems; all other water will be disposed of according to normal ConocoPhillips processes. We propose to add water to two sections of land: the same treated section as before and the untreated section. This will be to demonstrate the potential for using treated water to improve soil quality in areas with raw produced water spills.

As part of the NMSBA program funding, we will be partnering with Los Alamos National Laboratory for part of this work. Jeri Sullivan will be providing a new pre-treatment process that would be compared to the UF system. This will be done in conjunction with or in parallel to the other pilot operations.

Due to the prohibitive cost, we request elimination of the full set of VOCs and PAHs, as they have all been at non-detect levels. We also request a decreased frequency of testing and suggest a test at the beginning of the pilot and at the end of the pilot in 2009 which would test all three plots of land and any treated water that is added to the land. Analyses that are critical to assessment of the desalination effectiveness (i.e. major anions, cations, TOC, pH, alkalinity) will be tested on a daily bases by Sandia personnel.

Table 6. Proposed Analyses – 2009 Pilot Operations

Analyte	Frequency (SOIL)	Frequency (WATER)
Miscellaneous/Anion		
pH	1x/mo[1]	At least 1x/day
Conductivity (@ 25°C)	1x/mo[1]	At least 1x/day
TDS (@180 °C)	1x/mo[1]	At least 1x/mo
SAR (calculated)	1x/mo[1]	At least 1x/day
TOC	1x/mo[1]	At least 1x/day
Nitrate (as NO_3-N)	1x/mo[1]	At least 1x/mo
Fluoride	1x/mo[1]	At least 1x/day
Chloride	1x/mo[1]	At least 1x/day
Sulfate	1x/mo[1]	At least 1x/day
Total Alkalinity (as HCO_3)	1x/mo[1]	At least 1x/day
Radium, Uranium		
Uranium	Twice[2]	Twice[2]
Ra-226 + Ra-228	Twice[2]	Twice[2]
Cation		
Arsenic	Twice[2]	Twice[2]
Aluminum	Twice[2]	Twice[2]
Barium	1x/mo[1]	At least 1x/mo
Boron	Twice[2]	Twice[2]

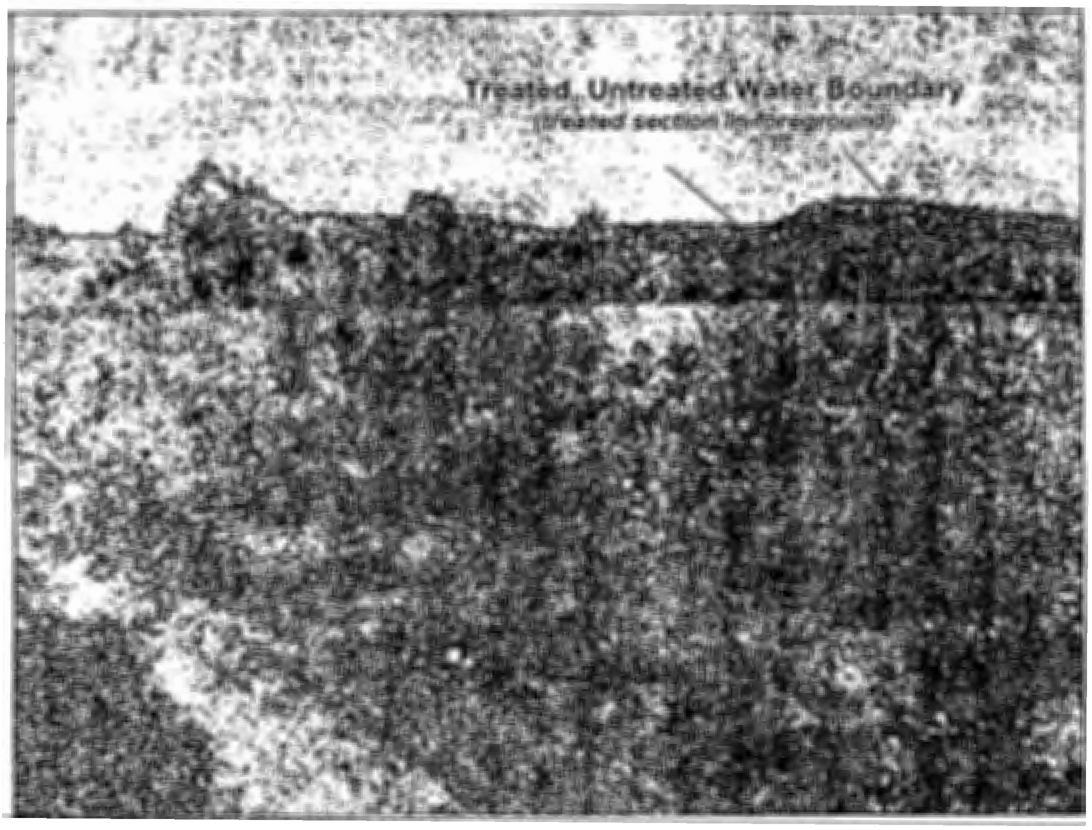
Analyte	Frequency (SOIL)	Frequency (WATER)
Cadmium	Twice[2]	Twice[2]
Calcium	1x/mo[1]	At least 1x/day
Chromium	Twice[2]	Twice[2]
Cobalt	Twice[2]	Twice[2]
Copper	Twice[2]	Twice[2]
Iron	1x/mo[1]	At least 1x/day
Lead	Twice[2]	Twice[2]
Magnesium	1x/mo[1]	At least 1x/day
Manganese	Twice[2]	Twice[2]
Mercury	Twice[2]	Twice[2]
Molybdenum	Twice[2]	Twice[2]
Nickel	Twice[2]	Twice[2]
Potassium	Twice[2]	Twice[2]
Selenium	Twice[2]	Twice[2]
Silver	Twice[2]	Twice[2]
Sodium	1x/mo[1]	At least 1x/day
Zinc	Twice[2]	Twice[2]
Purgeable VOCs:		
Benzene	Twice[2]	Twice[2]
Toluene	Twice[2]	Twice[2]
Ethylbenzene	Twice[2]	Twice[2]
Xylenes, total	Twice[2]	Twice[2]

Cartridge filters were analyzed for disposal purposes. Preliminary analyses are below. ConocoPhillips (through Frank McDonald) will coordinate all disposals of past and future cartridge filters and reverse osmosis membranes.

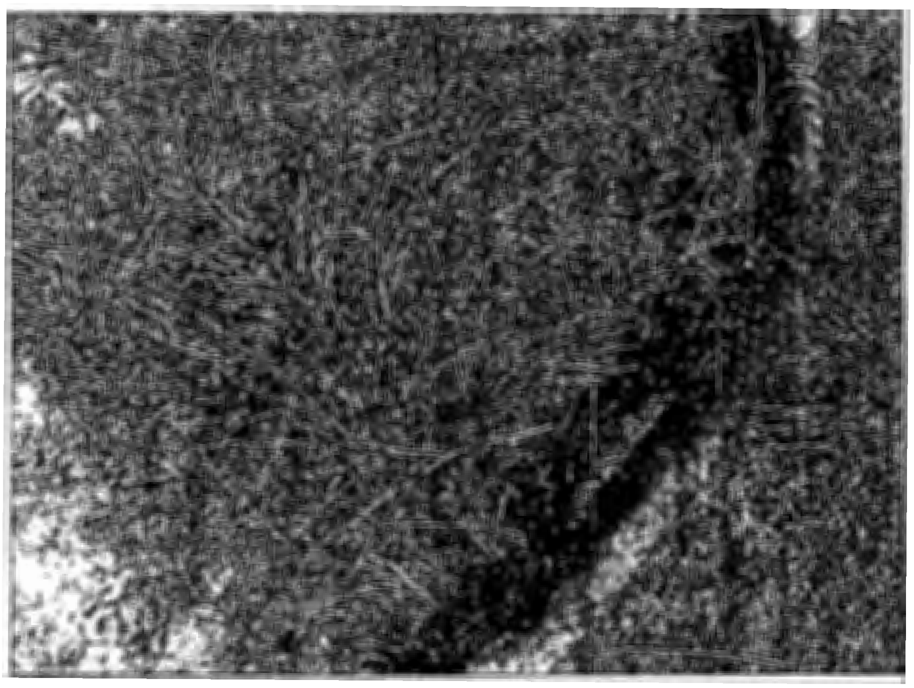
Table 7. Cartridge Filter Analysis Results

Analyte	Units	1 micron	5 micron	20 micron
Benzene	ug/kg	3.1	3.7	ND
Toluene	ug/kg	128	119	103
Ethybenzene	ug/kg	19.5	14.5	19.4
p,m-Xylene	ug/kg	139	136	235
o-Xylene	ug/kg	51.9	62.2	57.3
Arsenic	mg/kg	0.109	0.005	0.012
Barium	mg/kg	630	72.9	15.3
Cadmium	mg/kg	0.021	0.013	0.011
Chromium	mg/kg	1.46	0.62	0.189
Lead	mg/kg	0.114	0.356	0.018
Mercury	mg/kg	ND	ND	ND
Selenium	mg/kg	ND	ND	ND
Silver	mg/kg	ND	0.008	0.007
Corrosivity		Negative	Negative	Negative
pH		9.94	10.29	10.46

Pilot Pictures



Water Application areas



Section with mixed water (untreated + treated)

ConocoPhillips

Delivered in person

San Juan Business Unit
P.O. Box 4289
Farmington, NM 87402-4289
(505) 326-9700

May 22, 2009

Mr. David Mankiewicz
Bureau of Land Management
1235 La Plata Highway
Farmington, NM 87401

RE: Produced Water Pilot Project for the San Juan 32-8 Unit #237A

Dear Mr. Mankiewicz:

ConocoPhillips Company is requesting approval to apply treated produced water on portions of the San Juan 32-8 Unit #237A (T31N, R8W, Section 23, Unit I) location as part of a pilot project described below. This request is being resubmitted because the permit from your office expires June 7, 2009, and we wish to continue and improve our water treatment train especially in pretreatment produced water. We propose to further treat some of the grasses by a method described below. An important difference from our previously granted permit is that is that only treated/desalinated water would be applied to the ground. No application of untreated water on the soil is included in this request.

ConocoPhillips is seeking to find alternative use methods for produced water generated by the oil and gas industry. New Mexico State University (Agricultural Science Center, Farmington) and the US Department of Agriculture (Jornada Experimental Range, Las Cruces) have watered grasses around the ConocoPhillips San Juan 32-8 Unit #237A well pad on a limited/spot basis. The watering accompanies a pilot desalination operation constructed by Sandia National Laboratories on that pad. Use of the treated/desalinated water is critical to this plan. Work of this nature has been conducted on the aforementioned location and was conducted under a two-year permit from your office dated June 7, 2007, as well as being conducted under numerous concurrent permits from the New Mexico Oil Conservation Division.

The planted grasses on that well pad were watered about 0.5-1.0 inches each time. The existing grasses on the well pad were treated in the following manner:

- ~1/3 was spot watered with treated/desalinated water,
- ~1/3 was spot watered with untreated water, produced water,
- ~1/3 received no watering at all.

The treated water would always come from the pilot desalination operation. Earlier discussions between the U. S. Bureau of Land Management (BLM) and Sandia suggested that TDS of the treated water no greater than 1,500 ppm could be satisfactory. In reality, the TDS of the treated water was less than 400 ppm. The TDS of the untreated produced water from this particular well is ~12,000 ppm. A summary of last year's work is attached.

In summary, we request the following:

- Make improvements in the water treatment train (see page 8 of the attachment).
- Permission is requested to add water, as before, to the two sections of land that were previously treated: the same plot that received treated water as before and the same section that received untreated water as before. In this instance, only treated water will be applied to **both** sections of the land. Again, no application of untreated water on the soil is envisioned in this request. The application of treated water on the soil plot that had previously had untreated water applied may well demonstrate the potential for using treated water to improve/remediate soil quality in areas where raw produced water spills did occur. Detail is provided on the text of Page 8 of the attachment.

In the broader picture, this is a portion of the DOE-sponsored Southwest Regional Partnership on Carbon Sequestration of which ConocoPhillips is a member. One aspect of the sequestration of carbon dioxide could be to use treated produced water (emanating from injection of carbon dioxide in coal seams) to restore impaired riparian areas.

Another aspect of the broader picture is to ramp up the desalination operation and conduct it at a saltwater disposal facility. The grasses at the facility could be used for further study.

For now, however, we simply request permission to apply both desalinated/treated water and produced water to the planted grasses around the ConocoPhillips San Juan 32-8 Unit #237A well pad as described in the paragraphs above. Produced water has been a basic concern for both oversight agencies and producers. It is hoped that with additional research of this nature, positive results will evolve from this continuing concern.

Sincerely,

Monica D. Johnson

Monica D. Johnson
Sr. Environmental Scientist

Attachment

Cc: Dale Wirth - Bureau of Land Management
Barney Wegener - Bureau of Land Management
Brad Jones - NMOCD, Santa Fe
Carl Chavez - NMOCD, Santa Fe
Brandon Powell - NMOCD, Aztec
Rebekah Miller - ConocoPhillips
Warren Emerson - ConocoPhillips
Gwen Frost - ConocoPhillips
Bob Wirtanen - ConocoPhillips
Frank McDonald - BEST
Rick Arnold - NMSU
Malynda Cappelle - Sandia National Labs, MS-1373
Allan Sattler - Sandia National Labs, MS-0706

ATTACHMENT: PAST ANALYSIS SUMMARY AND PROPOSED ANALYSIS PLAN

2008 Sample Analysis Summary

To do all analyses requested and required by our previous OCD permit, it cost $1130 per sample ($5,650 per sampling event). Many of the constituents were consistently at non-detect levels and we suggest minimizing or eliminating those constituents from the required analyses. Table 1 describes all analyses obtained for water and soil samples during 2008 pilot operations.

Table 1. 2008 Sample Analysis Summary

	SOIL		WATER		
Analyte	**Det. Limit**	**Units**	**Det. Limit**	**Units**	**OCD permit req?**
Miscellaneous/Anion					
pH		su			Y
Conductivity (@ 25°C)		uS/cm			
TDS (@180 °C)		mg/L			Y
SAR (calculated)					
TOC	0.1	%C	1.0	mg/L	
Nitrate (as NO_3-N)	0.1	mg/L	0.1	mg/L	Y
Cyanide	0.01	mg/L	0.01	mg/L	Y
Fluoride	0.001	mg/L	0.001	mg/L	Y
Chloride		mg/L		mg/L	Y
Sulfate	0.1	mg/L	0.1	mg/L	Y
Total Alkalinity (as HCO_3)		mg/L		mg/L	
Bicarbonate Alkalinity (as HCO_3)		mg/L		mg/L	
Carbonate Alkalinity (as CO_3)		mg/L		mg/L	
OH Alkalinity (as OH)		mg/L		mg/L	
Radium, Uranium					
Uranium	0.7	mg/kg-dry	30	ug/L	Y
Ra-226 + Ra-228	0.8	pCi/g-dry	5.1	pCi/L	Y
Cation					
Arsenic	0.001	mg/kg	0.001	mg/L	Y
Aluminum	0.001	mg/kg	0.001	mg/L	Y
Barium	0.001	mg/kg	0.001	mg/L	Y
Boron	0.001	mg/kg	0.001	mg/L	Y
Cadmium	0.001	mg/kg	0.001	mg/L	Y
Calcium	0.001	mg/L	0.001	mg/L	
Chromium	0.001	mg/kg	0.001	mg/L	Y
Cobalt	0.001	mg/kg	0.001	mg/L	Y
Copper	0.001	mg/kg	0.001	mg/L	Y
Iron	0.001	mg/kg	0.001	mg/L	Y
Lead	0.001	mg/kg	0.001	mg/L	Y
Magnesium	0.001	mg/L	0.001	mg/L	
Manganese	0.001	mg/kg	0.001	mg/L	Y
Mercury	0.033	mg/kg	0.00020	mg/L	Y
Molybdenum	0.001	mg/kg	0.001	mg/L	Y
Nickel	0.001	mg/kg	0.001	mg/L	Y
Potassium	0.001	mg/kg	0.001	mg/L	
Selenium	0.001	mg/kg	0.001	mg/L	Y

	SOIL		WATER		
Analyte	**Det. Limit**	**Units**	**Det. Limit**	**Units**	**OCD permit req?**
Silver	0.001	mg/kg	0.001	mg/L	Y
Sodium	0.001	mg/L	0.001	mg/L	
Zinc	0.001	mg/kg	0.001	mg/L	Y
Purgeable VOCs:					
Benzene	1.0	µg/kg	1.0	µg/L	Y
Toluene	1.0	µg/kg	1.0	µg/L	Y
Ethylbenzene	1.0	µg/kg	1.0	µg/L	Y
Xylenes, total	1.0	µg/kg	1.0	µg/L	Y
Methyl tert-butyl ether (MTBE)	1.0	µg/kg	1.0	µg/L	
1,2,4-Trimethylbenzene	1.0	µg/kg	1.0	µg/L	
1,3,5-Trimethylbenzene	1.0	µg/kg	1.0	µg/L	
1,2-Dichloroethane (EDC)	1.0	µg/kg	1.0	µg/L	Y
1,2-Dibromoethane (EDB)	1.0	µg/kg	1.0	µg/L	Y
Napthalene	1.0	µg/kg	1.0	µg/L	
1-Methylnapthalene	2.0	µg/kg	2.0	µg/L	
2-Methylnapthalene	2.0	µg/kg	2.0	µg/L	
Bromobenzene	1.0	µg/kg	1.0	µg/L	
Bromochloromethane	1.0	µg/kg	1.0	µg/L	
Bromodichloromethane	1.0	µg/kg	1.0	µg/L	
Bromoform	1.0	µg/kg	1.0	µg/L	
Bromomethane	1.0	µg/kg	1.0	µg/L	
Carbon tetrachloride	1.0	µg/kg	1.0	µg/L	Y
Chlorobenzene	1.0	µg/kg	1.0	µg/L	
Chloroethane	2.0	µg/kg	2.0	µg/L	
Chloroform	1.0	µg/kg	1.0	µg/L	Y
Chloromethane	1.0	µg/kg	1.0	µg/L	
2-Chlorotoluene	1.0	µg/kg	1.0	µg/L	
4-Chlorotoluene	1.0	µg/kg	1.0	µg/L	
cis-1,2-Dichloroethene	1.0	µg/kg	1.0	µg/L	
cis-1,2-Dichloropropene	1.0	µg/kg	1.0	µg/L	
1,2-Dibromo-3-chloropropane	2.0	µg/kg	2.0	µg/L	
Cibroomchloromethane	1.0	µg/kg	1.0	µg/L	
Dibromoethane	2.0	µg/kg	2.0	µg/L	
1,2-Dichlorobenzene	1.0	µg/kg	1.0	µg/L	
1,3-Dichlorobenzene	1.0	µg/kg	1.0	µg/L	
1,4-Dichlorobenzene	1.0	µg/kg	1.0	µg/L	
Dichlorodifluoromethane	1.0	µg/kg	1.0	µg/L	
1,1-Dichloroethane	1.0	µg/kg	1.0	µg/L	Y
1,1-Dichloroethene (a.k.a. 1,1-DCE)	1.0	µg/kg	1.0	µg/L	Y
1,2-Dichloropropane	1.0	µg/kg	1.0	µg/L	
1,3-Dichloropropane	1.0	µg/kg	1.0	µg/L	
2,2-Dichloropropane	1.0	µg/kg	1.0	µg/L	
1,1-Dichloropropene	1.0	µg/kg	1.0	µg/L	
Hexachlorobutadiene	1.0	µg/kg	1.0	µg/L	
Isopropylbenzene	1.0	µg/kg	1.0	µg/L	
4-Isopropylbenzene	1.0	µg/kg	1.0	µg/L	
Methylene chloride	3.0	µg/kg	3.0	µg/L	Y
n-Butylbenzene	1.0	µg/kg	1.0	µg/L	

	SOIL		WATER		
Analyte	Det. Limit	Units	Det. Limit	Units	OCD permit req?
n-Propylbenzene	1.0	μg/kg	1.0	μg/L	
sec-Butylbenzene	1.0	μg/kg	1.0	μg/L	
Styrene	1.0	μg/kg	1.0	μg/L	
tert-Butylbenzene	1.0	μg/kg	1.0	μg/L	
Tetrachloroethene (PCE)	1.0	μg/kg	1.0	μg/L	Y
1,1,1,2-Tetrachloroethane	1.0	μg/kg	1.0	μg/L	
1,1,2,2-Tetrachloroethane	1.0	μg/kg	1.0	μg/L	Y
trans-1,2-Dichloroethane	1.0	μg/kg	1.0	μg/L	
trans-1,3-Dichloropropene	1.0	μg/kg	1.0	μg/L	
Trichloroethene (TCE)	1.0	μg/kg	1.0	μg/L	Y
Trichlorofluoromethane	1.0	μg/kg	1.0	μg/L	
1,2,3-Trichlorobenzene	1.0	μg/kg	1.0	μg/L	
1,2,4-Trichlorobenzene	1.0	μg/kg	1.0	μg/L	
1,1,1-Trichloroethane	1.0	μg/kg	1.0	μg/L	Y
1,1,2-Trichloroethane	1.0	μg/kg	1.0	μg/L	Y
1,2,3-Trichloropropane	2.0	μg/kg	2.0	μg/L	
Vinyl Chloride	2.0	μg/kg	2.0	μg/L	Y
Polychlorinated biphenyls (PCBs)	0.0	μg/kg	1.0-5.0*	μg/L	Y
benzo-a-pyrene	0.01	μg/kg	0.1	μg/L	Y
Phenols	0.2	μg/kg	2.5	μg/L	Y
PAHs (EPA 8310)					
Napthalene	0.3	μg/kg	2.0	μg/L	Y
1-Methylnapthalene	0.3	μg/kg	2.0	μg/L	Y
2-Methylnapthalene	0.3	μg/kg	2.0	μg/L	Y
Fluorene	0.03	μg/kg	0.8	μg/L	Y

*All PCB's detection limits are 1.0 μg/L, except for Arochlor 1221, which is 5.0 μg/L

Water Analysis Summary

At least one sample per week was taken on all water streams for a limited analysis at Sandia (major ions, alkalinity, TOC). At each water application, the RO permeate and untreated waters were sampled for all OCD-required analyses plus analyses useful for determination of treatment efficiencies. Treated water quality was typically less than 200 mg/L in salinity and most constituents were removed entirely by the reverse osmosis system.

Although only in operation for several hours, the ultrafiltration system appeared to make fairly good quality of water (significant turbidity and TOC removal attainable). A properly functioning ultrafiltration system will be required for full scale operation; the reverse osmosis membranes would need to be replaced too frequently to be cost effective otherwise.

