GEOLOGIC AND ENGINEERING REVIEW OF JULY 8, 2002 REPORT BY MR. GREGORY D. LAZEAR ENTITLED: "THE LATEST FINDINGS CONCERNING THE IMPACT OF CBM DEVELOPMENT ON WATER RESOURCES ON THE SOUTH SIDE OF GRAND MESA DELTA COUNTY, COLORADO"

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Prepared for: Gunnison Energy Corporation
Denver, Colorado

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GEOLOGIC AND ENGINEERING REVIEW

Of July 8, 2002 Report From Mr. Gregory D. Lazear Entitled "The Latest Findings Concerning The Impact of CBM Development on Water Resources on the South Side of Grand Mesa Delta County, Colorado"

1.0 PURPOSE

At the request of Gunnison Energy Corporation, Wright Water Engineers, Inc. (WWE) has evaluated the July 8, 2002 report prepared by Mr. Gregory D. Lazear entitled: "The Latest Findings Concerning the Impact of CBM Development on Water Resources on the South Side of Grand Mesa Delta County, Colorado" ("Lazear Report"). That report purports to address Gunnison Energy Corporation's application for five exploratory wells, but it goes far beyond the actual application and assumes full development of the project with CBM wells. The present request by Gunnison Energy is to drill five exploration wells to obtain data of this kind; only after reviewing the data from these and likely additional exploration wells will a decision be made on whether to pursue production drilling.

The purpose of this report is to summarize our findings regarding the Lazear Report[1]. For this review, WWE[2] was joined by Mr. Richard Dunrud, P.E.[3] and Mr. John Rold, C.P.G.[4], with whom

[1] Wright Water Engineers, Inc. (WWE) also reviewed an earlier report (undated) prepared by Mr. Lazear and other contributors entitled: *The Potential Impact of Coal Bed Methane Development on Water Resources on the South Side of Grand Mesa* (Appendix B). However, WWE's review comments are directed primarily at the July 8, 2002 Lazear report.

[2] WWE (with offices in Denver, Glenwood Springs and Durango) was founded 41-years ago. WWE has strong experience in the Oil and Gas industry, for such clients as ExxonMobil, BP/Amoco, Barrett Resources, ARCO and others. WWE is quite familiar with water resources issues in the North Fork Gunnison Basin, having worked on numerous hydrologic and water quality issues at the West Elk Mine near Somerset since 1995. WWE also has conducted many assignments for the federal government and state and local governments. Representative governmental clients include: U.S. Environmental Protection Agency; U.S. Department of Energy; Colorado State Engineers' Office; Colorado Water Conservation Board; the 39 cities and counties comprising the Denver Urban Drainage and Flood Control District (WWE prepared the *Denver Urban Storm Drainage Criteria Manual* in 2001); Gunnison County Commissioners (review of on-site wastewater disposal criteria and slope limitations); Towns of Hotchkiss and Paonia (water supply); City of Glenwood Springs; Eagle County; Boulder County; Garfield County; La Plata Water Conservancy District and many others. In 1996, WWE was privileged to receive one of Colorado's highest business awards—*Colorado Ethics in Business Award*. In 1999, WWE was similarly honored to receive a national business ethics award from the Society of Financial Service Professionals. The primary WWE staff that

we have worked closely on many assignments involving the impacts of mining and oil and gas development on water resources. A number of these assignments have been in the North Fork Gunnison River Valley. (Throughout this report, "WWE" is inclusive of Messrs. Dunrud and Rold.)

2.0 BACKGROUND

The Lazear Report suggests a number of potential adverse effects of proposed natural gas development by Gunnison Energy in Gunnison and Delta counties (see Figure 1 for general location map). Without proper planning, development, and operations, there can be negative impacts to surface water and groundwater quantity and quality from natural gas wells. Such impacts must be carefully evaluated, minimized to the extent feasible and then appropriately mitigated and monitored.

prepared this review for Gunnison Energy were Jonathan E. Jones, P.E. and Chief Executive Officer of WWE and Gary Witt, P.G., Senior Hydrogeologist.

[3] Richard Dunrud, P.E. is an internationally recognized authority on coal mine subsidence and its associated effects. He has extensive experience in the North Fork Gunnison River Basin, having prepared official U.S. Geological Survey (USGS) geologic maps and technical reports of the area. Mr. Dunrud's geologic mapping experience spans the full width of the study area cited by Mr. Lazear. Mr. Dunrud worked for 30-years at the USGS and has associated with WWE on many projects since retiring. Mr. Dunrud's work has been frequently cited by other parties who have commented on the Gunnison Energy Proposal.

[4] John Rold, C.P.G. was the Colorado State Geologist for approximately 23 ½ years. Upon his retirement from that position nine years ago, he began a regular association with WWE on wide-ranging projects including landslides, rock fall, slope instability, expansive soils, hydrologic and water quality consequences of mining, etc. Mr. Rold has considerable personal knowledge of the North Fork Gunnison area due to many assignments there while Colorado State Geologist and with WWE at the West Elk Mine, including both the east and west sides of the study area. Mr. Rold also has considerable personal experience with coal bed methane, having overseen the state of Colorado's original feasibility study on this topic, in the early 1980s.

3.0 SUMMARY OF FINDINGS

WWE disagrees with many of Mr. Lazear's key assumptions, interpretations and findings, which collectively overstate the anticipated hydrologic impacts of both the exploratory and production drilling proposed by Gunnison Energy in Delta and Gunnison Counties. A synopsis of our findings follows:

1. Many of the documents cited herein and listed in the "References" section at the conclusion of this report clearly state that the Mesaverde formation is not water rich and that it does not contain two highly productive zones (aquifers) as indicated in the Lazear report. Representative quotations regarding the lack of water in the Mesaverde formation include:

   The Mesaverde formation in the study area transmits little groundwater because of the negligible transmissivity of the 1,300-feet of fine-grained sandstone, coal and shale comprising the formation (Brooks 1983).

