NM STATE UNIVERSITY

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

Research Report 771

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ABSTRACT

Revegetation of disturbed oil and natural gas well sites in semi-arid lands requires rapid stabilization of ecological processes and soil resources. The most frequent goal of revegetation is to re-establish an ecosystem that will structurally and functionally resemble the undisturbed native ecosystem. Moisture is probably the most critical element for revegetation success. Revegetation of these disturbed well sites, which have annual precipitation levels averaging between 8 and 13 in., depends on rainfall received the first two years after planting. In this study, coal bed methane produced water (CBMPW) was applied with a solid-set sprinkler system at rates averaging in total dissolved solids (TDS) of between 3,838 and 7,983 ppm and at irrigation levels ranging from 4.5 to 8.4 in. The study was conducted on Williams Production (WP) Rosa 159A and ConocoPhillips 242A and 207A for native and non-native grass stand establishment. This research found that CBMPW can effectively be used to enhance germination and stand establishment of Arriba, Chief Intermediate, Luna Pubescent, Hycrest Crested, San Luis Slender, and Anatone Bluebunch wheatgrass varieties; Bozoisky Russian and Canada wild ryegrass varieties; and bottlebrush squirreltail. Over 23 million barrels (42 gal/barrel) of CBMPW are produced per year, and normally this water is injected back into the soil profile at a considerable expense. This research has shown that it is possible to think of this water as a benefit instead of waste.

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 that they often form the chief vegetation. They owe their dominance in such regions to their ability to survive under conditions where flowering plants can't live at all, their aggressive methods of natural vegetative propagation, and their abundant seed crop and its wide dispersal by natural conditions, such as wind and water (Wheeler, 1950). The grasses that persist naturally in any given region over long periods of time are those that have adapted to the factors that limit growth, withstanding extremes of drought, cold, wind, diseases, insects, competition, and grazing (Wheeler, 1950).

Activities associated with oil and natural gas exploration and production can damage large areas of semi-arid rangeland in San Juan and Rio Arriba counties of New Mexico. Construction of drill-

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ing sites, roads, pipeline rights-of-way, and on-site disposal of drilling fluids can reduce forage and domesticated and non-domesticated browse production, increase soil erosion, and, in many cases, result in persistent stands of undesirable weeds (McFarland et al., 1987; U.S. Department of the Interior, 2006). In extreme climatic regimes, desert and/or tundra ecosystems have often been cited as being among the most difficult biome types to revegetate following disturbance (Chambers and Wade, 1992; Allen, 1988).

In the semi-arid region of northwest New Mexico, moisture is the most critical element for revegetation success. Revegetation of disturbed areas with annual rainfall levels less than 8 to 10 in. depends heavily on the amount and timing of rainfall after planting (Arnold, 2009; Wright, 2005). Seeding in these areas of low rainfall is problematic and may require several re-seeding attempts, depending on weather patterns in any given year (Wright, 2005).

In the San Juan Oil and Gas Producing Basin in the intermountain region of northwest New Mexico, it is estimated that 20,000 to 30,000 acres of disturbed lands created by oil and natural gas drilling will need to be revegetated during the next 10 years (S. Henke and D. Wirth, personal communication, 2009).

Annual rainfall in this area ranges from 8 to 12 in., depending on location. The San Juan Basin is located in the Four Corners region, which consists of counties in southwest Colorado, northwest New Mexico, northeast Arizona, and southeast Utah. It is the leading producer, by volume, of coal bed methane in the world. These wells produce not only coal bed methane (a type of natural gas) but also low to high amounts of coal bed methane produced water (CBMPW). This water is high in total dissolved solids (TDS), making it either saline, sodic, or saline-sodic. This CBMPW is considered waste by the Oil and Gas Conservation Division of New Mexico, and approximately 98% of this water is injected back down into the well formation by deep salt water disposal (SWD) (Cox et al., 1993; D. Mankiewicz, S. Henke, and K. Roberts, personal communication, 2010).