Table 2. 2008 Water Analysis Summary

Analyte	Units	Untreated	RO Perm
Turbidity	NTU	8.3	0.23
pH	su	7.6	5.9
Conductivity (@ 25°C)		19800	203
TOC	mg/L	21.3	6.5
SAR (calculated)		265	13.7
Alkalinity, as HCO3	mg/L	8048	55.7
TDS (@180 °C)	mg/L	12625	131
Nitrate (as NO3-N)	mg/L	1.6	0.2
Chloride		2833	23.3
Phosphate	mg/L	13	0.1
Sulfate	mg/L	2.4	0.1
Barium	mg/L	30	0.4
Calcium	mg/L	14.4	0.4
Iron	mg/L	1.2	0.1
Magnesium	mg/L	9.2	0.1
Potassium	mg/L	25.6	0.4
Sodium	mg/L	4897	32.2

Significant fouling occurred on the membranes and a crude autopsy was performed to evaluate the cause. It appears that much of the fouling was caused by iron precipitate, organic constituents, and some phosphate and barium.

Soil Analysis Summaries

Soil samples were collected and analyzed after each water application. Approximately 60 bbl each of raw produced water and treated water was applied to separate 4,500 land sections four times during the 2008 pilot. There was a third section, dubbed "mother nature", which received no additional watering. This section was sampled three times.

As expected, there was an increase in the soil salinity in the section that received untreated/raw produced water. The treated section had a slight improvement in overall quality. Finally, there was variation in the mother nature section that is not understood. This variation in the control section makes comparisons to the other plots difficult at this time. Additional samples will be obtained and analyzed in 2009.

There was a section of land that happened to get a mixture of untreated and treated water due to piping arrangements and drainage from the irrigation pipes. This section thrived, which may be an indication that higher TDS waters are a better match for spot irrigation. As shown by NMSU and others, many grasses and plants can thrive on 1,000 mg/L TDS or higher.

Table 3. Untreated/Raw Water Application – Soil Analyses

Analyte	**Units**	**9/12/08**	**10/15/08**	**10/30/08**	**11/12/08**
Miscellaneous/Anion					
pH	su	9.17	8.61	9.34	9.26
Conductivity (25 °C)	uS/cm		553	1100	1040
TDS (@180 °C)	mg/L	170	388	640	480
SAR (calc)		3.100	3.140	10.187	2.699
TOC	%C	0.56	0.82	0.47	1
Nitrate (as NO3-N)	mg/L	15.3	<0.01	<0.01	7.55
Cyanide	mg/L	0.002	0.002	<0.01	0.010
Fluoride	mg/L	2.08	1.4	2.97	0.195
Chloride	mg/L	12.7	101	163	91
Sulfate	mg/L	5.2	4.98	5.13	3.2
Total Alkalinity (as HCO3)	mg/L	304	168	418	354
Radium, Uranium					
Uranium	mg/kg-dry	0.7	1	0.6	0.7
Ra-226 & Ra-228	pCi/g-dry	0.8	0.29	1.8	ND
Cation					
Calcium	mg/L	100	43.1	35.6	84
Magnesium	mg/L	4.88	1.78	0.968	2.44
Sodium	mg/L	15.2	77.5	226	92.1
Arsenic	mg/kg	0.076	0.088	0.088	0.044
Aluminum	mg/kg	321	40.4	202	183
Barium	mg/kg	27.9	26.6	21	12.4
Boron	mg/kg	ND	0.101	1.36	0.582
Cadmium	mg/kg	0.005	0.012	0.012	0.006
Chromium	mg/kg	0.181	0.286	0.186	0.167
Cobalt	mg/kg	0.155	0.004	0.147	0.116
Copper	mg/kg	0.220	0.54	0.248	0.154
Iron	mg/kg	303	7.68	209	176
Lead	mg/kg	0.358	0.437	0.429	0.311
Manganese	mg/kg	15.6	2.12	17.3	17.7
Mercury	mg/kg	0.036	ND	ND	ND
Molybdenum	mg/kg	0.004	0.008	0.01	0.004

Analyte	Units	9/12/08	10/15/08	10/30/08	11/12/08
Nickel	mg/kg	0.135	0.706	0.246	0.244
Potassium	mg/kg		2.57	0.793	0.788
Selenium	mg/kg	ND	ND	ND	ND
Silver	mg/kg	ND	ND	ND	ND
Zinc	mg/kg	0.783	0.486	0.821	0.51
Purgeable VOCs, PAHs, PCBs	mg/kg	ND	ND	ND	ND

Table 4. Treated Water Application – Soil Analyses

Analyte	Units	9/12/08	10/15/08	10/30/08	11/12/08
Miscellaneous/Anion					
pH	su	7.98	7.74	7.8	7.68
Conductivity (25 oC)	uS/cm			223	239
TDS (@180 oC)	mg/L	69	319	132	180
SAR (calc)		0.008	0.0004	0.497	0.078
TOC	%C	0.98	0.98	0.83	1
Nitrate (as NO3-N)	mg/L	5.41	2.01	<0.01	1.47
Cyanide	mg/L	<0.01	0.01	<0.01	0.010
Fluoride	mg/L	2.23	1.42	3.45	0.127
Chloride	mg/L	2.53	2.63	2.12	5.83
Sulfate	mg/L	2.6	0.861	0.986	1.52
Total Alkalinity (as HCO3)	mg/L	72	154	146	172
Radium, Uranium					
Uranium	mg/kg-dry	1	0.8	0.6	0.7
Ra-226 & Ra-228	pCi/g-dry	0.8	1	0.8	0.39
Cation					
Calcium	mg/L	45.6	56.4	40.6	52.4
Magnesium	mg/L	3.17	1.95	1.67	2.91
Sodium	mg/L	0.202	0.01	11.9	2.16
Arsenic	mg/kg	0.06	0.058	0.067	0.043
Aluminum	mg/kg	185	220	176	163
Barium	mg/kg	18.9	25.5	20	14.7
Boron	mg/kg	0.118	0.117	0.411	0.56
Cadmium	mg/kg	0.008	0.01	0.013	0.01
Chromium	mg/kg	0.133	0.352	0.144	0.147
Cobalt	mg/kg	0.108	0.015	0.178	0.119
Copper	mg/kg	0.189	0.307	0.204	0.156
Iron	mg/kg	152	25.9	152	168
Lead	mg/kg	0.353	0.399	0.43	0.305
Manganese	mg/kg	17.6	2.25	20.2	17.3
Mercury	mg/kg	0.033	ND	0.033	ND
Molybdenum	mg/kg	0.006	0.008	0.008	0.005
Nickel	mg/kg	0.044	0.493	0.22	0.234
Potassium	mg/kg		1.7	2.23	6.5
Selenium	mg/kg	ND	ND	ND	ND
Silver	mg/kg	ND	ND	0.018	ND
Zinc	mg/kg	0.494	0.453	0.72	0.59
Purgeable VOCs, PAHs, PCBs	mg/kg	ND	ND	ND	ND

Table 5. No Water Application (Mother Nature) – Soil Analyses

Analyte	Units	10/15/08	10/30/08	11/12/08
Miscellaneous/Anion				
pH	su	7.85	7.44	7.57
Conductivity (25 oC)	uS/cm		347	311
TDS (@180 oC)	mg/L	317	232	176
SAR (calc)		0.299	0.065	0.507
TOC	%C	1	0.52	0.58
Nitrate (as NO3-N)	mg/L	7.09	6.09	13.9
Cyanide	mg/L	0.008	0.001	<0.01
Fluoride	mg/L	1.55	2.83	0.101
Chloride	mg/L	2.29	26.5	23
Sulfate	mg/L	3.92	3.57	2.71
Total Alkalinity (as HCO3)	mg/L	153	157	159
Radium, Uranium				
Uranium	mg/kg-dry	0.8	0.8	0.5
Ra-226 & Ra-228	pCi/g-dry	0.207	0.8	0.29
Cation				
Calcium	mg/L	48	73.5	57.7
Magnesium	mg/L	3.2	2.83	4
Sodium	mg/L	7.94	2.1	0.9
Arsenic	mg/kg	0.051	0.077	0.064
Aluminum	mg/kg	193	274	202
Barium	mg/kg	24.8	20.5	14.2
Boron	mg/kg	0.107	1.03	0.66
Cadmium	mg/kg	0.009	0.025	0.017
Chromium	mg/kg	0.381	0.122	0.017
Cobalt	mg/kg	0.015	0.136	0.144
Copper	mg/kg	0.324	0.676	0.19
Iron	mg/kg	23.3	146	203
Lead	mg/kg	0.411	0.516	0.346
Manganese	mg/kg	2.58	6.86	19.5
Mercury	mg/kg	ND	0.057	ND
Molybdenum	mg/kg	0.004	0.004	0.004
Nickel	mg/kg	0.469	0.191	0.205
Potassium	mg/kg	0.762	0.895	0.905
Selenium	mg/kg	ND	0.019	ND
Silver	mg/kg	ND	ND	ND
Zinc	mg/kg	0.453	0.621	0.7
Purgeable VOCs, PAHs, PCBs	mg/kg	ND	ND	ND

2009 Proposed testing protocol & Analysis Plans

2009 pilot operations will continue at the same San Juan 32-8 Unit #237A well pad. Partners will continue to be ConocoPhillips, Biosphere Environmental Science & Technology (BEST), New Mexico State University (NMSU), and the United States Department of Agriculture (USDA).

This year's pilot will primarily focus on optimization of the ultrafiltration system (UF). A new unit is to be purchased, installed, and operated for at least one month. None of this UF-treated water will be applied to the land and will be disposed of according to normal ConocoPhillips processes.

Once the UF has been optimized, it will be paired with the existing desalination system for a final treatment. Two types of desalination membranes will be tested: nanofiltration and reverse osmosis. Nanofiltration membranes offer a lesser degree of desalination at significantly lower pressure. The only water that will be applied to the land will be the water that has passed through the UF and reverse osmosis systems; all other water will be disposed of according to normal ConocoPhillips processes. We propose to add water to two sections of land: the same treated section as before and the untreated section. This will be to demonstrate the potential for using treated water to improve soil quality in areas with raw produced water spills.

As part of the NMSBA program funding, we will be partnering with Los Alamos National Laboratory for part of this work. Jeri Sullivan will be providing a new pre-treatment process that would be compared to the UF system. This will be done in conjunction with or in parallel to the other pilot operations.

Due to the prohibitive cost, we request elimination of the full set of VOCs and PAHs, as they have all been at non-detect levels. We also request a decreased frequency of testing and suggest a test at the beginning of the pilot and at the end of the pilot in 2009 which would test all three plots of land and any treated water that is added to the land. Analyses that are critical to assessment of the desalination effectiveness (i.e. major anions, cations, TOC, pH, alkalinity) will be tested on a daily bases by Sandia personnel.

Table 6. Proposed Analyses – 2009 Pilot Operations

Analyte	Frequency (SOIL)	Frequency (WATER)
Miscellaneous/Anion		
pH	1x/mo[1]	At least 1x/day
Conductivity (@ 25°C)	1x/mo[1]	At least 1x/day
TDS (@180 °C)	1x/mo[1]	At least 1x/mo
SAR (calculated)	1x/mo[1]	At least 1x/day
TOC	1x/mo[1]	At least 1x/day
Nitrate (as NO_3-N)	1x/mo[1]	At least 1x/mo
Fluoride	1x/mo[1]	At least 1x/day
Chloride	1x/mo[1]	At least 1x/day
Sulfate	1x/mo[1]	At least 1x/day
Total Alkalinity (as HCO_3)	1x/mo[1]	At least 1x/day
Radium, Uranium		
Uranium	Twice[2]	Twice[2]
Ra-226 + Ra-228	Twice[2]	Twice[2]
Cation		
Arsenic	Twice[2]	Twice[2]
Aluminum	Twice[2]	Twice[2]
Barium	1x/mo[1]	At least 1x/mo
Boron	Twice[2]	Twice[2]

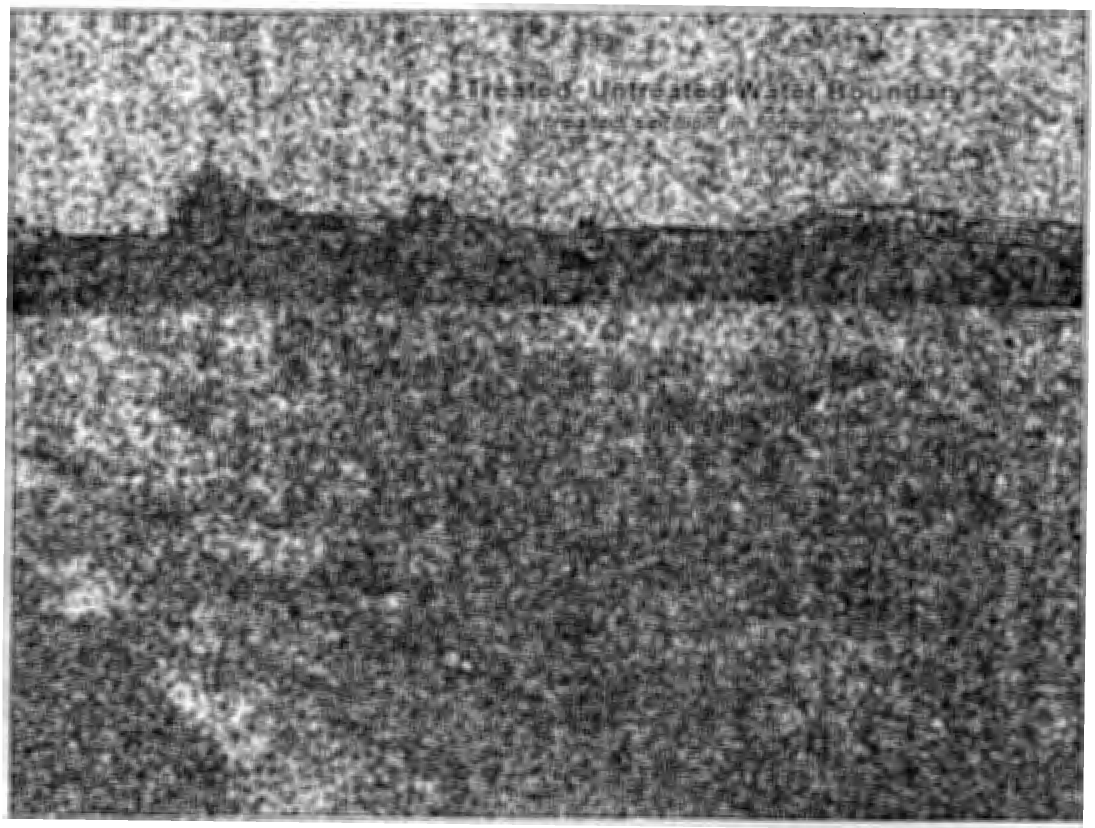
Analyte	Frequency (SOIL)	Frequency (WATER)
Cadmium	Twice[2]	Twice[2]
Calcium	1x/mo[1]	At least 1x/day
Chromium	Twice[2]	Twice[2]
Cobalt	Twice[2]	Twice[2]
Copper	Twice[2]	Twice[2]
Iron	1x/mo[1]	At least 1x/day
Lead	Twice[2]	Twice[2]
Magnesium	1x/mo[1]	At least 1x/day
Manganese	Twice[2]	Twice[2]
Mercury	Twice[2]	Twice[2]
Molybdenum	Twice[2]	Twice[2]
Nickel	Twice[2]	Twice[2]
Potassium	Twice[2]	Twice[2]
Selenium	Twice[2]	Twice[2]
Silver	Twice[2]	Twice[2]
Sodium	1x/mo[1]	At least 1x/day
Zinc	Twice[2]	Twice[2]
Purgeable VOCs:		
Benzene	Twice[2]	Twice[2]
Toluene	Twice[2]	Twice[2]
Ethylbenzene	Twice[2]	Twice[2]
Xylenes, total	Twice[2]	Twice[2]

Cartridge filters were analyzed for disposal purposes. Preliminary analyses are below. ConocoPhillips (through Frank McDonald) will coordinate all disposals of past and future cartridge filters and reverse osmosis membranes.

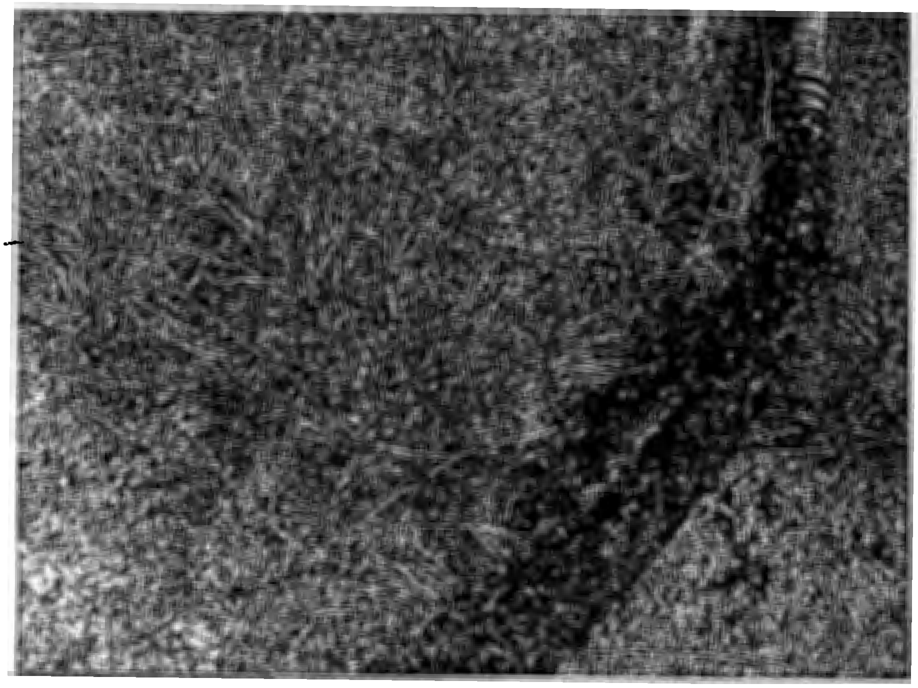
Table 7. Cartridge Filter Analysis Results

Analyte	Units	1 micron	5 micron	20 micron
Benzene	ug/kg	3.1	3.7	ND
Toluene	ug/kg	128	119	103
Ethybenzene	ug/kg	19.5	14.5	19.4
p,m-Xylene	ug/kg	139	136	235
o-Xylene	ug/kg	51.9	62.2	57.3
Arsenic	mg/kg	0.109	0.005	0.012
Barium	mg/kg	630	72.9	15.3
Cadmium	mg/kg	0.021	0.013	0.011
Chromium	mg/kg	1.46	0.62	0.189
Lead	mg/kg	0.114	0.356	0.018
Mercury	mg/kg	ND	ND	ND
Selenium	mg/kg	ND	ND	ND
Silver	mg/kg	ND	0.008	0.007
Corrosivity		Negative	Negative	Negative
pH		9.94	10.29	10.46

Pilot Pictures

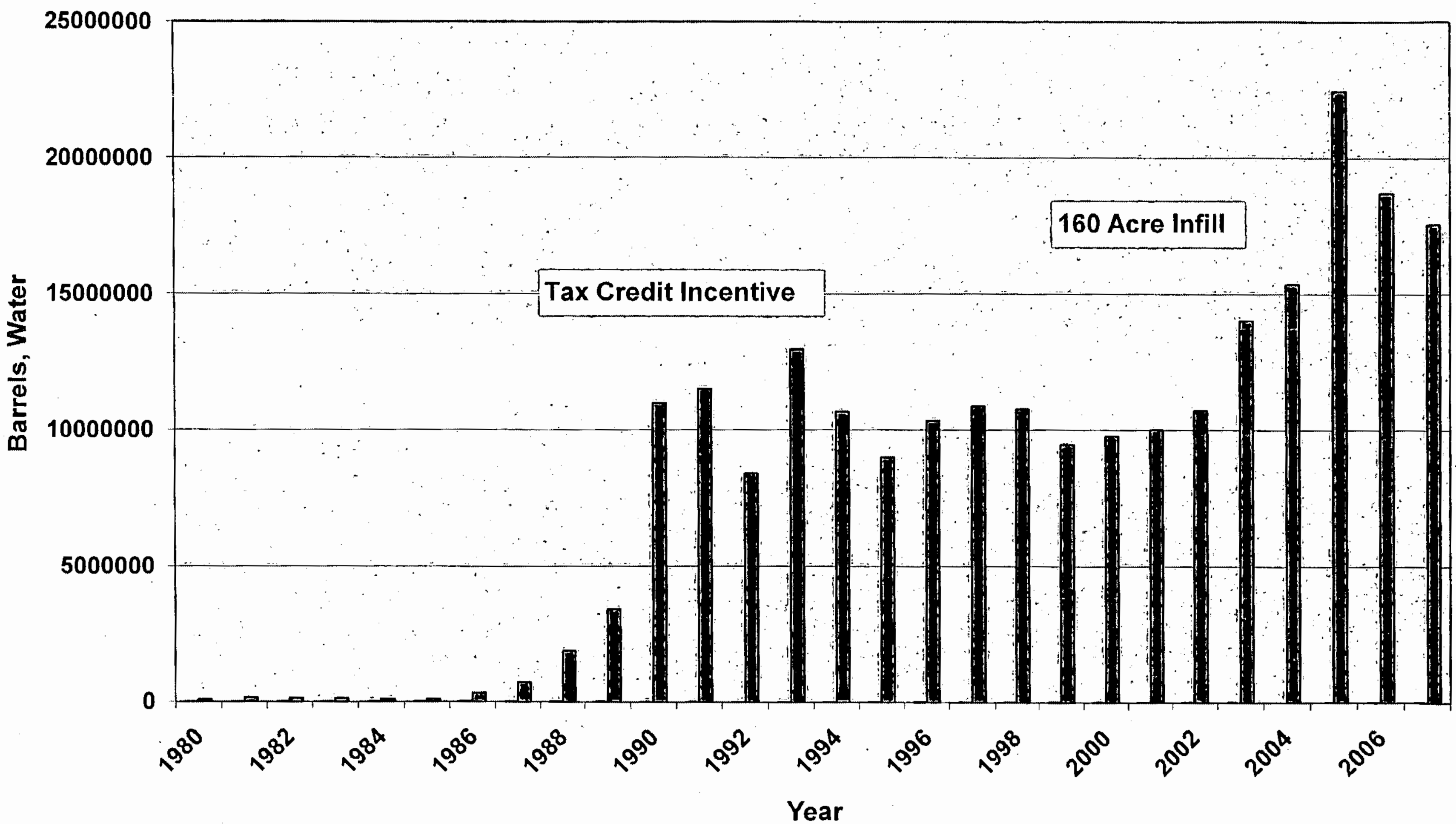


Water Application areas



Section with mixed water (untreated + treated)

San Juan Basin (NM): Fruitland Coal Water Production
Cumulative: 230 million barrels, 4982 wells



MAPQUEST

Sorry! When printing directly from the browser your directions or map may not print correctly. For best results, try clicking the Printer-Friendly button.