   The Mesaverde does not typically have productive aquifers in this area due to poor lateral continuity, inappropriate petrology or poor recharge topography. The Rollins Sandstone regional aquifer is rather dry in this area as the seam is a cliff former and little recharge is possible. No impacts are predicted for this aquifer as the discontinuous sandstones, siltstones, shales and coals between the mining zones and the Rollins preclude migration of water. (Colorado Division of Minerals and Geology report entitled: *Cumulative Hydrologic Impact Study of the Tongue Creek Watershed*).

2. The Lazear report calculates a water production rate for each natural gas well of 2,540 bbls/day/well. This estimate was calculated and not based on actual produced water data

from local natural gas wells. The calculation is based on assumptions that are not supportable.

Based on a thorough review of records at the offices of the Colorado Oil and Gas Conservation Commission (COGCC) and Colorado Division of Minerals and Geology (CDMG), coupled with literature review and the experiences of coal mines in the North Fork Gunnison Valley, the estimate of 2,540 bbls/day/well dramatically overstates the water yields that would likely be experienced—probably by 1-2 orders of magnitude (factor of 10-100). For example, a comprehensive survey of natural gas wells in the Piceance Basin conducted by the Bureau of Economic Geology at the University of Texas and the Gas Research Institute (1995) determined that water yields for eight producers (Barrett, Conquest, Fuelco, Orxy, Chevron, Anadarco, Unocal and "other") ranged from 0 to 188 bbls/day, or 0 to 5.5 gpm. A flow of 5-6 gpm is about the flow of a garden hose.

The estimates in the Lazear report for total volume of water ("1/3 the volume of Blue Mesa Reservoir") and number of truckloads of water that would need to be shipped significantly overstate what will actually happen.

3. The Lazear report suggests a groundwater model which indicates essentially continuous fracturing from the top of the Grand Mesa through the Green River, Wasatch and Mesaverde formations to the Mancos shale. There is no evidence to support this postulate. To the contrary, the literature reviewed by WWE from such entities as CDMG, the U.S. Geological Survey (USGS), U.S. Bureau of Land Management (BLM), U.S. Forest Service (USFS) and individual coal mines indicates that extensive, continuous fracturing is not present in the area.

4. The Lazear report omits discussion of the critically important and extensive alluvial and colluvial deposits that are found in much of the study area. Such deposits provide the

vast majority of the domestic, agricultural and industrial/commercial water supply in the study area.

5. The Lazear report correctly indicates that faults exist under some of the major drainages in the study area (many of which are ephemeral). Mr. Lazear suggests that these faults provide a pathway for the entry of surface flows into the sub-surface. However, in many locations, such a pathway does not exist because the major drainages are filled with eroded Wasatch formation material which is fine-grained and plastic in nature, thereby effectively sealing the channel bottoms.

6. For all of the reasons listed above, the groundwater model for the south side of the Grand Mesa described in the Lazear report has serious deficiencies and is inaccurate. This model cannot be utilized to reliably project the hydrologic consequences of the proposed exploratory or production drilling by Gunnison Energy. The model:

   - mischaracterizes the water-bearing nature of the Mesaverde formation,
   - provides a natural gas well water production rate of 2,540 bbls/day/well, which is a dramatic overstatement,
   - postulates that there are continuous fractures from the surface of the Grand Mesa to the Mancos shale, when there is overwhelming evidence to suggest that the opposite is the case,
   - omits the critically important alluvial and colluvial groundwater systems in the region,
   - and suggests that faults beneath major drainages will permit entry of surface flows into the sub-surface, without accounting for the highly effective sealing of most of the channel bottoms that has occurred due to deposition of eroded Wasatch formation material.

7. WWE strongly disagrees with Mr. Lazear's assertion that no additional hydrogeologic data are needed. To the contrary, water production data for natural gas wells in the study area is a high priority.

4.0 BASIS OF FINDINGS

To develop the findings listed above regarding the Lazear report, WWE did the following:

1. Obtained and reviewed reports/records/data from the COGCC, CDMG, USGS, USFS, BLM, Gunnison Energy, Delta County and other sources.

2. WWE staff, and Messrs. Dunrud and Rold, have reviewed their files from previous assignments in the study area, including geologic maps, photographs, etc. We have also relied on our relevant personal experience.

3. We interviewed various people who are knowledgeable about water-related implications of coal bed methane (CBM) development in the study area including Mr. Bruce Bertram (Delta County Local Government Designee), Mr. Daniel Hernandez of CDMG, Mr. Gerry Loucks, and COGCC and other CDMG staff who assisted with records research.

4. We conducted a limited field investigation and have reviewed aerial photographs, topographic maps, geologic maps, etc. We prepared the graphics that accompany this report.

5.0 HYDROGEOLOGIC CHARACTERISTICS OF ROCK UNITS

The hydrogeologic characteristics of the rock units that occur in the Grand Mesa, Cedaredge and Paonia area directly control the movement of groundwater and the interaction of groundwater and surface water. Different authors cite slightly different thicknesses for the units. This report for the most part uses USGS figures (Brooks 1983) and the geologic maps prepared by Richard

Dunrud, P.E. and other USGS staff (USGS Coal Investigations Maps C-115 and 116, dated 1989 and Map C-109 dated 1987). The descriptions below are based on the literature cited at the back of this report, coupled with the observations of Messrs. Dunrud and Rold. Figure 2 provides a geologic map of the study area from the USGS. Figure 3 is a geologic cross-section. Table 1 summarizes hydrogeologic parameters for the various hydrostratigraphic units described below, based on USGS data.

