**Mailing Address**:
Water Resources Data System
University of Wyoming, Dept 3943
1000 E University Avenue
Laramie, WY 82071

**Physical Address:**
Wyoming Hall, Room 249
University of Wyoming
Laramie, WY 82071

**Phone:** (307) 766-6651
**Fax:** (307) 766-3785

***Funding for WRDS and the creation of this electronic document was provided by the Wyoming Water Development Commission (http://wwdc.state.wy.us)***

# *EXECUTIVE SUMMARY*

*for:*

*Spotted Horse Creek Confluence with the Powder River*

# THREE HORSES WATERSHED PLAN

# LEVEL I STUDY

Prepared for:

**Wyoming Water Development Commission**

Submitted by:

***EnTech, Inc.***

***Consulting Engineers***

***Sheridan, Wyoming***

***in association with***

***Environmental Design Engineering***

***RIMCON, L.L.C.***

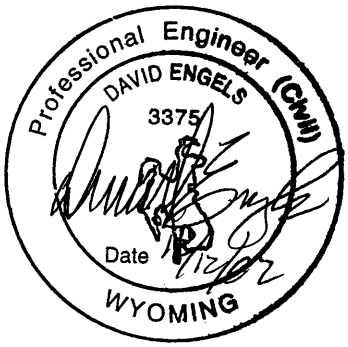
**December, 2002**

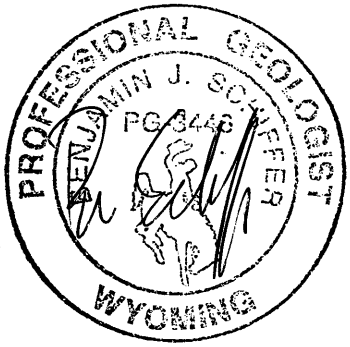
# *EXECUTIVE SUMMARY*

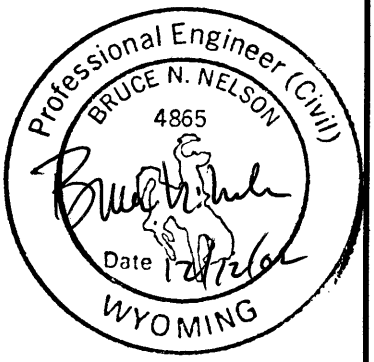
*for:*

# THREE HORSES WATERSHED PLAN

# LEVEL I STUDY




Prepared for:

**Wyoming Water Development Commission**

Submitted by:

***EnTech, Inc.***

***Consulting Engineers***

***Sheridan, Wyoming***

***in association with***

***Environmental Design Engineering***

***RIMCON, L.L.C.***

**December, 2002**

# TABLE OF CONTENTS


| | | Page |
|---|---|---|
| 1. | INTRODUCTION | 1 |
| 2. | DESCRIPTIONS OF WATERSHEDS | 2 |
| 3. | COAL BED METHANE IMPACTS | 4 |
| 4. | WATERSHED MANAGEMENT ALTERNATIVES | 4 |
| 5. | ANALYSIS OF WATER MANAGEMENT ALTERNATIVES AND RECOMMENDED WATERSHED MANAGEMENT PLAN | 6 |
| 6. | PROJECT FINANCING PLAN | 10 |
| 7. | PATH FORWARD | 10 |


## TABLES


| TABLE NO. | TITLE | |
|---|---|---|
| 1 | SURFACE AND MINERALS OWNERSHIP | 1 |
| 2 | CLIMATOLOGICAL DATA | 3 |
| 3 | WDEQ CLASSIFIED STREAMS AND TRIBUTARIES | 3 |
| 4 | SUMMARY OF WATER MANAGEMENT ALTERNATIVES | 7 |


## FIGURES


| FIGURE NO. | TITLE |
|---|---|
| 1 | LOCATION MAP |
| 2 | THREE HORSES STRATIGRAPHIC COLUMN |

# 1. INTRODUCTION

In September 2000, the Lake DeSmet Conservation District and Campbell County Conservation District, in cooperation with local landowners, industry, and state and federal agencies, submitted a joint application to the Wyoming Water Development Commission to develop management plans for three watersheds that are tributary to the Powder River in northeastern Wyoming. These watersheds are the Dead Horse Creek Watershed (DHCW), Wild Horse Creek Watershed (WHCW) and Spotted Horse Creek Watershed (SHCW), together known as "the Three Horses". The principal reason that these diverse groups outlined above submitted this application was due to their concern about the potential cumulative impacts of existing and future development of coal bed methane gas (CBM) in the three basins.

CBM development is one of the critical issues currently facing the Three Horses watersheds. With the ever-increasing demand for energy sources by the United States, there is little doubt that the important energy reserves within the Powder River Basin (PRB), of which CBM is a significant part, will be developed. As of August 2002, over 9,000 CBM wells have been permitted in the PRB by the State of Wyoming Oil and Gas Conservation Commission. Of this number, approximately 3400 wells have been permitted in the Three Horses. Estimates place the total number of CBM wells to eventually be drilled in the PRB at over 51,000.