START **1220 S Saint Francis Dr**
Santa Fe, NM 87505-4225
1220 S Saint Francis Dr
Santa Fe, NM 87505-4225

END **1235 la Plata Hwy**
Farmington, NM 87401-8754
1235 la Plata Hwy
Farmington, NM 87401-8754

Total Estimated Time: 3 hours 25 minutes
Total Estimated Distance: 210.29 miles
Total Estimated Fuel Cost:

▼ Directions from A to B:

START	1: Start out going SOUTH on S ST FRANCIS DR/US-285 S/US-84 S toward COLUMBIA ST.	2.2 mi
SOUTH 25	2: Merge onto I-25 S toward ALBUQUERQUE.	40.2 mi
242 EXIT	3: Take the NM-165 E/US-550 W exit, EXIT 242, toward RIO RANCHO/PLACITAS.	0.3 mi
NORTH 550	4: Merge onto US-550 N/NM-44 W toward BERNALILLO/RIO RANCHO/FARMINGTON.	151.8 mi
WEST 64	5: Turn LEFT onto W BROADWAY AVE/US-64. Continue to follow US-64 W.	11.3 mi
WEST 64 BUS	6: Turn SLIGHT RIGHT onto US-64 BR W/E BROADWAY. Continue to follow US-64 BR W.	1.0 mi
WEST 64	7: US-64 BR W becomes US-64 W.	3.4 mi
	8: Turn SLIGHT RIGHT onto LA PLATA HWY/NM-170.	0.2 mi
END	9: End at 1235 la Plata Hwy Farmington, NM 87401-8754	

Estimated Time: 3 hours 25 minutes Estimated Distance: 210.29 miles

Total Estimated Time: 3 hours 25 minutes **Total Estimated Distance:** 210.29 miles

Fax Note 7671	Date 5/20 # of pages ▶ 3
To Pat Jones	From Alan Sattler
Co./Dept.	Co.
Phone #	Phone #
Fax #	Fax #

N M OCD
505 - 476 - 3462

MAPS & DIRECTIONS

Driving Directions > Directions Results

PRINT Save Email Text Only Edit My Route Add a Stop

FROM: 1220 S Saint Francis Dr
Santa Fe, NM 87505-4225

TO: 1235 La Plata Hwy
Farmington, NM 87401-8754

STEPS: 11 **EST. DRIVE TIME:** 3 hours, 25 minutes **EST. DISTANCE:** 210 miles

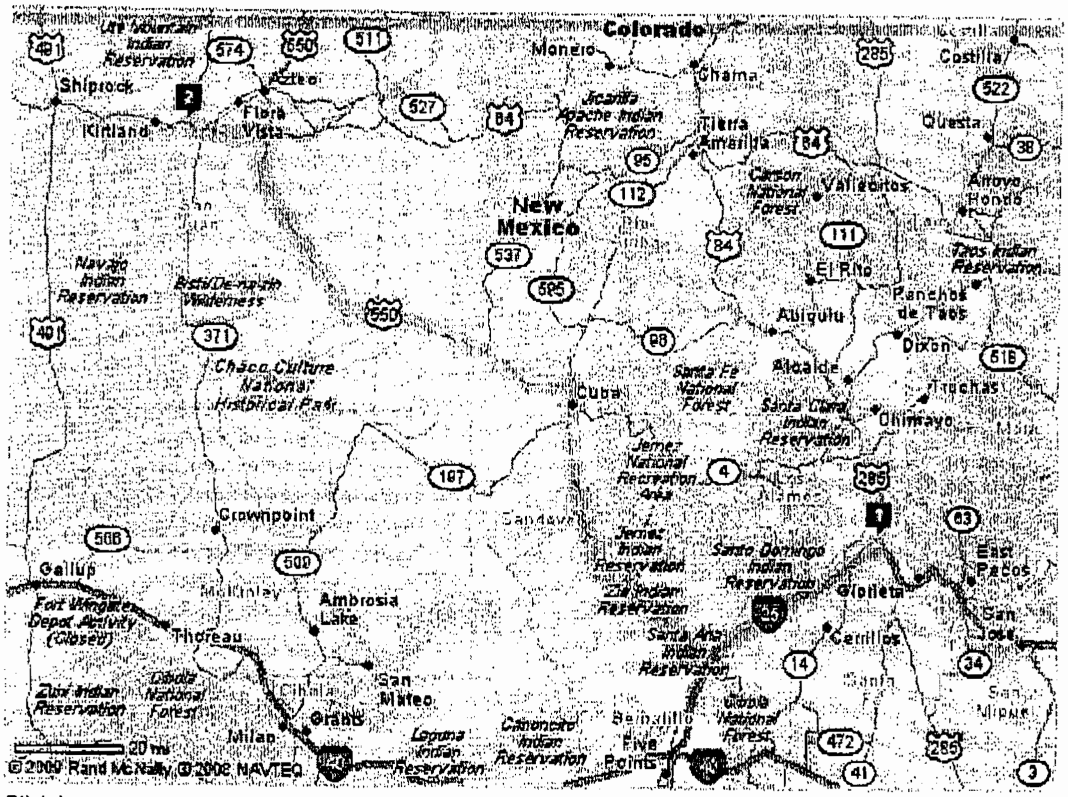
STEP	DIRECTIONS	DISTANCE
1	You are at 1220 S Saint Francis Dr, Santa Fe, NM 87505-4225	
2	Go South on US-84 S (US-285 S, S St. Francis Dr) Show Map	2.2 miles
3	Take I-25 S (Albuquerque) ramp on R Show Map	40.2 miles
4	Take Exit 242 (NM-44 W, NM-165 E, Rio Rancho, Placitas) on R Show Map	0.3 miles
5	Turn R onto US-550 N (NM-44 W) Show Map	151.4 miles
6	Turn L onto US-64 (US-550, W Broadway Av) Show Map	0.1 miles
7	Continue onto US-64 (W Broadway Av) Show Map	0.9 miles
8	Continue onto US-64; street becomes E Murray Dr Show Map	13.6 miles
9	Bear L onto US-64 W (W Main St) Show Map	1.2 miles
10	Turn R onto NM-170 (La Plata Hwy) Show Map	0.2 miles
11	You are at 1235 La Plata Hwy, Farmington, NM 87401-8754	

ROUTE SUMMARY

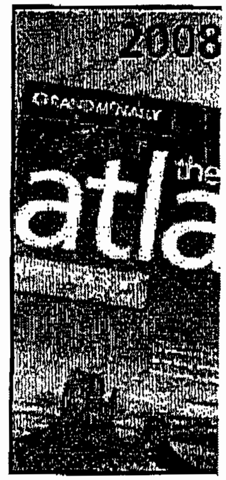
STEPS: 11 **EST. DRIVE TIME:** 3 hours, 25 minutes **EST. DISTANCE:** 210 miles

PRINT Save Email Text Only Edit My Route Add a Stop

OVERVIEW



Click here or on the map above for an adjustable version.



Rand McNally Folded Map: Farmington, Durango
$4.95

Rand McNally Personal Journeys Pinable US Wall Map
$84.99
$74.99

Rand McNally EasyToFold Map: New Mexico
$7.95

Rand McNally America
$39.95
$29.95

Web Offers

- Schools in Farmington
- Real Estate in Farmington
- Jobs in Farmington
- Ca

Chavez, Carl J, EMNRD

From: Johnson, Monica [Monica.Johnson@conocophillips.com]
Sent: Monday, June 29, 2009 1:54 PM
To: Chavez, Carl J, EMNRD
Cc: Frost, Gwendolynne
Subject: RE: NM Oil Conservation Division Produced Water Diversion Quarterly Report (April 1 - June 30, 2009) Reminder

Our project has not started up yet for the summer. Thus, our numbers for the second quarter are zero (0).

Please let me know if you have additional questions.

Thank you!

Monica D. Johnson
Sr. Environmental Scientist
ConocoPhillips Company
3401 East 30th Street
Farmington, NM 87402
Office: (505) 326-9829
Cell: (505) 320-9056
Direct Fax: (918) 662-1826
Office Fax: (505) 599-4005

From: Chavez, Carl J, EMNRD [mailto:CarlJ.Chavez@state.nm.us]
Sent: Monday, June 29, 2009 9:01 AM
To: jgolob@maralexinc.com; Frost, Gwendolynne; Johnson, Monica; Karen Evans; Mayberry, Don; Jennifer.vancuren@dvn.com
Subject: NM Oil Conservation Division Produced Water Diversion Quarterly Report (April 1 - June 30, 2009) Reminder

Ladies and Gentlemen:

Reminder for the quarterly diversion numbers. Thanks.

Carl J. Chavez, CHMM
New Mexico Energy, Minerals & Natural Resources Dept.
Oil Conservation Division, Environmental Bureau
1220 South St. Francis Dr., Santa Fe, New Mexico 87505
Office: (505) 476-3490
Fax: (505) 476-3462
E-mail: CarlJ.Chavez@state.nm.us
Website: http://www.emnrd.state.nm.us/ocd/index.htm
(Pollution Prevention Guidance is under "Publications")

Chavez, Carl J, EMNRD

From:	Johnson, Monica [Monica.Johnson@conocophillips.com]
Sent:	Monday, June 29, 2009 3:31 PM
To:	Jones, Brad A., EMNRD; Chavez, Carl J, EMNRD
Cc:	Powell, Brandon, EMNRD; Dale_Wirth@nm.blm.gov; Sattler, Allan R; Cappelle, Malynda A; Wirtanen, Bob A; Miller, Rebekah E.; Frank McDonald, B.E.S.T.; Rick Arnold; Dave_Mankiewicz@nm.blm.gov; barney_wegener@nm.blm.gov; Emerson, Warren; Frost, Gwendolynne
Subject:	Produced Water Pilot Project Permit #EPWM-002 amendment request
Attachments:	OCD pilot study letter amendment 6-29-09.pdf

Dear Mr. Jones and Mr. Chavez,

Please find attached an electronic letter requesting permission to amend permit #EPWM-002 for the San Juan 32-8 Unit #237A water pilot project.

Should you have any further questions, please let me know.

Thank you!

Monica D. Johnson
Sr. Environmental Scientist
ConocoPhillips Company
3401 East 30th Street
Farmington, NM 87402
Office: (505) 326-9829
Cell: (505) 320-9056
Direct Fax: (918) 662-1826
Office Fax: (505) 599-4005

ConocoPhillips

San Juan Business Unit
P.O. Box 4289
Farmington, NM 87402-4289
(505) 326-9700

Sent Via Email

June 29, 2009

Mr. Brad Jones and Mr. Carl Chavez
Environmental Bureau Engineers
New Mexico Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, NM 87505

RE: Produced Water Pilot Project Permit # EPWM - 002 for the San Juan 32-8 Unit #237A

Dear Mr. Jones and Mr. Chavez:

ConocoPhillips Company is requesting approval to apply treated produced water on portions of the San Juan 32-8 Unit #237A (T31N, R8W, Section 23, Unit I) location as part of a pilot project described below. The New Mexico Oil Conservation Division (NMOCD) previously granted permission to apply certain quantities of treated and untreated water to the subject location. This request is being resubmitted because the permit expires July 28, 2009, and we wish to continue and improve our water treatment train especially in pretreatment produced water. We propose to treat some of the grasses by a method described below. An important difference from our previously granted permits is that only treated/desalinated water would be applied to the ground. No application of untreated water on the soil is included in this request.

ConocoPhillips is seeking to find alternative use methods for produced water generated by the oil and gas industry. New Mexico State University's Agricultural Science Center, Farmington and the U. S. Department of Agriculture's Jornada Experimental Range, Las Cruces will water grasses on the subject well pad on a limited/spot basis. The watering is to accompany a pilot desalination operation constructed by Sandia National Laboratories on the same well pad. Use of the treated/ desalinated water is critical to this plan.

The complete details of our request were found in our letter and the attachment hand delivered during a meeting dated May 28, 2009. Subsequent to that letter, additional discussions about the permit application were held with Allan Sattler at your office. It was felt that an amendment to the original May 28, 2009 permit request would be appropriate.

Pilot operations would remain as in the original permit request, in that a study of ultrafiltration pre-treatment combined with reverse osmosis desalination will be used to treat produced water at the San Juan 32-8 Unit #237A well pad. The original permit requested elimination of analyses that had previously shown "non-detect" levels, as well as a decrease in the frequency of analysis. From the above mentioned discussions, however, the permit sampling types and frequency for complete laboratory analysis (NMAC 20.6.2.3103, Subsections A-C) are now amended as follows:

1. Due to the fact that pilot operations plan to water an area previously watered with untreated produced water, both the treated water and the soil will require analysis:
    a. The treated water (permeate) will be analyzed once per NMAC 20.6.2.3103, Subsections A-C.
    b. The soil where untreated produced water was previously added will be analyzed prior to watering and after each watering event, per NMAC 20.6.2.3103, Subsections A-C (estimated to be once per month).
    c. The soil where treated/desalinated produced water was previously added will be analyzed prior to watering and after the last watering event, per NMAC 20.6.2.3103, Subsections A-C.
    d. The area with no additional water ("mother nature") requires no additional testing.
2. If the treatment train is modified significantly (differing membrane configurations or types or significant additional pretreatment schemes), then the treated water and the soil plot where treated water will be applied will be tested as summarized above. Change of mechanical filters only is not considered a change in the treatment train.
3. All cartridge filters, UF membranes, and RO membranes will be disposed of in an approved landfill, as before. Prior to disposal, they will be tested according to NMAC 19.15.35.8.
4. Additional tests will be performed to assess the treatment effectiveness and impacts on the soil. However, this item is neither a part of the permit request nor a permit requirement. It is included for information only. (See comment in item 5 below.)
    a. Each of the water streams (untreated produced water, ultrafiltration filtrate, reverse osmosis feed, concentrate, and permeate/treated) will be analyzed as summarized originally in the permit application.
    b. Each of the soil plots where water has/was applied may be analyzed for anions and other constituents of interest as originally in the permit application.
5. Other methods of treatment may be evaluated during this year's efforts, such as nanofiltration, LANL-developed pre-treatment, etc. However, no treated water will be placed on any ground surface as a result of these operations. **This particular item and item 4. above are neither a part of the permit request nor a permit requirement.** Any available information from these two items will be included in the information sent to the NMOCD as a matter of course to help expand their produced water database.

If you should have additional questions or comments, you can reach me at 505-326-9829.

Sincerely,

Monica D. Johnson

Monica D. Johnson
Sr. Environmental Scientist

Attachment

Cc: Brandon Powell - NMOCD, Aztec
David Mankiewicz - Bureau of Land Management

Dale Wirth - Bureau of Land Management
Barney Wegener - Bureau of Land Management
Rebekah Miller - ConocoPhillips
Warren Emerson - ConocoPhillips
Gwen Frost - ConocoPhillips
Bob Wirtanen - ConocoPhillips
Frank McDonald - BEST
Rick Arnold - NMSU
Malynda Cappelle - Sandia National Labs, MS-1373
Allan Sattler - Sandia National Labs, MS-0706

Chavez, Carl J, EMNRD

From:	Chavez, Carl J, EMNRD
Sent:	Tuesday, April 21, 2009 5:50 PM
To:	'jgolob@maralexinc.com'; 'gwendolynne.frost@conocophillips.com'; 'monica.johnson@conocophillips.com'; 'karen.evans@altelainc.com'
Subject:	RE: Produced Water Diversion Quarterly Report (Jan 1 - March 31, 2009)

Ladies and Gentlemen:

I am writing to request that you mark your calendars to report your diversion numbers (gallons) to me the day after each quarter ends, since the numbers must be reported to OCD Management by the 6th day after each quarter or period ends.

Please contact me if you have questions. Thank you.

Carl J. Chavez, CHMM
New Mexico Energy, Minerals & Natural Resources Dept.
Oil Conservation Division, Environmental Bureau
1220 South St. Francis Dr., Santa Fe, New Mexico 87505
Office: (505) 476-3490
Fax: (505) 476-3462
E-mail: CarlJ.Chavez@state.nm.us
Website: http://www.emnrd.state.nm.us/ocd/index.htm
(Pollution Prevention Guidance is under "Publications")

From: Chavez, Carl J, EMNRD
Sent: Tuesday, April 14, 2009 8:48 AM
To: 'jgolob@maralexinc.com'; 'gwendolynne.frost@conocophillips.com'; 'monica.johnson@conocophillips.com'; 'karen.evans@altelainc.com'
Cc: Prouty, Jane, EMNRD
Subject: Produced Water Diversion Quarterly Report (Jan 1 - March 31, 2009)

Ladies and gentlemen:

Could you please send me your numbers for treated and diverted produced for the quarter listed above ASAP? Thank you.

Carl J. Chavez, CHMM
New Mexico Energy, Minerals & Natural Resources Dept.
Oil Conservation Division, Environmental Bureau
1220 South St. Francis Dr., Santa Fe, New Mexico 87505
Office: (505) 476-3490
Fax: (505) 476-3462
E-mail: CarlJ.Chavez@state.nm.us
Website: http://www.emnrd.state.nm.us/ocd/index.htm
(Pollution Prevention Guidance is under "Publications")

From: Jones, Brad A., EMNRD
Sent: Wednesday, February 18, 2009 2:04 PM
To: Chavez, Carl J, EMNRD
Subject: RE: Request to Give Presentation, meet with OCD

These are the numbers for treated and diverted produced for the last quarter of 2008.

D. Jeremy Golob

Sr. Engineer
Maralex Resources, Inc.
Office: (970) 563-4000
Cell: (970) 799-4278
Fax: (970) 563-4116

Maralex:
672,000 gallons/ 16,000 bbls

Matt Bruff
Vice President or
Karen K. Evans
Executive Administrator

ALTELA, INC.
DENVER TECHNOLOGY CENTER
5350 South Roslyn Street, Suite 430
Englewood, CO 80111

PHONE: (303) 993-1952 **FAX:** (303) 993-1955
EMAIL: karen.evans@altelainc.com **WEB:** altelainc.com

Altela, Inc.:
4,480 gallons/ 107 bbls

Monica D. Johnson
Sr. Environmental Scientist
ConocoPhillips Company
3401 East 30th Street
Farmington, NM 87402
Office: (505) 326-9829
Cell: (505) 320-9056
Direct Fax: (918) 662-1826
Office Fax: (505) 599-4005

ConocoPhillips/Burlington Resources/BLM/Sandia Labs/NM Tech Project:
7,560 gallons/ 180 bbls

The total volume of treated and diverted produced for the last quarter of 2008 is **684,040 gallons** or **16,287 barrels.**

RECEIVED
2008 MAR 10 PM 1 55

ConocoPhillips

San Juan Business Unit
P.O. Box 4289
Farmington, NM 87402-4289
(505) 326-9700

Sent Via Email & Certified Mail No. 7099 3400 0018 4215 2438

March 7, 2008

Mr. Wayne Price
Environmental Bureau Chief
New Mexico Oil Conservation Division
1220 S. St. Frances Dr.
Santa Fe, NM 87505

RE: Water Pilot Project – San Juan 32-8 Unit #237A

Dear Mr. Price,

ConocoPhillips Company is requesting approval to apply untreated produced water and treated produced water on portions of the San Juan 32-8 Unit #237A (T31N, R8W, Section 23, Unit I) location as part of a pilot project described below. The New Mexico Oil Conservation Division (NMOCD) previously granted permission to apply certain quantities of treated and untreated water to the subject location. This request is being resubmitted because the application of the quantities of water stated in the original request was not accomplished by December 1, 2007, the expiration date of NMOCD's approval. The pilot operation did not make sufficient treated / desalinated water by December 1, 2007. Design changes to the pilot operation are being made to assure sufficient quantities of water as stated in the original request letter. For your convenience, the essential parts of that earlier request letter are repeated below (with appropriate updates).

ConocoPhillips is seeking to find alternative use methods for produced water generated by the oil and gas industry. New Mexico State University's Agricultural Science Center – Farmington and the U.S. Department of Agriculture's Jornada Experimental Range – Las Cruces will water grasses on the subject well pad on a limited / spot basis. The watering is to accompany a pilot desalination operation constructed by Sandia National Laboratories on the same well pad. Use of the treated / desalinated water is critical to this plan.

The basic plan is to spot water the planted grasses at that well pad with a watering of one (1) to two (2) inches each time, with a cumulative amount of water between four (4) and eight (8) inches, depending on the amount of desalinated water made available by the pilot operation. The existing grasses on the well pad will be treated as follows:

- 1/3 will be spot watered with treated / desalinated water;
- 1/3 will be spot watered with untreated produced water; and
- 1/3 will receive no watering at all.

Each test plot will be approximately 50 feet by 80 feet. The water will be applied in a manner that will confine the water to the existing ConocoPhillips location. Earthen berms have been constructed and a limited amount of watering has already been accomplished.

The treated water will come from the pilot desalination operation. Earlier discussions between the Bureau of Land Management (BLM) and Sandia National Laboratories suggested that a total dissolved solids (TDS) of the treated water of approximately 1,500 parts per million (ppm) could be satisfactory. The TDS of the treated water is actually less than 500 ppm. The TDS of the untreated produced water from this particular well is approximately 11,000 ppm. The most recent water analysis from the subject well is attached.

There are many existing precedents for this work of putting produced water on the soil to enhance grass growth in the San Juan Basin. This includes the recent written permission from the NMOCD to ConocoPhillips dated July 2, 2007 and a letter from the BLM dated June 2, 2007.

Moreover, the numerous earlier procedures were done with approvals from the NMOCD and the BLM. Then comparable amounts of produced water, with TDS values between approximately 5,000 and 12,000 ppm were placed on the soil to enhance grass growth. In virtually all those previously approved cases, critical soil parameters, Sodium Adsorption Ratio and Electrical Conductivity, remained below critical limits of 25 and 15 decisiemens respectively. These parameters (along with any possible sodium build up and, of course, water quality) would be carefully monitored in this work and made available to both the NMOCD and BLM.

In the broader picture, this is a portion of the Department of Energy sponsored Southwest Regional Partnership on Carbon Sequestration of which ConocoPhillips is a member. One aspect of the sequestration of carbon dioxide could be to use treated produced water (emanating from injection of carbon dioxide in coal seams) to restore impaired riparian areas. The proposed work should shed information on the feasibility of such possible future endeavors.