There are topographic and hydrogeologic differences from the east side of the study area (roughly Somerset) to the west side (roughly Cedaredge), as noted in various documents. Brooks (1983) states that:

> *A greater area of bedrock in the Cedaredge study area is overlain by thick, unconsolidated Quaternary deposits than in the Paonia area. This is due to the differences in topography of the two areas. The Cedaredge study area in western Delta County is rugged, but not nearly as steep as the Paonia study area in the eastern part of the county. The steeper slopes and greater stream gradients in eastern Delta County create a greater potential for sediment transport in streams, resulting in the erosion of surficial deposits from local valley walls and cliff fronts facing the North Fork Gunnison River, and exposure of the underlying bedrock.*

Mr. Bruce Bertram also describes these differences in his June 2002 report as follows:

> *There is a significant difference in the existing surface terrain (topography) between the eastern project area near Paonia and the western project area near Cedaredge. The valleys narrow and are surrounded by very steep slopes in the eastern area and contain few if any of the out wash alluvium terraces that begin to dominate the lower slopes of the Grand Mesa toward the west. Specific recognizable terraces are: (among others) Pitkin Mesa, Hanson Mesa, Rogers Mesa, Redlands Mesa, Cedar Mesa, and numerous smaller mesas (having*

minimal alluvium caps) around the Cedaredge area. The significant difference at Cedaredge is the entire Surface Creek Valley is for the most part a large out wash of alluvium beginning high in the scrub oak and lower aspen levels of the Grand Mesa tapering out but not disappearing until reaching the Gunnison River. There are increased occurrences of springs and successful shallow (most less than 300-ft) water wells in areas covered with the outwash alluvium.

Brooks (1983) indicates that: "the Mesaverde formation and overlying unconsolidated Quaternary deposits are more saturated in the Cedaredge study area than in the Paonia study area," although he notes that only about 7-12 gpm of water entered the Red Canyon Mine about three miles northwest of Cedaredge. He also stated that an abandoned mine adjacent to the Red Canyon Mine required a pumping rate of about 16 gpm to keep pace with the inflow. Both of these inflow rates are small; therefore, it is highly improbable that a single coal bed well could generate 74 gpm (equivalent to 2,540 bbls/well/day) of water as calculated by Mr. Lazear, when an entire coal mine in the same area generates 7-16 gpm.

The following text reviews the key rock units.

5.1 Unconsolidated Surficial Materials

A thick blanket of geologically young material covers much of the southern slope of Grand Mesa (Figure 2). The materials consist of glacial till, landslides, colluvium and alluvium. The material has high permeability and easily transmits groundwater. It can reach several hundred feet in thickness. Most springs in the area arise from this material. Many of the water wells derive their water from this material or from the weathered bedrock immediately below it. Waters from these units are usually fresh and are calcium sodium bicarbonate.

Deposits derived from the Wasatch formation are unconsolidated, consisting primarily of clay, with some sand and silt. They underlie the unconsolidated surficial deposits and overlie the bedrock described below. The deposits were mobilized during periods of high precipitation in

the geologic past (Pleistocene). The deposits also include heterogeneous to well-sorted and stratified basalt gravel and boulders. The deposits, which are as much as several hundred feet thick, have a very low permeability where they are heterogeneous, are very permeable where they are well-sorted and stratified. The well-sorted and stratified part usually occurs near the top of the deposits.

Table 1 demonstrates differences in water chemistry between the unconsolidated surficial materials and the deeper coal zones in the Mesaverde formation. These differences are also discussed by Brooks (1983 and 1985), CDMG (2001) and Bertram (2002), among others.

5.2 Basalt Flows (Tbb, as shown on Figure 2) Approximately 200-Feet Thick

The Tertiary basalt flows form the erosion-resistant cap to Grand Mesa. The undisturbed rock has almost no permeability. However, weathered interflow zones and a fractured rubble zone at the base of the basalt have high permeability and transmit large volumes of water. The numerous landslides fracture and dislocate the basalt providing excellent vertical permeability. Many landslides in the basalt form sag ponds and lakes which saturate the surrounding and down slope unconsolidated materials. Most fresh water springs tapped at the source for domestic water use by the Town of Cedaredge, Colby Canyon, and Orchard City are on Grand Mesa high above the coal interval. They are located in, or around, the edge of the area formed by the top of large land rotational slump blocks forming the depressions where nearly all the natural lakes exist on Grand Mesa (Bertram, 2002).

5.3 Green River Formation (Tgr and Tu) 1,000 Feet Thick

The Green River Formation immediately underlies the basalt cap. The Green River formation consists mainly of thinly-bedded, low grade oil shales, marlstones, siltstones and calcareous shales. The unit has little horizontal permeability and very limited vertical permeability.

5.4 Tertiary Wasatch Formation (Two) Approximately 1,000 Feet Thick

The Wasatch Formation consists mainly of variegated reddish soft mudstones and claystones with a few lenticular sandstones. The mudstones and claystones have very small horizontal or vertical permeabilities. At depth, the overburden pressure forces the weak material to seal fractures and faults. There are few springs or domestic water wells in the Wasatch Formation.

5.5 Cretaceous Mesaverde Formation (Kmv) 2,500-2,800 Feet Thick

The Department of Energy and Colorado Oil and Gas Conservation Commission have designated the Mesaverde as "tight gas sand." Tight gas sands do not serve as aquifers. The Mesaverde Formation consists of the Ohio Creek member, "Barren Zone" member, the lower Coal-Bearing member (also called the Cameo) and in the subject area, a basal Rollins member forms the base of the formation.

The Ohio Creek member consists of 500-900 feet of fine to course-grained lenticular sandstone and interbedded mudstone and shales.

The Barren member consists of 500 feet of fine-grained lenticular sandstones, shale and mudstone with occasional thin coal beds. These discontinuous sandstones have low permeability and transmit little water. According to the 1983 and 1985 USGS reports prepared by Brooks, and experience of mines in the North Fork Valley, the Barren member has very low horizontal and vertical permeability. Perched water tables commonly occur in this unit. The small amount of water found in this unit is usually high in total dissolved solids and of the sodium bicarbonate type. In many places throughout the Piceance basin, natural gas is entrapped in the lenticular sands.