Although CBM development is occurring in several areas within Wyoming, the current focus is within northeastern Wyoming, and Campbell, Johnson and Sheridan Counties in particular. The DHCW is located within Campbell and Johnson Counties, and both the WHCW and SHCW are located within Campbell and Sheridan Counties. Thus it is understandable that the conservation districts within these counties have taken a considerable interest in protecting these watersheds from impacts that may occur as a result of this development.

# 2. DESCRIPTIONS OF WATERSHEDS

The Three Horses watersheds encompass lands within northeastern Wyoming, and Campbell, Johnson and Sheridan Counties in particular (See Figure 1). The total area of the Three Horses watersheds is approximately 614 square miles. The highest elevation in the three watersheds is 5,184 feet (located in the DHCW), and the lowest elevation is 3,520 feet (located in the SHCW). These three watersheds lie within the larger Upper Powder River watershed.

Ownership of the surface and the minerals beneath within the Three Horses watersheds is depicted in Table 1.

**Table 1**
**Surface and Minerals Ownership**

| Ownership | Federal (sq. mi.) | State and Private (sq. mi.) |
|---|---|---|
| **Dead Horse Creek Watershed** | | |
| Surface | 29.2 | 124.4 |
| Minerals | 123.9 | 29.7 |
| **Wild Horse Creek Watershed** | | |
| Surface | 64.8 | 300.2 |
| Minerals | 225.4 | 139.6 |
| **Spotted Horse Creek Watershed** | | |
| Surface | 9.9 | 86.4 |
| Minerals | 51.0 | 45.3 |
| **Total Surface Ownership** | 103.9 (17%) | 511.0 (83%) |
| **Total Minerals Ownership** | 400.3 (65%) | 214.6 (35%) |

As can be seen, while the vast majority of surface lands within the Three Horses watersheds are owned by either the State or private interests, the majority of minerals are owned by the federal government.

Figure 2 portrays a typical stratigraphic column for the Three Horses drainage areas. Covering the entire drainages (except for the main channel areas and local colluvial deposits) is the Wasatch Formation. The Wasatch Formation is composed of fluvial sands, silts and shales, as well as paludal carbonaceous material. Groundwater in the Wasatch Formation is normally confined in lenticular sandstones, coals and clinker beds, and it is generally local in nature.

Beneath the Wasatch is the Fort Union formation, which represents the principal coal-bearing and thus CBM-laden formation. Various coal seams exist within the Fort Union formation, with a maximum seam thickness of 160 feet in the Wyodak member of the Fort Union. The general dip of the Fort Union formation within the Three Horses watershed is to the west at approximately 1°. Underlying the Tongue River member of the Fort Union formation is the Lebo Shale. This confining unit, composed of carbonaceous shales and thin, discontinuous fine-grained sandstones, is a barrier to vertical groundwater movement throughout the PRB.

Lower, Cretaceous aquifers of importance consist of the Lance Formation, Fox Hills Sandstone and Pierre Shale formations. With sediments derived from the regression of Late Cretaceous seas, the units represent a coarsening upward sequence, thus the fine-grained shales of the Pierre act as a significant barrier (i.e., aquitard) to water contained in the coarser Fox Hills and Lance formations.

