BLM

Appendix 4

Water Resources Monitoring Plan

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Appendix 4
Water Resources Monitoring Plan

1.0 Introduction

In 2005, the Bureau of Land Management (BLM) funded the United States Geological Survey (USGS) to create a regional framework for Water Resources Monitoring Related to Energy Exploration and Development (Regional Framework). The Regional Framework (McMahon et al. 2007) is a universal water resource monitoring methodology that can be applied to any BLM field office facing energy development. The Regional Framework was funded as part of the BLM's Assessment, Inventory, and Monitoring (AIM) Strategy (Toevs et al. 2011). As an example of its use, the Regional Framework approach was applied to the Piceance Creek and Yellow Creek watersheds in White River Field Office (WRFO), in the Mesaverde Play Area (MPA). Baseline data collection recommended in the Regional Framework for the MPA began in 2007. Information from this data collection effort has been included in the water resource sections in Chapter 3 and considered in Chapter 4 of the Proposed Resource Management Plan Amendment and Final Environmental Impact Statement (RMPA/EIS) for Oil and Gas Development.

The purpose of this Water Resource Monitoring Plan (Water Monitoring Plan) is to document current condition and identify future water resources data collection, management and information gathering strategies for implementing the decisions in the RMPA/EIS. In addition, this Water Monitoring Plan describes baseline data collected, reports completed and outlines the authority, policy, and methods WRFO uses to manage oil and gas activities that have the potential to impact water resources. This Water Monitoring Plan is built on the Regional Framework and past research efforts in the MPA; outlines baseline data collected for ground and surface water in the MPA; is informed by USGS reports funded by the BLM; includes current monitoring efforts; describes standard operating procedures and policies; and describes partnerships and coordination with local government, State of Colorado, other federal agencies, and the oil and gas industry to monitor water resources in the MPA. Proposed future monitoring efforts are presented in Section 4 Water Monitoring Plan Implementation, to be accomplished as funding and time allow.

The first step to implementing the Regional Framework for the MPA was to assess existing information. The BLM funded data gap studies and a data repository to collect and analyze existing water resource information (http://rmgsc.cr.usgs.gov/cwqdr/Piceance/). The Piceance Basin, due to interest in oil shale since the 1930s, has a tremendous amount of baseline data, scientific research papers, USGS reports, monitoring wells and other information directly pertinent to the MPA. There are well over 200 active and inactive monitoring wells in the MPA and an extensive network of historic USGS streamflow sites. These past studies and reports (available from http://library.mines.edu/Tell_Ertl) were used to the greatest extent possible to shape the goals and scope of monitoring efforts and inform this Water Monitoring Plan.

The National Environmental Policy Act (NEPA) mandates a systematic, interdisciplinary approach to ensure an integrated use of natural and social sciences in planning and decision making and the Federal Land Policy and Management Act of 1976 gives the BLM the authority to conduct investigations, studies, and experiments, on its own initiative or in cooperation with others involving the management, protection, development, acquisition, and conveyance of the public lands. This monitoring plan and the Regional Framework are in keeping with this authority.

2.0 Water Resource Management Plan Components

Plan components are the specific implementation decisions and assumptions necessary to achieve effective monitoring for the RMPA/EIS. Methods for implementing plan components are provided in *Section 4.0 Water Monitoring Plan Implementation* of this document and components are built on the conceptual models presented in *Section 3.0 Application of the Regional Framework to the MPA*.

1) The BLM will conduct a review of the Water Monitoring Plan within one year of signing the Record of Decision (ROD), and every third year thereafter. This plan will be updated and refined as needed to achieve an adaptive management approach to water resource monitoring.
2) This Water Monitoring Plan may be modified with a maintenance action as necessary to comply with law, regulation, and policy and to address new information and changing circumstances.
3) The BLM will promote the implementation of reasonable mitigation, control measures, monitoring, and design features through appropriate mechanisms, including lease stipulations and conditions of approval, notices to lessees, and permit terms and conditions as provided for by law and consistent with lease rights and obligations.
4) The BLM will ensure that water resources management strategies, Best Management Practices (BMPs) and stormwater control measures (both operator committed and BLM required mitigation) are enforceable by including specific Conditions of Approval (COAs) in permits to protect water resources based on environmental review (see Appendix B – Best Management Practices and Conditions of Approval).
5) The BLM recognizes that long-term surface water streamflow, climate, water quality, and biological monitoring are essential to define climate conditions, measure long-term trends, and to evaluate the effectiveness of oil and gas management strategies. The BLM will continue to maintain and support groundwater, streamflow, and climate sites with the USGS and at BLM maintained sites as funding and personnel allow.
6) The BLM will work collaboratively with state, local, and federal agencies responsible for water resource management. This strategy will include participation in local stakeholder groups like the White River Water Quality Group, the Source Water Protection Committees for Rangely and Meeker, the Piceance Basin Steering Committee and other groups in a position to augment and partner in efforts to monitor water quality and quantity in the White River Field Office.
7) The BLM will facilitate cooperative efforts with the oil and gas industry, state, local, and federal agencies to establish, fund, operate, and design specific water resource studies as they relate to furthering the overall water resource monitoring goals described.

3.0 Application of the Regional Framework to the MPA

A seven-step process to develop conceptual models was implemented for the MPA and is the basis of the Regional Framework and is adopted for this Water Monitoring Plan:

1) Specify monitoring goals and objectives.
2) Characterize anthropogenic stressors.
3) Develop questions and conceptual models.
4) Suggest indicators.
5) Estimate the sensitivity of indicators.
6) Describe thresholds of change and receptors.
7) Identify clear connections between the monitoring program and management.

