Docket No. WM-00062

Contents

Grand Junction to Rifle Road Log for the IAEA RSLS Site Tour

August 17, 2012

Compiled by Richard Dayvault and Rich Bush

Much of the information in this road log came from two sources: 1) *The Green River Formation in Piceance Creek and Eastern Uinta Basins* and 2) *Rocky Mountains and the Colorado Plateau* (see full citations in "Additional Reading" following the road log). Other sources derived from published LM literature and other Web-based information were not cited, but we wish to express our appreciation for the authors' intellectual generosity.

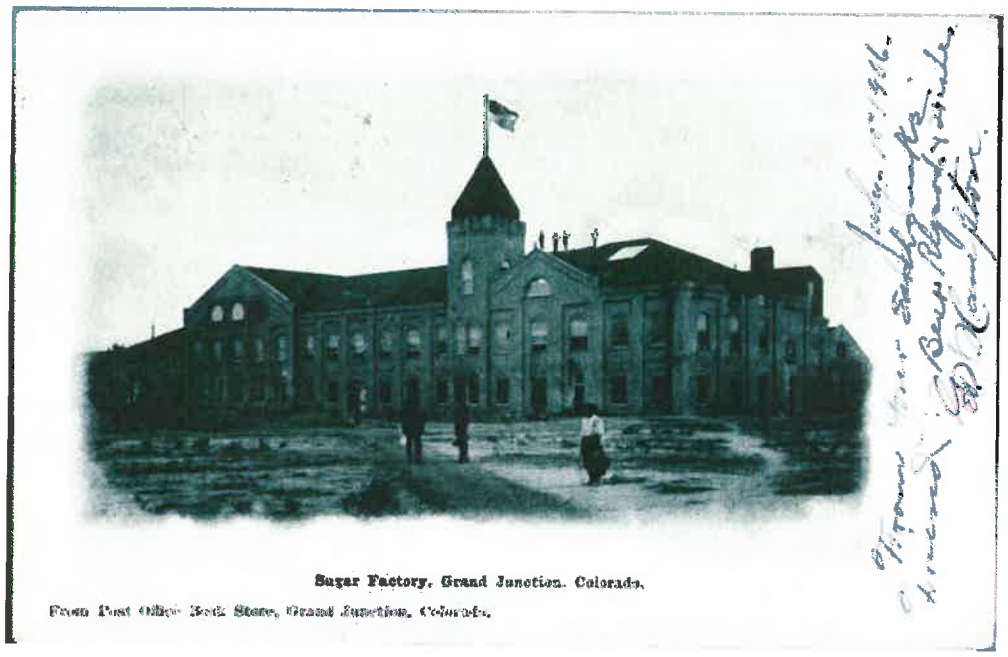
Starting mileage 0.0

0.0

From Two Rivers Convention Center: head east, enter roundabout, go straight to Fourth St. (0.2), turn right (south) on Fourth St., turn left (east) on Pitkin Ave. (0.3), turn right (south) on Fifth St. and proceed south over the overpass that crosses the railroad tracks (0.8), exit overpass at Riverside Parkway, go east on parkway (1.0).

1.5

The parkway continues through an area that was once occupied by the Climax uranium mill. The only mill building that remains today began as a sugar beet factory and was constructed more than a 100 years. Sugar beets were once an important source of sugar in arid regions of the country, such as parts of Utah and Colorado that could not support sugar cane growth. The Western Sugar Land Company built a modern mill in 1899 supported by local sugar beet growers (see post card from 1906). The economics to support the venture changed several decades later when the sugar cane industry lowered production costs, and transportation costs decreased.



Postcard from 1906 of the first sugar beet factory in Colorado, owned and operated by the Western Sugar Land Company. The warehouse is all that remains today.

Portions of the old sugar mill remained in 1950 when the Climax Uranium Corporation built its mill on the same site. The photograph of the mill from 1956 shows the size of the operation. Four raffinate ponds are south of the mill toward the Colorado River; the light-colored sands southwest of the ponds are uranium mill tailings that eventually totaled 2.2 million tons.

The Climax mill produced 11.7 million pounds of uranium oxide and 46 million pounds of vanadium oxide before it closed in 1970. The large brick building on the right is the former sugar beet factory warehouse.

Climax uranium mill in 1956 reused most of the old sugar mill.
Raffinate ponds are in the foreground, and light-colored tailings are on the left of the photo.

This site was cleaned up during the UMTRA Project along with over 4,000 vicinity properties, and all residual radioactive materials were hauled to the Grand Junction Disposal Site (formerly known as the Cheney Disposal Cell) by 1996.

1.75

On the left is the former sugar beet factory warehouse, the only building remaining from remediation.

A 100-year-flood dike was constructed along the property before it was transferred to the City of Grand Junction. The City constructed a sidewalk on the dike as part of the Riverfront Trail and has used the northern portion of the site as a corridor for the Riverside Parkway, a long-needed bypass through town. An oblique aerial photograph from 2006 shows the appearance of the site after cleanup and construction of these infrastructures. Today, the remaining open land is called Las Colonias in honor of the Hispanic community who lived near the old sugar beet factory a hundred years ago.

Stay on the Parkway heading east.

Oblique aerial view northward of the former mill site after cleanup. All that remains is the old warehouse. The Riverside Parkway traverses the old site, and an elevated sidewalk runs on top of a 100-year-flood dike.

3.1

On the left is the Grand Junction Regional Center, whose mission is "… to promote quality of life, safety, and independence for people with developmental disabilities." It was formerly the Teller Institute, which was constructed in 1885 to provide a boarding school for Native American students, including children from the Ute, Navajo, Papago Moquis, Shoshone, and Pima Tribes. About 200 students attended the school by 1900; a decade later the government decided that it was wiser for the tribes to educate their children. The institute closed in 1911, and students were sent to their respective tribes.

During the 1990s, the Regional Center was one of the largest complex commercial vicinity properties in the valley to be cleaned up as part of the UMTRA Project. About 65,000 cubic yards of residual radioactive materials were removed from foundations, pipelines, and other infrastructure and placed in the Grand Junction Disposal Site.

3.4

On the left is the Veterans Memorial Cemetery of Western Colorado, authorized by the state legislature and completed in 2002. It was constructed to honor the memory of Colorado's veterans of the armed services, their spouses, and eligible dependents.

Proceed east on the Riverside Parkway.
Note: The Parkway becomes D Road when it crosses 29 Road.

Continue east on D Road to 32 Road.

Straight ahead (east) is the Grand Mesa, which has a surface area of more than 500 square miles and is one of the largest mesas in the Colorado. The Mesa is capped by 9.5- to 10-million-year-old basalt flows that erupted from fissures on top of the Mesa and extended farther to the west at one time. In fact, at the time of the basalt eruptions, the entire valley was probably at about the same level as the top of the Mesa, and the difference between the 10,000+ foot Grand Mesa and the 4,600-foot valley is a result of erosion by the Gunnison and Colorado Rivers and their antecedents. Much of this erosion is thought to have occurred during the past 5 million years from regional uplift of the entire Colorado Plateau. Therefore, gigantic volumes of sediment from the Plateau region are now in the Gulf of California.