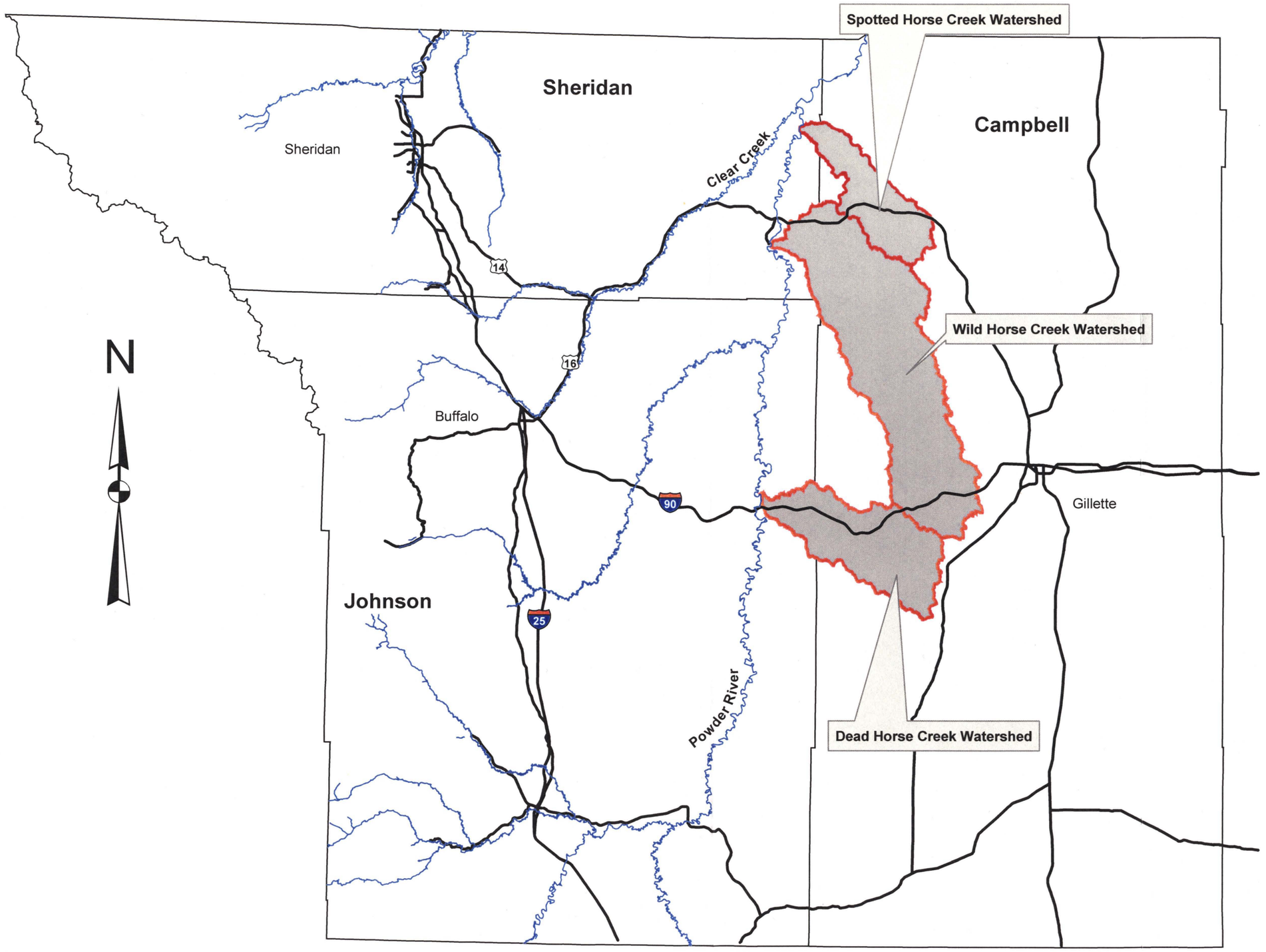
Soils within the Three Horses drainage areas are comprised principally of fine-textured soils, with over 80 percent of the soils within the DHCW and WHCW being of this texture. The SHCW has more sandy and coarse loamy soils than the other two watersheds, with only 66% of its soils being fine-textured in nature. Figures portraying soils mapping units for each watershed are contained within the final report.

The flow of all three main streams and their tributaries is intermittent. As a result, there is very little historical baseline surface water quality data available. A gaging station currently exists on Wild Horse Creek, whereas there is no gaging station on Spotted Horse Creek and the gaging station on Dead Horse Creek is no longer in use. Surface water is generally sulfate-based, although its electrical conductivity (EC), an indication of the water's salinity, varies widely. Sodium Adsorption Ratio (SAR) values, a measurement of the sodium cation in relation to the calcium and magnesium cations, for all baseline surface water samples taken is generally low (less than 11). With few exceptions, the concentrations of parameters within the surface water quality sample suites taken generally fall within the limits for the designated purposes of irrigation and livestock/wildlife watering as defined by the Wyoming Department of Environmental Quality (WDEQ).

Important groundwater resources exist in the Three Horses watersheds in both the Wasatch and Fort Union formations. Groundwater mostly from the Fort Union formation must be extracted in order to allow CBM to be produced.

Large variations in groundwater quality often exist between aquifers, depending upon distance from recharge zone (both vertically and horizontally), depth and nature of confinement. Where the potential for communication with surface water exists, the water type is likely to be sodium sulfate, while deeper groundwater (i.e., farther from the recharge area, or confined) is a sodium bicarbonate water type. For the Fort Union formation, EC values for the groundwater quality samples analyzed varied from 860 to 3800 μmhos/cm, and SAR values varied from 9 to 32.

Erodibility of soils within the Three Horses watersheds due to water and wind varies with soil texture. Silts and silt loams are most susceptible to water erosion. In contrast, fine sands, loamy sands, and coarse sandy loams of the area are most susceptible to wind erosion. Water erosion primarily occurs during spring snowmelt and in summer from thunderstorms that cause intensive runoff and flash




This data has been produced for informational purposes only. Although data represented on this figure is believed to be accurate at the time of printing, it is being provided merely on an "as is" basis without warranties of any kind, either expressed or implied.

| DESIGN | NO. | AMENDMENT | DATE | INT. |
|---|---|---|---|---|
| JDS | | | | |
| CHECK DTE | | | | |
| DATE DEC 02 | | | | |