The Regional Framework identified specific goals needed to add water quality parameters to USGS streamflow measurement sites for the White River, Piceance Creek and Yellow Creek; and BLM began funding this effort in 2007. The RMPA/EIS and the Regional Framework addressed the first five steps in the framework by defining goals and management objectives for water resource management and also by identifying aspects of the proposed action that may impact water quality (anthropogenic stressors). However, the Regional Framework did not define conceptual models for monitoring; therefore, this Water Monitoring Plan begins on the third step of the Regional Framework, which is to develop conceptual models for monitoring water resources. It is useful to separate ground and surface waters; therefore two conceptual models are presented.

The overall goals the Regional Framework were to develop robust and cost-effective baseline monitoring for water resources. This has been accomplished for the MPA for surface waters and groundwater by achieving the following monitoring goals and objectives:

8) Evaluate existing water-resources data for uniformity.
    a) This goal was accomplished by baseline assessment reports for groundwater (http://pubs.usgs.gov/sir/2012/5198/) and surface water quality (http://pubs.usgs.gov/sir/2013/5015/). The groundwater report included sampling results from private domestic wells. Parameters sampled for both surface water and groundwater are listed in these reports.
9) Develop a web-accessible common data repository that provides energy operators, researchers, consultants, agencies, and interested stakeholders equal access to the latest information.
    a) This goal was accomplished by the Piceance Basin Stake holder Group and data repository (http://rmgsc.cr.usgs.gov/cwqdr/Piceance/).
10) Perform and publish a baseline assessment of available water-resources data.
    a) Baseline assessment reports for groundwater and surface water quality (http://pubs.usgs.gov/sir/2013/5015/ and http://pubs.usgs.gov/sir/2012/5198/).

11) Use this information to inform regional monitoring strategies to more economically fill data gaps by reducing duplication of effort while still meeting regulatory requirements.

   a) The BLM funded water quality data collection at seven USGS streamflow measurement sites, established three conductivity probes on the White River, two on Piceance Creek and one on Yellow Creek since 2007.

   b) The BLM has supported additional water quality sampling in the White River, Piceance Creek and Yellow Creek. Water quality sampling measured the following parameters:

      i) Physical: pH, temperature, specific conductance, dissolved oxygen (DO), DO saturation, turbidity, salinity, and hardness.

      ii) Nutrients: Inorganic nitrogen (nitrate plus nitrite), total phosphorus, orthophosphate, ammonia, and Kjeldahl nitrogen.

      iii) Metals: Aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc.

      iv) Other: alkalinity, bicarbonate, boron, calcium, carbonate, chemical oxygen demand, chloride, hydroxide, magnesium, sodium, potassium, sulfate, total organic carbon, total dissolved solids (TDS), total suspended solids (TSS), BTEX (e.g., benzene, toluene, ethylbenzene, and xylenes).

      v) Isotopic Analysis – The groundwater sampling program used multiple approaches to isotopic analysis to look at ages and source of water (McMahon 2013).

      vi) Real-time: Conductivity probes were installed on three sites in the White River, two sites on Piceance Creek and one on Yellow Creek.

      vii) BTEX was measured for five years at three sites on the White River, two on Piceance Creek and one on Yellow Creek. There was not enough record to apply the trend analysis in (Table 1). BTEX are some of the volatile organic compounds (VOCs) found in petroleum derivatives such as gasoline or diesel fuel, but there are also natural sources for BTEX from hydrocarbon sources that may show up in groundwater. Natural sources of BTEX are discussed in more depth with the Groundwater Conceptual Model.

   c) Six new streamflow measurement sites were established in the MPA and are maintained by the BLM to measure stream discharge, conductivity, air and water temperature, and conduct water quality and macroinvertebrate sampling. Two precipitation measurement sites and one weather station were established and maintained by the BLM for this area.

   d) Two USGS technical reports of the results of BLM funded water resource monitoring were generated:

      i) Chemistry and age of groundwater in bedrock aquifers of the Piceance and Yellow Creek watersheds, Rio Blanco County, Colorado, 2010–12 (available at http://pubs.er.usgs.gov/publication/70048381).

ii) Characterization of Surface-Water Hydrology and Surface-Water Quality of Piceance Creek in the Alkali Flat Area, Rio Blanco County, Colorado, March 2012 (Thomas in Review).

3.1 Surface Water Conceptual Model

The previous section described the monitoring goals and objectives for the surface water. Ideally, the level of monitoring would continue for surface waters at the current level by maintaining the USGS and the BLM stream monitoring sites and this monitoring would be the basis for the Surface Water Conceptual Model.

The second step in the Regional Framework is to characterize anthropogenic stressors. This step was completed with the impact analysis in the RMPA/EIS. The direct water quality impacts, the RMPA/EIS impact analysis identified the potential for increased runoff and soil erosion from surface disturbance associated with oil and gas development. Eroded soil carried via surface runoff may increase turbidity, salinity, and suspended sediment loads in surface waters. These changes can impact aquatic life, water supply and irrigation, and recreation which are identified beneficial uses for streams.

The impact analysis also identified that freshwater use by oil and gas development may decrease surface flows in streams and increase the proportion of baseflow from groundwater thereby increasing salinity concentrations in surface waters. Another impact to surface waters may occur from unintentional spills and leaks. A conceptual model of the regional salinity and sediment transport in creeks and rivers in the WRFO could potentially be developed using existing data from studies done by the USGS and other agencies during the past 30 years, data collected by the USGS for the Regional Framework since 2007, and from records maintained by the BLM and other agencies.

Step three and four in the Regional Framework are to develop questions, conceptual models and suggest indicators. The logic for a conceptual model for surface water would be with increased surface disturbance, increased freshwater use, and the potential of spills form oil and gas development in the MPA, it is anticipated the stressors would result in upward long term trends or short-term spikes, in dissolved solids, suspended sediment, BTEX, and trace elements such as selenium.