4.7

At right across near valley, the low-lying shale cliffs are capped by gravel terraces of the ancestral Colorado River that provide fertile agricultural land for Orchard Mesa.

6.9

At 32 Road, turn left (north). You will now be on Colorado Highway 141. On the right is the headquarters for Halliburton, a large support organization for the local gas drilling industry.

8.1

Canal on right supplies irrigation water for the valley. Without irrigation, the valley would be brown except for a narrow corridor along the Colorado River.

8.7

Drive to the junction with the I-70 Business Loop and turn right (northeast). You are driving through the community of Clifton, which was greatly enlarged in the early 1980s due to development of oil shale resources.

9.7

Exit onto I-70 and proceed east toward Denver. The cliffs to the north are the Book Cliffs, named by early explorers who thought they resembled pages of a book. The lower gray sediments were laid down around 80–100 million years ago during the Late Cretaceous time, when the area was covered by a shallow sea, know as the Western Interior Seaway. This shale, about 4,000 feet thick in this area, is termed the Mancos Shale and can be found in many of the western states. The upper sandstone cliffs are part of the Mesaverde Group, which resulted from sand, clay, and peat deposition when the seas retreated and near-shore sedimentary environments predominated. Some of the peat deposited here compacted into coals seams, which can be seen as dark bands near the tops of the cliffs.

11.0

The promontory on the left is Mount Garfield, named after President James Garfield, who was assassinated in 1881, the year the Grand Valley was opened for settlement. It rises 2,000 feet from the valley floor.

12.3

On the left (north) about halfway up the Book Cliffs for about next 2 miles you will see boulders that are supported on columns of Mancos Shale and alluvium. The boulders have slowed erosion of the underlying materials, creating formations known as "hoodoos." On the right is the community of Palisade, the center of the valley's fruit industry. Wine grapes were grown starting in 1890, and by 1910 about 1,000 growers were recorded. Prohibition ended most of the wine grape industry, and the valley switched to growing fruit. Some of the finest peaches anywhere are grown in the Grand Valley. Excellent cherries, apricots, plumbs, pears, apples, and other fruit and vegetables are grown and distributed around this region. No citrus fruits grow in this climate. Around 1970, wine producers rediscovered the Grand Valley, and the industry has been expanding ever since. In 1990, the area was granted status as an American Viticultural Area, and currently 20 wineries are thriving in the valley. About 75 percent of the grapes are red varietals such as Cabernet Sauvignon, Merlot, and Syrah; white varietals include Chardonnay, Riesling, Viognier, and Gewürztraminer. Wines are also made and blended from other fruit such as peach, apple, apricot, and pear. One winery has taken advantage of the local dinosaur mystique and markets wines with names like Tyrannosaurus Red and Pterodactyl Peach. The valley has two wine events annually, the Colorado Mountain Winefest and a charity event called Viva el Vino, where vintners make their products available for tasting.

15.0

Large boulders from above infrequently make their way to the south side of I-70.

15.8

Remnants of the Gerhart coal mine in the Mesaverde Group sandstones is visible on the left (north). This coal seam is termed the Palisade coal bed.

16.8

As you cross the Colorado River, you are entering DeBeque Canyon. The section of the valley frequently experiences high winds as they funnel into the narrow canyon. In the early spring, a frequent breeze out of DeBeque Canyon is known as the "Million Dollar Breeze," because it mixes freezing air stratified by near-surface temperature inversions with warmer air above and reduces frost kill to fruit buds. This gives Palisade the longest growing season in Colorado.

17.0

The structure in the river is a newly constructed fish ladder to allow T&E species easier access to upstream spawning areas.

17.9

On the right are remnants of the reclaimed Cameo coal mine. On the left is the Cameo Station, a power plant scheduled to cease operations in 2010. Parts of the power station were constructed with tailings from the Climax mill, so the radioactive tailings material will be disposed of at the Grand Junction Disposal Site after the plant shuts down. In early 2010, Abengola Solar installed a demonstration solar

photovoltaic system just west of the Cameo Station to aid in pre-heating water for the plant during its last year of operation.

19.8

Exit 47, Island Acres State Park was created from gravel pits used for construction of the interstate. DeBeque Canyon contains the next-to-last section of I-70 constructed; Glenwood Canyon, about 60 miles east, contains the last.

The rocks of the canyon consist of the Mesaverde Group, predominantly river-lain sandstones and shales about 3,000 feet thick. Some of the deposits were formed in near-shore, organic-rich swampy regions that were buried and heated, converting peat deposits into coal seams. The coal is most important to the area's economy, both for coal production and for a source of gas in the tight gas sandstones of the Piceance (pronounced Pē-ăwnce) Basin. The thick sequence of sandstone that forms cliffs of the canyon here is buried thousands of feet below the surface farther east near the towns of Parachute and Rifle.

20.8

The "Cameo" rock, namesake for the Cameo power plant, is visible on left across the river about halfway up the cliff. It resembles a person's face in profile.

21.6

Exit 49 at Plateau Creek Canyon is the beginning of the Grand Mesa Scenic Byway and is the main access to the ranching communities of Mesa, Molina, and Collbran. The byway passes next to Powderhorn ski resort, which is frequented by many residents of Grand Junction.

22.0

The Highline Diversion Dam, or "Roller Dam" as it is known locally, was a critical infrastructure for the success of agriculture in the Grand Valley because it diverted life-giving water from the Colorado River to farmers and ranchers in the valley. Completed in 1918, it is 14 feet high and 546 feet long and is the largest dam of its kind in the United States. The name derives from its roller-crest configuration, a German design that allows water to flow over the steel rollers. The four tower houses contain machinery that raises and lowers the rollers. The Roller Dam diverts about 730,000 acre-feet per year to the Grand Valley and irrigates 35,000 acres.

22.6

Entering the Beavertail tunnel, named after the shape of the river meander it cuts through.

24.0

The landslide on the right has been observed for over 100 years. It was called the Tunnel Landslide in the 1880s and is now called the DeBeque Canyon Landslide. Union Pacific Railroad reportedly constructed their tracks, in part, on the north side of the river to avoid this geological hazard. A major slide in the early 1900s partially diverted the flow of the river and damaged the railroad tracks and a work camp. The slide heaved 24 feet in 1958 when the toe was removed by road crews. It heaved again in 1998 after construction of the larger interstate highway, when the highway was translated 10 feet toward the river. Colorado Department of Transportation geologists have mapped a triangular structure measuring 1,000 × 950 × 650 feet that is moving slowly toward the river. Unfortunately, I-70 lies in its path. This will certainly be a geologic hazard for the long term.

DeBeque Canyon landslide as viewed from the east, covering about 36 acres, originates 500 feet above the south side of I-70 and the Colorado River.