The coal or Cameo zone (also called the Coal-Bearing member) underlies the Barren zone. As the name implies, it contains most of the Mesaverde coals. The Coal-Bearing member is about 350-650 feet thick. The coal beds contain methane, which is typically adsorbed within the coal and held there by water pressure in the cleats and fractures. However, in the study area, based on experiences at the West Elk and Sanborn Mines in areas with greater than 1,500-ft of overburden,

substantial quantities of methane have been found in formations that do not have significant amounts of water. The coal beds exhibit more permeability than the normally thick sands. Water, where found, is of the sodium bicarbonate type and usually of poor quality. Quality of water decreases with increased depth and distance from the outcrop. As discussed below, most of the coal mines in the North Fork Valley have experienced small amounts of water in the coal seams.

The Rollins Sandstone lies beneath the coal zone and ranges from 100-200 feet in thickness. Most of the Rollins is tightly cemented except in a few cases where a porous, permeable zone 5 to 20 feet thick of a sandy material creates a ponded aquifer at the top of the Rollins. Usually the water found is of poor quality and sodium bicarbonate in type. The Rollins Sandstone contains visible clay and calcareous matrix cementation of varying amounts throughout the western area of the CBM project (Bertram, 2002). The Rollins Sandstone rarely has springs or evidence of surface water flows at the outcrop within the body of the thick sand or less common at the base of the sand (Bertram, 2002). This statement was confirmed by Richard Dunrud based upon his field observations while preparing the geologic maps of the area published by the USGS.

5.6 Cretaceous Mancos Formation (Km) 4,000-4,500 Feet Thick

The dominantly gray marine shales of the Mancos are the oldest rocks exposed in the study area. Normally, the Mancos forms a basal seal for this hydrologic system. Occasionally, limited quantities of very poor quality water are found in fracture zones and sand leases.

5.7 Hydrogeologic Interpretation

5.7.1 Richard Dunrud Observations

During parts of the 1970s and early 1980s, the USGS commissioned Richard Dunrud to map the bedrock and surficial geology of the Somerset/Paonia/Cedaredge areas. He also was charged with mapping structural and lithologic features in coal mines in the Somerset area.

The primary purpose of the project was to determine lithologic and structural characteristics of the coal seams and bedrock that affected and/or controlled coal mine deformation processes—such as rock bursts, coal outbursts, squeezes, and subsidence.

During the course of surface and underground geologic mapping, Mr. Dunrud also noted the hydrologic conditions of the area being mapped, because the presence of water tends to soften, and otherwise weaken, the coal and rock, and therefore affects mine deformation processes.

During the surface mapping of the Somerset/Paonia/Cedaredge area, samples collected from the sandstone bedrock were observed by Mr. Dunrud to be of low permeability primarily because they are fine to very fine grained sandstone with the pore space (the space between sand grains), filled with clay and calcareous material. This is highly relevant for the discussion on fractures in section 5.3.

No springs were observed during surface mapping that had a visible source from the sandstones. This includes the Rollins Sandstone and the lenticular sandstones and siltstones of the coal bearing member, Barren member, and Ohio Creek member. Springs, however, were locally observed in surficial material (sand and soil) that appeared to be primarily the result of the flow from rain and snow melt water from within the surficial material. Springs typically occur at the downslope edges of these deposits.

No large flows of water were observed during core drilling and rotary drilling operations where Mr. Dunrud mapped. He recalls that it was necessary to haul water to the core-drilling sites that he was involved in. Foam was used in most rotary drilling operations, which indicates that very little groundwater was encountered. Foam could not have been used if significant flows of water had been encountered.

During periods of high precipitation in the geologic past, the clays of the Wasatch formation were mobilized and flowed over much of the bedrock of the Mesaverde formation. This clay blanket is present on the north side of the North Fork Valley from Terror Creek to Dirty George

Creek west of Cedaredge (see Coal Investigations Maps C-115 and C-116). Compared to the total area covered by these clays, only a small aerial percentage of Mesaverde bedrock is exposed.

The clays of the Wasatch formation transmit water very slowly. One can observe this while driving unpaved roads in Wasatch clays during heavy rainstorms. The road gets very slick quickly, then dries out quickly after the rain has stopped. This happens because the water can only soak into the clay a very short distance.

Mr. Dunrud mapped structural and lithologic features in the coal and roof rock in the "B" seam of the Somerset Mine, the "C" seam of the Bear Mine, and the "E" seam of the Hawk's Nest Mine. Small amounts of water were locally observed where faults and fractures intersected the coal seam. The flows were sometimes located beneath ravines located in Mesaverde rocks that showed up as linear features on aerial photographs. These areas of underground flow, however, were observed where the Wasatch clays were not present to seal surface flow to the mines below.

5.7.2 USGS Interpretations in 1983 and 1985

Mr. Dunrud's observations are consistent with those of Mr. Brooks in his 1983 and 1985 USGS reports. Quoting from his 1983 report: *Hydrology and Subsidence Potential of Proposed Coal-Lease Tracts in Delta County Colorado:*

> *The Mesaverde formation and Quaternary deposits are the primary hydrogeologic units within the study areas; each has distinct hydrologic properties. The overlying siltstone, mudstone, and shale of the Wasatch Formation probably transmit little water. The Wasatch Formation is not considered an aquifer in the study areas. The Mesaverde formation is recharged in outcrops along the North Fork Gunnison River valley. The formation probably transmits very little water because its transmissivity is small. Ground water may*

be transmitted downdip and northward within the Mesaverde formation and may discharge somewhere north of the Grand Mesa, or it may discharge somewhere down the North Fork Gunnison River valley. Any discharge would be small and likely subject to evapotranspiration.