Long-term significantly relevant trends for water quality parameters in surface waters were analyzed in the Thomas et al. (2013) report. This report indicated increasing dissolved solids loads from upstream to downstream on the White River (Table 1). The total dissolved solids load from the White River Basin was represented by the most downstream site (White River below Boise Creek, near Rangely), where the load in water year 2000 was 245,000 tons. Loads from Piceance Creek at White River for water year 2000 were about 26,600 tons, which was about 11 percent of the total load from the White River Basin. The dissolved solids load was disproportionate to Piceance and Yellow Creek's contribution to stream discharge in the White River, which was 4.1 percent of the streamflow measured in water year 2000 (USGS 2013).

Table 1. Water Quality Trend Analysis of Selected USGS Gaging Stations in the WRFO

Site Number	Site Name	Period of Record, Trend Direction[(1)(2)]	Parameter[(3)] (Units)
White River			
09304200	White River above Coal Creek	1992-2002, down 1990-2009, no trend 1990-2002, down 1990-2002, down 1991-2001, down 1990-2001, no trend	Sodium (mg/L) Chloride (mg/L) Sulfate (mg/L) Dissolved Solids (mg/L) Total Rec. Iron (µg/L) Suspended Sediment (mg/L)
09304800	White River below Meeker	1990-2009, no trend 1990-2009, no trend 1990-2009, down 1990-2009, down 1990-2009, no trend 1991-2002, no trend 1991-2009, down	Sodium (mg/L) Potassium (mg/L) Chloride (mg/L) Sulfate (mg/L) Dissolved Solids (mg/L) Total Rec. Iron (µg/L) Selenium (µ/L)
09306290	White River below Boise Creek, near Rangely	1998-2009, down 1999-2009, down 1990-2009, down 1990-2009, down 1998-2009, down 1991-2001, no trend 1990-2009, down 1990-2009, down	Sodium (mg/L) Potassium (mg/L) Chloride (mg/L) Sulfate (mg/L) Dissolved Solids (mg/L) Total Rec. Iron (µg/L) Selenium (µg/L) Suspended Sediment (mg/L)
09306305	White River below Taylor Draw Reservoir, above Rangely	1996-2002, down	Suspended Sediment (mg/L)
Piceance Creek			
09306200	Piceance Creek below Ryan Gulch, near Rio Blanco	1997-2009, up* 1990-2009, no trend 2003-2009, up* 1990-2009, down 2003-2009, up* 1990-2009, no trend 1999-2009, down 1990-2009, down	Sodium (mg/L)* Potassium (mg/L) Chloride (mg/L)* Sulfate (mg/L) Dissolved Solids (mg/L)* Dissolved Iron (µg/L) Selenium (µg/L) Suspended Sediment (mg/L)

Table 1. Water Quality Trend Analysis of Selected USGS Gaging Stations in the WRFO

Site Number	Site Name	Period of Record, Trend Direction[(1)(2)]	Parameter[(3)] (Units)
09306222	Piceance Creek at White River	1990-2009, no trend 1990-2009, no trend 1990-2009, down 2004-2009, up* 1990-2009, down 2001-2009, up* 1999-2009, down 2003-2009, up*	Sodium (mg/L) Potassium (mg/L) Chloride (mg/L) Sulfate (mg/L)* Dissolved Solids (mg/L) Dissolved Iron (μg/L) Selenium (μg/L) Suspended Sediment (mg/L)*
Yellow Creek			
09306242	Corral Gulch near Rangely	1990-2008, down 1990-2008, no trend 2002-2008, up* 1990-2008, down 1993-2008, down	Sodium (mg/L) Potassium (mg/L) Chloride (mg/L)* Sulfate (mg/L) Dissolved Solids (mg/L)
09306255	Yellow Creek near White River	1990-2009, no trend 1990-2009, no trend 1999-2009, up* 1990-2009, down 1991-2009, up*	Sodium (mg/L) Potassium (mg/L) Chloride (mg/L)* Sulfate (mg/L) Dissolved Iron (μg/L)*

NOTES: Adapted from Thomas et al. 2013
(1) Only selected parameters with potential oil and gas impacts and considered in this summary.
(2) Results that failed the test for enough data were not included and only the latest time frame available was included
(3) Parameters are for "Filtered" unless otherwise noted.
* Parameters with an upward trend during the most recent time period

Both Yellow Creek and Piceance Creek have high dissolved solid loads due to groundwater upwelling. The Thomas et al. (2013) report indicated Piceance Creek is showing an upward trend in dissolved solids (Table 1). Between the White River above Coal Creek and the White River below Meeker more than 60,000 tons of dissolved solids load are generated through an outcrop of Mancos shale before the confluence with Piceance Creek. This is confirmed by past studies on water quality including Boyle et al. (1984), which also noted spikes in specific conductivity and dissolved solids downstream of Mancos shale outcrops (e.g., the Meeker Dome and loads from Piceance and Yellow Creek).

One possible question to be answered by the conceptual model would be with the potential for leaks or spills due to failure of well integrity, drilling practices or from surface sources such as pits, or tanks, would specific parameters that could be indicators such as sodium, chloride, iron, sulfate, BTEX and dissolved solids be indicated by upward trends and/or spikes in future monitoring data.