27.8

At this point the interstate is beginning to emerge from DeBeque Canyon.

28.0

Seeps on right erode shales within the Mesaverde Group and undermine the sandstones.

29.6

Large cottonwood trees along the river for the next few miles often host golden and bald eagles during the winter.

30.7

The interstate has now exited DeBeque Canyon. To the northeast are the Roan Cliffs. The light-colored cliffs are part of the Green River Formation, which is a thick sequence of sediments deposited in Eocene time between 37 - 50 million years ago in a large lake that extended from Glenwood Springs in western Colorado to Soldier Summit in Utah (about the size of Lake Erie). The fossil lake, called Lake Uinta, was frequently choked with algae. Upon burial for millions of years, the algae decomposed into kerogen and produced dark, organic-rich shale called oil shale, "the rock that burns." When freshly broken, the rocks in the white cliffs are almost black. Stories are told of early pioneers in this area who unknowingly used slabs of oil shale from nearby drainages to construct their fireplaces and chimneys, which, upon being heated, caught fire and burned.

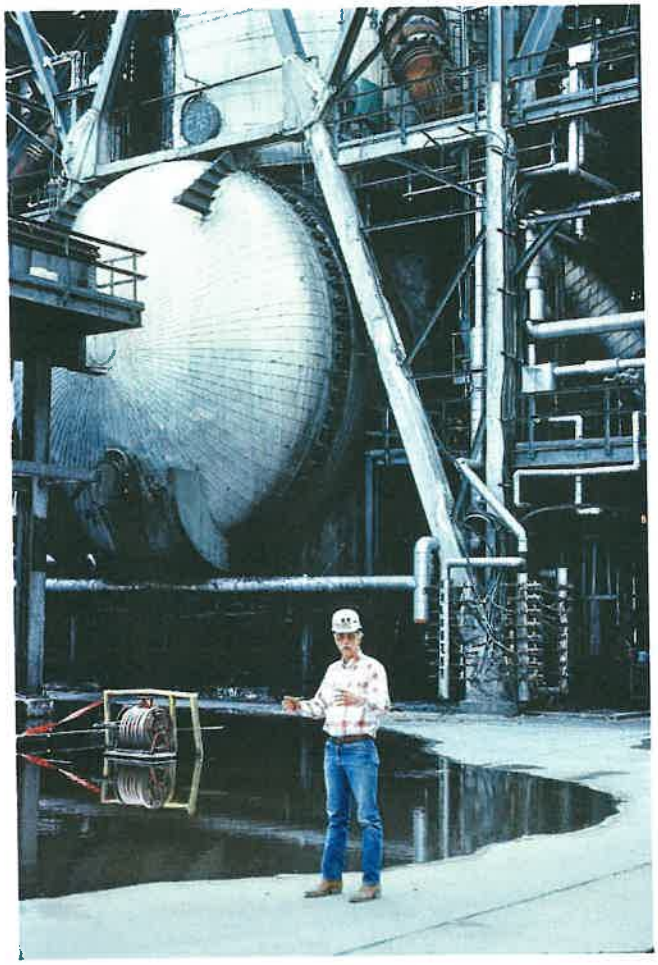
The U.S. government and the private sector have tried to develop this immense resource for over a century. The shales contain about 15 gallons of oil per ton, or an estimated 1.8 trillion barrels of oil (a standard barrel of oil is 42 gallons). This is about three times the proven oil reserves in the world. About 60 billion barrels of oil are within shales that contain 25 gallons of oil per ton. The richest sections of the deposit can produce 50 gallons or more of oil from a ton of shale. The last big push to develop the resource was in the 1970s and early 1980s. Atlantic Richfield, Exxon, Union Oil, Chevron, Occidental Oil Shale, and others invested huge sums to develop mines and produce oil from the kerogen held tightly in the shale. The government offered a $42 per barrel subsidy to support research and development. On Sunday, May 2, 1982, after several years of mine and infrastructure development, Exxon famously—and without warning—abruptly pulled the plug on its $5 billion Colony Shale Project headquartered in nearby Parachute, leaving thousands without work. This made national headlines as Black Sunday.

Union Oil lasted until 1991 and actually produced oil from their retort process. Oil shale was ground to a small gravel size, and 100 tons were loaded into a large retort heated by natural gas. With enough heat, the kerogen broke down into an oil substance called syncrude that could be collected and further processed. Eventually, Union produced 5 million barrels of oil from 9 million tons of oil shale mined from 43 miles of underground workings and spent about 1 billion dollars on the facility and mine.

Partial view of Union Oil's retort facility on a 5-acre bench above East Fork of Parachute Creek in 1992. The facility was partly disassembled and reused elsewhere by Union Oil; the remainder was completely razed several years ago. Tailings from the retort were deposited below in 10-foot lifts and armored with topsoil.

Another well-known mineral commodity found in the same Green River Formation is sodium bicarbonate that occurs as the mineral nahcolite. An estimated 43 billion tons of this evaporite mineral are deposited in the deepest part of the basin. Commercial production depends on injection of super-heated water into beds of the water-soluble nahcolite, piping it to the surface, and precipitating it.

The Green River Formation is famous among paleontologists for its fish, leaf, and insect fossils. The fossils appear as carbon films on the bedding planes of the rocks. Similar basins in Wyoming, also containing the Green River Formation, produce most of the fossil fish seen in gift or natural history shops around the country. This basin is more famous for fossil leaves, insects, and spiders. Incredibly detailed preservation of insect wings or hair on spider legs can be found in the fine-grained shale (which is actually a mud-rich limestone). A few examples from this area are shown. Through the generous efforts of local collectors, the U.S. Museum of Natural History at the Smithsonian Institution has assembled a large collection.



The retort vessel could receive 100 tons of ground oil shale lifted by piston from a platform below this level. The shale was heated with natural gas, converting kerogen in the shale to a form of crude oil that was collected and processed.

Fossils from the Green River Formation of Eocene age, about 48 million years old. Fish specimen is from Kemmerer, Wyoming; others are from the Piceance Basin of western Colorado. Perch eating a fish is about 10 inches long; Sycamore leaf is 7 inches across; cricket, grasshopper, and spider are about one inch long, dragonfly is about 2.5 inches across.

33.8

Exit 62 to DeBeque, a ranching community named after Dr. Wallace A. E. DeBeque, who settled here in 1883.

To the north, badlands cropping out below the Roan Cliffs are reddish to greenish variegated sands and shales of the Paleocene-Eocene Wasatch Formation deposited by streams and rivers before Lake Uinta formed. Turtle and crocodile fossils and remains of a water bird called a duck-flamingo are recovered from its sediments.

38.4

To the right (south) the first large drilling rig for gas is probably visible. The Piceance Basin is one of the biggest gas plays in the nation. Estimates from the central part of the basin range from 60 to 120 billion cubic feet of gas per square mile. For the past 10 years, companies have been drilling to depths of 4,000 to 7,000 feet before encountering the gas-producing rock units. The deeper holes extract gas from the Williams Fork Formation of the Mesaverde Group; in the shallower holes, production is from the Molina Member of the Wasatch Formation.