Unconsolidated Quaternary deposits locally recharge and discharge in the North Fork Gunnison River valley, ultimately contributing water to the river. These deposits comprise the more productive aquifers in the Delta-Paonia area. This is especially true in the Paonia area where most water supplies are developed from valley alluvium along the North Fork Gunnison River. Valley-slope deposits consist of landslide deposits and other unconsolidated Quaternary deposits which receive recharge on the higher slopes and discharge water from the lower slopes. All springs inventoried in the Paonia study area originate from unconsolidated deposits, which in many places are underlain by the less permeable Mesaverde formation.

No wells completed in the Mesaverde formation produce sufficient water for any use within the Paonia study area, although domestic wells completed in the Mesaverde formation have been used for several years in the Cedaredge area.

The Mesaverde formation transmits little water. Water within the Mesaverde formation normally is limited to relatively small and isolated lenticular sandstones.

The 600-ft thick coal member above the Rollins Sandstone member conducts more water through secondary hydraulic conductivity features such as fractures than it does otherwise; however, core drilling indicates that fracture zones probably are not areally extensive.

The Barren member probably is the least permeable unit in the Mesaverde formation.

Small transmissivity values and small storage coefficients are characteristic of the Mesaverde formation in the Delta-Paonia area.

Transmissivity values and storage coefficients reported for unconsolidated Quaternary deposits are greater than those reported for the Mesaverde formation.

6.0 GEOLOGIC AND ENGINEERING ANALYSIS

6.1 Characteristics of Mesaverde Formation

The Mesaverde formation in the study area transmits little groundwater because of the negligible transmissivity of the 1,300-feet of fine-grained sandstone, coal and shale comprising the formation (Brooks, 1983). Based on mining and drilling data and spring and seep surveys, groundwater in the Mesaverde formation is limited to isolated sandstone beds in the Barren and coal bearing members, the Rollins Sandstone member, and along fault and fracture zones (USBLM and USFS, 1999).

These statements regarding the Mesaverde aquifer are consistent with the January 31, 2001 Colorado Division of Minerals and Geology (CDMG) report entitled *Cumulative Hydrologic Impact Study (CHIA)—North Fork of the Gunnison River* which addresses the following mines: Hawk's Nest, West Elk, Sanborn Creek, Bear, Blue Ribbon, Terror Creek and Bowie. This report indicates that "the laterally discontinuous lenticular sandstones within the upper Mesaverde formation support only localized groundwater flows, and are considered to be insignificant in terms of the overall hydrologic balance." Regarding the Rollins Sandstone, the CHIA states: "due to the steepness of the topography in the outcrop areas and the narrowness of the stream valleys, the Rollins Sandstone receives little recharge except in the area under the North Fork of the Gunnison River and its associated alluvial deposits . . . recharge along outcrops

and sub crops above the level of the North Fork is generally insufficient to sustain groundwater wells developed in the Rollins . . . aside from the domestic use of Rollins water along the North Fork near the Hawk's Nest mines, its water quality elsewhere is considered too saline for domestic use."

On the west side of the study area in the Lazear report, there is another hydrologic impact evaluation prepared by CDMG entitled *Cumulative Hydrologic Impact Study of the Tongue Creek Watershed*, which focuses on the Red Canyon Mine and Tomahawk Mine. Red Canyon mined the "E" seam of the Mesaverde formation while six seams were mined at Tomahawk (seams A-F). The Tongue Creek CHIA reached similar conclusions regarding the hydrogeologic characteristics of the Mesaverde formation, including:

> *The Mesaverde does not typically have productive aquifers in this area due to poor lateral continuity, inappropriate petrology or poor recharge topography.*
>
> *The Rollins Sandstone lies 150-feet below the Red Canyon 'D' seam. This regional aquifer is rather dry in this area as the seam is a cliff-former and little recharge is possible. No impacts are predicted for this aquifer as the discontinuous sandstones, siltstones, shales and coals between the mining zones and the Rollins preclude migration of water.*

Various references refer to the Rollins Sandstone as the Rollins "aquifer," but this is a mischaracterization in the Lazear study area given its very low water yield. The term "aquifer" is defined by the widely-cited 1987 groundwater reference *Glossary of Geology* by Bates and Jackson (American Geological Institute) as:

> *Aquifer—a body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.*

For this evaluation, WWE also reviewed text from the files at CDMG regarding probable hydrologic consequences for these mines: Orchard Valley (Bowie #1), Somerset, Sanborn Creek, Bear 1, 2 and 3, Bowie #2 and West Elk. (These mines are on the east side of the study area whereas the Red Canyon and Tomahawk Mines are on the west side.) The characterizations of the Mesaverde aquifer found in all of these mine reports are consistent and indicate that the Mesaverde formation contains little groundwater. For example, the following text is cited from page 2.04-24 ~~if~~ of the Bowie #2 Permit Application:

> *All of the mines in the region report a similar experience as that observed at the Bowie #2 Mine. The Mesaverde formation does not contain extensive aquifers. Typically, the formation is dry or the rock units are of such low permeability they yield insufficient water for sustained use. Even the extensive Rollins Sandstone, the recognized aquifer in the region, is highly cemented and a low producer.*

The Lazear report states: "preliminary analysis of existing data has determined that there are two aquifer levels in the Mesaverde, the Rollins Sandstone and a zone 600-feet above it stratigraphically." There is no support for this conclusion based on WWE's extensive literature review and the experience of Messrs. Dunrud and Rold in the study area. In fact, the upper "aquifer" shown in Figure 2 of the Lazear report would be in the Barren member of the Mesaverde formation, and numerous references characterize this zone as containing no appreciable water (see Section 6 of this report).