Step five in the Regional Framework is to estimate the sensitivity of indicators. Generally, the characterization and data-gap analysis study (Thomas et al. 2013) indicated that there was either no trend or a net, downward trend in most water quality parameters measured over the period of

1990-2009, including the parameters selected as indicators. During the years of 1990 to 2009 the region experienced increasing oil and gas development. There were a few upward trends presented in the data gap analysis study that could indicate potential oil and gas or other anthropomorphic impacts and are indicated with an asterisk in (Table 1). The data-gap analysis study reported exceedances in recommended standards for domestic water supplies for chloride in Piceance Creek and sulfate in the upstream area of the White River basin associated with Mancos shale, but no other exceedances of water quality standards. The surface water baseline assessment report did not show upward trends in the parameters identified as indicators for the surface water conceptual model.

Step six in the Regional Framework's list of items needed for a conceptual model is to determine thresholds; these thresholds are identified in the RMPA/EIS as significance criteria:

- Exceeding Colorado Department of Health and the Environment (CDPHE) water-quality standards as result of BLM permitted activities.
- Impacts to administered water rights due to freshwater withdrawals to support BLM permitted activities.
- Violating or exceeding BLM Public Land Health Standards specifically for erosion.

Yellow Creek was listed for iron on the 303(d) impaired waters listed in 2012 and was likely in part due to the upward trend in dissolved iron shown in the trend summary table (Table 1). These are the kinds of trends that can lead to an exceedance of a water quality standard. The cause of the upward trend has not been identified by CDPHE and is uncertain from existing data. The RMPA/EIS impact analysis evaluated water quality conditions in detail and there are currently portions of Piceance Creek and Yellow Creek that are listed as impaired for aquatic life standards and specific parameters such as iron by CDPHE.

Determining a cause for impairment is difficult and impairments may result or include natural sources and as such exceeding numeric standards may not require a specific management response. Qualitative thresholds such as Public Land Health Standards may be easier to identify and attribute to a specific cause. For example, rills forming on a reclaimed slope near a drilling pad can be clearly attributed to the surface disturbance and are an indicator of a failure of Public Land Health Standards. Whereas, an increasing trend in suspended sediments might be attributable to natural occurring events or other anthropomorphic causes and may not require a specific management response, but instead require further study to identify causes.

Additional stressors from oil and gas development that may contribute to exceeding the thresholds described above are:

- Increased soils erosion due to increased hillslope and surface-erosion rates. Erosion may increase sediment loading and an increase in associated water-quality constituents (salinity, nutrients, and metals) in receiving streams.
- Loss of vegetation, compaction of soils, and concentrating drainage may increase surface-water runoff volume and frequency.
- The storage, transport, use, and production of fluids and the use of industrial chemicals for drilling, stimulation, and hydraulic fracturing of wells, increases the risk of spills or leaks.

Historically, the stressors that affect salt loading between groundwater and surface water sources in the MPA have been relatively static. With the increased surface disturbances from the expansion of the current gas play in the study area, noticeable impacts to sediment yields and subsequent salt loading to streams on a regional basis is likely (McMahon et al. 2007).

Currently, Piceance Creek at the White River shows an upward trend in suspended sediment concentrations and it is possible this upward trend is due in part to surface disturbance from energy development. Due to the complexities of sediment transport dynamics and the increased sedimentation of these systems, the Regional Framework looked at a modeling approach that would augment the suspended sediment measurements in surface waters (McMahon et al. 2007) recommended intensive spatial and temporal sampling may be needed to separate sediment yield resulting from energy development from sediment yield resulting from natural variables and other land uses. Some of these approaches, as well as step seven, identify connections between monitoring and management and BLM policy are discussed in Section 4.0 Water Management Plan Implementation along with proposed monitoring efforts.

3.2 Groundwater Conceptual Model

For the purposes of the groundwater conceptual model, the Piceance Creek Basin refers to the portion of the structural basin bounded by the MPA (Piceance Creek and Yellow Creek). The first step in the Regional Framework is to develop monitoring goals and objectives, these goals and objectives were changed from the 2007 document to establish dedicated groundwater monitoring wells instead of collecting regional water levels.

The 2007 Regional Framework recommended that the most effective groundwater indicators would be water-level and stream discharge measurements due to freshwater use by oil and gas development. However, it became clear as oil and gas development has progressed in the Piceance Creek Basin that groundwater is not now nor is it likely to be the primary source of freshwater for oil and gas development in this area. This is because of the widespread reuse and recycling of both fresh and produced water and operators successfully obtaining surface water rights. Surface sources for freshwater supply are more likely to be used as compared to groundwater sources, due to the available surface water rights in the Basin. Groundwater development as a freshwater source for oil and gas development has been limited because of the difficultly in providing augmentation water to offset impacts to senior water rights on streams and springs. Therefore, the assumption that regional groundwater levels would change or stream discharge would be noticeably impacted by groundwater withdrawals is not realistic. However, the RMPA/EIS indicates that water quality impacts resulting from surface water withdrawals may lead to reductions in streamflow. Current sources of freshwater include in-priority withdrawals from Piceance Creek and its tributaries, water withdrawals from the White River, and water purchased from Rangely or Meeker. Applications for Permit to Drill (APDs) must specify all water sources and the validity of water rights used for these purposes is evaluated by the BLM before approval of APDs.

If groundwater becomes a primary source for freshwater in the future, operators will be required to provide augmentation water to offset their depletions to surface streams and springs. In addition, freshwater supply wells will also require land use authorization from the BLM if such wells are located on BLM lands. If oil and gas operators divert groundwater that depletes surface streams, they could injure senior water rights holders. The use of groundwater as a source of freshwater could also injure senior water rights held by the BLM on springs. Operators would likely require augmentation water to offset their depletions to surface streams and springs. The Colorado Division of Water Resources (CDWR) has monitored regional water levels since 1991. Trends in regional water levels appear to be linked to climatic conditions and not groundwater use. Regional changes in water levels would be considered in permitting any new groundwater withdrawals and any resulting impacts would be evaluated in an environmental review before approving new groundwater wells.