About 23 million barrels (42 gal/barrel) of CBMPW were produced in the San Juan Basin in 2009 (J. Prouty, personal communication, 2010). At an approximate cost of $2.00 per barrel for hauling and injecting this CBMPW, the average annual disposal cost is about $46 million per year (N. Atcitty, personal communications, 2010).

Because of the limited rainfall in the basin, germination of non-irrigated native and non-native grass mixtures has been minimal. In the Powder River Basin of Wyoming, King et al. (2004) found that plant biomass on sites irrigated with CBMPW exceeded that of non-irrigated sites after two to three seasons.

In the same region of Wyoming, Bauder and Garcia (2008) indicated that selected native and introduced livestock forage plants irrigated with CBMPW with low concentrations of total salts can become well-adapted and have a yield potential 300 to 400% higher than non-irrigated species.

This research discusses results of direct land application of CBMPW applied at different TDS levels on three well sites that were planted with selected native and non-native grasses in northwest New Mexico.

OBJECTIVE

Demonstrate beneficial use of CBMPW with different levels of TDS applied by sprinkler application for stand establishment of native and non-native grasses.

MATERIALS AND METHODS

Research plots were planted on August 6, 2003; April 21, 2004; and April 10, 2005, on disturbed well sites of Williams Production (WP) Rosa 159A and ConocoPhillips 242A and 207A to evaluate the effects of CBMPW application on native and non-native grass stand establishment. Table 1 indicates the location, date of planting, and the years research plots were evaluated. Research plots were planted with a cone seeder in six 10-in. rows, each 25 ft long. The experimental design was a randomized complete block with four replications. Table 2 gives the names of the variety or cultivar and pounds of pure live seed (pls) per acre (lb pls/ac) planted at all three sites. Soil samples were taken from all sites at a depth of 0 to 12 in. approximately two weeks before and after CBMPW application. Soil samples were analyzed by the Navajo Agricultural Products Industry Soils Lab of Farmington, NM, for pH, electrical conductivity (EC), calcium (Ca), magnesium (Mg), sodium (Na), texture, and

Table 1. Location, Date of Planting, and Year Research Plots were Evaluated

Location	Date of planting	Years evaluated
Williams Production Rosa 159A	August 6, 2003	3
ConocoPhillips 242A	April 21, 2004	2
ConocoPhillips 207A	April 10, 2005	1

Table 2. Names of Cultivars or Varieties Planted at Each Site, 2003 to 2005

Variety or cultivar	Seeding rate (lb pls/ac)
Arriba Western wheatgrass	8.0
Chief Intermediate wheatgrass	10.0
Luna Pubescent wheatgrass	10.0
Hycrest Crested wheatgrass	5.0
VNS[a] Canada wild ryegrass	7.0
Bozoisky Russian wild ryegrass	5.0
Critana Thickspike wheatgrass	6.0
VNS[a] bottlebrush squirreltail	8.0
Redondo Arizona fescue	3.0
Paloma Indian ricegrass	6.0
Anatone Bluebunch wheatgrass	9.0
VNS[a] Junegrass	4.0
Covar sheep fescue	2.0
San Luis Slender wheatgrass	6.0
VNS[a] needle and threadgrass	8.0

[a]VNS = variety or cultivar not specified.

sodium adsorption ratio (SAR). Table 3 shows the results of soil samples before and after CBMPW application.

A 400-barrel (16,800 gal) tank for storing the CBMPW was provided at each well site. The CBMPW was supplied by a water hauling trucking service and was from the same salt water disposal (SWD) unit for each site. It was then pumped through a 3-in. aluminum irrigation system with a lateral spacing of 50 ft and a sprinkler spacing of 30 ft using Rainbird 25 ASFP-TNT sprinkler heads with 11/64-in. nozzles. Table 4 shows the application dates and amounts of CBMPW applied at each study site. The CBMPW was applied to WP Rosa 159A on August 13 and 19 and September 17 and 23, 2003, at 1.12 in. per application for a total amount of 4.5 in.; CBMPW was applied to ConocoPhillips 242A and 207A on April 28 and May 10 and 18, 2004, and May 12, 19, and 25, 2005, at 2.8, 2.8, 2,8, 2.8, 1.4, and 1.4 in. per application, respectively, for a total amount of 8.4 and 5.2 in. in 2004 and 2005, respectively (Table 4).