PROJECT NO. 01006

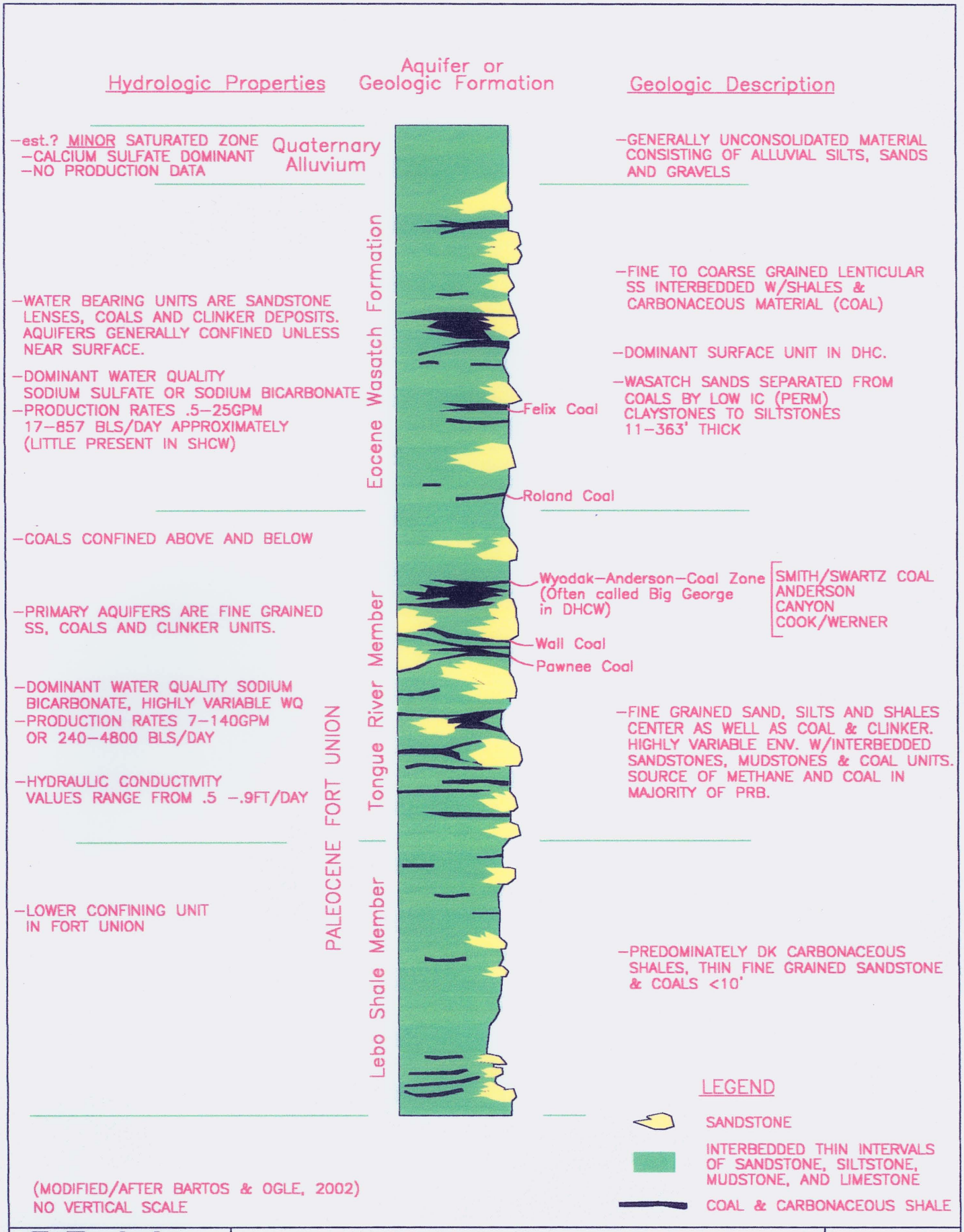
LOCATION MAP

THREE HORSES
WATERSHED PLAN
LEVEL I STUDY


EnTech, Inc.
Consulting Engineers
Transportation - Municipal - Environmental - Water Resources

1949 Sugarland Drive, Suite 205
Sheridan, Wyoming 82801
Phone 307-673-1542
Fax 307-673-1547
E-mail entech@entechusa.net


FIG. 1




EnTech, Inc.
Consulting Engineers
Transportation • Municipal • Environmental • Water Resources
1949 Sugarland Drive, Suite 205
Sheridan, Wyoming 82801
Phone 307-673-1542
Fax 307-673-1547
E-mail entech@entechusa.net

**THREE HORSES**
**STRATIGRAPHIC COLUMN**

**FIG. 2**

flooding. Streams in the Three Horses area that have deep, incised channels will erode continually through the caving of channel banks and through headward erosion of the parent material within drainage bottoms. Upland erosion will occur simultaneously due to sheet and rill erosion. The sparse vegetative cover on steep slopes exposes more soil to raindrop impact.

Most areas within the Three Horses watersheds are likely undergoing moderate natural rates of erosion. The highest natural rate of geologic erosion by water occurs in areas with naturally low vegetative cover, soil crusting, low organic matter content, and soft shales. In areas high in sodium where clays are disbursed, overall soil particles are more easily detached by wind and water. Areas with greater amounts of vegetative cover and organic matter content and/or lower sodium content have a lower natural rate of erosion by water. In addition, areas with harder rock fragments on or near the surface are less susceptible to erosion by either water or wind. Areas with unstable soils on the surface or at depth are susceptible to slumping, sliding and soil creep.