How did this great gas field come to be? About 80 million years ago, the Mancos Sea retreated from the continent, leaving swampy lowlands. Peat and other organic debris were deposited in thick beds that became coal after sufficient compaction and dewatering. As the continental mass continued to rise, a vast river system became established, depositing coarser sands and gravels in the river channels and silts and clays in overbank areas. Eventually, a three-dimensional network of sinuous sands was deposited, representing the river channels that were separated by more widespread, muddier sequences. The muds became the dominant type of deposition afterward, producing a basinwide, fine-grained clayey deposit that capped the river channel sands. All of this was deeply buried in the Piceance Basin, compacted, and eventually lithified.

Coal seams below the river channel sands began degassing, as all coals do. As the gas rose toward the surface, it contacted impermeable shale beds that prevented further upward movement. As gas accumulated beneath the impermeable beds, it began to pressurize. In many places, the pressure was so great that the gas displaced the water in the sandstone, leaving the gas bound tightly within the pores of the rock. This condition is termed "tight gas sand," and the gas is not easily recovered. Drilling companies have developed a method to fracture, or "frac" the formation to create pathways for the gas to escape. The method involves drilling through the shale into the sandstone, then injecting a proprietary mixture of water, sand, surfactants, and undisclosed chemicals that break the sandstone matrix and hold it open, allowing the gas to flow into the wellbore. This may be performed on 300 feet to more than 1,000 feet of the wellbore. The wells can produce gas economically for up to 30 years as they slowly bleed off the gas from the sandstone.

Because groundwater is often used as a source of domestic drinking water, a national debate currently centers on the unknown but possibly deleterious health effects of ingesting domestic water that has been contaminated with trace amounts of fracturing fluids.

The mass of infrastructure and networks of roads installed by the drilling companies continues to cause environmental concern. The maximum well density allowed in this area is one well for every 10 acres. Drilling companies are using an offshore technology to drill multiple wells on a single pad and decrease the environmental impact. Large drilling platforms called "flex rigs" are employed that can drill up to 22 wells from one location. By use of a technique called directional drilling, a well can be drilled vertically downward for some distance, at which point the well takes off at an angle to the desired depth. Below is an example of a large flex rig used in the Piceance Basin.

Large flex-rig is used to drill up to 22 holes from one location, reducing land disturbance. The technology was adapted from offshore drilling techniques.

If you see red or red and white trucks with unusual fittings and valves traveling in groups along the interstate, they belong to Halliburton; similar blue or blue and white trucks belong to Schlumberger—both oil field support companies. They do not drill the wells, but they fracture the formations for gas production.

Drilling slowed a couple of years ago due to the economic downturn, but the pace is picking up again. The drilling has brought a tremendous economic benefit to the area.

46.3

Exit 75 to Parachute and Battlement Mesa. The town of Parachute was named by a Hayden survey member in 1876 because he thought the snowpack on top of a nearby peak resembled a parachute. Battlement Mesa was constructed during the last oil shale boom in the early 1980s. Since the bust brought about by Exxon's

Black Sunday, the town has been marketed as a retirement community. The large underground Union Oil mine is located 5 miles north of Parachute along Parachute Creek.

53.1

On the left (north) side of the interstate, you can see a dirt switchback road that terminates at the base of the Roan Cliffs. This road leads to the Anvil Points oil shale mine opened by the U.S. Bureau of Mines in 1945. It provided rich oil shale to a retort demonstration facility below. From 1964 to 1980, the Colorado School of Mines and the Paraho Development Corporation conducted further research on oil shale beneficiation that was funded by oil companies. The large adits at the top of the road were sealed by the BLM this year.

52.7

Exit 83 to Rulison, which was the site of the earliest oil shale retort, built in 1890.

About 5 miles up a mesa to the south of the interstate, a plaque marks the location of Project Rulison, where a 43-kiloton nuclear device was detonated 8,426 feet below ground surface. Project Rulison was part of the Plowshare Program, which was created in the late 1950s to demonstrate peaceful uses of nuclear energy. The U.S. Atomic Energy Commission, in conjunction with Austral Oil Company of Houston, Texas, drilled into the Williams Fork Formation (within the Mesaverde Group) and detonated the device on September 10, 1969. The purpose was to create a cavity for accumulation of natural gas and, concurrently, fracture the surrounding formation to open up flow paths for the gas. The detonation shook windows in Rifle and other nearby towns, and the ground shock was felt briefly in Grand Junction, 40 miles away. In about one-millionth of a second, the explosion vaporized the surrounding rock and formed a 150-foot-diameter cavity; as the rock material cooled, it formed a puddle of vitrified rock, or "melt glass" in the bottom of the cavity. Shortly after the detonation, gravity caused the roof of the cavity to collapse into the cavity chamber. This progressively upward collapsing of fractured rock into the cavity chamber formed a chimney of broken rock to an estimated height of about 274 feet above the point of detonation. Fractures created by the detonation extended radially outward an estimated 263 ft. Although approximately 455 million cubic feet of natural gas was produced, elevated levels of radioactivity in the gas made it unacceptable for use.

Today this location is known as the Rulison Site, which is part of DOE's Offsites Program. LM has inherited institutional controls (ICs) at the site, which include subsurface rights beginning at 6,000 feet below the ground and control of the 40-acre area around surface ground zero. LM monitors for tritium in several commercial natural gas wells farther away from the ICs area. The Colorado Oil and Gas Conservation Commission (COGCC), which regulates gas permits in the state, has established two wider boundaries—one at 3 miles and at one-half-mile from surface ground zero. Any permit request within a 3-mile radius of surface ground zero requires notification to DOE, who is allowed to comment on the application. Any permit request within a one-half-mile radius of surface ground zero requires a full hearing before the COGCC (state regulator for drilling) before a permit is granted. To date, no gas sample has had a tritium concentration that exceeded the 0.1 picocurie per cubic centimeter limit established by the Colorado Department of Public Health and Environment.

54.8

Road under interstate to north went to Anvil Points Research Facility. Nothing is left of the facility.

55.8

To the north are compressor stations—buildings with large fans that compress the gas as it travels through the pipeline until it arrives at the gas plant. A gas plant for Williams Energy Services is north of Parachute.

56.5

The floodplain on the right is within the IC boundary for the New Rifle Processing Site located farther east. Gas wells have been drilling inside the IC area. One energy company has responded to a complaint by the COGCC that one of their wells located inside DOE's IC boundary is leaking gas. Two of DOE's wells were sampled for BTEX (benzene, toluene, ethylbenzene, and xylenes), and benzene concentration in a sample from one well slightly exceeded the state standard. Benzene is a by-product of the gas resource. This sampling activity continues at this writing.