Water samples taken during each application were analyzed by EnviroTech Laboratory for pH, TDS, SAR, and EC (Table 5), with averages given in Table 6. The native and non-native cool-season grasses were rated on a scale from 1 to 9, with 1 being no stand establishment or survival and 9 being 100% stand establishment or survival. Stand establishment ratings were subjected to analysis of variance, and treatment means were separated by the Fisher's LSD test at the 5% level of significance (CoHort Software, 2001). There were no year by treatment interactions in establishment ratings for WP Rosa 159A and ConocoPhillips 242A, so data were combined. Evaluation of research plots for stand establishment at WP Rosa 159A and ConocoPhillips 242A and 207A is given in Table 7.

RESULTS AND DISCUSSION

Rainfall averages: Rainfall measurements were taken at a Community Collaborative Rainfall, Hail and Snow Network observation site in Ignacio, CO, approximately 2.1 miles NNE from the study sites. From August to December 2003, 2.8 in. of precipitation were measured at the site; in 2004, 2005, and 2006, 10.9, 16.8, and 13.4 in. of precipitation were measured, respectively. Average annual precipitation measured at this site for 2004 to 2006 was 13.7 in.

Soil tests: Soil tests taken before and after CBMPW application averaged a pH of 7.3 and 7.6, EC of 2.6 and 3.3 deciSiemens per meter (dS/m), Ca content of 445 and 235 ppm, Mg content of 54 and 52 ppm, Na content of 405 and 477 ppm, and SAR of 5 and 7.1, respectively.

Electrical conductivity 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 dS/m. Usually, soils with an EC of 15 dS/m or above are unsuitable for most crops, and a severe decrease in forage production occurs. For example, crested wheatgrass, western wheatgrass, slender wheatgrass, Canadian and Russian wild ryegrass, and intermediate wheatgrass are moderately tolerant to tolerant at EC levels ranging from 10 to 15 dS/m. All three locations showed soil EC

Table 3. Soil Sample Results Before and After Coal Bed Methane Produced Water (CBMPW) Application on WP Rosa 159A, 2003; ConocoPhillips 242A, 2004; and ConocoPhillips 207A, 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
ConocoPhillips 242A (before)	7.67	3.4	324	75	422	5.5	loam
ConocoPhillips 242A (after)	7.76	3.6	282	61	526	7.4	loam
ConocoPhillips 207A (before)	7.13	1.0	100	21	102	2.4	sandy clay loam
ConocoPhillips 207A (after)	7.39	1.2	84	16	180	4.7	sandy clay loam

[a] "before" = soil samples taken before CBMPW application, and "after" = soil samples taken after last CBMPW application.

Table 4. Location, Date, and Total Amount of Coal Bed Methane Produced Water (CBMPW) Applied, 2003 to 2005

Location	Date CBMPW was applied	Amount of CBMPW applied at each application (in.)	Total amount of CBMPW applied at each location (in. and gal)
Williams Production Rosa 159A	August 13 and 19, September 17 and 23, 2003	1.12	4.5 in., or 26,880 gal
ConocoPhillips 242A	April 28, May 10 and 18, 2004	2.8	8.4 in., or 50,400 gal
ConocoPhillips 207A	May 12, 19, and 25, 2005	2.8, 1.4, and 1.4	5.2 in., or 33,600 gal

Table 5. Coal Bed Methane Produced Water (CBMPW) Analysis for WP Rosa 159A, 2003; ConocoPhillips 242A, 2004; and ConocoPhillips 207A, 2005