Based on a better understanding of oil and gas development in MPA, monitoring objectives and goals were redirected to sampling groundwater quality from existing and improved monitoring wells instead of duplicating the CDWR's efforts at measuring regional groundwater levels.

The following items were selected as potential stressors in a revised groundwater monitoring approach completed in 2008 by the WRFO:

- Lost circulation zones during natural gas drilling have the potential to introduce contaminants to shallow aquifers.
- Injection wells and water storage or treatment ponds have the potential to contaminate shallow aquifers or surface water through fault driven pathways. This may occur through exceeding fracture pressures of formations and by pit liners failing.
- Poor cementing of gas wells and failures in well bore integrity, drilling techniques, and or well bore design may introduce pathways for contamination of shallow aquifers from high salinity zones and/or producing formations. Well bore failure can also lead to alteration of local and regional ground-water flow systems.

The WRFO groundwater monitoring well network can help to identify changes in groundwater flow paths or introduced contaminants from these stressors. The following tasks have been accomplished to achieve the monitoring goals and objectives for groundwater:

- GIS products developed within the USGS Energy Resource Program's Central Energy Team were utilized to better understand the groundwater hydrology of the basin. Historical studies for the area were also reviewed.
- A partnership with USGS and Shell Exploration and Production was formed to inventory and do geophysical logging of 40 existing groundwater monitoring wells in order to identify wells for use in the monitoring network and to determine methods for low-flow sampling.
- The BLM funded the recompletion of two wells and drilled one new monitoring well on the TH75-13 pad near Black Sulphur Creek. This allows the A-Groove, B-Groove and the Uinta formation to be sampled from one pad site.
- Groundwater sampling of 14 wells in the MPA for parameters of concern including gaseous samples and extensive isotopic analysis. Sampling is planned for fiscal year 2013 and 2014, but future years are uncertain.
- A site specific study of ground and surface water interaction on Piceance Creek below Alkali Flats was conducted by USGS and funded by the BLM.
- WRFO also completed an inventory of springs on BLM administered lands within the MPA. This four year effort was completed in the summer of 2012. The next step is to compile this information and identify specific springs for future monitoring.
- Developed a stakeholder group and water quality database; participants include Rio Blanco, Garfield, and Delta Counties; Colorado River Conservation District, USGS,

Encana Corporation, Williams as well as other oil and gas operators. A groundwater assessment for the Piceance Basin was published (Thomas et al. 2013).

Preliminary results from the groundwater monitoring wells found three BTEX compounds (benzene, toluene, and ethylbenzene) in water from six of the monitoring wells. None of the concentrations exceeded drinking-water standards. The groundwater monitoring indicated a widespread occurrence of trace quantities of these BTEX compounds in the bedrock aquifers, specifically benzene and toluene (McMahon et al. 2013). The source of these BTEX compounds needs further study, but preliminary indications point to the BTEX compounds being liberated from the oil shales in the Mahogany zone. Little detection of these BTEX compounds were found in groundwater wells and the concentrates were low when they were detected.

4.0 Water Management Plan Implementation

Although many of the goals of the Regional Framework have been achieved, this effort would be meaningless without continued support of ground and surface water monitoring during future oil and gas development. Funding is looking to be one of the most challenging aspects of continuing the current level of monitoring. The BLM has invested well over one million dollars and much time to building the current monitoring network. The Water Monitoring Plan must continue to build on this robust framework and serve as a model for identifying and collecting information necessary for the regional assessment of oil and gas development to be successful. The BLM will continue to apply resources as they are available to maintain and expand the water monitoring program in the Piceance Basin. The BLM faces a substantial challenge in developing and implementing monitoring programs that are effective and efficient across multiple scales, and capable of satisfying multiple institutional and legal requirements associated with environmental compliance and land-use planning.

The overall goal for the implementation of the Water Resources Monitoring Plan is to develop a practical approach to integrated water-resources monitoring related to energy development that capitalizes on existing monitoring programs and readily available data and information. The BLM and the appropriate state regulatory agency will investigate. If water resource impacts result, then existing monitoring data will be used to identify a specific cause. If existing monitoring data are insufficient, then additional data collection may be required.

4.1 Implications of Approaching or Exceeding Thresholds

The BLM is committed to protecting the integrity of surface waters within its management authority and accomplishes this goal by the administration of oil and gas development according to the Onshore Oil and Gas Orders (Onshore Orders). The scope of any future monitoring will be influenced and implemented with management decisions and processes specified in the Onshore Orders and other BLM policies. Implementation will also include identifying future monitoring and study efforts and must be built on partnerships and collaborations with oil and gas operators and local governments.

Indicators of the potential impact of oil and gas development stressors on surface waters from the MPA are detectable changes in water quality in Piceance Creek, Yellow Creek, or the White River. Monitoring for water quality in perennial streams should be implemented for real-time and long-term temporal scales to evaluate the impact of stressors identified in the RMPA/EIS. Real-time data collected every 15 minutes such as conductivity, water temperature, and streamflow can be evaluated for anomalies that may indicate the potential for persistent or episodic spills and leaks. For example, if there is a loss of saline produced water from a pipeline or on the surface, conductivity levels may spike as the plume moves through surface waters. A more long-term change in conductivity due to surface disturbance or persistent leaks or spills may require trend analysis and complex statistics over time to detect, but still benefits from the frequency of measurement.