57.7

Tall storage bins on the right (south) of I-70 were used for loading sodium bicarbonate onto railroad cars.

58.2

Exit 87, West Rifle exit. The floodplain to the right is within the IC boundary of the New Rifle Processing Site. Uranium levels in the groundwater exceed the maximum concentration limit or background concentration in this area.

59.0

On the left is an open field that is the former New Rifle mill site. By 1996, all of the tailings and surface contamination were removed from the site and placed in an engineered disposal cell north of town, in an area known as Estes Gulch. The site is now owned by the City of Rifle and by Umetco (now Dow Chemical). DOE is responsible for managing groundwater contamination that remains from the milling operation.

To left are two lakes produced by a former gravel pit operation. The easternmost lake waters are contaminated by uranium, molybdenum, and nitrate above allowable maximum concentration limits. ICs have been placed on the ponds to limit access by livestock.

Straight ahead in the distance is a geological structure known as the Grand Hogback, a great flexure in the earth that marks the boundary between the southern Rocky Mountains and the Colorado Plateau. It is manifested by steeply dipping rocks ranging in age from Permian to Late Cretaceous and extends in a northwest direction for many miles. The top or north end of the Rifle Disposal Site abuts the Grand Hogback.

61.6

Exit 90, North Rifle. Take exit and go through the roundabout, turning left (north). You are now on State Highway13.

There are three theories regarding Rifle's unique name. One story relates that it was so named when an early explorer left his rifle leaning against a tree and later returned for it or later pioneers found it. The second story claims that it was named for the custom of firing one's rifle to signal others. The third story states that an 1880 group of soldiers were working on the road between Rifle and Meeker. One man left his rifle at camp along a stream bank. In returning for it he named the creek Rifle Creek and the town took its name from the creek. Rifle is a unique name for a town in the U.S.

61.7

Turn left on Lions Park Circle and proceed to the Visitor Center and Rest Stop. BREAK/REST.

Return to State Highway 13 and proceed north across the Colorado River and stay in the right lane.

63.0

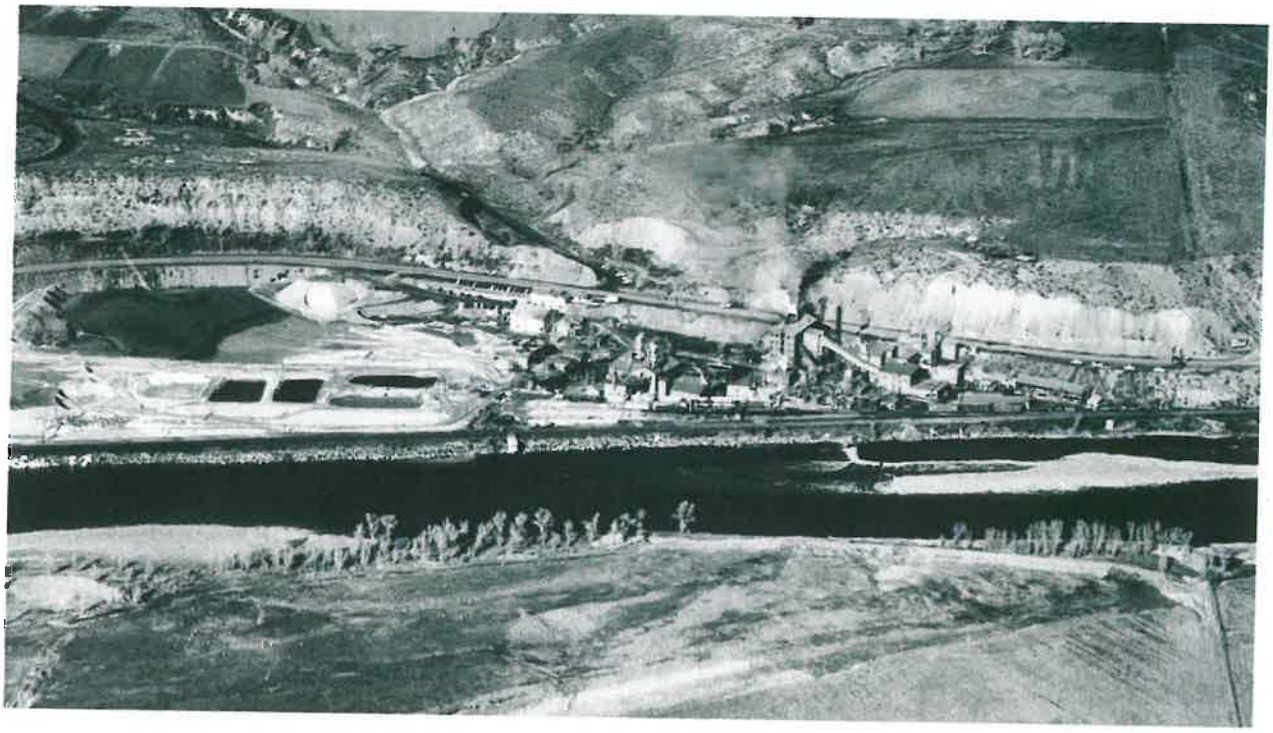
Turn right (east) onto U.S. Highway 6 (East Centennial Parkway). The gravels on the left of the road were deposited by the ancestral Colorado River.

63.3 STOP 1

Pull off on the overlook area on the right, for viewing Old Rifle mill site and the Rifle Integrated Field-Scale Subsurface Research Challenge (IFRC) site. Depart buses and congregate at overlook for presentations. Presentation materials start at the end of this road log.

The Old Rifle Processing Site began as a vanadium mill that was constructed in 1924. Roscoelite, a vanadium mica, was mined a few miles north of Rifle. Vanadium is used as a hardener for steel. After WWII, the mill processed both vanadium and uranium until it closed in 1958 when Union Carbide built a new mill a few miles to the west. This is called the New Rifle Processing Site. Union Carbide cleaned up the site in the mid-1960s, but it was further remediated during the UMTRA Project in the mid-1990s. The site was transferred to the City of Rifle via a quitclaim deed in 2004. The City constructed the maintenance facility on the east end of the site in 2008 and has allowed research work to be conducted on the west end since 2002.

The only contamination remaining at the processing site is uranium, vanadium, and selenium in the ground water. Through an agreement with the NRC, the site was accepted as a natural flushing candidate, but concentrations of these metals have not decreased since monitoring was initiated a decade ago. LM is investigating the reasons for the recalcitrant nature of the metals in the subsurface. Researchers from national laboratories are helping with the studies.



View to the northwest of the Old Rifle mill about 1957. The current Rifle maintenance facility is located about where the former mill was situated. Raffinate ponds on the left are near the area of highest levels of groundwater contamination today. Light-colored materials are tailings.

View to the east of Old Rifle Processing Site about 1998 after surface cleanup, recontouring, and reseeding.

ALTERNATIVE STOP 1. Tour may continue down the hill.

63.2

Turn right, go down the hill, and enter the City of Rifle recycle center and operations and maintenance facility.