Location	Application date	pH	TDS (ppm)	SAR	EC (dS/m)
WP Rosa 159A	8-13-2003	8.5	5,440	71	16.1
WP Rosa 159A	8-19-2003	8.0	10,682	122	17.4
WP Rosa 159A	9-17-2003	8.2	7,785	96	17.2
WP Rosa 159A	9-23-2003	8.1	8,025	105	16.9
ConocoPhillips 242A	4-28-2004	8.1	3,640	67	6.3
ConocoPhillips 242A	5-10-2004	8.5	4,020	76	7.1
ConocoPhillips 242A	5-18-2004	8.1	3,850	65	7.0
ConocoPhillips 207A	5-12-2005	8.7	2,464	51	3.7
ConocoPhillips 207A	5-19-2005	9.8	6,030	250	9.5
ConocoPhillips 207A	5-25-2005	9.3	4,660	80	7.5

Table 6. Coal Bed Methane Produced Water (CBMPW) Analysis Averages for WP Rosa 159A, 2003; ConocoPhillips 242A, 2004; and ConocoPhillips 207A, 2005

	pH	TDS (ppm)	SAR	EC (dS/m)
Location	- - - - - - - - - - - Averages - - - - - - - - - - -			
WP Rosa 159A	8.2	7,983	99	16.9
ConocoPhillips 242A	8.2	3,838	69	6.8
ConocoPhillips 207A	9.3	4,387	127	6.9

Table 7. Three-Year, Two-Year, and One-Year Average Stand Establishment of Native and Non-Native Grasses, Rated from 2004 to 2006

		Stand establishment[b]		
Cultivar[a]	lb pls/ac	WP Rosa 159A[c]	ConocoPhillips 242A[d]	ConocoPhillips 207A[e]
Arriba Western wheatgrass	8.0	1.8	4.8	4.6
Chief Intermediate wheatgrass	10.0	2.6	2.8	2.5
Luna Pubescent wheatgrass	10.0	2.6	2.8	2.5
Hycrest Crested wheatgrass	5.0	2.8	4.5	4.3
VNS Canada wild ryegrass	7.0	2.5	6.5	6.5
VNS Bozoisky Russian wild ryegrass	5.0	2.7	2.8	2.8
Critana Thickspike wheatgrass	6.0	2.0	6.5	6.3
VNS bottlebrush squirreltail	8.0	1.3	6.0	5.6
Redondo Arizona fescue	3.0	1.0	1.2	1.5
Paloma Indian ricegrass	6.0	1.5	1.2	1.5
Anatone Bluebunch wheatgrass	9.0	1.5	5.5	5.3
San Luis Slender wheatgrass	6.0	2.6	6.5	6.3
VNS needle and threadgrass	8.0	2.0	4.1	3.4
VNS Junegrass	4.0	1.5	1.1	1.3
Covar sheep fescue	2.0	1.6	1.6	1.5
Alma blue grammagrass	6.0	1.0	1.3	1.3
LSD 0.05		0.5	0.3	

[a] VNS = variety or cultivar not specified.

[b] Rated on a scale from 1 to 9, with 1 being no stand establishment and 9 being 100% established.

[c] Disturbed area planted on August 6, 2003. CBMPW applied on August 13 and 19 and September 17 and 23, 2003, with a total amount of 4.5 in. Rated on October 26, 2004; July 28, 2005; and July 26, 2006.

[d] Disturbed area planted on April 21, 2004. CBMPW applied on April 28 and May 10 and 18, 2004, with a total amount of 8.4 in. Rated on July 29, 2005, and July 26, 2006.

[e] Disturbed area planted on April 10, 2005. CBMPW applied on May 12, 19, and 25, 2005, with a total amount of 5.2 in. Rated on July 26, 2006.

levels below 6 dS/m after CBMPW was applied (Table 3).

An SAR value evaluates the sodium content of the soil. The SAR describes the ratio of sodium relative to calcium and magnesium and to other cations that moderate the adverse effects of sodium. The greater the SAR value, the more sodium relative to calcium and magnesium, and the greater the toxicity to plants. An SAR value of 15 or greater indicates an excess of sodium will be absorbed by the soil clay particles, inhibiting germination and growth of desired plants. Excess sodium can cause soil to be hard and cloddy when dry, to crust badly, and to absorb water very slowly, causing excess runoff and soil erosion. The SAR values of all three sites were below 10 after CBMPW was applied, which is below the described values for restricting forage production for most of the grasses planted in this study (Table 3).