Soils susceptibility to water erosion in the Three Horses watersheds is generally moderate in the subsurface topsoil horizon, and moderate to severe in the subsoil horizons due to clay content, low permeability and non-cohesive soils, as well as steep slopes. These soils represent the majority of the drainage areas, with 80 percent of the drainage area within both the DHCW and WHCW being of clay content. Average runoff potential is moderate to high. Overall wind erosion potential is low to moderate due to the low percentage of sandy and coarse loamy soils in the three basins.

Two field stations within the Three Horses watersheds produce climatological data that is collected by the Western Regional Climate Center. A third field station is located between the WHCW and the SHCW. Pertinent data collected from these three field stations, which provides a general summary of the climate within the area, is portrayed in Table 2.

**Table 2**
**Climatological Data**

| Parameter | Dead Horse Ck. | Echeta 2NW | Arvada 3N |
|---|---|---|---|
| Location (Lat/Long) | 44°11', 105°55' | 44°29', 105°54' | 44°42', 106°06' |
| Elevation (Feet) | 4470 | 4000 | 3680 |
| Avg. Annual Precipitation (inches) | 11.37 | 15.68 | 11.55 |
| Average Annual Snowfall (inches) | 30.6 | 55.6 | 34.41 |
| Average Max. Temp. (July) (°F) | 87.0 | 88.7 | 90.6 |
| Average Min. Temp. (January) (°F) | 7.6 | 7.2 | 3.4 |

Typically, over 60% of the annual precipitation at these field stations falls between March and July as either rain or snow, and more than 30% of the snow is reported during the months of March and April.

The WDEQ has recently classified streams within the Three Horses watershed areas. Those streams and tributaries to those streams are listed in Table 3.

**Table 3**
**WDEQ Classified Streams and Tributaries**

| Watershed | Tributary |
|---|---|
| Dead Horse Creek | North Prong Dead Horse Creek |
| Wild Horse Creek | North Prong Wild Horse Creek |
| | Middle Prong Wild Horse Creek |
| | Twenty Mile Creek |
| | Beke Bridge Draw |
| | South Draw |
| | North Draw |
| | Kingsbury Creek |
| Spotted Horse Creek | Southwest Draw |

All of the above listed streams and tributaries have been classified as 3B. A 3B stream is defined in WDEQ's Chapter 1 of its Rules and Regulations for water quality as follows:

> "Class 3B waters are tributary waters including adjacent wetlands that are not known to support fish populations or drinking water supplies and where those uses are not attainable. Class 3B waters are intermittent and ephemeral streams with sufficient hydrology to normally support and sustain communities of aquatic life, including invertebrates, amphibians, or other flora and fauna which inhabit waters of the state at some stage of their life cycles. In general, 3B waters are characterized by frequent linear wetland occurrences or impoundments within or adjacent to the stream channel over its entire length."

Several flora and fauna species that may possibly occur within the Three Horses drainage areas have been afforded special status by federal and state agencies, including the U.S. Fish & Wildlife Service, the U.S. Forest Service, the Bureau of Land Management and the Wyoming Game & Fish Department. Special status designations include:

- Threatened and endangered species as listed by U.S. Fish & Wildlife Service,
- Sensitive species as listed by the Bureau of Land Management and U.S. Forest Service, and
- Special concern species as categorized by the Wyoming Game & Fish Department.

A listing of flora and fauna species that are included within these designations and that may exist within the subject drainage areas is contained within the final report.

## 3. COAL BED METHANE IMPACTS

There has been a great deal of discussion and controversy surrounding the CBM play in Wyoming, especially within the PRB. This is due to the rapid increase in the number of permits issued each year for CBM development. Potential impacts include:

- Vegetation,
- Roads,
- Pipelines,
- Erosion,
- Surface Water Quality and Quantity,
- Groundwater Quality and Quantity, and
- Historical Agricultural Practices.

Impacts are not necessarily envisioned to be negative; in fact, many of the impacts are viewed as being positive. Many of the impacts are minor in scope, are temporary and can be successfully mitigated with existing resources, cooperation and common sense.

## 4. WATERSHED MANAGEMENT ALTERNATIVES

The previous section defined potential areas of impact potentially resulting from CBM activities within the Three Horses watersheds. While many impacts were perceived to be somewhat minor, such is not the case with the potential impacts due to CBM-produced water discharges. This area is one in which proper planning must be attempted in order to provide maximum coordination among local landowners, CBM operators, public officials, and the states of Montana and Wyoming. Only by successfully addressing the concerns and problems expressed by all of these parties associated with water discharges can reasonable solutions move forward.

Several water management alternatives have been briefly analyzed as part of this report. Several assumptions were made in the development of these water management alternatives, assumptions that were developed after discussion with CBM operators, regulatory agencies and representatives of the Coal Bed Methane Coordination Coalition. Factors that affect the quantity of CBM water produced include:

- the amount of time that the well has produced water;
- the coal seam in which the well is located;
- the physical properties of the aquifer;
- the number of wells producing water;
- the spacing of the wells;
- the number of coal seams producing water; and
- the location of the well with respect to other producing wells.

After discussions were held and information evaluated, it was decided that the following assumptions would be used to forecast the amount of water that will be produced.