63.5

Go through green gate to enter the Rifle IFRC. Park by the trailer. This is the field trailer for the Rifle IFRC and study area.

63.8

Return to Highway 6, turn left (west). Proceed west through the intersection with the traffic light.

65.9

Turn left across the railroad tracks to the New Rifle Processing Site. The site is to the right (west).

66.0 STOP 2

Vista for New Rifle Processing Site. Depart buses and congregate for discussion of the New Rifle Processing Site and the Rifle Disposal Site.

The New Rifle Processing Site was constructed by Union Carbide in 1958 for recovering uranium and vanadium. It was a large facility that accepted vanadium concentrates from other company mills on the Colorado Plateau for final processing. The mill closed in the early 1980s and underwent surface cleanup from about 1988 to 1996. All residual radioactive materials were hauled to the engineered repository 6 miles north of Rifle. The site was transferred to the City of Rifle in 2004 via a quitclaim deed. The City built a state-of-the-art wastewater treatment plant on the site that was completed in 2009. About 60 percent of the energy needs for the plant are supplied by a photovoltaic array constructed on site. The City also has plans to grow switch grass, used as a source of biofuel, as a pilot study in association with the Colorado State University. The City will also provide land for a composting operation that will use waste generated by the treatment plant.

Groundwater is contaminated with uranium, vanadium, molybdenum, arsenic, and nitrate. Discussions continue with the Nuclear Regulatory Commission and the Colorado Department of Public Health and Environment on a final groundwater compliance strategy for the site.

View of the New Rifle mill looking southeast about 1970 during operation. Notice the large tailings pile on the right of photograph and ponds to the east of the pile. The highest concentrations of groundwater contamination are beneath the former ponds.

View to west of the New Rifle Processing Site in August 1989 during early stages of site remediation. Notice the large tailings pile on the west side of the site.

Return to Highway 6, turn right (east). Proceed back to Visitor Center/Rest Stop. BREAK/REST and return to Interstate 70 west and Grand Junction.

END OF LOG

Additional Reading

Grand Junction Geological Society, 1995. *The Green River Formation in Piceance Creek and Eastern Uinta Basins*. Detailed articles on regional stratigraphy; structural controls; oil shale resources, mining, and retorting; sodium mineral resources; gilsonite; fossils from the Green River Formation, and more.

AIPG (American Institute of Professional Geologists), 2009. *Rocky Mountains and the Colorado Plateau.* Proceedings from the AIPG 2009 Geology and Resources Conference, Grand Junction, Colorado, October 3–7.

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IAEA International Workshop on Management and Regulatory Oversight of Uranium Legacy Sites:

Perspectives from Regulators and Operators

Rifle Disposal Site

(Estes Gulch)

Rich Bush, Rifle Site Manager

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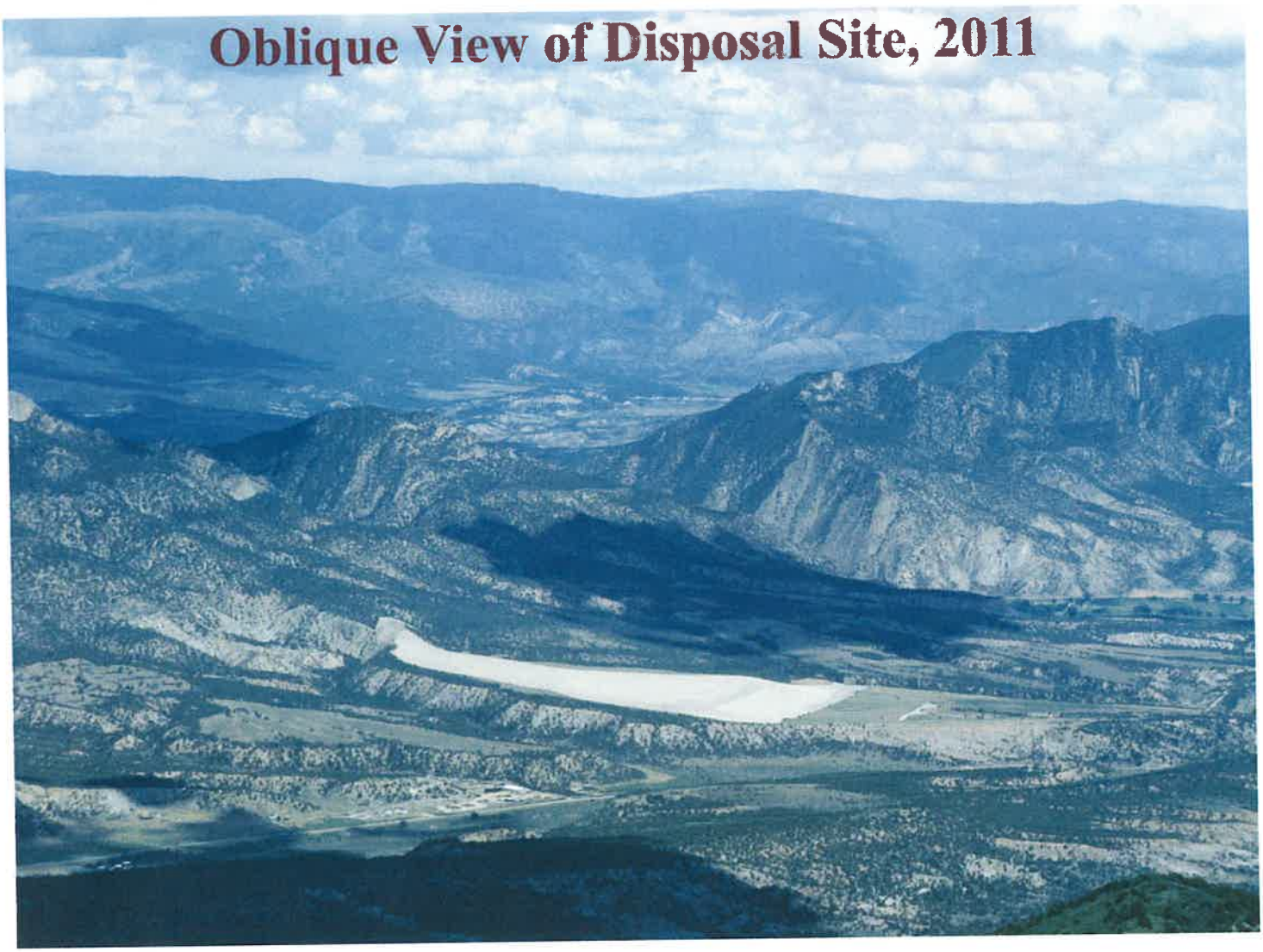
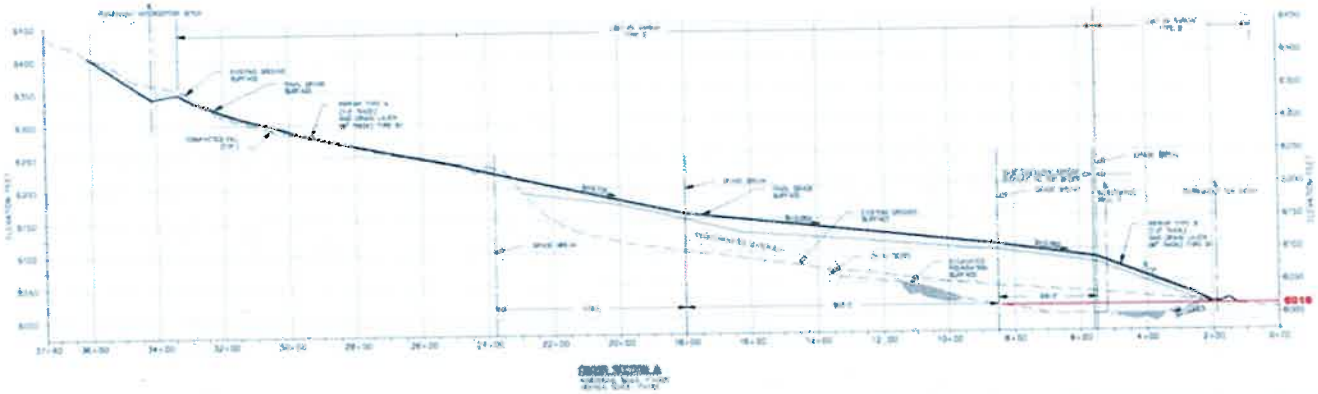
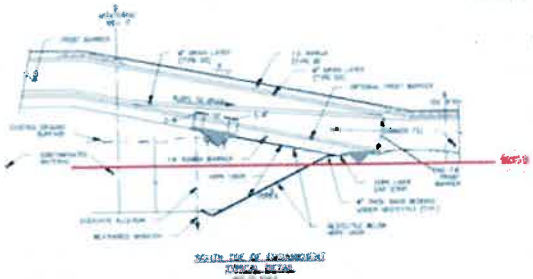
Pre-Site Disturbance Aerial Photo