For now, however, we simply request permission to apply both desalinated / treated water and produced water to the planted grasses around ConocoPhillips' San Juan 32-8 Unit #237A wellpad as described in the paragraphs above. Produced water has been a basic concern for both regulatory agencies and producers. It is hoped that with research of this nature, positive results will evolve from this continuing concern. If you have any questions, please contact me at (505) 326-9829.

Sincerely,

Monica D. Johnson

Monica D. Johnson
Sr. Environmental Scientist

Attachment

Cc: Brandon Powell - NM Oil Conservation Division District III
David Mankiewicz - Bureau of Land Management
Dale Wirth - Bureau of Land Management
Rebekah Miller - ConocoPhillips
Darren Randall - ConocoPhillips
Ben Way - ConocoPhillips
Bob Wirtanen - ConocoPhillips
Rick Arnold - NMSU
Allan Sattler - Sandia National Labs
Frank McDonald - BEST

LABORATORY ANALYSIS
ConocoPhillips Company
San Juan 32-8 Unit #237A
Water Pilot Project
October 7, 2007

Analyte	Raw, Untreated Water Concentration Units	Treated, Desalinated Water Concentration Units
Organics		
Gasoline Range (C5-C10)	ND ug/L	NOT MEASURED
Diesel Range (C10-C28)	ND ug/L	NOT MEASURED
Total Petroleum Hydrocarbons	ND ug/L	NOT MEASURED
Benzene	0.9 ug/L	NOT MEASURED
Toluene	32.9 ug/L	NOT MEASURED
Ethylbenzene	1.8 ug/L	NOT MEASURED
p,m-Xylene	9.8 ug/L	NOT MEASURED
o-Xylene	2.3 ug/L	NOT MEASURED
Total BTEX	47.7 ug/L	NOT MEASURED
Metals & Anions		
Al	0.018 mg/L	0.12 mg/L
As	0.001 mg/L	ND mg/L
B	2.65 mg/L	1.01 mg/L
Ba	28.1 mg/L	0.34 mg/L
Cu	0.003 mg/L	0.003 mg/L
Mn	0.013 mg/L	ND mg/L
Se	ND mg/L	ND mg/L
Silica	17.5 mg/L	0.492 mg/L
Fe	0.047 mg/L	0.002 mg/L
Ca	24 mg/L	<0.01 mg/L
Mg	<0.01 mg/L	<0.01 mg/L
K	25.9 mg/L	<0.01 mg/L
Na	4270 mg/L	94.1 mg/L
N	1.5 mg/L	<0.1 mg/L
Cl	2420 mg/L	52 mg/L
F	2.05 mg/L	0.06 mg/L
S04	0.6 mg/L	<0.1 mg/L
ortho Phosphate	25.4 mg/L	0.3 mg/L
Total Phosphate	25.4 mg/L	0.8 mg/L
Bicarbonate (as HC03)	7170 mg/L	158 mg/L
Carbonate (as C03)	<0.1 mg/L	<0.1 mg/L
General Information		
pH	8.27	6.75
Temperature	21.9 °C	21.5 °C
Conductivity (@ 25 °C)	18850 mS/cm	426 mS/cm
Specific Gravity	1.0059	1.00002
TDS (@ 180 °C)	12220 mg/L	248 mg/L
TDS (calculated)	11150 mg/L	240 mg/L
TSS	60 mg/L	44 mg/L
Dissolved Oxygen	3.5 mg/L	4.9 mg/L
Total Alkalinity (as CaC03)	7170 mg/L	158 mg/L
Total Hardness (as CaC03)	60 mg/L	<0.1 mg/L

*NOTE: *Rather than including the several pages of the official laboratory data, this is a compilation of such. The official data can be provided by ConocoPhillips upon request.*

Main Technical Challenge, Pretreatment: Removal of Coal Fines, Organic Material in the Brackish Produced Water

Methods used to remove coal fines will include:

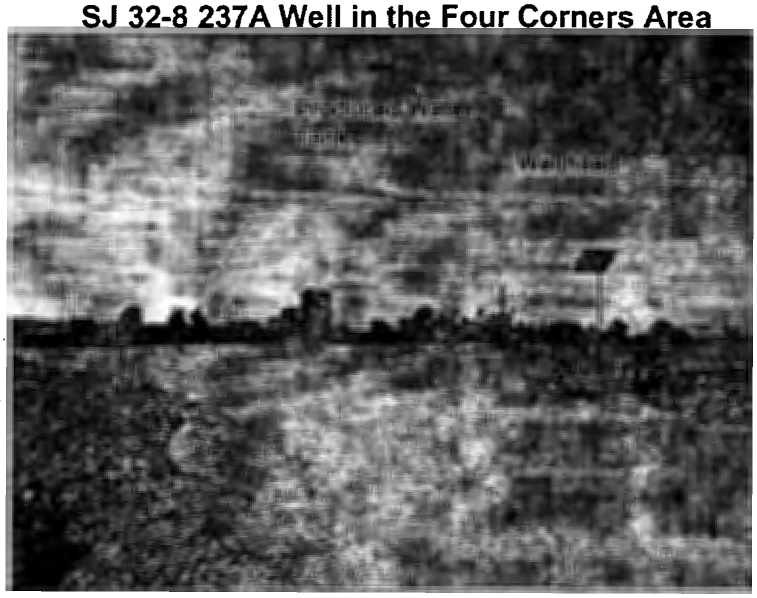
- Simple filter bank,
- Gravitational removal of the coal fines in a settling tank,
- Centrifuge (cyclone separator).

Methods to remove organic material include:

- Mechanical filter system including a carbon filter,
- A (hydrophilic) membrane process, ultra filtration

Reverse Osmosis to be used to Desalinate Water

Work Will be Done on the Site of the ConocoPhillips SJ 32-8 237A Well in the Four Corners Area



Pilot Demonstration of Pretreatment and Desalination Technology for Coal Bed Methane Produced Water used for Rangeland Rehabilitation

Sponsors:
DOE: Natural Gas and Oil Technology Partnership
DOE: Southwest Regional Partnership for Carbon Sequestration

Rangeland Rehabilitation and Use of Treated CBM Produced Water

- ~4000- ~12,000 TDS untreated produced water has been used to water grass seedlings

- Goal: <1500 TDS water desired, for rangeland improvement

NEW MEXICO ENERGY, MINERALS and NATURAL RESOURCES DEPARTMENT

BILL RICHARDSON
Governor
Joanna Prukop
Cabinet Secretary
Reese Fullerton
Deputy Cabinet Secretary

Mark E. Fesmire, P.E.
Director
Oil Conservation Division

July 2, 2007

Certified Mail
Return Receipt #: 7006 3450 0000 0451 8087

Mr. Ed Hasely
ConocoPhillips/ Burlington Resources
PO Box 4289
Farmington, NM 87499

RE: Request to use produced water for Water Pilot Project on the San Juan 32-8 Unit #237A.

Dear Mr. Hasely:

The New Mexico Oil Conservation Division (OCD) has reviewed ConocoPhillips request, dated June 1, 2007 from your office, to use produced water for revegetation. The application is approved for the San Juan 32-8 Unit #237A well location shown in your application.

The following conditions will apply:

1. ConocoPhillips assumes all liability for potential contamination.
2. A record showing volumes of water used and the appropriate analysis will be provided to both the OCD District III Aztec Office and the OCD Environmental Bureau Office, 1220 South Saint Francis Drive, Santa Fe New Mexico 87505.
3. Chloride analysis for the soil will be required after each application of water in addition to the testing previously performed for the pilot project.
4. ConocoPhillips will be required to apply for, and receive any applicable landowner and other regulatory agencies approvals.

To allow adequate time for the pilot project, this approval for the discharge of produced water in accordance with the pilot project will expire December 1, 2007. Due to the scope of work and the ongoing nature of the project, future applications for approval will need to be submitted to the OCD's Environmental Bureau and a copy sent to the district office.

Please be advised OCD approval does not relieve ConocoPhillips from liability should contamination pose a future threat to surface water, groundwater, human health or the environment. OCD approval does not relieve ConocoPhillips of compliance with other federal, state, tribal, or local laws and regulations.

If you have any questions, please call me at 505-334-6178, ext. 15.

Sincerely yours,

Brandon Powell

Brandon Powell
Environmental Specialist
Brandon.Powell@state.nm.us

CC: Dave Mankiewicz, Bureau of Land Management

ConocoPhillips

San Juan Business Unit
P.O. Box 4289
Farmington, NM 87402-4289
(505) 326-9700

June 1, 2007

RCVD JUN4'07
OIL CONS. DIV.
DIST. 3

Mr. Brandon Powell
New Mexico Conservation Division
1000 Rio Brazos Road
Aztec, New Mexico 87410

Mr. David Mankiewicz
Bureau of Land Management
1235 La Plata Highway
Farmington, NM 87401

RE: Water Pilot Project – San Juan 32-8 Unit #237A

Dear Mr. Powell and Mr. Mankiewicz:

ConocoPhillips is requesting approval to apply untreated produced water and treated produced water on portions of the subject location as part of a pilot project described below.

ConocoPhillips is seeking to find alternative use methods for produced water generated by the oil and gas industry. New Mexico State University (Agricultural Science Center Farmington) and the US Department of Agriculture (Jornada Experimental Range, Las Cruces) will water grasses on the San Juan Unit 32-8 #237A (Unit Letter I – Sec 23 - T31N – 8W) well pad on a limited/spot basis. The watering is to accompany a pilot desalination operation constructed by Sandia National Laboratories on the same well pad. Use of the treated/desalinated water is critical to this plan.

The basic plan is to spot water the planted grasses at that well pad with only a watering of 1-2 inches each time where the cumulative amount of water would be between 4 and 8 inches depending on the amount of desalinated water made available by the pilot operation. The existing grasses on the well pad to be treated in the following manner:

- ~1/3 will be spot watered with treated/desalinated water,
- ~1/3 will be spot watered with untreated water, produced water,
- ~1/3 will receive no watering at all.

Each test plot will be approximately 50 feet by 80 feet. The water will be applied in a manner that will confine the water to the existing ConocoPhillips location. The applied water will not be allowed to run off the location. Earth berms will be constructed, if necessary.

The treated water would come from the pilot desalination operation. Earlier discussions between the Bureau of Land Management (BLM) and Sandia National Laboratories suggested that a TDS of the treated water ~1,500 ppm could be satisfactory. In reality, it is now expected that the TDS of the treated water will be less than 1,000 ppm, probably closer to 500. The TDS of the untreated produced water from this particular well is ~11,000 ppm. A water analysis from the San Juan 32-8 Unit #237A well is attached.

There are many existing precedents for this work of putting produced water on the soil to enhance grass growth in the Four Corners area. These earlier procedures were done with approvals from the Oil Conservation Division (OCD) and the BLM. Then comparable amounts of produced water, with TDS values between ~5000 and ~12,000 ppm were placed on the soil to enhance grass growth. In virtually all those previously approved cases, critical soil parameters, Sodium Adsorption Ratio and Electrical Conductivity, remained below critical limits 25 and 15 decisiemens units respectively. These parameters (along with any possible sodium build up and, of course, water quality) would be carefully monitored in this work and made available to both the OCD and BLM.

In the broader picture, this is a portion of the DOE-sponsored Southwest Regional Partnership on Carbon Sequestration of which Conoco Phillips is a member. One aspect of the sequestration of carbon dioxide could be to use treated produced water (emanating from injection of carbon dioxide in coal seams) to restore impaired riparian areas. The proposed work should shed information on the feasibility of such possible future endeavors.

For now, we simply request permission to apply both desalinated/treated water and produced water to the planted grasses around the ConocoPhillips San Juan Unit 32-8 #237A well pad as described in the paragraphs above. Produced water has been a basic concern for both oversight agencies and producers. It is hoped that with research of this nature positive results will evolve from this continuing concern. If you have any questions, please contact me at (505) 326-9841.

Sincerely,

Ed Hasely
Environmental Specialist

Attachment: Water Analysis

Cc: Jim Schlabaugh
Rebekah Miller
Bruce Gantner
Byron Chandler
Allan Sattler – Sandia National Labs
Correspondence
File

Explanation of codes	
B	Analyte Detected in Method Blank
E	Result is Estimated
H	Analyzed Out of Hold Time
N	Tentatively Identified Compound
S	Subcontracted
1-9	See Footnote

SANDIA NATIONAL LABORATORIES
attn: **ALLAN R. SATTLER**
PO BOX 5800 (MS-0706)
ALBUQUERQUE NM 87185

STANDARD

Assaigai Analytical Laboratories, Inc.

Certificate of Analysis

All samples are reported on an "as received" basis, unless otherwise noted (i.e. - Dry Weight).

Client: **SANDIA NATIONAL LABORATORIES**
Project:
Order: **0606256 SAN01** Receipt: **06-12-06**

William P. Biava: President of Assaigai Analytical Laboratories, Inc.

Sample: ***SAN JUAN METHANE WELL*** Collected: *06-12-06 9:30:00* By: *EDW*
Matrix:

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Prep Date	Run Date
0606256-0001A		**SW846 5030B/8260B Purgeable VOCs by GC/MS**					By:	TRS		
V06291	XG.2006.774.9	71-43-2	Benzene	ND	ug/L	1	1		06-13-06	06-13-06
V06291	XG.2006.774.9	100-41-4	Ethylbenzene	ND	ug/L	1	1		06-13-06	06-13-06
V06291	XG.2006.774.9	95-47-6	o-Xylene	ND	ug/L	1	1		06-13-06	06-13-06
V06291	XG.2006.774.9	108-38-3/106-42	p/m-Xylenes	ND	ug/L	1	2		06-13-06	06-13-06
V06291	XG.2006.774.9	108-88-3	Toluene	ND	ug/L	1	1		06-13-06	06-13-06
0606256-0001B		**SW846 5030A/8015B GRO by GC/FID**					By:	EJB		
V06294	XG.2006.776.5		Gasoline Range Organics	ND	mg/L	1	0.25		06-15-06	06-15-06
0606256-0001B		**SW846 8015B Diesel Range Organics by GC/FID**					By:	SDW		
S06333	XG.2006.791.6		Diesel Range Organics	ND	mg/L	1	25		06-19-06	06-23-06
0606256-0001C		**SM 5310B/9060**					By:	CMC		
HEAL0606212	SB.2006.239.3	10-35-5	Carbon, Total Organic, TOC	ND	mg/L	10	10	S	06-19-06	06-19-06
0606256-0001D		**SM 4500-P-B,D**					By:	MJN		
W06451	WC.2006.1477.14		Phosphorous, Total as P	0.89	mg/L	1	0.02		06-16-06	06-16-06
0606256-0001E		**EPA 4.1.1/200.7 ICP**					By:	TGA		
M06606	MT.2006.1080.29	7440-21-3	Silica, dissolved	14.4	mg/L	11	0.5		06-13-06	06-16-06
0606256-0001F		**EPA 120.1 Specific Conductance**					By:	MJN		
WCOND-06-082	WC.2006.1487.11	10-34-4	Conductivity	17540	umhos/cm	1	1		06-19-06	06-19-06
0606256-0001F		**EPA 150.1 pH, Electrometric**					By:	NJL		
WPH06087	WC.2006.1495.1	10-29-7	pH	8.05	units	1	0.1		06-13-06	06-13-06
WPH06087	WC.2006.1495.1		sample temperature @	15.7	deg C	1	0		06-13-06	06-13-06

STANDARD

Assaigai Analytical Laboratories, Inc.

Certificate of Analysis

All samples are reported on an "as received" basis, unless otherwise noted (i.e - Dry Weight).

Client: **SANDIA NATIONAL LABORATORIES**

Project:

Order: **0606256** **SAN01** Receipt: **06-12-06**

Sample: ***SAN JUAN METHANE WELL*** Collected: *06-12-06 9:30:00* By: *EDW*

Matrix:

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Prep Date	Run Date
0606256-0001F		**EPA 160.1 Total Dissolved Solids**					By:	MJN		
WTDS-06-064	WC.2006.1460.6	10-33-3	Total Dissolved Solids	11210	mg/L	1	10		06-14-06	06-15-06
0606256-0001F		**EPA 300.0 Anions by IC**					By:	JTK		
W06443	WC.2006.1451.31	16887-00-6	Chloride	2060	mg/L	500	0.05		06-13-06	06-14-06
W06443	WC.2006.1451.14	14265-44-2	Orthophosphate, as P	0.330	mg/L	5	0.05		06-13-06	06-13-06
W06443	WC.2006.1451.14	14808-79-8	Sulfate	1.30	mg/L	5	0.05		06-13-06	06-13-06
0606256-0001F		**EPA 310.1 Alkalinity, Titrimetic**					By:	NJL		
WALK06027	WC.2006.1490.22	71-52-3	Alkalinity, Bicarbonate	8550	mg/L	1	2		06-19-06	06-19-06
WALK06027	WC.2006.1490.22	3812-32-6	Alkalinity, Carbonate	ND	mg/L	1	2		06-19-06	06-19-06
WALK06027	WC.2006.1490.22	T-005	Alkalinity, Total	8550	mg/L	1	2		06-19-06	06-19-06
0606256-0001G		**EPA 4.1.3/200.7 ICP**					By:	TGA		
M06623	MT.2006.1102.33	7440-70-2	Calcium	22.5	mg/L	1	0.5		06-20-06	06-20-06
M06623	MT.2006.1102.33	7439-89-6	Iron	ND	mg/L	1	0.5		06-20-06	06-20-06
M06623	MT.2006.1102.33	7439-95-4	Magnesium	17.7	mg/L	1	0.5		06-20-06	06-20-06
M06623	MT.2006.1102.33	7440-09-7	Potassium	39.2	mg/L	1	0.5		06-20-06	06-20-06
M06623	MT.2006.1140.39	7440-23-5	Sodium	6100	mg/L	100	0.5		06-20-06	06-25-06
0606256-0001G		**SM 2340B**					By:	DMS		
HARD	MT.2006.1155.1		Hardness, as CaCO3	129	mg/L	1	0		06-28-06	06-28-06
0606256-0001H		**EPA 1664 - Solid Phase Extraction**					By:	NJL		
O&G06032	WC.2006.1450.9	10-30-0	Oil & Grease	ND	mg/L	1	5		06-13-06	06-13-06
0606256-0001I		**EPA 418.1 Total Recoverable Petroleum Hydrocarbons**					By:	PW		
S06346	WC.2006.1539.4	10-90-2	TRPH	ND	mg/L	1	1		06-23-06	06-26-06

Unless otherwise noted, all samples were received in acceptable condition and all sampling was performed by client or client representative. Sample result of ND indicates Not Detected, ie result is less than the sample specific Detection Limit. Sample specific Detection Limit is determined by multiplying the sample Dilution Factor by the listed Reporting Detection Limit. All results relate only to the items tested. Any miscellaneous workorder information or foonotes will appear below.

Analytical results are not corrected for method blank or field blank contamination.

Sandia National Laboratories
Operated for the United States Department of Energy by
LOCKHEED MARTIN

Allan R. Sattler
Distinguished Member of the Technical Staff
Geothermal Research Department 6211
P.O. Box 5800 MS 1033
Albuquerque, NM 87185-1033
Telephone: (505) 844-1019
Fax: (505) 844-3952
Res: (505) 298-1059
Email: arsattl@sandia.gov

Sandia National Laboratories
Operated for the United States Department of Energy by
LOCKHEED MARTIN

Malynda Aragon, MS ChE
Lead Engineer
Arsenic Water Technology Partnership
P.O. Box 5800 MS 0754
Albuquerque, NM 87185-0754
Phone: (505) 844-1288 Fax: (505) 844-7354
Cell: (505) 331-0945
Email: malarag@sandia.gov

Michael K. (Myke) Lane
Sr. Environmental Specialist
Environmental-Four Corners Area
Energy Services

Williams

188 County Road 4900
Bloomfield, New Mexico 87413
505/632-4625
505/632-4781 fax
505/330-3198 mobile
michael.k.lane@williams.com

BIOSOURCE, INC.

1200 Millbury St.
Worcester, MA 01607 USA

tel 508.363.2367
fax 508.753.2495

dragonfly@flowtc.com
www.flowtc.com
CELL 774-696[illegible]

Marc Andelman
President

BURLINGTON RESOURCES

San Juan Division

Jim Schlabaugh
Engineering Advisor

3401 E. 30th St. 87402-8807
P.O. Box 4289
Farmington, NM 87499-4289

Office: (505) 326-9788
Fax: (505) 599-4062
jschlabaugh@br-inc.com

Dale L. Wirth
Natural Resource Specialist

U.S. Department of the Interior
Bureau of Land Management
1235 La Plata Highway
Farmington, New Mexico 87401

Phone: (505) 599-6320
FAX: (505) 599-8998
Email: dale_wirth@nm.blm.gov

ConocoPhillips

Monica D. Johnson
Environmental Specialist
Lower 48 Exploration & Production
San Juan Business Unit
HSE, SD, & SE Department

monica.johnson@conocophillips.com

ConocoPhillips Company
Rm 461 Farmington Office
3401 E. 30th Street
P.O. Box 4289
Farmington, NM 87402
phone 505.326.9829
fax 505.599.4005
cell 505.320.9056

Resource Exploration
Resource Development
Reservoir Management

Carbonate Scale Inhibition
Injection Strategy
Injection Augmentation

Dick Benoit
Geothermal Resource Consultant

629 Jones Street
Reno, Nevada, 89503 USA
Phone 775.323.3078
Fax 775.323.1977

Email dickbenoit@hotmail.com

Charles Carter Waid, Ph.D.
Chief Research Analyst

Western Atlas International
A Litton/Dresser Company

ATLAS WIRELINE SERVICES

10011 Meadowglen Lane / 77042
P.O. Box 1407, Houston, TX 77251
Bus: (713) 972-4736
Res: (713) 973-7543
Telex: 6717302

TELEPHONE 247-4016

JOHN A. SEIBEL, M.D.
ENDOCRINOLOGY & INTERNAL MEDICINE

PRESBYTERIAN PROFESSIONAL BUILDING
SUITE 607
201 CEDAR STREET, S.E.
ALBUQUERQUE, N. MEX. 87106

OFFICE HOURS
BY APPOINTMENT

cell 505-670-5220

AmeriCulture

Damon E. Seawright, Ph.D.
Vice President

HC 65 Box 260 C, Animas, NM 88020
Ph: 888-TILAPIA Fax: 505.548.2631
548-2328
e-mail: damon@vtc.net
www.americulture.com

NEW MEXICO STATE UNIVERSITY

Agricultural Science Center at Farmington

Richard N. Arnold

P.O. Box 1018
Farmington, NM 87499

Phone: (505)-327-7757 (3)
Cell: (505)-860-5713
Email: riarnold@nmsu.edu

Dept. of EPP&WS
Pest Management Specialist
Weeds & Insects

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

H. WILLIAM HOCHHEISER
Manager
Oil and Gas Environmental Research
Office of Fossil Energy

U.S. Department of Energy
1000 Independence Ave., SW
Forrestal Bldg. FE-32
Washington, DC 20585

TEL: 202-586-5614
FAX: 202-586-6221
william.hochheiser@hq.doe.gov

ConocoPhillips

Ayman M Gazawi
Plant Engineer
San Juan Business Unit
Discipline Engineering

ayman.m.gazawi@conocophillips.com

ConocoPhillips Company
264 Farmington Office
3401 E. 30th Street
P.O. Box 4289
Farmington, NM 87402
phone 505.324.6162
fax 505.599.4084
cell 505.608.1581

B.E.S.T.
Biosphere Environmental Sciences & Technologies, LLC

Office: (505) 566-3703
Fax: (505) 566-3698
Cell: (505) 486-0058
Home: (505) 326-1356

5101 N. College Blvd. Suite 5061
Farmington, NM 87402

Frank McDonald
Senior Environmental Specialist

Email: fmcd_best@hotmail.com

-3081
-5709
-8347

Donna Jo Purchase
Group Service Representative
National Account Service
Mutual of Omaha Insurance Company
United of Omaha Life Insurance Company

C/O SANDIA NATIONAL LABORATORIES
P.O. BOX 5800, MS 1022
ALBUQUERQUE, NM 87175
PHONE (505) 844-0657, FAX (505) 844-7535
E-MAIL: donna.jo.purchase@mutualofomaha.com

BlackMountainTech@earthlink.net

State of California
California Energy Commission
Energy Technology Development Division
Research and Development Office
www.energy.ca.gov

Pablo Gutiérrez Santana
Associate Mechanical Engineer

1516 9th Street, MS 43
Sacramento, CA 95814-5512
(916) 654-4663
FAX (916) 653-6010
pgutierr@energy.state.ca.us

ConocoPhillips

Robert Wirtanen
SHE&R ~~Supervisor~~
Safety, Health, Environmental and Regulatory
Exploration & Production
San Juan Basin - Mid Americas Business Unit

bob.a.wirtanen@conocophillips.com

ConocoPhillips Company
~~5525 Hwy 64~~ 3401 E. 30th
Farmington, NM 8740~~2~~
phone 505.~~599.3462~~ 599-9781
fax 505.599.~~3442~~ 5400
cell 505.320.6631
~~pager 505.599.7168~~
www.conocophillips.com

...AND THE ENVIRONMENT

Notice to Users of this Report

This report has been prepared as an aid to the Agricultural Science Center Staff in analyzing the results of the various research during the past year and for recording pertinent data for future reference. This is not a formal Agricultural Experiment Station Report of research results.