Long-term changes in water quality should be evaluated based on statistically rigorous trend analysis. Part of the BLM funded baseline data collection effort included trend analysis on the White River, Piceance Creek, and Yellow Creek. The Characterization and Data-Gap Analysis of Surface Water Quality in the Piceance Study Area (Thomas et al. 2013) looked at changes in historical water quality trends and included sites relevant to the MPA. This trend analysis should be repeated after development gains momentum and the long-term data needed to support this type of trend analysis can be collected. If surface water quality data is not collected in the future or if there are data gaps due to lack of funding, trend analysis may not be possible.

Subsurface activities related to energy development may affect rates of salt dissolution in ground water and ground-water/surface-water interactions that contribute salinity to area streams. Additionally, surface disruption resulting from drilling of wells, and construction of pipelines and roads for both gas and oil-shale development may increase sediment yields, resulting in increases in salt and sediment loading to area streams and rivers. The receptors of the effects of these stressors would likely be Piceance Creek, Yellow Creek, and subsequently the White River.

The BLM will investigate, alert and assist CDPHE or Colorado Oil and Gas Conservation Commission (COGCC) to take the lead in appropriate measures for stopping and remediating leaks or spills. On public lands and for federal minerals, the BLM will participate in the planning for the cleanup process in order to be sure water resources are properly protected. The BLM will also keep track of CDPHE changes in water quality classification, standards, or listing of impaired waters and provide monitoring information when appropriate. If long-term upward trends are detected in groundwater or surface waters, specific studies to determine causality and identify design features, mitigation, policy changes or BMPs that would reduce the upward trends of parameter of concern may be implemented.

The connection between monitoring, thresholds and management decisions for both the groundwater and surface water conceptual models would come when real-time monitoring indicates a potential leak or spill, there is a significant change in water yield, or a long-term upward trend in water quality parameters is identified that can be attributed to oil and gas development.

4.2 BLM Water Resources Land Management Policies

The BLM administers federal mineral resources which include oil and gas operations according to the Onshore Oil and Gas Orders. Onshore Oil and Gas Orders implement and supplement the oil and gas regulations found under 43 CFR 3160. Onshore Order No. 1 (Approval of Operations) covers requirements for APDs for all proposed oil and gas and service wells, certain subsequent well operation and abandonment. Included in APDs are the requirements for drilling and a surface use plan for operations. These plans provide information on reclamation, the protection of groundwater resources and other details that allow the BLM to assess the specific impacts associated with the drilling activity. Based on an environmental review, the BLM may apply COAs to the approved APDs that require measures to mitigate specific impacts identified during the review process. These COAs typically include casing or drilling requirements to protect freshwater aquifers, secondary containment measures to reduce impacts from spills or leaks, additional drainage features for roads and pads to reduce overland flow impacts, BMPs to provide more stability to roads and pads, and reclamation requirements among others (refer to Appendix B).

4.2.1 Freshwater Use and Water Rights

Oil and gas operators are required to provide accurate information for the location and type of water supply used during development including the source, amount of diversions, timing of diversions, access route, and transportation method for freshwater used in their Surface Use Plan of Operations. Proposed water use amounts and sources are evaluated for potential injury to water rights and to water-dependent values during site specific environmental review before a project and its associated water use is approved. The BLM will continue to maintain and protect beneficial water uses on public lands through this review process. In addition, the Colorado BLM has also developed a programmatic consultation with the U.S. Fish and Wildlife Service with regard to water depletions that could jeopardize the recovery of endangered Colorado River fish species. The consultation requires reporting of water use amounts and locations by operators, and also requires mitigation to address potential impacts to the endangered fish. Long-term monitoring at USGS and BLM streamflow measurement sites are used to monitor the success of these policies to protect water-dependent values on public lands.

In anticipation of future freshwater use from oil and gas development as well as oil shale, the BLM has recommended instream flow rights for lower Piceance Creek and lower Yellow Creeks to the Colorado Water Conservation Board (CWCB). The Colorado Water Conservation Board is the only entity authorized under Colorado law to hold instream flow water rights, and that law directs the CWCB to consider instream flow recommendations from federal agencies. If the proposed instream flow water rights are appropriated, they would be junior to existing water rights. However, instream flow water rights can help protect flows by preventing diversions by new, junior water rights during times of the year when the instream flow water right isn't satisfied. Parties who seek to change senior water rights must also insure that when the proposed change is implemented, flows through the protected stream reach aren't reduced beyond what was experienced prior to the proposed change.

Water use amounts and sources are evaluated for potential injury to water rights during site specific environmental review before project approvals.

4.2.2 Floodplains and Wetlands

Executive Order 11988 requires federal agencies to avoid to the extent possible the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. Executive Order 11990 requires federal agencies to take action to minimize the destruction, loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. The BLM first attempts to avoid locating infrastructure in floodplains or wetlands during planning. When areas cannot be avoided the BLM may apply COAs to minimize impacts, allow for mitigation of impacts, and restore the natural conditions after occupancy.

Operators show in their APD that U.S. Army Corp of Engineers (USACE) Section 404 requirements have been addressed. There are various strategies that can be employed to identify waters of the US and it is up to operators to determine the strategy needed to meet Section 404 requirements; strategies typically include the use of nationwide permits. For more permanent features and nonlinear features such as drilling pads, and for projects that are likely to exceed minimums for minor discharges based on fill estimates for nationwide permits, individual permits may be required. Nationwide permits typically have Regional Conditions specific to Colorado (USACE 2012). The type of permit needed is under the discretion of the USACE, but the BLM assures compliance before approvals are granted.