Oblique View of Disposal Site, 2011







RIFLE DISPOSAL CELL CROSS SECTION

Disposal Site Under Construction, c. 1992

Disposal Site Under Construction, c. 1994

View of MW-3 and Evaporation Pond

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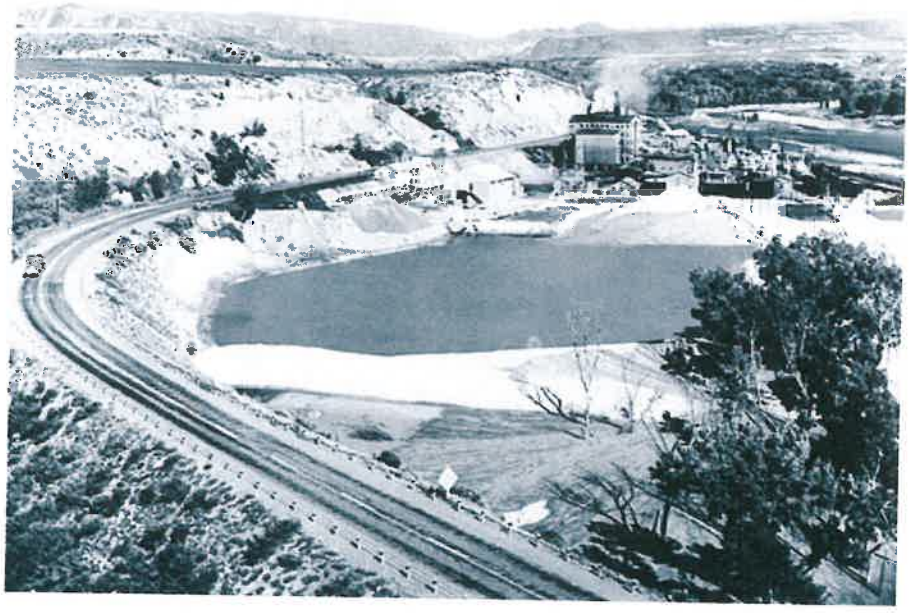
Union Carbide Mill—circa 1957