Water analysis: Individual water analysis results are given in Table 5 and averages are given in Table 6. Total dissolved solids indicates that the water sample contained mainly sodium, chloride, and calcium carbonate. The pH of CBMPW applied at the WP Rosa 159A site averaged 8.2, and TDS, SAR, and EC averaged 7,983 ppm, 99, and 16.9 dS/m, respectively (Table 6). Average CBMPW values for ConocoPhillips 242A and 207A were a pH of 8.2 and 9.3, TDS of 3,838 and 4,387 ppm, SAR of 69 and 127, and EC of 6.8 and 6.9 dS/m, respectively (Table 6). Usually, if the irrigation water EC value is more than 3 dS/m (except for tolerant crops, usually 8 to 12 dS/m) and SAR value is more than 26 (values less than 10 are acceptable for production), that water is unsuitable for production.

The water quality guideline with the most influence on crop productivity is the salinity hazard as measured by EC. The primary effect of high EC water on crop productivity is the plant's inability 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 1.0 dS/m contain approximately 2,000 lb of salt for every acre foot of water applied (Bauder et al., 2007). With this in mind, approximately 6.3, 4.7, and 2.9 tons of salt were applied to WP Rosa 159A and ConocoPhillips 242A and 207A, 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 (usually above 15) the soil becomes more dispersed, will readily crust, and will have water infiltration and permeability problems. However, many factors, including soil texture, organic matter, crop type, climate, irrigation system, and management, determine how sodium in the irrigation water affects soils and desirable plants. A relatively small amount of CBMPW had high EC and SAR values, and we hope that most of the salt-tolerant native and non-native grasses planted in these studies will survive and become established, productive grasses on these disturbed locations.

Stand establishment: Grass stand establishment averages are shown in Table 7. At the WP Rosa 159A site, three-year average stand establishment ratings ranged from 2.5 to 2.8 for Chief Intermediate, Luna Pubescent, Hycrest Crested, and San Luis Slender wheatgrass varieties, and variety not specified (VNS) Canada and Bozoisky Russian wild ryegrass. At the ConocoPhillips 242A site, Arriba Western, Hycrest Crested, Critana Thickspike, Anatone Bluebunch, and San Luis Slender wheatgrass varieties; VNS Canada wild ryegrass; and VNS bottlebrush squirreltail all had average stand establishment ratings above 4.3 two years after CBMPW was applied (Table 7). At ConocoPhillips 207A, Arriba Western, Hycrest Crested, Critana Thickspike, Anatone Bluebunch, and San Luis Slender wheatgrass varieties and VNS Canada and Bozoisky Russian wild ryegrass averaged 3.0 or better approximately 15 months after planting (Table 7). On both ConocoPhillips well sites, VNS Canada wild ryegrass and Critana Thickspike and San Luis Slender wheatgrass varieties had ratings of 6 or better (Table 7).

CONCLUSIONS

Moisture is probably the most critical element for revegetation success. Revegetation of these disturbed well sites, which have average annual precipitation levels of 8 to 13 in., depends on rainfall received the first two years after seeding. Coal bed methane produced water is considered a waste by the New Mexico Oil and Gas Conservation Department, and over 98% of CBMPW is injected back into the rock formation by salt water disposal (SWD). Hauling and injecting this CBMPW is expensive. The CBMPW applied at these three study sites had TDS levels ranging from 3,838 to 7,983 ppm. Arriba Western, Chief Intermediate, Luna Pubescent, Hycrest Crested, Critana Thickspike, Anatone Bluebunch, and San Luis Slender wheatgrass varieties; VNS Canada and Bozoisky Russian wild ryegrass varieties; and VNS bottlebrush squirreltail had the ability to germinate and demonstrated the potential to become established stands. In the future, we may want to think of CBMPW as a benefit for rangeland grass establishment in the semi-arid intermountain region of northwest New Mexico.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to the following individuals and/or oil and gas companies for their 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, ConocoPhillips; Mr. Bob Wirtanen; and the San Juan Cattle Growers Association.

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October 2010 **Las Cruces, NM**