- Wells are spaced at 80 acres.
- Each well produces eight gallons per minute.
- Two coal seams are tapped at the 80-acre spacing.

It has been reported that, with time, flows have decreased to closer to five gallons per minute. As such, the eight gallons per minute figure may be overly conservative. However, initial pumping rates have been shown to be considerably greater, and eight gallons per minute as believed to be a reasonable number given the fact that new wells are coming online continually.

Some of the water management alternatives considered include regional solutions to addressing water concerns. These particular alternatives assume that there is full development throughout the Three Horses watersheds, and that this development occurs simultaneously so that all wells are pumping at the same time. Such a scenario may indeed be a maximum case estimate. However, should natural gas prices escalate significantly, CBM development may increase considerably above current levels, and with it the need to effectively manage produced water may become even more important.

In describing and outlining the viability of each water management alternative, the following information is provided as a tool for comparison purposes:

- a description of the management alternative;
- the purpose and principles of that particular alternative;
- the design criteria that would have to be followed in order to implement the alternative;
- the benefits and/or advantages gained in implementing the alternative;
- the detriments and/or disadvantages inherent to the alternative
- any permitting and/or regulatory requirements that would have to be addressed in order to implement the alternative; and
- cost estimates to implement the alternative, portrayed on a cost per 1000 gallon basis.

In order to develop the cost per 1000 gallons for water management facilities that will have an extended life, an annualized rate of return must be used for cost comparison purposes. It is assumed that the annualized rate of return is 4% for a term of 20 years. While some may question amortizing facilities for a twenty-year period when some wells' life expectancy would be considerably less than this length of time, the fact that multiple coal seams may be tapped at one site and continue to utilize the water management facilities leads to the conclusion that the 4% @ 20 year figure is reasonable.

Some of these alternatives may be more applicable in one of the drainages than in the other two; i.e., injection or land application. However, no cost differentiation has been assumed relative to the specificity of the respective watershed.

It is important to recognize in the review of the cost comparison figures that they represent merely gross conceptual estimates on various water management alternatives at a reconnaissance level as intended by the scope of this study. Actual costs for implementation could vary considerably from those portrayed in this section. Still, these figures represent a means with which to compare the various water management alternatives.

Table 4 provides a summary of the water management alternatives considered and their respective evaluations based upon the criteria described above.

## 5. ANALYSIS OF WATER MANAGEMENT ALTERNATIVES AND RECOMMENDED WATERSHED MANAGEMENT PLAN

The previous section provided information on various water management alternatives and associated reconnaissance level costs estimated to implement these alternatives. Based upon the water management alternatives evaluated, the following general recommendations are made.

A. Those water management alternatives that entail a basinwide solution; i.e., collecting, treating, piping outside of the drainage basins, or mixing with other sources, should not be pursued at this time. Reasons why these basinwide solutions should not be pursued include the following:

- The duration of CBM production in the three watersheds is difficult to predict, and may be relatively brief, as has been demonstrated in the Belle Fourche River basin to the east of the PRB. Within the Belle Fourche basin, CBM wells are already approaching a "mature" status after just five to seven years of production. As such, a stable, long-term financing plan required for the capital infrastructure necessary may prove unattractive to CBM producers, who may be reluctant to retire debt over a long period of time when the source of revenue (i.e., CBM) will have been depleted.

- As has been the case over the last year, suppression of the price of energy (and thus price of natural gas) makes the amount of drilling activity and associated CBM well development highly variable. Low energy prices can lead to a decrease in the cost-effectiveness of CBM production. Once water-producing activities at a CBM well commence, "shutting in" the well is more difficult than conventional gas wells, as groundwater levels will return to previous levels in the event of a shutdown in pumping. As a result, the previous water pumping will have gone to little benefit for the CBM operator. Therefore, concerns about the long-term price of natural gas will make CBM operators reluctant to enter into long-term financing plans that address water disposal solutions.

- The amount of water that will be generated over the long term by CBM production is highly variable, and will make the prediction of the sizing of the required capital facilities extremely difficult. Basinwide water management alternatives portrayed in this study (Piping Water to the Powder River for Direct Discharge, Piping Water to the Powder River with Water Treatment, Lake DeSmet Storage Releases) assume almost simultaneous development, which is very unlikely unless natural gas prices rise significantly. Previous predictions on the amount of water estimated to be produced have varied widely, and most have proven to be higher than the actual amount of water produced. The U.S. Department of Interior BLM Draft Environmental Impact Statement on Coal Bed Methane predicted 10 gallons per minute per well; this study uses 8 gallons per minute per well; the current average production is 5 gallons per minute, and is expected to continue to decrease with time as wells "mature".

- In order to implement basinwide solutions, the coordination and project financing mechanisms will require substantial amounts of time. The reality is that if there are other alternatives available, the delays that will be necessary to coordinate basinwide solutions will preclude CBM companies from actively participating in such plans for water management.