4.2.3 Water Sampling on BLM Administered Lands

Sampling requirements to comply with COGCC and CDPHE regulations is a source of monitoring data for BLM administered lands. The COGCC recently issued rule 609 which will require groundwater sampling within 0.5 mile of any well. The BLM has helped establish and is an active member in the stakeholders group to provide resources to make water quality sampling data available in public repositories. Public repositories such as this could be useful for oil and gas operators to help them comply with COGCC requirements. The COGCC requires sampling of injection formations, produced water, and other information that can be beneficial for monitoring efforts. This data is often submitted to the BLM as part of COAs, and becomes public record. Data collected for one purpose does not always benefit another purpose, but often with some forethought can be designed for both. For example parameters of interest for determining if a specific formation is acceptable for water disposal may not be the same parameters of interest for groundwater monitoring efforts, but if a few parameters are added during the review it might be used for both purposes.

4.2.4 Public Availability and Reporting of Monitoring Data

The Piceance Basin Data Repository was built to house data collected in the Piceance Structural Basin. This area includes most of the WRFO and extends through the I-70 corridor and down as far south as Delta, Colorado. Data from the repository is being migrated to the (http://www.coloradowaterdata.org/).

The BLM collected water quality samples have also been published on the Colorado Data Share Network. The Steering Committee for the Piceance group is looking to team with COGCC to either include data from its database on this site or to develop some type of link between the databases that can assist in making sampling data available. Four peer-reviewed technical reports have been generated by the USGS with support from the BLM:

- Overview of Groundwater Quality in the Piceance Basin, Western Colorado, 1946–2009. By J.C. Thomas and P.B. McMahon (http://pubs.usgs.gov/sir/2012/5198/).
- Characterization and Data-Gap Analysis of Surface-Water Quality in the Piceance Study Area, Western Colorado, 1959–2009. By Judith C. Thomas, Jennifer L. Moore, Keelin R. Schaffrath, Jean A. Dupree, Cory A. Williams, and Kenneth J. Leib. (http://pubs.usgs.gov/sir/2013/5015/).
- Chemistry and age of groundwater in bedrock aquifers of the Piceance and Yellow Creek watersheds, Rio Blanco County, Colorado, 2010-2012: U.S. Geological Survey Scientific Investigations Report. By J.C. Thomas and P.B. McMahon (http://pubs.er.usgs.gov/publication/70048381).
- Characterization of Surface-Water Hydrology and Surface-Water Quality of Piceance Creek in the Alkali Flat Area, Rio Blanco County, Colorado, March 2012. By Judith C. Thomas

4.3 Future Monitoring Projects

Monitoring should be flexible and help identify specific areas for concentrated study. This section contains projects that would add to the overall monitoring goals, information collected to date, and could be implemented based on funding and/or personal in future years.

4.3.1 Aquatic Life

Algae, fish and invertebrate assemblages are the most direct and effective measure of the ecological integrity of streams, living systems have evolved under specific environmental conditions (Karr and Chu 1999). These living systems can respond in somewhat predictable ways to human disturbances such as large-scale landscape changes related to energy development.

In 2012, CDPHE listed or provisionally listed four stream segments in the MPA for aquatic life as impaired. This decision was based on policy statement 10-1, which developed aquatic life use attainment standards for rivers and streams in Colorado. Policy statement 10-1 identified bioassessment and biological thresholds to be used for assessing a streams ability to meet aquatic life criteria. A Multi-Metric Index (MMI) was developed for Colorado to be used as a tool to assess macroinvertebrate communities. Aquatic benthic macroinvertebrates are animals without backbones that live on submerged rocks, logs, sediment, debris and aquatic plants during some period of their life. Reference streams identified in Colorado and the decision for impairment was based on biological community metrics that reflect a significant departure from a reference or expected conditions as indicated by the MMI measured.

The BLM financially supports the National Aquatic Monitoring Center located at Utah State University (the Bug Lab). The WRFO facilitated coordination with the Bug Lab and CDPHE to assure consistency with the CDPHE protocol. The BLM streamflow sites were sampled in 2012 and will continue to be sampled as BLM staff resources allow. Three of the BLM streamflow sites are located in listed stream segments (Yellow Creek, Piceance Creek, and Black Sulphur Creek). Coordination with CDPHE and EPA on future additional monitoring and evaluation of these impaired waters is needed and additional sampling sites may be added in the future as the need arises.

4.3.2 Surface Disturbance, Erosion and Sedimentation Modeling

As part of the RMPA/EIS, the BLM is implementing a data collection and database management project designed to accurately track surface disturbance and reclamation associated with oil and gas (See Appendix D). This project employs extensive ground truthing, remote sensing, and new requirements for electronic reporting on behalf of operators. This data is the type of detailed information that can be effectively utilized by erosion models such as Water Erosion Prediction Project (WEPP) model or the KINematic Runoff and EROSsion model, (KINEROS) on a hillslope or subwatershed level. Model output can then be combined in a tool such as the Automated Geospatial Watershed Assessment (AGWA) tool for hydrological analysis. This approach can be paired with continued suspended sediment measurement at USGS streamflow sites to evaluate and monitor overall sedimentation rates.

This tool could be used at the Master Development Plan level to identify targeted BMPs for specific locations to be attached as COAs based on predicted erosion rates. This tool could also be used to assess the success of BMPs used and adapt new BMPs that may be more effective. Base layers for soils, vegetation data from Assessment, Inventory and Monitoring (AIM) protocol, information from the reclamation and disturbance database, slopes and other geospatial information can be used to improve hydrologic model performance and predict erosion.

4.3.3 Natural Spring Monitoring

Groundwater springs are an important element in monitoring and essential for identifying potential impacts from energy development. A spring inventory begun in 2008 in the MPA measured field water quality and flow information for over 500 springs in the Piceance area. This inventory can be used to identify springs in a statistically rigorous way for more intense sampling. More detailed monitoring could include the installation of permanent flow monitoring sites and more intensive sampling that would include potential stressors such as BTEX as recommended by Thomas et al. (2013) along with isotopic analysis. Isotopic analysis can be informative about sources and transit times and recharge areas for groundwater.