The analysis utilized by Mr. Lazear to justify two aquifers, described on page 6 of his July 8th report (and based upon his interpretation of the data in Figure 2) is not supportable. His graph of "Hydrostatic Head versus Elevation" does not substantiate that there are two separate aquifers within the Mesaverde formation. No statements regarding statistical confidence are associated with Figure 2. There do not appear to be enough data points upon which to base a conclusion regarding the presence of two aquifers. That is, there are many more monitoring well data in the Mesaverde formation in the study area than are shown on Figure 2. Visual inspection indicates

that the slopes of the lines on Figure 2 where there are allegedly two aquifers are not significantly different from the slopes on the other parts of the graph. Mr. Lazear does not discuss how water levels fluctuate for the wells that comprise Figure 2. In fact, WWE is not certain which wells were used to prepare Figure 2—an accompanying data summary would have been helpful.

6.2 Analysis of Projected Water Production Rates for CBM Wells

The Lazear report states that each CBM well will produce 2,540 bbls of water per day (74 gpm), which will "require 20 truckloads per day of hauling water over Grand Mesa for each exploration well." He also notes that "this rate of dewatering is about 15 times the usage rate of all Mesaverde domestic well users combined" and that "300 CBM wells would dewater the Mesaverde Aquifer of 240,000 acre feet (AF) or 1/3 the volume of Blue Mesa Reservoir." These projections are dramatic overstatements, as indicated by the following facts:

- Mr. Lazear's value of 2,540 is *calculated* and *not* based on actual well data. The assumptions for his calculations are not supportable, as discussed below.

- WWE researched the COGCC website and their office files for oil and gas and CBM well produced water data in the area studied by Mr. Lazear. WWE staff reviewed files for every oil & gas well in the 432 square mile area defined on Figure 1 of the Lazear report. In this area, there were records for 39 wells, 31 are dry plugged and all of these are abandoned. The remaining wells are permitted, proposed or shut in. There were no water production data for any of the 39 wells in the COGCC files. All 39 of the wells are shown on Figure 1 of this report (large map exhibit).

- WWE broadened our review of files at the COGCC website to include one additional range to the east (range 91 west) and one additional township to the north (township 10 south). After broadening the study area in this manner, WWE located five wells that had water production data, four oil/gas wells and one natural gas well. These are

designated with letters "A" through "E" on Figure 1. The yields of all five wells were very low, with a maximum yield of 5 bbls/day/well. In addition, the Somerset well drilled in the early 1980s by Amoco in Section 9 of Township 12 south, Range 90 west had an initial water production rate of 150 bbls/day (6,300 gallons per day) which declined after six months to 35 bbls/day (1,500 gallons per day).

WWE's research at the COGCC offices indicates that the vast majority of the wells shown in the area defined on Figure 1 of the Lazear report are abandoned, plugged and/or have no produced water yield data. WWE strongly disagrees with Mr. Lazear's statement that: "It is apparent from the map that there is an abundance of existing oil and gas well data and that new exploration wells will not provide any critical data regarding geology or hydrology." In WWE's view, produced water yield data from natural gas wells in the area is an *essential need*. WWE also notes that in Mr. Lazear's first report, his view on the need for additional data differed, as per the following quotations on page 16:

With such dire consequences at stake, this model needs to be tested by acquiring new hydrologic data to see if the predictions are verified.

We recommend this be done with a minimal number of monitoring wells in which base line hydrologic data is measured for all aquifers between the surface and the coal beds (water quality, pressure, flow rates).

Once base line data is established and the hydrologic model is updated, a new assessment of the impact of CBM production can be made.

We recommend that until this is completed, no hydrofracturing or CBM development should be allowed.

- The Reference *Geologic and Hydrologic Assessment of Natural Gas from Coal: Greater Green River, Piceance, Powder River, and Raton Basins, Western United States* (1995) contains substantial data for natural gas wells in the Piceance Basin throughout Colorado. Table 2 summarizes the data and demonstrates that actual water yields have ranged from a low of 0 bbls/day/well to a high of 188 bbls/day/well. The high value of 188 bbls/day/well is equivalent to 5.5 gpm which is the flow of a typical garden hose. Table 2 indicates that the average water yield of Piceance Basin natural gas wells is less than 100 bbls/day/well, *or nearly 25 times smaller than the estimate from Mr. Lazear*.

- A production rate of this magnitude (2,540 bbls/day/well) is inconsistent with observations of the Mesaverde formation developed by public and private entities as described earlier in this report. The estimate is also inconsistent with Cumulative Hydrologic Impacts Analyses conducted by the CDMG, and Annual Hydrology Reports (AHRs) prepared by local coal mines. The many coal mines in the North Fork Valley have, in general, not experienced significant groundwater inflows.

- The USGS Fact Sheet FS-156-00 (Nov 2000) provides these CBM produced water average values for Colorado:

  - Raton Basin: 266 bbl/day/well (7.8 gpm)

  - San Juan Basin: 25 bbl/day/well (0.7 gpm)

- Mr. Lazear does not account for the fact that natural gas wells typically start with high flows followed by sharp reductions in water yield over time.

- It would not be economically feasible for Gunnison Energy to pump this magnitude of water every day—i.e., the proposal would not be feasible.

- The calculations that Mr. Lazear uses to arrive at the 2,540 bbls/day estimate (see page 7 of his report) are based on unrealistic assumptions. For example, there is not a 100-ft thick saturated seam in the Mesaverde to be dewatered. Even if there were such a seam, the CBM production process would not result in complete dewatering—only enough water needs to be removed to release the CBM into the well bore. His use of the parameter "specific capacity" is inappropriate for isolated, discontinuous lenses of groundwater that are found in the Mesaverde—this parameter is to be applied to true aquifers. Even if the use of this parameter were appropriate, the reported value of 0.74 gpm/ft of drawdown is based on data from only five wells, whereas there are hundreds of Mesaverde monitoring wells in the study area which report data on file with CDMG.