Information in this report represents results from only one year's research. The reader is cautioned against drawing conclusions or making recommendations as a result of data in the report. In many instances, data in this report represents only one of several years of research results that will constitute the final formal report. It should be pointed out, however, that staff members have made every effort to check accuracy of the data presented.

This report was not as a formal release; therefore, none of the data or information herein is authorized for release or publication without the written approval of the New Mexico Agricultural Experiment Station.

Mention of a proprietary pesticide does not imply registration under FIFRA as amended or endorsement by New Mexico State University.

Project Number 900393: Funds Provided by Several Oil and Gas Producers in the San Juan Oil and Gas Producing Basin and in Cooperation with the San Juan Cattle Growers Association of San Juan County and Bureau of Land Management Farmington Field Office, 2003-2006

Using Coal Bed Methane Produced Water from Well-Sites for Native and Non-Native Grass Stand Establishment.

Objectives

- Select several native or non-native cool and warm season cultivar's that are adapted to the intermountain regions of northwest New Mexico.
- Applying coal bed methane produced water varying in Total Dissolved Salts, to native and non-native grasses for stand establishment.

Material and methods

Research plots were established in August, 2003, April 2004 and 2005, to look at possible coal bed methane produced water for native and non-native grass establishment. Table 1 indicates the location, date of planting and year's research plots were evaluated.

Table 1. Location, date of planting and year research plots were evaluated.

Location	Date of Planting	Years Evaluated
William Production Rosa 159A	August 6, 2003	3
BP Americas K5M[a]	August 6, 2003	1
Conoco/Phillips 242A	April 21, 2004	2
Conoco/Phillips 207A	April 10, 2005	1
Williams Production 224	April 19, 2005	1

[a] BP Americas K5M was only rated on July 29, 2004 due to no grass established in 2005.

Research plots were planted with a cone seeder with six, ten in rows 25 ft long. The experimental design was a randomized complete block with four replications for all sites. Table 3 gives the names of the variety or cultivar planted at all five sites. A soil sample was taken from all sites at a depth from 0 to 12 inch before and after produced water was applied to determine pH, electrical conductivity (EC), calcium, magnesium, sodium, texture, and sodium adsorption ratio (SAR). Table 4 shows the results of soil samples before and after produced water application. EC describes the amount of electrical current conducted by a saturated soil extract at a fixed temperature. The more salts in solution, the greater the EC reading and the greater the toxicity to plants. This test does not distinguish between salt types; units of measure are usually in decisiemens per meter (dS/m). SAR describes the ratio of sodium relative to calcium and magnesium, to cations that moderate the adverse effects of sodium. The greater the SAR value, the more sodium relative to calcium and magnesium, the greater the toxicity. A 400-barrel tank (holds approximately 16,800 gallons) was supplied and put on each well site. Produced water was then pumped through a 3 in irrigation pipe consisting of a line spacing of 50 ft and a sprinkler spacing of 30 ft. Rainbird 25 ASFP-TNT sprinkler heads with 11/64 nozzles were used. Table 2 gives the location, date, and amount and total amount of produced water applied from 2003 to 2005.

Table 2. Location, date, and total amount of produced water applied, 2003 to 2005.

Location	Date produced water was applied	Amount of produced water applied at each application	Total amount of produced was applied at each location in inches and gallons
William Production Rosa 159A	August 13 and 19, September 17 and 23, 2003	1.12 inch	4.5 inches, or 26,880 gallons
BP Americas K5M[a]	August 12 and 21, September 16, 2003	2.8 inch	8.4 inches, or 50,400 gallons
Conoco/Phillips 242A	April 28, May 10 and 18, 2004	2.8 inch	8.4 inches or 50, 400 gallons
Conoco/Phillips 207A	May 12, 19, and 25, 2005	2.8, 1.4, and 1.4 inches	5.2 inches or 33,600 gallons
Williams Production 224	April 18, May 11 and 18, 2005	2.8, 1.4, and 1.4 inches	5.2 inches or 33,600 gallons

Water samples were taken during each application and sent to EnviroTech Labs for analysis. Table 5 gives the water analysis for Williams Production (WP) Rosa 159A and BP British Petroleum Americas (BP) Florence K5M and Conoco/Phillips 242A and 207A and Williams Production (WP) 224. Evaluation of research plots for stand establishment of WP Rosa 159A and 224, BP Americas Florence K5M, and Conoco/Phillips 242A, 207A are given in Table 7.

Results and discussion

Rainfall Averages: Cumulative rainfall was taken from Ignacio, Colorado at approximately 2.1 miles NNE from the Community Collaborative Rain, Hail and Snow Network (CoCo-RaHS) observation site. From August 1 to December 2003 approximately 2.8 in of moistured was measured. In 2004, 2005 and 2006 approximately 10.9, 16.8 and 13.4 inch of moisture was measured. Average moisture accumulation from 2004 to 2006 was 13.7 inch, respectively.

Soil Tests: Before and after soil test results are given in Table 4. Soil tests for pH, taken before produced water applications on all five sites averaged 7.2 and after produced water application of 7.5. Soil samples taken on BP Americas Florence K5M and WP 224, after 8.4 and 5.2 inch of produced water applied, averaging approximately 6432 and 9973 mg/L (milligrams per liter) in total dissolved salts (TDS), 86 and 142 in SAR, and 14.1 and 17.7 in EC dS/M values, (Table 6) and had the greatest increase in EC and SAR of 4.3 and 3.5 dS/m and 11.0 and 13, Table 4. Usually an EC in dS/m above 15 from a soil salinity test is unsuitable for most crops and where a severe decrease in forage production occurs. For example crested wheatgrass, western wheatgrass, slender wheatgrass, Canadian and Russian wild ryegrass, and intermediate wheatgrass, are moderate to tolerant at EC levels ranging from 10 to 15 dS/m. All five locations showed after soil EC levels in dS/m, below 6 after produced water was applied. An SAR value evaluates the sodium content of the soil. A value of 15 or greater indicates an excess of sodium will be adsorbed by the soil clay particles. Excess sodium can cause soil to be hard and cloddy when dry, to crust badly, and take water very slowly. The after soil SAR values of all sites were below 12, after produced water was applied, except for WP 224. Except for the after soil SAR value of 19.6 for WP 224, the after soil EC and SAR values for WP Rosa 159, BP Americas K5M, Conoco/Phillips 242A and 207A were under the described values for restricting forage production for most of these grasses planted Table 4.

Water Analysis: Individual water analyses are given in Table 5 and averages are given in Table 6. Water analyses were conducted by EnviroTech Labs, Farmington, New Mexico. WP Rosa 159 had approximately 4.5 inch of produced water averaging approximately 8061 mg/L TDS, 97 SAR and an EC of 16.8 Table 6. BP Americas and Conoco/Phillips 242A and Conoco/Phillips 207A and WP 224 had approximately 8.4 and 5.2 inch of produced water averaging 6432, 3838, 4384 and 9973 mg/L TDS, 86, 69, 127 and 142 SAR and EC of 14.1, 6.8, 6.9 and 17.7. Usually if the irrigation water EC values in dS/m are over 3 except for tolerant crops (usually 8 to 12) and SAR values are above 26 (values below 10 acceptable for production) that water is unsuitable for production. The most influential water quality guideline on crop productivity is the salinity hazard as measured by EC. The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water available to plants, even though a field may appear wet. Water sources with an EC value of approximately 1.0 dS/m contains approximately 2,000 lbs of salt for every acre foot of water applied. With this in mind approximately 6.3, 9.8, 4.7, 2.9, and 7.6 tons of salt were applied to WP Rosa 159A, BP Americas Florence K5M and Conoco/Phillips 242A, Conoco/Phillips 207A and WP 224, respectively. While EC is an assessment of all soluble salts in a sample, sodium hazard is defined separately because of its specific detrimental effects on soil physical properties. With higher SAR (usually above 15) values the soil becomes more dispersed, will readily crust and have water infiltration and permeability problems. However, many factors including soil texture, organic matter, crop type, climate, irrigation system, and management impact how sodium in the irrigation water affects soils. With the relative small amount of produced water containing high EC and SAR values, it is hoped that most of the salt tolerant native and non-native grasses planted in these studies will survive and become established productive grasses, on the these disturbed locations.

Stand Establishment: Averaged stand establishment of native and non native grasses is given in Table 7. Three year average for stand establishment on WP Rosa 159A showed Chief Intermediate, Luna Pubescent, Hy Crest Crested, and San Luis Slender Wheatgrasses, VNS Canada Wild, and Bozoisky Russian Wild Ryegrasses, averaged from 2.7 to 2.4. BP Americas Florence K5M indicated that Arriba Western Wheatgrass, VNS Bottlebrush Squirreltail, Paloma Indian Ricegrass, Anatone Bluebunch Wheatgrass, Four-Wing Saltbush, Covar Sheep Fescue, and VNS Needle and Threadgrass had a rating of 1.5 for stand establishment one year after produced water application. BP Americas Florence k5M was not rated the second year due to no grass present. Excellent stand establishment for Arriba Western, Hy Crest Crested, Critana Thickspike, Anatone Bluebunch, San Luis Slender Wheatgrasses, VNS Canada Wild Ryegrass, and VNS Bottlebrush Squirreltail, these all averaged above 4.3 for stand establishment two year after produced water was applied to Conoco/Phillips 242A, Table 7. Conoco/Phillips 207A showed that Arriba Western Wheatgrass, Hy Crest Crested Wheatgrass, VNS Canada Wild ryegrass, Bozoisky Russian Wild Ryegrass, Critana Thickspike Wheatgrass, Anatone Bluebunch Wheatgrass, and San Luis Slender Wheatgrass averaged 3.0 or better approximately 15 months year after planting Table 7. Only Bozoisky Russian Wild Ryegrass and VNS Russian Wild Ryegrass had a rating of 2.5 for grass establishment on WP 224 approximately 15 months after planting Table 7.

Table 3. Names of cultivars or varieties planted at each site 2003 to 2005.

Variety or Cultivar	Seeding Rate (lb/pls/A[a])
Arriba Western Wheatgrass	8.0
Chief Intermediate Wheatgrass	10.0
Luna Pubescent Wheatgrass	10.0
Hy Crest Crested Wheatgrass	5.0
VNS[b] Canada Wild Ryegrass	7.0
Bozoisky Russian Wild Ryegrass	5.0
Critana Thickspike Wheatgrass	6.0
VNS[b] Bottlebrush Squirreltail	8.0
Redondo Arizona Fescue	3.0
Paloma Indian Ricegrass	6.0
Anatone Bluebunch Wheatgrass	9.0
VNS[b] Junegrass	4.0
Four-Wing Saltbush	2.0
Covar Sheep Fescue	2.0
San Luis Slender Wheatgrass	6.0
VNS[b] Needle and Threadgrass	8.0

[a] pls = pure live seed
[b] VNS = variety or cultivar not stated

Table 4. **Soil sample results before and after produced water application on WP Rosa 159A and BP Americas Florence K5M, 2003, Conoco/Phillips 242A, 2004, Conoco/Phillips 207A, and WP 224, 2005**

Well Site[a]	pH	EC (dS/m)	Ca (ppm)	Mg (ppm)	Na (ppm)	SAR	Texture
WP Rosa 159A (before)	7.32	3.4	912	67	533	7.3	loam
WP Rosa 159A (after)	7.53	5.1	341	80	725	9.2	loam
BP Americas Florence K5M (before)	6.95	1.7	253	42	36.3	0.6	loamy sand
BP Americas Florence K5M (after)	6.92	6.0	346	75	917	11.6	loamy sand
Conoco/Phillips 242A (before)	7.67	3.4	324	75	422	5.5	Loam
Conoco/Phillips 242A (after)	7.76	3.6	282	61	526	7.4	Loam
Conoco/Phillips 207A (before)	7.13	1.0	100	21	102	2.4	Sandy clay loam
Conoco/Phillips 207A (after)	7.39	1.2	84	16	180	4.7	Sandy clay loam
WP 224 (before)	7.29	0.9	39	6	167	6.6	Sandy clay loam
WP 224 (after)	7.65	4.4	97	19	809	19.6	Sandy clay loam

[a] Before means sample taken before produced water application and after means soil samples taken after last produced water application.

Table 5. Produced water analysis for WP Rosa 159A and BP Americas Florence K5M, 2003, Conoco/Phillips 242A, 2004, Conoco/Phillips 207A and WP 224, 2005.

Location	Application date	pH	TDS (mg/L)	SAR	EC (dS/m
WP Rosa 159A	9-19-03	8.5	5440	71	16.1
WP Rosa 159A	9-17-03	8.0	10682	122	17.4
BP Americas Florence K5M	8-12-03	8.3	4190	51	11.1
BP Americas Florence K5M	8-20-03	8.4	6980	105	17.6
BP Americas Florence K5M	9-16-03	8.1	8126	101	13.6
Conoco/Phillips 242A	4-30-04	8.1	3640	67	6.3
Conoco/Phillips 242A	5-19-04	8.5	4020	76	7.1
Conoco/Phillips 242A	5-23-04	8.1	3850	65	7.0
Conoco/Phillips 207A	5-12-05	8.7	2464	51	3.7
Conoco/Phillips 207A	5-19-05	9.8	6030	250	9.5
Conoco/Phillips 207A	5-25-05	9.6	4660	80	7.5
WP 224	4-18-25	6.4	16410	23	30.1
WP 224	5-11-05	7.7	6130	54	11.0
WP 224	5-18-05	7.4	7380	65	11.9

Table 6. Produced water analysis averages for WP Rosa 159A and BP Americas Florence K5M, 2003, Conoco/Phillips 242A, 2004, Conoco/Phillips 207A and WP 224, 2005.

Location	pH	TDS (mg/L)	SAR	EC (dS/m)
	Averages			
WP Rosa 159A	8.3	8061	97	16.8
BP Americas Florence K5M	8.3	6432	86	14.1
Conoco/Phillips 242A	8.2	3838	69	6.8
Conoco/Phillips 207A	9.4	4384	127	6.9
WP 224	7.2	9973	142	17.7

Table 7. **Averaged stand establishment of native and non-native grasses approximately three, two and one year after planting on WP Rosa 159A on BP Americas Florence K5M, 2004, Conoco/Phillips 242A, 2005, Conoco/Phillips 207A, and WP 224, 2006.**

		Stand establishment[b]				
Cultivar[a]	lbs/pls/A	WP Rosa 159A[c]	BP Americas Florence K5M[d]	Conoco /Phillips 242A[e]	Conoco /Phillips 207A[f]	WP 224[f]
Arriba Western Wheatgrass	8.0	1.8	1.5	4.8	3.1	1.5
Chief Intermediate Wheatgrass	10.0	2.6	1.4	2.8	1.5	1.0
Luna Pubescent Wheatgrass	10.0	2.6	1.3	2.8	1.6	1.0
Hy Crest Crested Wheatgrass	5.0	2.8	1.3	4.5	3.6	2.0
VNS Canada Wild Ryegrass	7.0	2.5	1.1	6.5	3.9	2.5
Bozoisky Russian Wild Ryegrass	5.0	2.7	1.1	2.9	5.3	2.5
Critana Thickspike Wheatgrass	6.0	2.0	1.3	6.5	4.3	1.5
VNS Bottlebrush Squirreltail	8.0	1.3	1.5	6.0	2.9	2.0
Redondo Arizona Fescue	3.0	1.0	1.3	2.4	1	1.0
Paloma Indian Ricegrass	6.0	1.9	1.5	1.6	1.5	2.0
Anatone Bluebunch Wheatgrass	9.0	1.8	1.5	5.5	4.5	1.0
VNS Junegrass	4.0	1.5	1.3	1.1	1.0	1.0
Four-Wing Saltbush	2.0	1.0	1.5	1.3	1.0	1.0
Covar Sheep Fescue	2.0	2.6	1.5	1.6	1.0	1.0
San Luis Slender Wheatgrass	6.0	2.0	1.0	6.5	3.0	2.0
VNS Needle and Threadgrass	8.0	2.0	1.5	4.1	2.8	2.0

[a] VNS equal variety or cultivar not stated.
[b] Rated on a scale from one to nine with one being no stand establishment and nine being 100 percent established.
[c] Three year average stand establishment rating on October 26, 2004 and July 28, 2005, and July 26, 2006.
[d] Location was only rated once on October 26, 2004, no grass survival in 2005.
[e] Two year average stand establishment rating on July 29, 2005 and July 26, 2006.
[f] Locations rated on July 26, 2006.

Acknowledgements

The author wishes to express his appreciation to the following individuals and/or oil and gas industries for there financial support and/or assistance during the course of this research, Bureau of Land Management Farmington Field Office, Mr. Steve Henke, Mr. Ray Sanchez, Mr. Dale Wirth, Mr. Dave Mankiewicz, Mr. Mark Kelly, Mr. Bill Papich, Mr. Daniel Sandoval, and Mr. Jeff Tafoya, El Paso Field Services, Mr. Ron Sipe and Mr. Joe Velasquez, BP Americas, Mrs. Brittany Benko, Mr. Jerry Huwe, and Mr. Ted Black, Williams Production, Mr. Stergie Katirgis and Mr. Mark Lepich, Burlington Resources, Mr. Chuck Smith and Mr. Terry Lowe, Pure Resources, Mr. Jeff Pickett and Mr. Mike Phillips, XTO Energy, Mr. Del Craddock and Mr. Terry Matthews, Conoco/Phillips, Mr. Bob Wirtanen, San Juan Cattle Growers Association, and New Mexico State University Agricultural Science Center, Mr. Daniel Smeal.

The End

Revegetation of Pipeline Right-of Way and or Well Sites with Selected Cool and Warm Season Cultivar's and Forbes for Palatability, Stand Establishment, and Erosion Control in the Intermountain Region of Northwest New Mexico.

BY: Richard N. Arnold

New Mexico State University

Agricultural Science Center

February 3, 2004

Notice to Users of this Report

This report has been prepared as an aid to the Agricultural Science Center Staff in analyzing the results of the various research during the past year and for recording pertinent data for future reference. This is not a formal Agricultural Experiment Station Report of research results.

Information in this report represents results from only one year's research. The reader is cautioned against drawing conclusions or making recommendations as a result of data in the report. In many instances, data in this report represents only one of several years of research results that will constitute the final formal report. It should be pointed out, however, that staff members have made every effort to check accuracy of the data presented.

This report was not as a formal release; therefore, none of the data or information herein is authorized for release or publication without the written approval of the New Mexico Agricultural Experiment Station.

Mention of a proprietary pesticide does not imply registration under FIFRA as amended or endorsement by New Mexico State University.

Project Number 09-06-61223: Funds provided by several oil and gas producers in the San Juan Oil and Gas producing basin and in Cooperation with the Bureau of Land Management Field Office.

Table of Contents

Establishment of native and non-native grasses on pipeline-right-of ways and/or well sites in the San Juan Oil and Gas producing basin.	1
Using Coal Bed Methane Produced Water from Well-Sites for Native and Non-Native Grass Stand Establishment.	7
Appendicies	11

Project Number 09-6-61223: Funds provided by several oil and gas producers in the San Juan Oil and Gas producing basin and in Cooperation with the Bureau of Land Management Farmington Field Office.

Revegetation of Pipeline Right-of-Way and/or well sites with selected cool and warm season Cultivar's, and Forbes for Palatability, stand establishment, and erosion Control in the Intermountain Region of Northwest New Mexico.

Establishment of native and non-native grasses on pipeline-right-of ways and/or well sites in the San Juan Oil and Gas producing basin.

Richard N. Arnold

Introduction

The true grasses comprise several thousand species and are found in all parts of the world, but it is in the drier, temperate regions they often form the chief vegetation. They owe their dominance in such regions to their ability to survive under all conditions where flowering plants can't live at all, to their aggressive methods of natural vegetative propagation, and to their usually abundant seed crop and its wide dispersal by natural conditions, such as wind and water.

The grasses that persist naturally in any given region over long periods of time are those that have been successful in adjusting themselves to the factors that limit growth. In order to survive, they must withstand extremes of drought, cold, wind, diseases and insects, competition, and grazing.

Objectives

- Select several native or non-native cool and warm season cultivar's that are adapted to the intermountain regions of northwest New Mexico.
- Determine the most adequate time of planting for establishment of the forages.

