# UNDERSTANDING AND OPTIMIZING THE WATER MANAGEMENT VALUE CHAIN FOR THE OIL & GAS INDUSTRY

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The development of effective water management strategies is critical to the success of future oil and gas activities, particularly those associated with the development of unconventional resources. This presentation will address the anticipated growth of world-wide oil and gas development and the environmental and economic implications of various water management strategies. Examples of hydraulic fracturing fluid composition, flowback water quality, and flowback rates will be discussed. The economics of integrating various aspects of sourcing, transportation, storage, disposal, and treatment will be overviewed. Finally, common treatment technologies employed for re-use and surface discharge of produced and hydraulic fracturing flowback waters will be discussed.

# THE GEOLOGIST'S ROLE IN COMPREHENSIVE RETHINKING OF WASTES FROM MINE SITES INTO RESOURCES

**James A. Jacobs and Stephen M. Testa**

Mining wastes and the associated environmental degradation have long plagued communities with abandoned mine sites. Comprehensive, and large-scale community driven processes and workplans are needed to convert abandoned mine sites and associated mining wastes into productive reuse. One of the greatest challenges at former mine sites is acid mine drainage (AMD) which is created from the oxidation of pyrite and other iron sulfide minerals exposed to water and oxygen in the atmosphere in the presence iron and sulfur oxidizing microbial communities. The resulting biogeochemical reactions create sulfuric acid and low pH waters, which in turn, solubilize other associated metals such as aluminum, manganese, iron and heavy metals contained in the surrounding rocks and sediments.

In addition to recycling water from former mine pits, acid rock drainage can be used as a source of resources including hydraulic fracture stimulation fluids for unconventional oil and gas production, but significant challenges exist. In several cases in West Virginia, Maryland and Pennsylvania, treated mine waters are being used to grow rainbow trout as aquaculture benefits from the dewatering of excess shallow groundwater from coal mines in areas where mine drainage problems are common. Recovery of metal resources and products can be enhanced by optimizing the microbial environment which favors bioleaching and precipitation using various biomining techniques. Wetlands construction provides valuable wildlife habitat and passive ecosystem services while passively treating acid drainage. Acid rock drainage case studies associated with water reclamation, aquaculture, biomining, community redevelopment, and wildlife habitat creation will be discussed in the context of sustainable remediation and green resource extraction practices. Long-range community planning processes can be linked to environmental solutions to seemingly independent challenges of mineral resources, water availability, local food production, ecosystem restoration and employment opportunities.

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# FROM BUTTES TO BOWLS: REPEATED INVERSIONS IN THE LANDSCAPE OF THE COLORADO PIEDMONT

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Mesas and buttes of the central Colorado Piedmont are composed of at least two distinct rock types, which differ in their cohesiveness and ability to withstand erosion. The lower parts are friable, Early to Middle Paleogene sandstones of the Dawson Formation. The caprock is composed of one or more resistant formations: Castle Rock Conglomerate, Wall Mountain Tuff, and Larkspur Conglomerate — all of late Paleogene age. The three resistant units were originally deposited in topographic lows. The lower slopes of the buttes are armored with colluvium composed of fragments of the capping units and commonly form “talus flatirons” or relict faceted slopes. Once the caprock of a butte or mesa has been removed by erosion, the poorly consolidated Dawson Formation quickly erodes out of the center. This leaves the armored, lower slopes of the former butte as an erosionally-resistant, circular ridge standing as much as 100 meters above the surrounding topography. This process produces a topographic low where the peak of the butte once stood. Some buttes have prominent alluvial fans that record the main phase of butte removal and excavation of the central part of the armored slopes. New OSL age dates provide clues to rates of caprock removal and climatic implications.

# SEPTIC SYSTEMS AND GROUNDWATER QUALITY IN A VULNERABLE MOUNTAINOUS TERRAIN

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On-going installation of on-site wastewater treatment systems (septic systems) in mountainous terrains such as the Black Hills of western South Dakota and many other areas raises significant questions and poses unique challenges with respect to protection of vulnerable groundwater recharge areas. In the Black Hills, overlapping and interconnected aquifer recharge areas for karst carbonate aquifers, fractured sedimentary and crystalline bedrock reservoirs, and shallow alluvial aquifers are further complicated by groundwater and surface-water interaction within all of these hydrogeologic settings. High velocity groundwater flow within portions of the Madison aquifer, western South Dakota's most valuable groundwater resource, as well as thin soil cover in many areas, heightens the need for appropriate protection measures.

Accurate characterization of the effects on groundwater and surface-water quality from effluent discharged by thousands of septic systems in these hydrogeologic settings is difficult to achieve, and city and county governments frequently are forced to balance the rights of private property owners with implementation of aquifer protection measures that affect property values, development potential, tax revenues, and privacy with respect to government regulations. However, undesirable societal effects from increased regulations must be weighed against potential economic losses ranging into the tens or hundreds of millions of dollars that could result from damage or partial loss of the Madison and other aquifers. Intangible benefits of clean water for drinking, recreation, and overall quality of life are more difficult to quantify economically, but are equally important.

# ASSESSING THE IMPACTS OF DRAWDOWN BY A PUMPING WELL ON LOCAL WATER RESOURCES: EXAMPLES FROM THREE AQUIFER SETTINGS

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In the not so distant past, understanding the impacts of a pumping well on local water resources was not routinely performed during the exploration, testing, and permitting phases. Understanding water resources has now taken on a holistic approach and transformed the way we evaluate the impacts of a pumping well to the surrounding ecosystem. We will look at three examples where additional groundwater is necessary to meet the growing demand of the population, aquifers are small and stressed, bedrock aquifers are untested, and the ecohydrologic impacts in these three settings are not well known. The three sites include an artesian sand and gravel aquifer, a bedrock well, and a traditional unconfined sand and gravel aquifer. Each site posed a different set of challenges to understand the groundwater-surface water interactions.