  Data from only five wells were used to calculate 0.74 gal/min/ft. This is too small a sample size to be statistically valid, and the five data points that were used range from 0.1 to 1.3 gal/min/ft. This is a wide range.

6.3 Assumption Regarding Extensive and Continuous Vertical Fractures

Central to Mr. Lazear's description of adverse impacts to local water resources due to CBM extraction is his assumption that the various formations are heavily fractured and faulted, thereby permitting free "communication" from top to bottom and transmittal of surface water from the Grand Mesa into the Mesaverde formation. The reports that WWE has reviewed from such organizations as the U.S. Geological Survey (USGS), CDMG, coal mining companies, Mr. Bruce Bertram and others indicate that fracturing of this nature does not characterize significant portions of the study area. The Lazear report does not acknowledge that most faults like those mapped in this area occurred during a period of mountain building called the Laramide Orogeny. This event, which occurred some 60 to 70 million years ago, formed the major structural uplifts or mountain ranges and basins that are apparent today. Therefore, the Mesaverde and older rocks would have been faulted and folded. Younger formations such as the Green River formation and

much of the upper Wasatch formation did not exist at that time and therefore, would not be faulted, except for any minor faulting that may have occurred later. As would be expected, all but one of the numerous faults shown in the Mesaverde rocks by Ellis, Gashill and Dunrud (USGS 1987) do not extend into the Wasatch and younger rocks.

In short, geologic history seriously contradicts Mr. Lazear's theory that waters from Grand Mesa predate downward into the Mesaverde and then seep to the surface.

The Lazear groundwater model does not acknowledge that fractures in the Green River and Wasatch formations (which underlie the Tertiary igneous caprock) *pre-date* the caprock, nor does the model account for the natural fracture "sealing" and "healing" that occur within the fine-grained, plastic materials that comprise the Green River and Wasatch formations, which are extensive in the study area. The Mesaverde formation is also characterized by layers of shale, claystone and siltstone which have been shown by the Colorado Geological Survey (CGS) to be effective at filling in subsidence cracks, as referenced in text at the offices of CDMG prepared by Arco Coal Company and Arch Coal Company on the West Elk Mine (regarding Probable Hydrologic Consequences and Annual Hydrology Reports)

The Bowie #2 Permit Document states on page 2.04-25:

> *The primary (granular) permeability is low due to the lithologic composition of the sandstone and the secondary (fracture) permeability is not well developed. Extensive core drilling within these strata shows that fracture zones are not well developed. Similar observations were made in the Orchard Valley underground mine. Fracture zones or zones of lost circulation during drilling do not appear to extend from hole-to-hole. Fracture and fault zones, although encountered, are not well developed.*

The CDMG January 31, 2000 report, *Cumulative Hydrologic Impact Study—North Fork of the Gunnison River* states that some fractures and faults transect the Mesaverde formation and

extend vertically to the surface, but that such faults and fractures produce no bands of secondary porosity within the rock strata. Extensive transmissivity data for the "B" seam and Rollins Sandstone collected by Mayo, et al. for the West Elk Mine in the late 1990s showed low transmissivity values.

The rates of inflow to coal mines associated with faults and fractures are often characterized by an initial surge of water which then either decreases significantly or ceases completely with time. Inflows from faults and fractures located outside of stream valleys, such as in the Bowie #1 mine, generally dry up with time or flow intermittently at discreet points along the fault or fracture. Where mine portals underlie colluvium, they typically experience small seasonal inflows of colluvial groundwater.

The USGS, CDMG and coal company hydrologic documents characterize the permeability of the coal seams in the Mesaverde formation. These references indicate that the coal seams generally contain little groundwater. For example, the 2001 North Fork CHIA notes that Mountain Coal Company found little, if any, water in the "F" seam and concluded that "aquifer tests indicate that the 'F' seam and the lenticular sandstones in the Barren member are poor aquifers at best . . ." This same report states: "observations made underground by the staff of CDMG at the Blue Ribbon, Hawk's Nest, West Elk, Somerset and Orchard Valley Mines indicate that the coal seams in the region are poor aquifers with very low transmissivities."

6.4 Importance of Colluvial and Alluvial Groundwater Systems

Of critical importance from the standpoint of regional hydrology is alluvial and colluvial groundwater, yet the July 8, 2002 Lazear report (and Lazear groundwater model) do not address this subject. This is in contrast to the many reports prepared by the USGS, BLM/USFS, CDMG coal mines, Mr. Bertram and others that were reviewed by WWE for this evaluation—all of these stress the importance of alluvial and colluvial groundwater in this area. This is a very significant omission because the Lazear report suggests that surface water on the Grand Mesa infiltrates

directly into faults and fractures which convey the water down into the Mesaverde formation. In fact, all of the reports, maps, etc. reviewed by WWE indicate that a substantial component of the water on the Grand Mesa that infiltrates becomes colluvial flow, and moves downslope until it emerges as springs/seeps or transitions into alluvial flow. As pointed out by Mr. Bertram in his June 2002 report on page 8, there is a very large separation distance between alluvial/colluvial groundwater systems and the Cameo coal zones where the CBM will be extracted.

Brooks, in his 1983 USGS report, *Hydrology and Subsidence Potential of Proposed Coal-Lease Tracts in Delta County, Colorado* describes the importance of alluvial/colluvial flows as follows:

> *Unconsolidated Quaternary deposits locally recharge and discharge in the North Fork Gunnison River Valley, ultimately contributing water to the river. These composites comprise the more productive aquifers in the Delta-Paonia area. This is especially true in the Paonia area where most water supplies are developed from valley alluvium along the North Fork Gunnison River. Valley-slope deposits consist of landslide deposits and unconsolidated Quaternary deposits which receive recharge on the higher slopes and discharge water from the lower slopes. All springs inventoried in the Paonia study area originate from unconsolidated deposits, which in many places are underlain by the less permeable Mesaverde formation.*

Almost all springs and wells in the unconsolidated materials or the weathered zone of Mesaverde bedrock and even the old water producing mines show large seasonal variations in water production. They produce heavily in the spring and during the irrigation seasons and lessen their production in the fall and dry time of the year (personal communications between John Rold and Messrs. Loucks and Bertram, 2002). If Mr. Lazear's theory that water in the wells and springs came from deep in the Mesaverde were correct, the wells and mines would not exhibit this marked seasonal variation.