- It is unlikely that a private entity will step forward and implement the basinwide solutions described in the previous section. This uncertainty would likely be due to the uncertainties discussed above regarding market conditions and lack of operator involvement or interest, particularly when other solutions could be implemented. If no private entity steps forward, it will be left to the State of Wyoming or some other public entity to implement a basinwide solution. Although such implementation is possible, the concept of constructing and operating a water management solution – particularly an expensive and potentially risky one - for the benefit of private enterprise will require lengthy debate and ultimate legislative approval. The time factor associated with such debate and approval will again prove detrimental to advancing forward with such a plan.

B. In lieu of the development of basinwide solutions, we instead recommend that site-specific solutions be pursued, recognizing that there is no "one-size-fits-all" solution for the problems associated with CBM water management within the Three Horses watersheds. A range of water management alternatives, integrated on a case-by-case basis to meet the needs of both landowners and the CBM operators, can more successfully be pursued. Listed below are those solutions that should be evaluated and considered each time that a permit is being considered for discharge.

- **Direct Discharge** Direct discharge into receiving streams is not recommended among the range of alternatives, unless there is concurrence within the drainage basins by all affected downstream landowners, **and** the states of Wyoming and Montana reach accord on the amount of discharge – if any – that could be made into the Powder River for ultimate delivery into Montana. Some landowners may desire to have CBM waters released onto their property, as it can provide valuable stock and wildlife water on a continual basis. Others, however, may not desire to have this water discharged to their property. The continual inflow of water along the stream will change the riparian vegetation directly adjacent to the stream, converting from the grasses historically seen to wetland species. Livestock operations could be affected by an encroachment upon areas historically used for calving operations. Stream crossings could prove to be a hindrance. Areas where spreader dikes exist could have water retained on a continual basis, affecting hay production and haying operations.

  For those downstream landowners that would receive these discharges, arrangements would have to be made by CBM operators to allow for these discharges to flow through these downstream properties. To address the concerns of downstream landowners, it may be possible to construct diversion facilities that would convey water around the spreader dike dams and channelize water (via ditch and pipeline construction) to avoid water spreading out in braided areas. Arrangements would have to be made, and facilities constructed accordingly, so that historical runoff events which have served as valuable irrigation sources would still be captured by the landowners.

  Experience to date within the WHCW has shown that direct discharge can be utilized without the CBM water ultimately reaching the Powder River. Releases are currently being made that are not ultimately making their way to the river. This may be due in part to the amount of water that can infiltrate into shallow aquifers being higher than originally predicted. Such an increase in infiltration quantities has occurred elsewhere.

  Although surface gradients within the Three Horses watersheds are generally steeper than those in the Belle Fourche basin, and soil characteristics may be somewhat different, there is evidence that similar infiltration is occurring within the Three Horses areas. It is

noteworthy that Belle Fourche River streamflow rates have changed little since the commencement of discharge of CBM water into receiving streams. Despite direct discharge of CBM water (vs. using containment facilities prior to discharge) into this stream which originates just east of the PRB, the data suggests that the actual amount of water flowing in the mainstream has had essentially no effect on total streamflows.

If the likelihood exists that CBM water will find its way to the Powder River (such as being in close proximity to the confluence), direct discharge should not be considered as a water management solution until Wyoming and Montana reach accord. Furthermore, if there is the possibility that CBM flows will reach downstream lands whose owners have not concurred with such releases, direct discharge should not utilized.

- **Containment-and-Loss Reservoirs** Containment-and-loss reservoirs, particularly those that are not constructed on-channel, have been shown and should continue to be an effective means of managing water within the Three Horses basins. As discussed above, infiltration rates potentially being higher than originally estimated and decreasing CBM flows with time may allow containment-and-loss facilities to provide a means to manage all water collected from CBM activities without requiring direct discharge.

  On-channel facilities offer the advantage of being available for use for stock water retention after CBM activities have been completed. Off-channel containment facilities, however, can likely address potential concerns of downstream landowners that would otherwise pose problems with the on-channel structures. If constructed on-stream, water rights factors can become issues, as CBM storage facilities with unused capacity store waters during runoff events that have historically flowed downstream and irrigated lands. Outlet works on these on-stream facilities can be of little or no benefit, as the water released is CBM water vs. natural runoff.

  On-channel facilities can be constructed to bypass all flows not related to CBM discharges. Constructing such facilities, however, can prove to be expensive and perhaps cost-prohibitive. As such, off-channel facilities usually are a better choice for impoundment of the CBM water to allow for infiltration and evaporation.

  Containment facilities can offer the additional advantage of providing additional wildlife habitat. Ducks, geese and numerous animal species have found CBM ponds to be attractive locations, and there is no evidence to date that there are consequences with their use of these ponds. However, the potential exists that CBM water seeping into the ground may find and follow an impermeable layer that eventually outcrops at the surface.

- **Containment-and-Release Reservoirs** This water management alternative can be potentially employed if there is concurrence by downstream landowners within each drainage, if release occurs in conjunction with major runoff events that would serve to dilute the stored CBM water. If the release occurs during the non-irrigation season, not only would there be the need to obtain downstream landowner concurrence, it is likely that similar concurrence would have to be received by the State of Montana. Assuming that releases are performed that would not prove detrimental to irrigators in Montana (due to the time of year or amount of water within the Powder River that releases occur), it is possible that Montana would provide such concurrence.