Material and methods

Research plots were established in April and October 2002 to determine time of planting and stand establishment of selected native and non-native grasses in the San Juan Oil and Gas producing region of northwest New Mexico. Individual plots were planted with a cone seeder with six, ten in rows by 25 ft long. El Paso Tapacitas pipeline right-of-way, BP Americas Arboles 29A, William Production Rosa Units 159A and 354 were all planted the first week in April. XTO Kutz 11E and Pure Resources Rincon Unit 172 were planted in mid October. The experimental design was a randomized complete with four to six replications depending on well site. The native and non-native grasses will be rated on a scale from 1 to 9 with 1 being no stand establishment or survival and 9 being 100% stand establishment or survival. El Paso Tapacitas pipeline right-of-way, BP Americas Arboles 29A, Williams Production Rosa Units 354 and 159A, and XTO Kutz 11E and Pure Resources Rincon Unit 172 were rated for stand establishment or survival in mid July and mid October 2003. Rain gauges have been installed at each well site to determine amount and time of rainfall. Table 1 gives the name of the cultivar or variety planted at each site.

Table 1. Names of cultivars or varieties planted at each site, April and October 2002.

Variety or Cultivar	Seeding Rate (lb/pls/A[a])
Arriba Western Wheatgrass	8.0
Chief Intermediate Wheatgrass	10.0
Luna Pubescent Wheatgrass	10.0
Hi-Crest Crested Wheatgrass	5.0
VNS[b] Canada Wild Ryegrass	7.0
Bozoisky Russian Wild Ryegrass	5.0
Critana Thickspike Wheatgrass	6.0
VNS[b] Bottle Brush Squirreltail	8.0
Redondo Arizona Fescue	3.0
Covar Sheep Fescue	2.0
Paloma Indian Ricegrass	6.0
Anatone Bluebunch Wheatgrass	9.0
San Luiz Slender Wheatgrass	6.0
VNS[b] Needle and Threadgrass	8.0
VNS[b] Junegrass	4.0
Alma Blue Gramagrass	6.0

[a] pls = pure live seed
[b] VNS = cultivar or variety not stated

Results and discussion

Stand Establishment or Survival: In Figures 1 and 2, cumulative precipitation collected in 2002 and 2003 is given. In 2002 data showed that WP Rosa 354 had the most precipitation of approximately 7.7 in and BP Americas Arboles 29A had the least amount of precipitation of 4.1 in. Most of the precipitation for all of the four sites fell with in the months of early September to early October. In 2003, WP Rosa 354 has the highest rainfall of 12.4 in and EL Paso Tapacitas had the least amount of rainfall of 5.9 in. The BP Americas Arboles 29A rain gauge was knocked over presumably by wild horses and moisture was not registered correctly since possibly September.

In Table 2, data showed that there was no significant differences in stand establishment for El Paso Tapacitas right-of-way plantings. BP Americas Arboles 29A indicated that Chief Intermediate Wheatgrass, San Luis Slender Wheatgrass, and Needle and Threadgrass had the highest stand establishment ratings of 2.3. The Williams Rosa units 354 and 159A indicated that, Paloma Indian Ricegrass and Canada Wild Ryegrass had the highest stand establishment ratings of 1.8 and 2.3. The overall average across all spring plantings, rated for stand establishment approximately 15 months after planting, showed that Arriba Western Wheatgrass, Canada Wild Ryegrass, San Luis Slender Wheatgrass, and Needle and Threadgrass averaged 1.5 or better. Data further showed that Redondo Arizona Fescue and Anatone Bluebunch Wheatgrass had the lowest overall average for stand establishment of 1.05 and 1.07. Of the fall plantings of 2002, XTO Energy Kutz 11E showed that Paloma Indian Ricegrass had the highest stand establishment rating of 3.8 followed by Needle and Threadgrass at 2.6. Pure Resources Rincon 172 did not show any grass stand survival one year after planting.

Table 2. Stand establishment of native and non-native grasses in 2003.

Cultivar	lbs/pls/A	Stand establishment[1] EL Paso Tapacitas[2]	BP Americas Arboles 29A[2]	Williams Prod. Rosa 354[2]	Williams Prod. Rosa 159A[2]	XTO Energy Kutz 11E[3]
Arriba Western Wheatgrass	8.0	1.3	2.0	1.2	1.5	1.2
Chief Intermediate Wheatgrass	10.0	1.3	2.3	1.0	1.2	1.0
Luna Pubescent Wheatgrass	10.0	1.3	1.8	1.0	1.0	1.4
Hi-Crest Crested Wheatgrass	5.0	1.0	1.5	1.0	1.0	1.0
Canada Wild Ryegrass	7.0	1.0	1.5	1.4	2.3	2.8
Bozoisky Russian Wild Ryegrass	5.0	1.3	1.5	1.2	1.8	1.0
Critana Thickspike Wheatgrass	6.0	1.3	1.8	1.0	1.3	1.0
Bottlebrush Squirreltail	8.0	1.3	1.0	1.4	1.3	1.6
Redondo Arizona Fescue	3.0	1.0	1.0	1.0	1.2	1.0
Covar Sheep Fescue	2.0	1.0	1.0	1.0	1.2	1.2
Paloma Indian Ricegrass	6.0	1.5	1.3	1.8	1.0	3.8
Anatone Bluebunch Wheatgrass	9.0	1.0	1.3	1.0	1.0	1.0
San Luis Slender Wheatgrass	6.0	1.3	2.3	1.0	1.7	2.0
Needle and Threadgrass	8.0	1.5	2.3	1.6	1.3	2.6
Junegrass	4.0	1.0	1.5	1.0	1.0	1.0
Alma Blue Grama Grass	6.0	1.0	1.5	1.0	1.0	1.2
LSD 0.05		ns	0.8	0.4	0.7	0.8

[1] Stand establishment rated on a scale from 1 to 9 with 1 being no stand establishment or survival and 9 being 100 percent stand establishment or survival.
[2] Areas planted in early April 2002 and rated in mid July 2003.
[3] Area planted in mid October 2002 and rated in mid October 2003.

Using Coal Bed Methane Produced Water from Well-Sites for Native and Non-Native Grass Stand Establishment.

Objectives

- Select several native or non-native cool and warm season cultivar's that are adapted to the intermountain regions of northwest New Mexico.
- Applying coal bed methane produced water varying in Total Dissolved Salts, to native and non-native grasses for stand establishment.

Material and methods

Research plots were established in mid August to look at possible coal bed methane produced water for native and non-native grass establishment. The Williams Production (WP) well site Rosa 159A and BP Americas Florence K5M were chosen for this research study. Research plots were planted on August 6 with a cone seeder with six, ten in rows 25 ft long. The experimental design was a randomized complete block with four replications for both sites. Table 1 gives the names of the variety or cultivar planted at both sites. A soil sample was taken from both sites at a depth from 0 to 12 in before and after produced water was applied to determine pH, electrical conductivity (EC), calcium, magnesium, sodium, texture, and sodium adsorption ratio (SAR). Table 2 shows the results of soil samples before and after produced water application. EC describes the amount of electrical current conducted by a saturated soil extract at a fixed temperature. The more salts in solution, the greater the EC reading and the greater the toxicity to plants. This test does not distinguish between salt types, units of measure are usually in decisiemens per meter (dS/m). SAR describes the ratio of sodium relative to calcium and magnesium, to cations that moderate the adverse effects of sodium. The greater the SAR value, the more sodium relative to calcium and magnesium, the greater the toxicity. The exchangeable sodium percentage (ESP) provides a measure of the amount of exchangeable sodium relative to the total cation exchange capacity of the soil expressed as a percentage. As ESP goes up, more exchangeable sodium is available, and the greater the potential for negative plant and soil impacts. A 400-barrel tank (holds approximately 16,800 gallons) was supplied and put on each well site. Produced water was then pumped through a 3 in irrigation pipe consisting of a line spacing of 50 ft and a sprinkler spacing of 30 ft. Rainbird 25 ASFP-TNT sprinkler heads with 11/64 nozzles were used. Produced water was applied on WP Rosa 159A on August 13 and 19, September 17 and 23 at approximately 1.12 in per application for a total of 4.48 in or 640 barrels (26,880 gallons). Produced water was applied to BP Americas Florence K5M on August 12 and 20, and September 16 at approximately 2.8 in per application for a total of 8.4 in or 1200 barrels (50,400 gallons). Water samples were taken during application and sent to EnviroTech Labs for analysis. Table 3 gives the water analysis for WP Rosa 159A and BP

Americas Florence K5M. Research plots for stand establishment will be rated approximately 12 to 15 months after planting.

Results and discussion

Soil Tests: Before and after soil test results are given in Table 2. Soil tests taken before produced water application on WP Rosa 159A showed a pH of 7.32, EC of 3.39 dS/m, sodium content of 533 parts per million (ppm) and an SAR value of 7.32. After application of 4.48 in of produced water pH, EC dS/m, sodium in ppm, and SAR values each increased to 7.53, 5.12, 725 and 9.17. The BP Americas Florence K5M site showed a significant increase in EC levels from 1.71 to 6 dS/m, sodium in ppm (36.3 to 917) and an SAR value (0.6 to 11.6) in the before and after soil samples. Usually an EC in dS/m above 15 from a soil salinity test is unsuitable for most crops and where a decrease in forage production occurs. For example crested wheatgrass, western wheatgrass, slender wheatgrass, Canadian and Russian wild ryegrass, and intermediate wheatgrass, are moderate to tolerant at EC levels ranging from 10 to 15 dS/m. The EC levels in dS/m for both WP Rosa 159A and BP Americas Florence K5M EC in dS/m levels are 6 and below after produced water was applied. An SAR value evaluates the sodium content of the soil. A value of 15 or greater indicates an excess of sodium will be adsorbed by the soil clay particles. Excess sodium can cause soil to be hard and cloddy when dry, to crust badly, and take water very slowly. At both sites the soil SAR value after produced water was applied were less than 15. Both the EC values in dS/m and SAR values were under the described values for restricting forage production for most of these grasses planted.

Water Analysis: Water analyses are given in Table 3. The water analysis conducted by EnviroTech Labs showed that WP Rosa 159A averaged approximately 8,061 milliequivalents per liter (meq/L) of total dissolved salts (TDS), SAR value of 96, and an EC value in dS/m of 17. BP Americas Florence K5M averaged 6432 meq/L TDS, SAR value of 86, and an EC value in dS/m of approximately 14. A total of 4.48 and 8.4 in of produced water containing the above average values were applied to WP Rosa 159A and BP Americas Florence K5M, during August and September 2003. Usually if the irrigation water EC values in dS/m are over 3 except for tolerant crops (usually 8 to 12) and SAR values are above 26 ((values below 10 acceptable for production) that water is unsuitable for production. The most influential water quality guideline on crop productivity is the salinity hazard as measured by EC. The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water available to plants, even though a field may appear wet. Usually water with an EC value of 1.15 dS/m contains approximately 2,000 lbs of salt for every acre foot of water. With this in mind approximately 5.52 and 8.52 tons of salt were applied to WP 159A and BP Americas Florence K5M, respectively. While EC is an assessment of all soluble salts in a sample, sodium hazard is defined separately because of its specific detrimental effects on soil physical properties. With higher SAR values the soil becomes more dispersed, will readily crust and have water infiltration and permeability problems. However, many factors including soil texture, organic matter, crop type, climate, irrigation system, and affects soils. With the relative small amount of produced water containing high EC and SAR values, it is hoped that most of the salt tolerant native and non-native grasses planted in these studies will survive and become established productive grasses of the these disturbed sites. We will continue this study by selecting two more sites for produced water application and grass establishment in the spring of 2004.

Table 1. Names of cultivars or varieties planted at each site, mid August 2003.

Variety or Cultivar	Seeding Rate (lb/pls/A[a])
Arriba Western Wheatgrass	8.0
Chief Intermediate Wheatgrass	10.0
Luna Pubescent Wheatgrass	10.0
Hy Crest Crested Wheatgrass	5.0
VNS[b] Canada Wild Ryegrass	7.0
Bozoisky Russian Wild Ryegrass	5.0
Critana Thickspike Wheatgrass	6.0
VNS[b] Bottlebrush Squirreltail	8.0
Redondo Arizona Fescue	3.0
Covar Sheep Fescue	2.0
Paloma Indian Ricegrass	6.0
Anatone Bluebunch Wheatgrass	9.0
San Luis Slender Wheatgrass	6.0
VNS[b] Needle and Threadgrass	8.0
VNS[b] Junegrass	4.0
Alma Blue Gramagrass	6.0

[a] pls = pure live seed
[b] VNS = cultivar or variety not stated

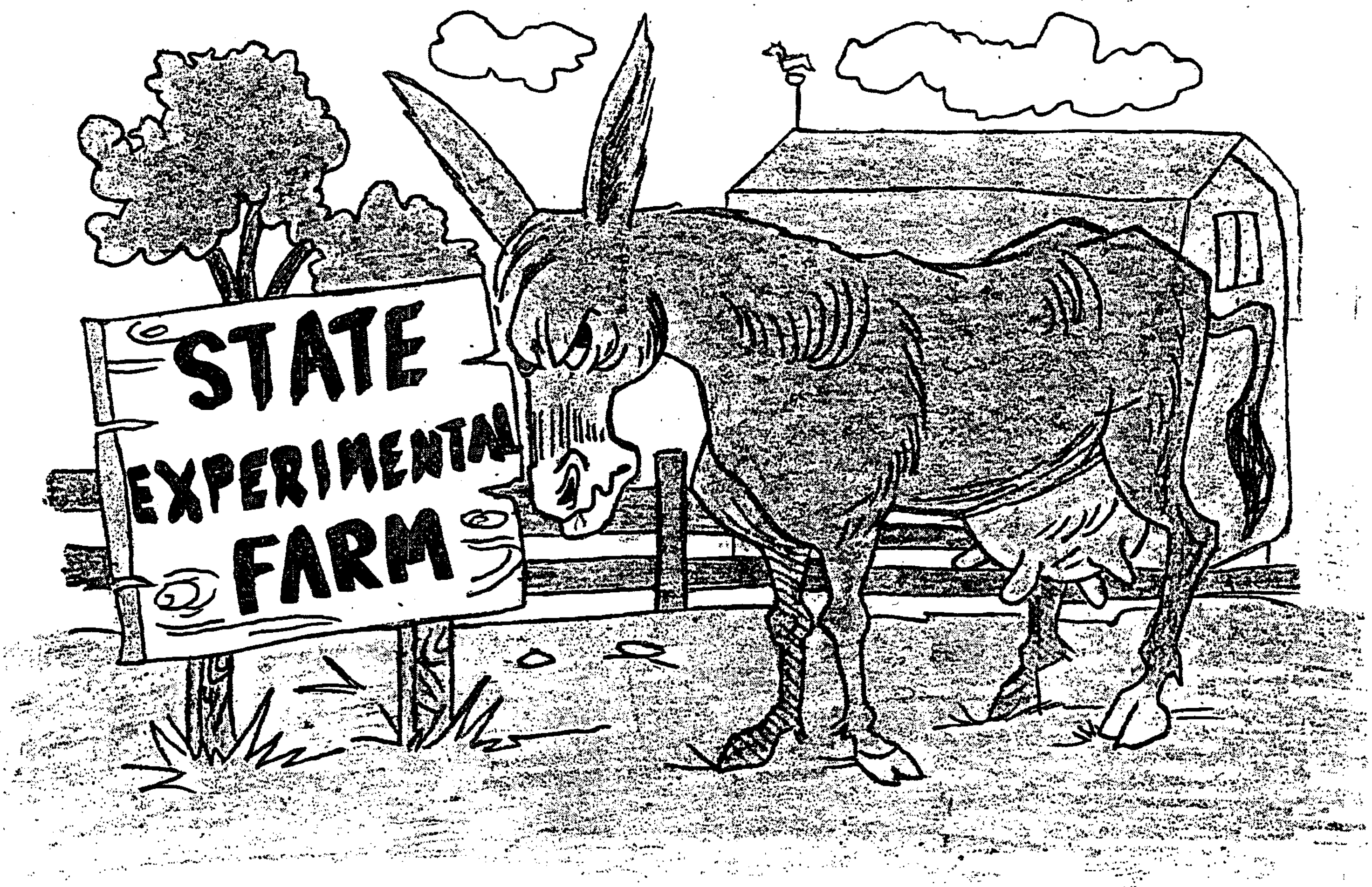
Table 2. Soil sample results before and after produced water application on WP Rosa 159A and BP Americas Florence K5M, 2003.

Well Site[1]	pH	EC (dS/m	Ca (ppm)	Mg (ppm)	Na (ppm)	SAR	Texture
WP Rosa 159A (before)	7.32	3.39	912	66.8	533	7.32	loam
WP Rosa 159A (after)	7.53	5.12	341	79.7	725	9.17	loam
BP Americas Florence K5M (before)	6.95	1.71	253	42.4	36.3	0.6	loamy sand
BP Americas Florence K5M (after)	6.92	6.0	346	74.6	917	11.6	loamy sand

[1] Before means sample taken before produced water application and after means soil samples taken after last produced water application.

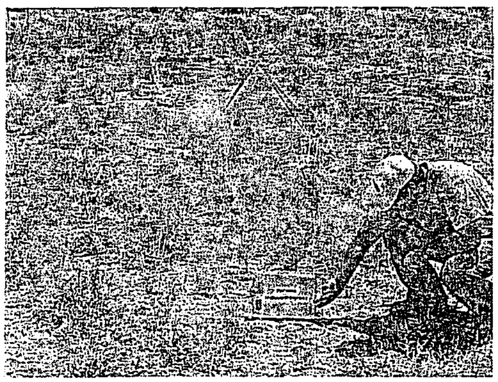
Table 3. Produced water analysis for WP Rosa 159A and BP Americas Florence K5M, 2003.

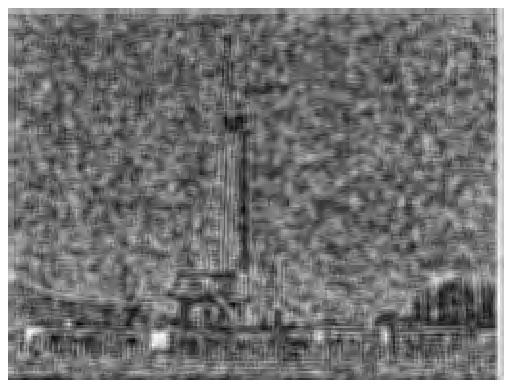
Well-site	Date	pH	TDS (meq/L)	SAR	EC (dS/m
WP Rosa 159A	9-19-03	8.5	5440	71.1	16.1
WP Rosa 159A	9-17-03	8.0	10682	122.4	17.4
BP Americas Florence K5M	8-12-03	8.3	4190	51.4	11.1
BP Americas Florence K5M	8-20-03	8.4	6980	105.2	17.6
BP Americas Florence K5M	9-16-03	8.1	8126	100.8	13.6



The End

Revegetation of Pipeline Right-of Way and or Well Sites with Selected Cool and Warm Season Cultivar's and Forbes for Palatability, Stand Establishment, and Erosion Control in the Intermountain Region of Northwest New Mexico.





BY: Richard N. Arnold

New Mexico State University

Agricultural Science Center

February 22, 2005

Notice to Users of this Report

This report has been prepared as an aid to the Agricultural Science Center Staff in analyzing the results of the various research during the past year and for recording pertinent data for future reference. This is not a formal Agricultural Experiment Station Report of research results.

Information in this report represents results from only one year's research. The reader is cautioned against drawing conclusions or making recommendations as a result of data in the report. In many instances, data in this report represents only one of several years of research results that will constitute the final formal report. It should be pointed out, however, that staff members have made every effort to check accuracy of the data presented.

This report was not as a formal release; therefore, none of the data or information herein is authorized for release or publication without the written approval of the New Mexico Agricultural Experiment Station.

Mention of a proprietary pesticide does not imply registration under FIFRA as amended or endorsement by New Mexico State University.

Project Number 09-06-61223: Funds provided by several oil and gas producers in the San Juan Oil and Gas producing basin and in Cooperation with the Bureau of Land Management Field Office.

Table of Contents

Establishment of native and non-native grasses on pipeline-right-of ways and/or well sites in the San Juan Oil and Gas producing basin.	1
Using Coal Bed Methane Produced Water from Well-Sites for Native and Non-Native Grass Stand Establishment.	9
Appendicies	14

Project Number 09-6-61223: Funds provided by several oil and gas producers in the San Juan Oil and Gas producing basin and in Cooperation with the Bureau of Land Management Farmington Field Office.

Revegetation of Pipeline Right-of-Way and/or well sites with selected cool and warm season Cultivar's, and Forbes for Palatability, stand establishment, and erosion Control in the Intermountain Region of Northwest New Mexico.

Establishment of native and non-native grasses on pipeline-right-of ways and/or well sites in the San Juan Oil and Gas producing basin.

Richard N. Arnold

Introduction

The true grasses comprise several thousand species and are found in all parts of the world, but it is in the drier, temperate regions they often form the chief vegetation. They owe their dominance in such regions to their ability to survive under all conditions where flowering plants can't live at all, to their aggressive methods of natural vegetative propagation, and to their usually abundant seed crop and its wide dispersal by natural conditions, such as wind and water.

The grasses that persist naturally in any given region over long periods of time are those that have been successful in adjusting themselves to the factors that limit growth. In order to survive, they must withstand extremes of drought, cold, wind, diseases and insects, competition, and grazing.

Objectives

- Select several native or non-native cool and warm season cultivar's that are adapted to the intermountain regions of northwest New Mexico.

- Determine the most adequate time of planting for establishment of the forages.

Material and methods

Research plots were established in April and October 2002 to determine time of planting and stand establishment of selected native and non-native grasses in the San Juan Oil and Gas producing region of northwest New Mexico. Individual plots were planted with a cone seeder with six, ten in rows by 25 ft long. El Paso Tapacitas pipeline right-of-way, BP Americas Arboles 29A, William Production Rosa Units 159A and 354 were all planted the first week in April. XTO Kutz 11E and Pure Resources Rincon Unit 172 were planted in mid October. The experimental design was a randomized complete with four to six replications depending on well site. The native and non-native grasses will be rated on a scale from 1 to 9 with 1 being no stand establishment or survival and 9 being 100% stand establishment or survival. El Paso Tapacitas pipeline right-of-way, BP Americas Arboles 29A, Williams Production Rosa Units 354 and 159A, and XTO Kutz 11E and Pure Resources Rincon Unit 172 were rated for stand establishment or survival in mid July and mid October 2003. Rain gauges have been installed at each well site to determine amount and time of rainfall. Table 1 gives the name of the cultivar or variety planted at each site.

Table 1. Names of cultivars or varieties planted at each site, April and October 2002 and 2003.