4.3.4 Expansion of the Groundwater Monitoring Network

The groundwater monitoring study recognized the limitations of fourteen wells to characterize groundwater chemistry in a 900 square mile study area (McMahon et al. 2013). Although great care was taken to inventory the available monitoring wells and select ones that may be representative of the aquifers and take into account spatial variability and trends identified in previous research, adding additional groundwater monitoring wells would likely greatly enhance the scope and clarity of sampling results. Also, due to funding limitations, a subset of sampling parameters and a subset of wells to be sampled has been used. Additional wells were recommended by McMahon et al. (2013) to improve the ability to define spatial variability and variability measured in chemical and isotopic composition of the water quality samples.

One of the key findings of this report was the need for pre-drilling groundwater sampling data in areas where development is proposed but not yet started. Groundwater sampling should be continued near pad sites as wells are drilled and completed to provide continued monitoring as activities. It is likely that if monitoring and sampling of the existing monitoring network one of the current monitoring wells could serve this purpose. However, establishing additional monitoring wells would likely improve the odds for having baseline data from a groundwater well nearby and down-gradient from future drilling activities. Maintaining a bi-annual or annual sampling of all 14 wells would also help in improving the odds of having a monitoring well with baseline information in the right place to assess impacts.

4.4 Partnerships and Collaboration

The level of energy development described in the RMPA/EIS requires targeted partnerships for developing data, dedicated data collection, expertise and monitoring infrastructure to understand regional surface and groundwater hydrology. Examples of these types of partnerships are:

- Shell Oil Groundwater Monitoring Collaboration. This began with Shell, the BLM and the USGS to inventory and conduct geophysical logging of existing monitoring wells and a Memorandum of Understanding (MOU) to transfer unused Shell monitoring wells to BLM. Information from this project has allowed the BLM to assemble a high quality monitoring well network at minimal cost and Shell to learn more about the regional hydrology than what might have occurred otherwise.
- Chevron and the Weber Sand Unit. Surface water sampling of Stinking Water Creek near Rangely to measure selenium and total dissolve solids from a historical oil and gas development in Mancos shale. A Water Monitoring Plan with a water quality sampling effort was developed for this project cooperatively with Chevron and funded by Chevron with in-kind support from the BLM.

- Piceance Basin Stakeholder Group. The BLM, Rio Blanco County, Garfield County, Delta County, USGS and other government agencies and with industry have created a regional water monitoring stakeholder group that has published a regional surface and groundwater study, built a web-accessible common data repository to assemble data collected from industry, local, State, federal, and other sources (http://www.usgs.gov/newsroom/article.asp?ID=3563).

Collaborative processes and partnerships are essential to building long-term monitoring programs in uncertain funding environments. These types of partnerships allow entities to pool resources by contributing funds, data, authority, materials, and expertise to understanding regional hydrology and pool resources. Surface water quality data, streamflow and groundwater information include water data collected at BLM sponsored USGS streamflow sites, natural spring inventories, water quality samples, streamflow and water quality data from the BLM along with water chemistry for major streams, groundwater wells, and aquatic studies collected by energy companies. This collaboration will benefit everyone as it will make the monitoring of direct and indirect impacts from energy development comprehensive and more economical.

5.0 References

Boyle, J.M., K.J. Covay, and D.P. Baur. 1984. Quantity and Quality of Streamflow in the White River Basin, Colorado and Utah. Water-Resources Investigations Report 84-4022. USGS Lakewood, Colorado.

Karr, J.R., and E.W. Chu. 1999. Restoring life in running waters: better biological monitoring: Washington D.C., Island Press. 205 p.

McMahon, P.B., J.C. Thomas, and A.G. Hunt. 2013. Chemistry and age of groundwater in bedrock aquifers of the Piceance and Yellow Creek watersheds, Rio Blanco County, Colorado, 2010-2012: U.S. Geological Survey Scientific Investigations Report 2013–5132, 89 p., Available at: http://pubs.usgs.gov/sir/2013/5132/.

Thomas, J.C. In Review. Characterization of Surface-Water Hydrology and Surface-Blanco County, Colorado, March 2012: U.S. Geological Survey Scientific Investigations Report.

Thomas, J.C., and P.B. McMahon. 2013. Overview of groundwater quality in the Piceance Basin, western Colorado, 1946–2009: U.S. Geological Survey Scientific Investigations Report 2012–5198, 204 p.

Thomas, J.C., J.L. Moore, K.R. Schaffrath, J.A. Dupree, C.A. Williams, and K.J. Leib. 2013. Characterization and data-gap analysis of surface-water quality data in the Piceance study area, western Colorado, 1959–2009: U.S. Geological Survey Scientific Investigations Report 2013–5015, 74 p.

Toevs, G.R., J.J. Taylor, C.S. Spurrier, W.C. MacKinnon, and M.R. Bobo. 2011. Bureau of Land Management Assessment, Inventory, and Monitoring Strategy: For integrated renewable resources management. Bureau of Land Management, National Operations Center, Denver, CO.

U.S. Army Corps of Engineers (USACE). 2012. Regional Conditions to Nationwide Permits in the State Of Colorado. Albuquerque District. Available at: http://www.nwo.usace.army.mil/Portals/23/docs/regulatory/CO/gen/CO%20Regional%20Conditions%20April%202013.pdf.

U.S. Geological Survey (USGS). 2013. Surface-Water Annual Statistics for the Nation. National Water Information System (NWIS). Available at: http://waterdata.usgs.gov/nwis, accessed June 6, 2013.

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