- **Injection** Although very site-specific and not feasible for use in many areas of the Three Horses watersheds, this water management alternative offers perhaps the greatest overall benefit to the State of Wyoming. By injecting this water back into the ground, water that

would otherwise be lost to downstream states can be restored in aquifers and made available for future use in Wyoming. However, as shown in the cost comparisons, injection can be a very expensive alternative for CBM operators, and unless receiving aquifers meet certain characteristics, economics will not allow for this alternative to be used. Most operators view the injection facilities as a complement to existing water management techniques rather than as a primary, stand-alone method of managing water.

- **Enhanced Evaporation Using Atomizers and Misters** These two techniques offer the advantage of dissipating CBM water through evaporation, thereby acting as another alternative for water management. Like many other alternatives, however, these techniques must be used in conjunction with others, primarily due to seasonal variations in the ability to evaporate water. Storage of CBM water during the months when evaporative losses are not high becomes an integral part of the decisions to select these water management alternatives.

  In those areas where atomizers or misters are used that water is not evaporated and falls to the ground, soil quality management techniques very similar to land application must be adhered to. Otherwise, those problems that result from land application of waters containing higher concentrations of EC and SAR will similarly result. Sites must also be chosen that do not allow the water that is not evaporated to travel overland and into downstream channels.

- **Water Treatment** Water treatment alternatives were focused on water treatment to produce water suitable for direct discharge or land application, or in conjunction with other alternatives to maximize the beneficial use of the water and/or meet discharge criteria. The three treatment techniques examined: 1) reverse osmosis, 2) ion exchange, and 3) ion ratio modification, require active operations of treatment facilities. Reverse osmosis is severely limited by costs and logistical considerations. Ion exchange has serious technical limitations. Ion ratio modification essentially is an adjustment of the SAR through addition of calcium or magnesium salts to shift the ratio of sodium to these cations and bring the SAR to within acceptable limits. The net effect, however, is to increase the EC.

- **Dust Abatement** Dust abatement is another water management alternative that, when employed in conjunction with other alternatives, offers promise as a means of water disposal and, to some extent, a beneficial use. Seasonal use, water quantities, and area-specific costs preclude this alternative from offering a total solution. As with other several other alternatives being considered, dust abatement also offers a means to provide for a beneficial use of this water that would otherwise be lost to the citizens of Wyoming.

- **Land Application** A water management alternative with significant potential, if properly employed, is the use of CBM water for irrigation purposes. Based upon the water quality and soils data collected, land application may be very site-specific, and chemical amendments to the soil will likely be required. In order for land application to be successful, intensive management of the process is necessary.

  Used in conjunction with containment facilities (which retain CBM water during the non-irrigation season), this water management alternative can eliminate the need for discharge while simultaneously providing needed irrigation water. Long-term success in this area, however, has not yet been shown, and success can be reached only as long as the locations selected have acceptable soil conditions and topography, and that the necessary chemical amendments are employed.

## 6. PROJECT FINANCING PLAN

The recommended water management alternative for the Three Horses watershed areas included an integrated approach for managing CBM water. This integrated approach assumes that all costs for managing CBM water will be the responsibility of the operators. This approach is consistent with current CBM development within the Three Horses drainages; i.e., there is no direct public financing involved in water management techniques, nor is any planned. As such, there will be no need for development of public entities that can utilize statutory mechanisms to provide for lower cost public financing.

## 7. PATH FORWARD

It would be ideal if the findings of this study identified one unique, innovative method that could successfully address the needs for effective CBM water management in the Three Horses watersheds. The findings, however, instead recommend in many ways a continuance of existing water management options; i.e., the employment of several water management alternatives by the individual CBM companies. Direct discharge to channels, containment-and-loss reservoirs, containment-and-release reservoirs, injection, enhanced evaporation using atomizers, dust abatement, and land application are all water management alternatives that are in use within the watersheds.

Due to the concerns expressed regarding basinwide solutions, it is believed that CBM water management should remain in the hands of the private sector, and that small, individual methods of water disposal continue to be utilized. As such, while the conservation districts should continue to play active roles in the monitoring and overseeing of CBM development within their various jurisdictions, their role should not be expanded to participate in publicly funded projects that would implement basinwide solutions. Conservation districts can hopefully use this study to also assist their constituents as CBM companies enter their properties to develop the CBM beneath their properties that they may or may not own.

A very important future development for the continuance of CBM activities will be the decisions reached in the negotiations between the State of Wyoming and State of Montana relating to discharges in the PRB. If decisions reached allow some discharge that exceeds historical water quality values observed along the Powder River, it will become even more imperative that the CBM companies and landowners along the Three Horses streams cooperate, as it is likely that direct discharges to channels will increase. Such direct discharges cannot be allowed to negatively impact the landowner's operations. If, on the other hand, state agreements do not allow for such discharges into the Powder River, landowners in the Three Horses areas are likely to see the other water management alternatives discussed above be used more extensively.