Variety or Cultivar	Seeding Rate (lb/pls/A[a])
Arriba Western Wheatgrass	8.0
Chief Intermediate Wheatgrass	10.0
Luna Pubescent Wheatgrass	10.0
Hy-Crest Crested Wheatgrass	5.0
VNS[b] Canada Wild Ryegrass	7.0
Bozoisky Russian Wild Ryegrass	5.0
Critana Thickspike Wheatgrass	6.0
VNS[b] Bottle Brush Squirreltail	8.0
Redondo Arizona Fescue	3.0
Covar Sheep Fescue	2.0
Paloma Indian Ricegrass	6.0
Anatone Bluebunch Wheatgrass	9.0
San Luiz Slender Wheatgrass	6.0
VNS[b] Needle and Threadgrass	8.0
VNS[b] Junegrass	4.0
Alma Blue Gramagrass	6.0

[a] pls = pure live seed

[b] VNS = cultivar or variety not stated

Results and discussion

Stand Establishment or Survival: In Figures 1, 2 and 3, cumulative precipitation collected in 2002 and 2003 is given. In 2002 data showed that WP Rosa 354 had the most precipitation of approximately 7.7 in and BP Americas Arboles 29A had the least amount of precipitation of 4.1 in. Most of the precipitation for all of the four sites fell with in the months of early September to early October. In 2003, WP Rosa 354 has the highest rainfall of 12.4 in and EL Paso Tapacitas had the least amount of rainfall of 5.9 in. The BP Americas Arboles 29A rain gauge was knocked over presumably by wild horses and moisture was not registered correctly since possibly September. In 2004, approximately 1 to 2.5 inches or more precipitation fell on these well sites as compared to 2003. WP Rosa 354 had the highest amount of precipitation of 14.5 inches

In Table 2, data showed that there was no significant differences in stand establishment for El Paso Tapacitas right-of-way plantings. BP Americas Arboles 29A indicated that Chief Intermediate Wheatgrass, San Luis Slender Wheatgrass, and Needle and Threadgrass had the highest stand establishment ratings of 2.3. The Williams Rosa units 354 and 159A indicated that, Paloma Indian Ricegrass and Canada Wild Ryegrass had the highest stand establishment ratings of 1.8 and 2.3. The overall average across all spring plantings, rated for stand establishment approximately 15 months after planting, showed that Arriba Western Wheatgrass, Canada Wild Ryegrass, San Luis Slender Wheatgrass, and Needle and Threadgrass averaged 1.5 or better. Data further showed that Redondo Arizona Fescue and Anatone Bluebunch Wheatgrass had the lowest overall average for stand establishment of 1.0 Of the fall plantings of 2002, XTO Energy Kutz 11E showed that Paloma Indian Ricegrass had the highest stand establishment rating of 4.0 followed by Needle and Threadgrass at 2.7 (Table 3). Pure Resources Rincon 172 did not show any grass stand survival one year after planting. Burlington Resources East 6M will be rated in early summer 2005.

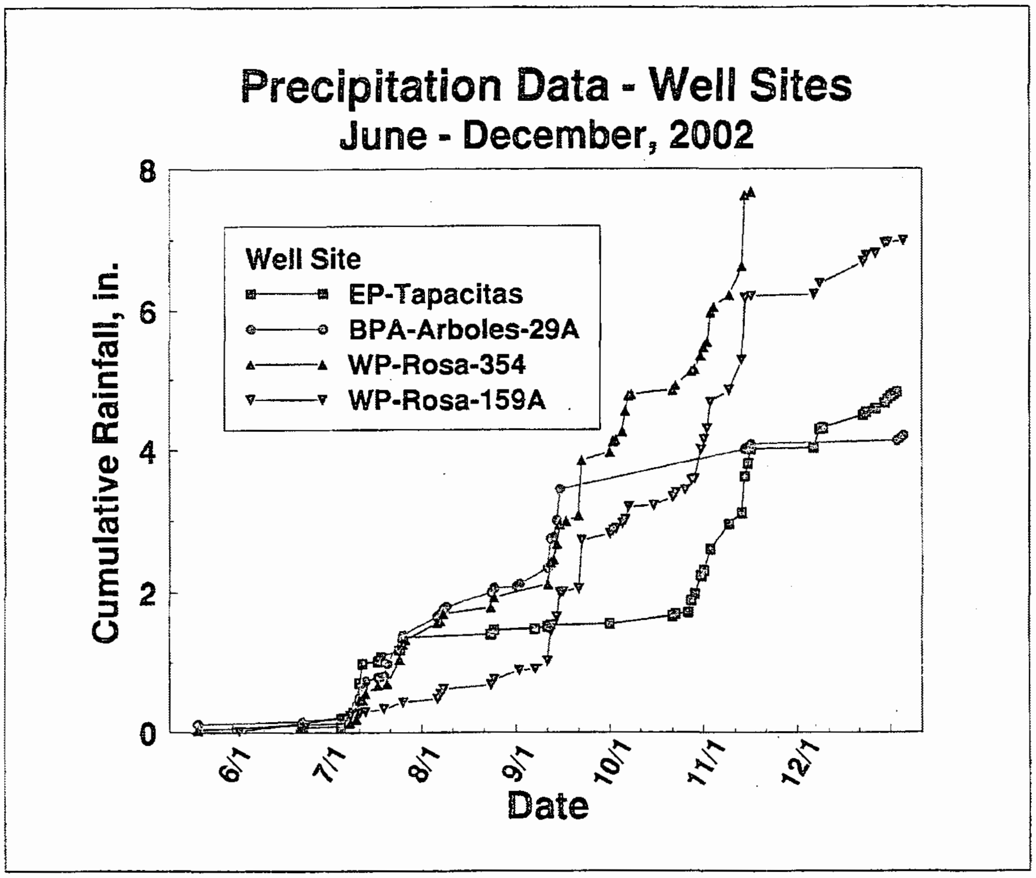


Figure 1. Cumulative precipitation collected from four well sites.

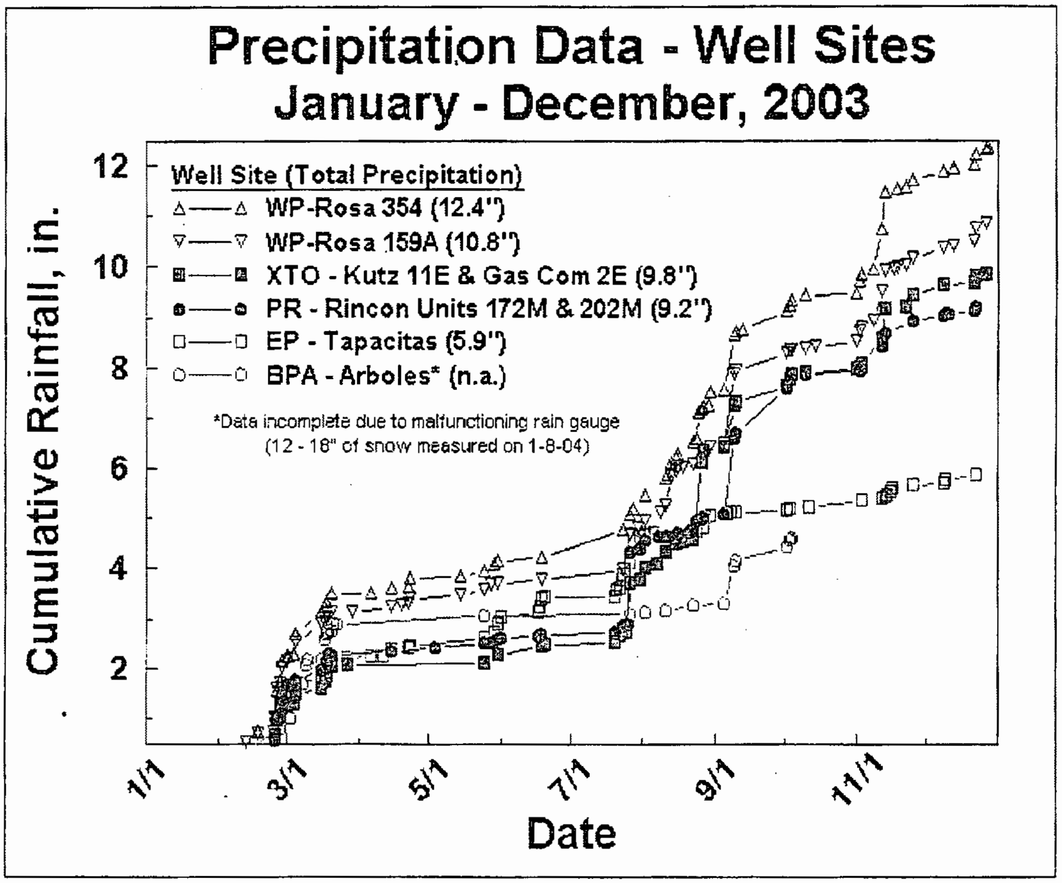


Figure 2. Cumulative precipitation collected from six well sites.

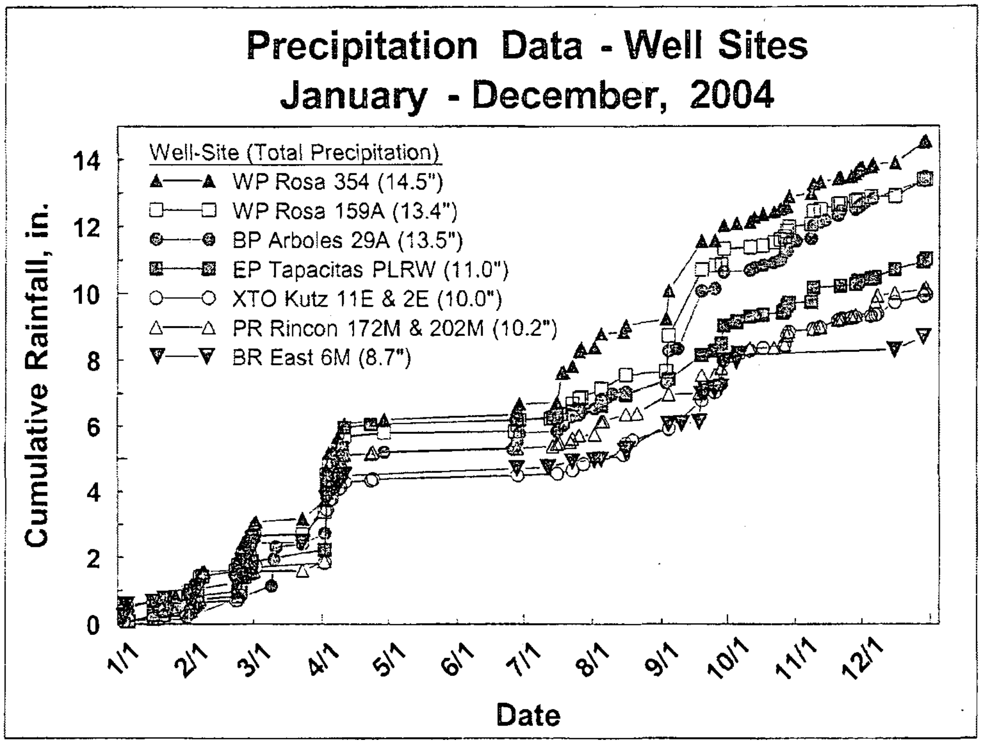


Figure 3. Cumulative precipitation collected from seven well sites.

Table 2. Stand establishment of native and non-native grasses in 2004.

Cultivar	lbs/pls/A	Stand establishment[1]						
		EL Paso Tapacitas[2]	BP Americas Arboles 29A[2]	Williams Prod. Rosa 354[2]	Williams Prod. Rosa 159A[2]	XTO Energy Kutz 11E[3]	XTO Energy 2E[4]	Pure Resources 202M[4]
		no						
Arriba Western Wheatgrass	8.0	1.9	1.8	2.5	2.3	1.6	1.0	1.8
Chief Intermediate Wheatgrass	10.0	1.5	2.8	1.0	1.3	1.2	1.3	1.5
Luna Pubescent Wheatgrass	10.0	1.8	2.1	1.0	1.3	1.2	1.0	1.0
Hy-Crest Crested Wheatgrass	5.0	1.8	2.1	1.0	1.3	1.2	1.0	1.4
Canada Wild Ryegrass	7.0	1.8	2.3	1.6	4.5	3.0	1.0	2.0
Bozoisky Russian Wild Ryegrass	5.0	1.9	1.8	1.4	2.0	1.0	1.0	3.3
Critana Thickspike Wheatgrass	6.0	1.8	2.1	1.0	1.0	1.2	1.0	1.5
Bottlebrush Squirreltail	8.0	1.9	1.6	1.6	2.6	1.4	1.3	2.3
Redondo Arizona Fescue	3.0	1.0	1.9	1.0	1.0	1.0	1.0	1.1
Covar Sheep Fescue	2.0	1.0	2.0	1.0	1.0	1.3	1.0	1.0
Paloma Indian Ricegrass	6.0	2.4	2.1	2.0	4.0	4.1	1.3	1.6
Anatone Bluebunch Wheatgrass	9.0	1.0	2.0	1.0	1.0	1.0	1.0	1.9
San Luis Slender Wheatgrass	6.0	1.8	2.3	1.0	3.6	2.0	1.0	1.8
Needle and Threadgrass	8.0	2.1	2.3	2.0	4.2	2.8	1.3	1.0
Junegrass	4.0	1.0	1.6	1.0	1.0	1.0	1.0	1.0
Alma Blue Grama Grass	6.0	1.0	1.9	1.0	1.0	1.4	1.0	1.3
LSD 0.05		0.6	ns	0.4	1.2	0.8	ns	ns

[1] Stand establishment rated on a scale from 1 to 9 with 1 being no stand establishment or survival and 9 being 100 percent stand establishment or survival.
[2] Areas planted in early April, 2002 and rated in late July, 2004 (second rating).
[3] Area planted in mid October, 2002 and rated in mid October, 2004 (second rating).
[4] Areas planted in late April, 2003 and rated in late July, 2004.

Table 3. Average stand establishment of native and non-native grasses from 2003 to 2004.

Cultivar	lbs/pls/A	EL Paso Tapacitas[2]	BP Americas Arboles 29A[2]	Williams Prod. Rosa 354[2]	Williams Prod. Rosa 159A[2]	XTO Energy Kutz 11E[3]
		Average stand establishment for 2 rating periods[1] — no				
Arriba Western Wheatgrass	8.0	1.6	1.3	1.9	1.9	1.4
Chief Intermediate Wheatgrass	10.0	1.4	2.5	1.0	1.2	1.1
Luna Pubescent Wheatgrass	10.0	1.5	1.9	1.0	1.2	1.3
Hy-Crest Crested Wheatgrass	5.0	1.4	1.8	1.0	1.2	1.1
Canada Wild Ryegrass	7.0	1.4	1.9	1.5	3.4	2.9
Bozoisky Russian Wild Ryegrass	5.0	1.6	1.6	1.3	1.9	1.0
Critana Thickspike Wheatgrass	6.0	1.5	1.9	1.0	1.2	1.1
Bottlebrush Squirreltail	8.0	1.6	1.3	1.5	2.0	1.5
Redondo Arizona Fescue	3.0	1.0	1.4	1.0	1.1	1.0
Covar Sheep Fescue	2.0	1.0	1.5	1.0	1.1	1.3
Paloma Indian Ricegrass	6.0	1.9	1.6	1.9	2.5	4.0
Anatone Bluebunch Wheatgrass	9.0	1.0	1.6	1.0	1.0	1.0
San Luis Slender Wheatgrass.	6.0	1.5	2.3	1.0	2.6	2.0
Needle and Threadgrass	8.0	1.8	2.3	1.8	2.8	2.7
Junegrass	4.0	1.0	1.6	1.0	1.0	1.0
Alma Blue Grama Grass	6.0	1.0	1.7	1.0	1.0	1.3

[1] Stand establishment rated on a scale from 1 to 9 with 1 being no stand establishment or survival and 9 being 100 percent stand establishment or survival.
[2] Averaged stand establishment of areas planted in early April 2002 and rated in mid and late July of 2003 and 2004.
[3] Averaged stand establishment of area planted in mid October 2002 and rated in mid October of 2003 and 2004.

Using Coal Bed Methane Produced Water from Well-Sites for Native and Non-Native Grass Stand Establishment.

Objectives

- Select several native or non-native cool and warm season cultivar's that are adapted to the intermountain regions of northwest New Mexico.
- Applying coal bed methane produced water varying in Total Dissolved Salts, to native and non-native grasses for stand establishment.

Material and methods

Research plots were established in mid August to look at possible coal bed methane produced water for native and non-native grass establishment. The Williams Production (WP) well site Rosa 159A and BP Americas Florence K5M were chosen for this research study. Research plots were planted on August 6 with a cone seeder with six, ten in rows 25 ft long. The experimental design was a randomized complete block with four replications for both sites. Table 1 gives the names of the variety or cultivar planted at both sites. A soil sample was taken from both sites at a depth from 0 to 12 in before and after produced water was applied to determine pH, electrical conductivity (EC), calcium, magnesium, sodium, texture, and sodium adsorption ratio (SAR). Table 2 shows the results of soil samples before and after produced water application. EC describes the amount of electrical current conducted by a saturated soil extract at a fixed temperature. The more salts in solution, the greater the EC reading and the greater the toxicity to plants. This test does not distinguish between salt types, units of measure are usually in decisiemens per meter (dS/m). SAR describes the ratio of sodium relative to calcium and magnesium, to cations that moderate the adverse effects of sodium. The greater the SAR value, the more sodium relative to calcium and magnesium, the greater the toxicity. The exchangeable sodium percentage (ESP) provides a measure of the amount of exchangeable sodium relative to the total cation exchange capacity of the soil expressed as a percentage. As ESP goes up, more exchangeable sodium is available, and the greater the potential for negative plant and soil impacts. A 400-barrel tank (holds approximately 16,800 gallons) was supplied and put on each well site. Produced water was then pumped through a 3 in irrigation pipe consisting of a line spacing of 50 ft and a sprinkler spacing of 30 ft. Rainbird 25 ASFP-TNT sprinkler heads with 11/64 nozzles were used. Produced water was applied on WP Rosa 159A on August 13 and19 and September 17 and 23, 2003 at approximately 1.12 in per application for a total of 4.48 in or 640 barrels (26,880 gallons). Produced water was applied to BP Americas Florence K5M and Conoco/Phillips 242A on August 12 and 20, and September 16, 2003 and April 28, May 10 and May 18, 2004 at approximately 2.8 in per application for a total of 8.4 in or 1200 barrels (50,400 gallons).

Water samples were taken during application and sent to EnviroTech Labs for analysis. Table 3 gives the water analysis for WP Rosa 159A and BP Americas Florence K5M and Conoco/Phillips 242A. Research plots for stand establishment of WP Rosa 159A and BP Americas Florence K5M are given in Table 4. Conoco/Phillips 242A stand establishment evaluations will be rated in 2005.

Results and discussion

Soil Tests: Before and after soil test results are given in Table 2. Soil tests taken before produced water application on WP Rosa 159A showed a pH of 7.32, EC of 3.39 dS/m, sodium content of 533 parts per million (ppm) and an SAR value of 7.32. After application of 4.48 in of produced water pH, EC dS/m, sodium in ppm, and SAR values each increased to 7.53, 5.12, 725 and 9.17. The BP Americas Florence K5M site showed a significant increase in EC levels from 1.71 to 6 dS/m, sodium in ppm (36.3 to 917) and an SAR value (0.6 to 11.6) in the before and after soil samples. Water analysis results for Conoco/Phillips 242A were similar to WP Rosa 159A, with soil analysis values slightly higher after produced water application, even though approximately 8.4 in of produced water was applied as compared to 4.48 in to WP Rosa 159A. Usually an EC in dS/m above 15 from a soil salinity test is unsuitable for most crops and where a decrease in forage production occurs. For example crested wheatgrass, western wheatgrass, slender wheatgrass, Canadian and Russian wild ryegrass, and intermediate wheatgrass, are moderate to tolerant at EC levels ranging from 10 to 15 dS/m. The EC levels in dS/m for WP Rosa 159A, BP Americas Florence K5M and Conoco/Phillips 242A are 6 and below after produced water was applied. An SAR value evaluates the sodium content of the soil. A value of 15 or greater indicates an excess of sodium will be adsorbed by the soil clay particles. Excess sodium can cause soil to be hard and cloddy when dry, to crust badly, and take water very slowly. At all three sites the soil SAR value after produced water was applied were less than 15. Both the EC values in dS/m and SAR values were under the described values for restricting forage production for most of these grasses planted.

Water Analysis: Water analyses are given in Table 3. The water analysis conducted by EnviroTech Labs showed that WP Rosa 159A, BP Americas Florence K5M and Conoco/Phillips 242A, averaged approximately 8,041 milliequivalents per liter (meq/L) of total dissolved salts (TDS), SAR value of 96, EC value in dS/m of 17, 6432 meq/L TDS, SAR value of 86, an EC value in dS/m of14 and 3837 meq/L TDS, SAR value of 69 and an EC value in dS/m of 7.0. A total of 4.48 and 8.4 in of produced water containing the above average values were applied to WP Rosa 159A, BP Americas Florence K5M and Conoco/Phillips 242A during August and September 2003 and April and May 2004. Usually if the irrigation water EC values in dS/m are over 3 except for tolerant crops (usually 8 to 12) and SAR values are above 26 (values below 10 acceptable for production) that water is unsuitable for production. The most influential water quality guideline on crop productivity is the salinity hazard as measured by EC. The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water available to plants, even though a field may appear wet. Usually water with an EC value of 1.15 dS/m contains approximately 2,000 lbs of salt for every acre foot of water. With this in mind approximately 5.5, 8.5 and 4.3 tons of salt were applied to WP 159A, BP Americas Florence K5M and Conoco/Phillips 242A, respectively. While EC is an assessment of all soluble salts in a sample, sodium hazard is defined separately because of its specific detrimental effects on soil physical properties. With higher SAR values the soil becomes more dispersed, will readily crust and have water infiltration and permeability problems. However, many factors including soil texture, organic matter, crop type, climate, irrigation system, and management impact how sodium in the irrigation water affects soils. With the relative small amount of produced water containing high EC and SAR values, it is hoped that most of the salt tolerant native and non-native grasses planted in these studies will survive and become established productive grasses of the these disturbed sites. We will continue this study by selecting one or two more sites for produced water application and grass establishment in the spring of 2005.

Stand Establishment: Stand establishment of native and non native grasses is given in Table 4. Chief intermediate wheatgrass, Hy-crest crested wheatgrass and San Luis slender wheatgrass had the best overall rating for stand establishment, ranging from 2.5 to 1.3

Table 1. Names of cultivars or varieties planted at each site, mid August 2003.