In short, WWE believes that the omission of colluvial and alluvial groundwater flow in the Lazear report is significant, and leads to an inaccurate characterization of groundwater flow in the region.

6.5 Faults and Surface Drainages

The Lazear report correctly indicates that faults exist under the major drainages of Surface Creek, Leroux Creek, Hubbard Creek and Terror Creek. The report goes on to state that "some of these faults are in close proximity to CBM exploration wells and may provide high permeability conduits connecting CBM watered zones horizontally to domestic water wells and vertically to surface water." This assertion ignores the fact that over thousands of years, erosion of material from the Wasatch formation with subsequent deposition in stream channels tends to "seal" the channel bottoms from the underlying faults. Representative photographs of the Wasatch formation are provided in Appendix C. The effectiveness of Wasatch formation materials at "sealing" was noted by Brooks in his 1983 report of the area: "alluvial deposits contain fine siltstone and clay sediments derived from the Wasatch formation. This silt and clay could seal subsidence cracks." Brooks (1983) also noted that few faults were reported in the Cedaredge/Paonia study area addressed by his report.

The West Elk Mine Probable Hydrologic Consequences (PHC) text (available at the CDMG office) also describes surficial crack "sealing" and "healing" mechanisms, and indicates that sub-surface coal mining in the vicinity of Minnesota Creek would be very unlikely to affect surface flow given the extensive and thick sediment load carried by the stream from the Wasatch formation. The Colorado Geological Survey has also investigated crack sealing/healing, with similar findings. The Lazear groundwater model should account for such mechanisms, which reduce the recharge quantity of surface flows.

6.6 Domestic Water Use Estimates

Mr. Lazear's estimates of domestic water use are low by reference to standard engineering references on municipal water supply. Assuming only incidental outside water, three people per residence, and 80 to 100 gal/capita/day of use, Mr. Lazear's estimate is low by a factor of two. Thus, Mr. Lazear's comparisons of CBM-produced water to domestic water are incorrect, not only because he significantly overstates the quantity of produced water, but also because he understates domestic water use.

7.0 CONCLUSION

The July 8, 2002 Lazear report mischaracterizes the hydrogeology of the study area and overstates expected produced water yields from the proposed natural gas exploration wells by 1-2 orders of magnitude (a factor of 10-100). The five exploratory wells proposed by Gunnison Energy would provide extremely valuable hydrogeologic data.

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TABLE 1

HYDROGEOLOGIC DATA SUMMARY

USGS Water-Resources Investigations Report 83-4069 and 84-4185

		Report 83-4069[1]			Report 84-4185[2]					
Hydrostratigraphic Unit	**Sub-Unit**	**Thickness (ft)**	**Transmissivity (ft^2/day)**	**Storativity[3]**	**Sample Points**	**Well Yield (gpm)**	**Conductance (µS/cm)**	**Dissolved Solids (mg/L)**	**Dominant Cation**	**Dominant Anion**
Alluvium (Stevens Gulch)	--	--	108-230	0.002 to 0.2	6 wells 8 Springs	1 to 750 Up to 200	80 to 3220 48 to 510	63 to 2970 46 to 305	Calcium Calcium	Bicarbonate Bicarbonate
Quaternary deposits	Unconsolidated	--	1900	--						
Mesaverde formation (upper)	Barren Member	500	0.33	--	19	0.7 to 25	325 TO 5390	206 TO 3360	Sodium	Bicarbonate and Sulfate
Mesaverde formation (lower)	Rollins Sandstone	200	--	--						
Mesaverde formation (lower)	Coal Beds	600	1.5-16.7	0.00004 to 0.097						

[1] *Information contained in USGS Report 83-4069 entitled "Hydrology and Subsidence Potential of Proposed Coal-Lease Tracts in Delta County, Colorado"*

[2] *Information contained in USGS Report 84-4185 entitled "Reconnaissance of Groundwater Resources in the Lower Gunnison River Basin, Southwestern Colorado"*

[3] *Defined in an aquifer as the ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity to the volume of that mass. (Also storage coefficient.)*

TABLE 2

Actual Water Production Rates for Individual Natural Gas Wells In the Piceance Basin[1]

Operating Company	Well Location (Field)	Water Yield (bbl/day)	Water Yield (gpm)
Barrett Resources	Parachute Field (Cameo coal beds)	5	0.15
	Parachute Field (shallow Mesaverde)	5	0.15
	Grand Valley Field	0	0
	Rulison Field	0	0
Conquest Oil/Bataa	South Shale Ridge Field (test well)	6	0.18
	South Shale Ridge Field (highest water yield of multiple wells)	120	3.5
Fuel Resources Development (Fuelco)	White River Field	38	1.1
	Rulison Field	72	2.1
	Rulison Field	96	2.8
Oryx Energy	Divide Creek Field	188	5.5
Chevron USA	Parachute and Skinner Ridge Fields	28	0.82
	Parachute and Skinner Ridge Fields	8	0.23
	Parachute and Skinner Ridge Fields	28	0.82
Anadarco Petroleum, Inc.	Bronco Flats	60	1.75
Unocal Exploration Corporation	Buzzard Creek Field	19	0.55
Other	Pinyon Ridge Field	121	3.5

[1] Tyler, et al. (1995) *Geologic and Hydrologic Assessment of Natural Gas from Coal: Greater Green River, Piceance, Powder River, and Raton Basins, Western United States*