Variety or Cultivar	Seeding Rate (lb/pls/A[a])
Arriba Western Wheatgrass	8.0
Chief Intermediate Wheatgrass	10.0
Luna Pubescent Wheatgrass	10.0
Hy Crest Crested Wheatgrass	5.0
VNS[b] Canada Wild Ryegrass	7.0
Bozoisky Russian Wild Ryegrass	5.0
Critana Thickspike Wheatgrass	6.0
VNS[b] Bottlebrush Squirreltail	8.0
Redondo Arizona Fescue	3.0
Covar Sheep Fescue	2.0
Paloma Indian Ricegrass	6.0
Anatone Bluebunch Wheatgrass	9.0
San Luis Slender Wheatgrass	6.0
VNS[b] Needle and Threadgrass	8.0
VNS[b] Junegrass	4.0
Alma Blue Gramagrass	6.0

[a] pls = pure live seed
[b] VNS = cultivar or variety not stated

Table 2. **Soil sample results before and after produced water application on WP Rosa 159A and BP Americas Florence K5M, 2003 and Conoco/Phillips 242A, 2004.**

Well Site[1]	pH	EC (dS/m	Ca (ppm)	Mg (ppm)	Na (ppm)	SAR	Texture
WP Rosa 159A (before)	7.32	3.39	912	66.8	533	7.32	loam
WP Rosa 159A (after)	7.53	5.12	341	79.7	725	9.17	loam
BP Americas Florence K5M (before)	6.95	1.71	253	42.4	36.3	0.6	loamy sand
BP Americas Florence K5M (after)	6.92	6.0	346	74.6	917	11.6	loamy sand
Conoco/Phillips 242A (before)[2]	7.67	3.37	324	75.0	422	5.49	Loam
Conoco/Phillips 242A (after)[2]	7.76	3.59	282	60.5	526	7.40	Loam

[1] *Before means sample taken before produced water application and after means soil samples taken after last produced water application.*
[2] *Soil samples taken in 2004.*

Table 3. **Produced water analysis for WP Rosa 159A and BP Americas Florence K5M, 2003 and Conoco/Phillips 242A, 2004.**

Well-site	Date	pH	TDS (meq/L)	SAR	EC (dS/m
WP Rosa 159A	9-19-03	8.5	5440	71.1	16.1
WP Rosa 159A	9-17-03	8.0	10682	122.4	17.4
BP Americas Florence K5M	8-12-03	8.3	4190	51.4	11.1
BP Americas Florence K5M	8-20-03	8.4	6980	105.2	17.6
BP Americas Florence K5M	9-16-03	8.1	8126	100.8	13.6
Conoco/Phillips 242A	4-30-04	8.17	3640	66.7	6.31
Conoco/Phillips 242A	5-19-04	8.47	4020	75.7	7.17
Conoco/Phillips 242A	5-23-04	8.12	3850	65.0	6.95

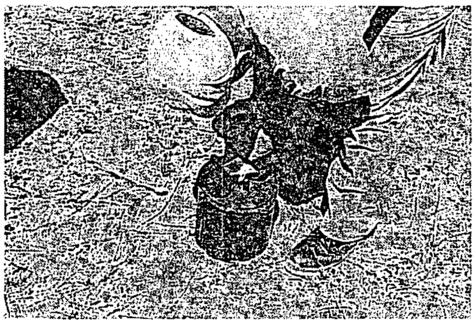
Table 4. Stand establishment of native and non-native grasses approximately 14 months after produced water was used to enhance germination and establishment on well sites WP Rosa 159A and BP Americas Florence K5M, 2004.

Cultivar	lbs/pls/A	Stand establishment[1] WP Rosa 159A[2]	Stand establishment[1] BP Americas Florence K5M[2]
Arriba Western Wheatgrass	8.0	1.5	1.5
Chief Intermediate Wheatgrass	10.0	2.5	1.4
Luna Pubescent Wheatgrass	10.0	2.3	1.3
Hy-Crest Crested Wheatgrass	5.0	2.5	1.3
Canada Wild Ryegrass	7.0	2.4	1.1
Bozoisky Russian Wild Ryegrass	5.0	2.6	1.1
Critana Thickspike Wheatgrass	6.0	1.9	1.3
Bottlebrush Squirreltail	8.0	1.3	1.5
Redondo Arizona Fescue	3.0	1.0	1.3
Covar Sheep Fescue	2.0	1.6	1.5
Paloma Indian Ricegrass	6.0	1.3	1.5
Anatone Bluebunch Wheatgrass	9.0	1.4	1.3
San Luis Slender Wheatgrass	6.0	2.3	1.5
Needle and Threadgrass	8.0	1.8	1.5
Junegrass	4.0	1.7	1.0
Alma Blue Grama Grass	6.0	1.0	1.5
LSD 0.05		1.0	ns

[1] Stand establishment rated on a scale from 1 to 9 with 1 being no stand establishment or survival and 9 being 100 percent stand establishment or survival.
[2] Areas planted in early August, 2003 and rated in late October, 2004

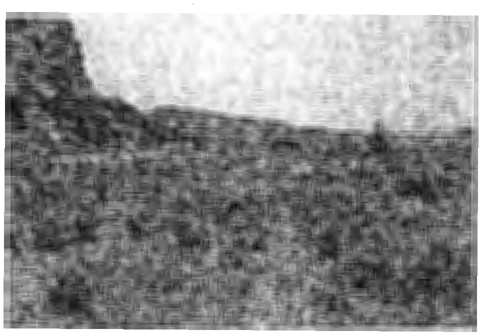
Appendices

Photos of Revegetated Disturbed Sites and Produced Coal Bed Methane Water for Stand Establishment of Selected Native and Non-Native Grasses in the San Juan Oil and Gas Producing Basin.

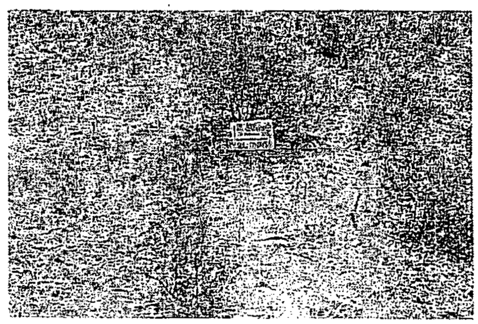


Picture showing rain gauge

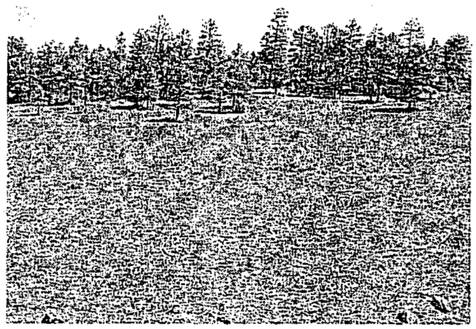
Picture showing rain gauge being read



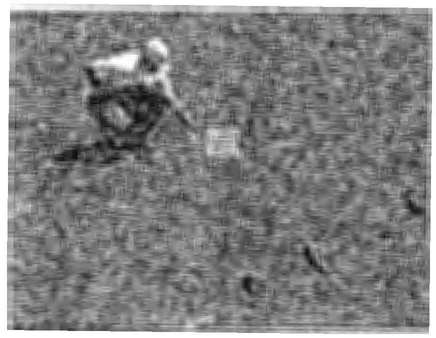
El Paso Tapacitas plot area, July 2003



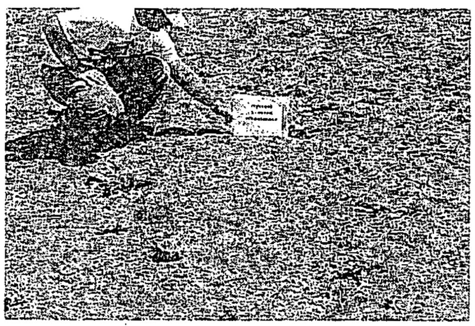
El Paso Tapacitas Paloma Indian Ricegrass, July 2003



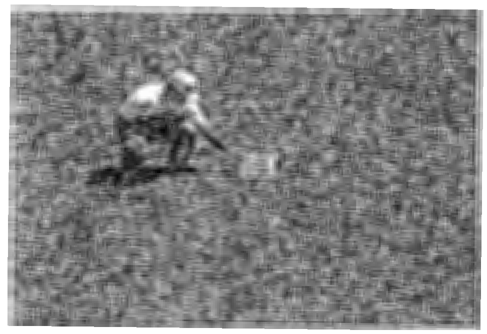
BP Americas Arboles 29A
plot area, July 2003



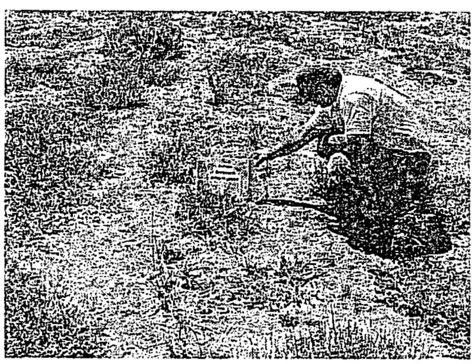
BP Americas Arboles 29
Needle and Threadgrass,
July 2003



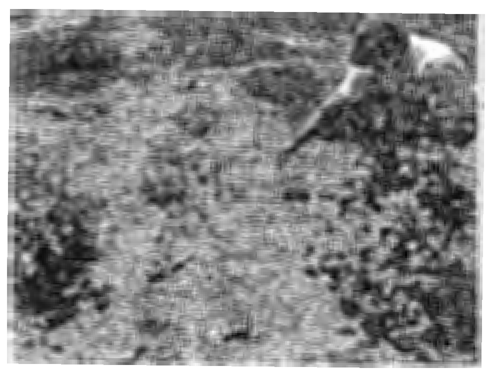
BP Americas Arboles 29
Hy Crest Crested Wheatgrass,
July 2003



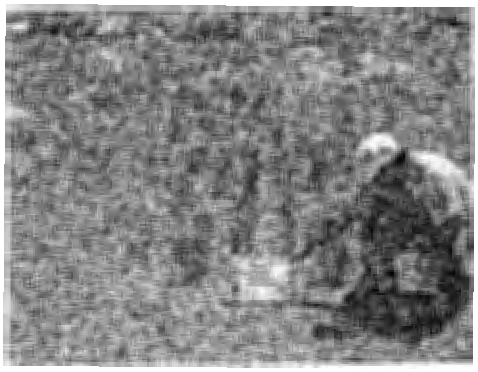
BP Americas Arboles 29
San Luis Slender Wheatgrass,
July 2003



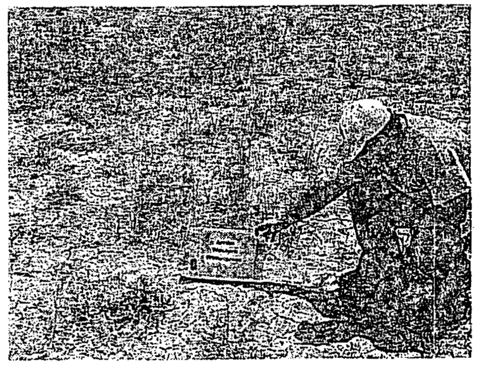
WP Rosa 354 Arriba Western
Wheatgrass, July 2004



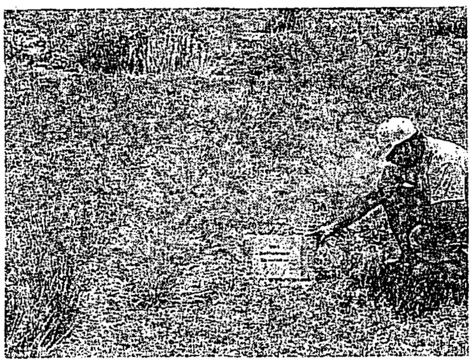
WP Rosa 354 Paloma Indian
Ricegrass, July 2004



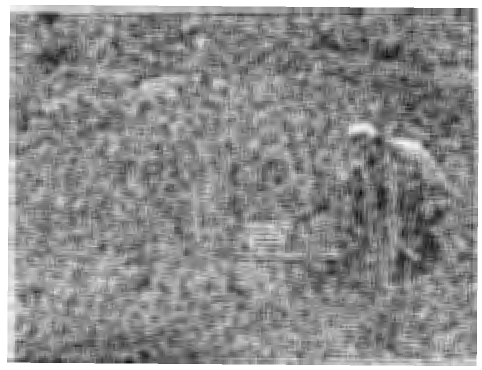
WP Rosa 159A San Luis Slender Wheatgrass, July 2004



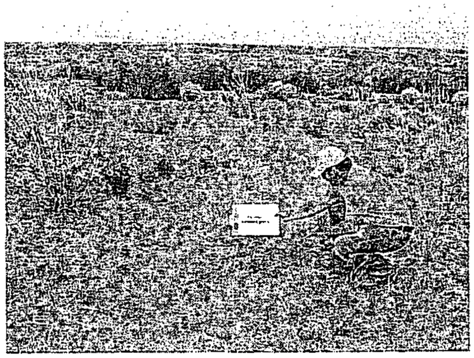
WP Rosa 159A Arriba Western Wheatgrass, July 2004



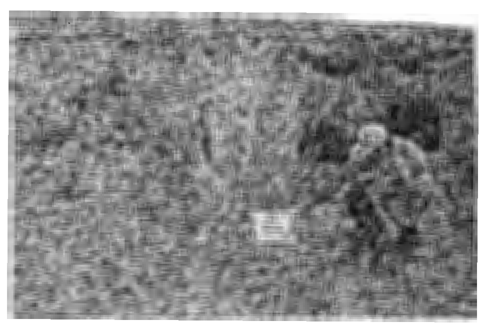
WP Rosa 159A Bottlebrush Squirrel tail, July 2004



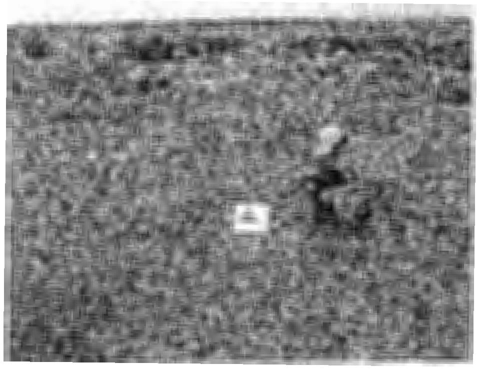
WP Rosa 159A Needle and Threadgrass, July 2004



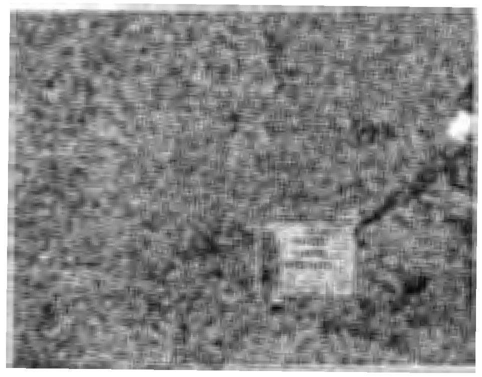
XTO Kutz 11E Paloma Indian Ricegrass, July 2004



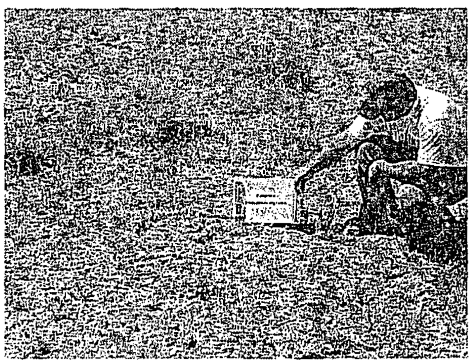
XTO Kutz 11E Needle and Threadgrass, July 2004



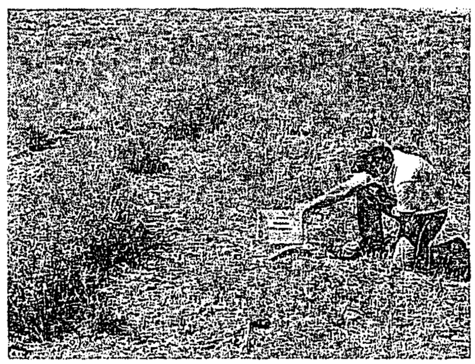
XTO Kutz 11E Canada Wildryegrass,
July 2004



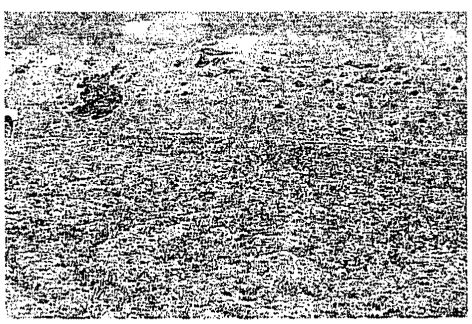
Pure Resources 202M Hycrest
Crested Wheatgrass, July 2004



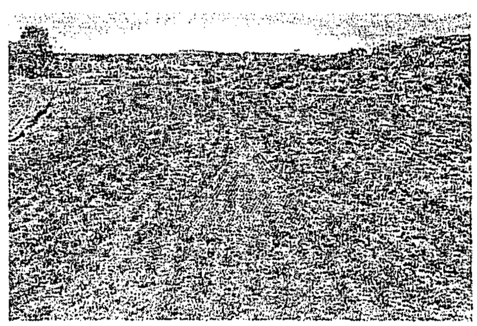
Pure Resources 202M Paloma
Indianricegrass, July 2004



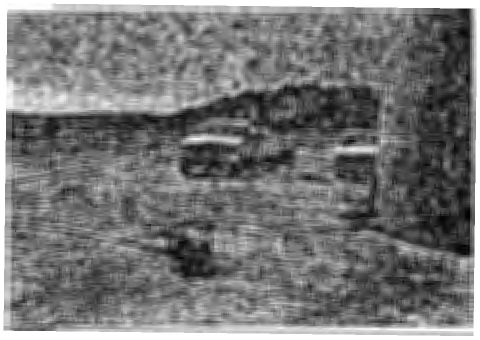
Pure Resources 202M Arriba
Western Wheatgrass, July 2004



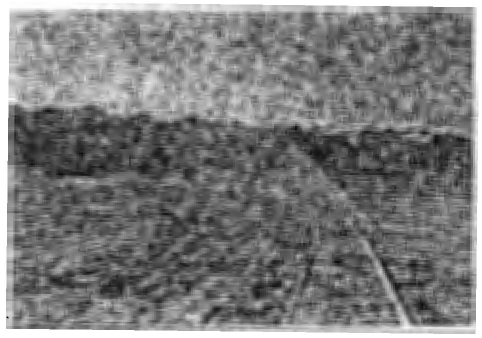
Burlington Resources Brookhaven
10, showing cage and seeded area,
May 2003



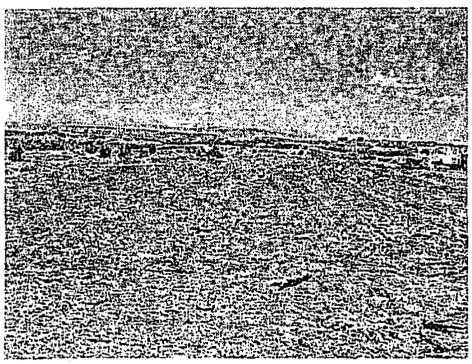
ConocoPhillips 253 showing
cage, and seeded area,
April 2003



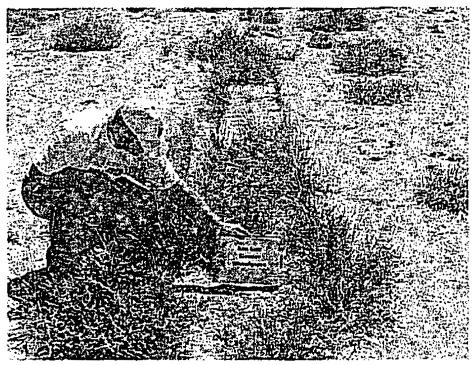
Williams Production Rosa 159A showing 400 barrel tank and pump, August 2003



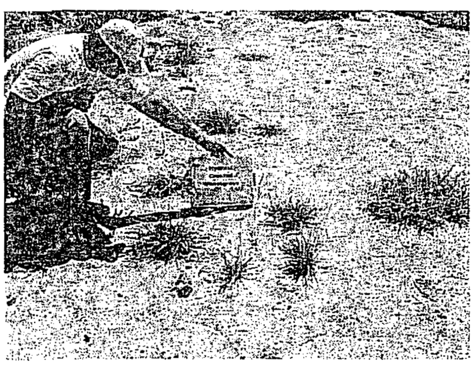
BP Americas Florence K5M showing sprinklers running, August 2003



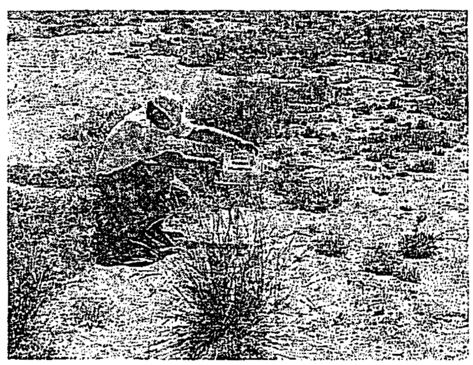
Conoco/Phillips 242A after application of produced water, May 2004



WP Rosa 159A San Luis Slender Wheatgrass stand approx. 14 months after produced water application, October 2004



WP Rosa 159A Hycrest Crested Wheatgrass stand approx. 14 months after produced water application, October 2004



WP Rosa 159A Arriba Western Wheatgrass stand approx. 14 after produced water application, October 2004

Acknowledgements

The author wishes to express his appreciation to the following individuals and/or oil and gas industries for there financial support and/or assistance during the course of this research, Bureau of Land Management Farmington Field Office, Mr. Steve Henke, Mr. Ray Sanchez, Mr. Dale Wirth, Mr. Dave Mankiewicz, Mr. Mark Kelly, Mr. Bill Papich, Mr. Daniel Sandoval, and Mr. Jeff Tafoya, El Paso Field Services, Mr. Ron Sipe and Mr. Joe Velasquez, BP Americas, Mrs. Brittany Benko, Mr. Jerry Huwe, and Mr. Ted Black, Williams Production, Mr. Stergie Katirgis and Mr. Mark Lepich, Burlington Resources, Mr. Chuck Smith and Mr. Terry Lowe, Pure Resources, Mr. Jeff Pickett and Mr. Mike Phillips, XTO Energy, Mr. Del Craddock and Mr. Terry Matthews, Conoco/Phillips, Mr. Bob Wirtanen, San Juan Cattle Growers Association, and New Mexico State University Agricultural Science Center, Mr. Daniel Smeal.