Old Rifle Site—1967
After Umetco Cleanup

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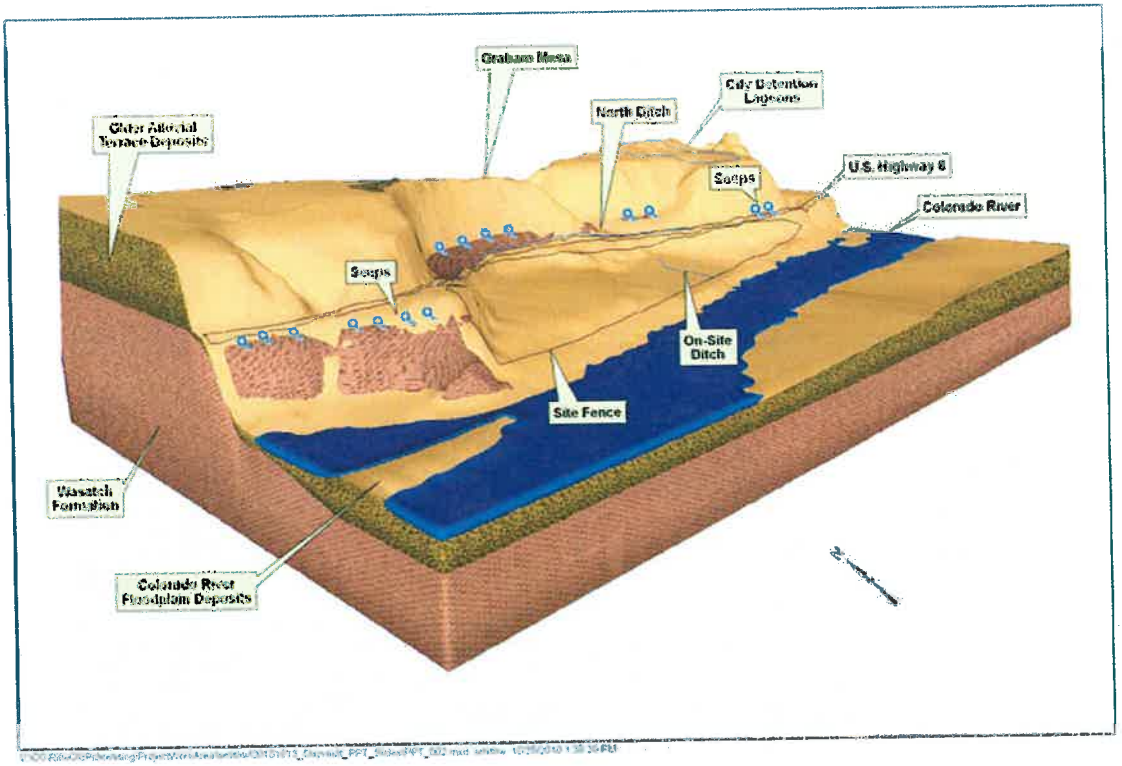
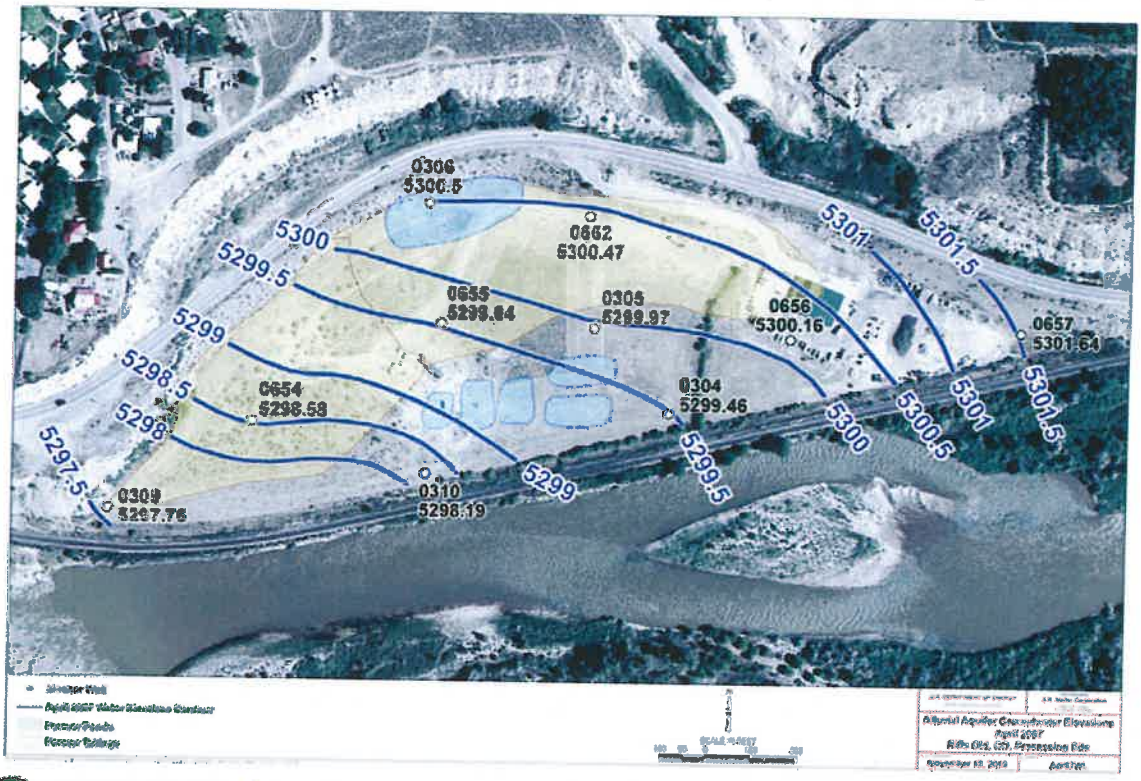
Site Conceptual Model Diagram



Groundwater Surface Map—Spring 2007



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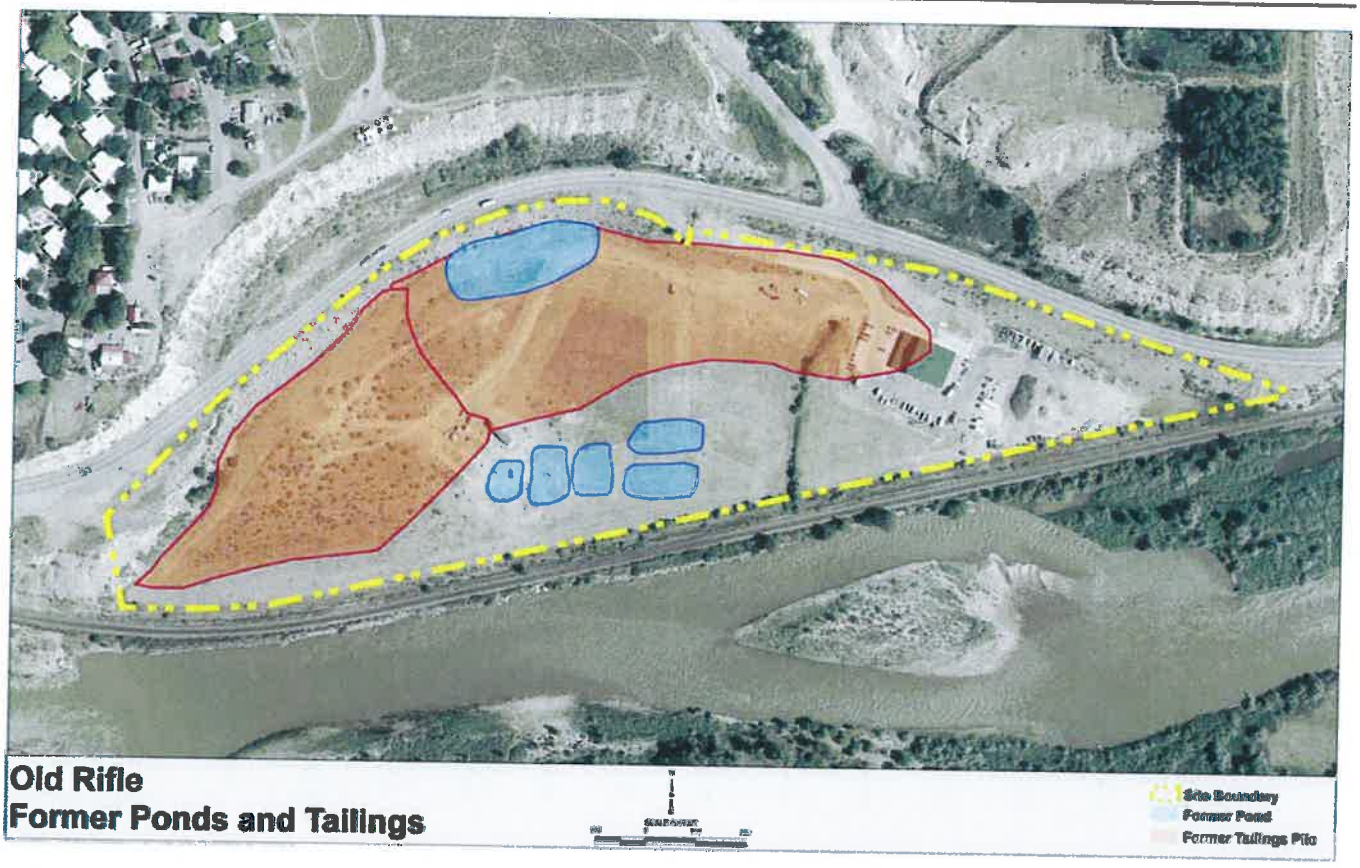
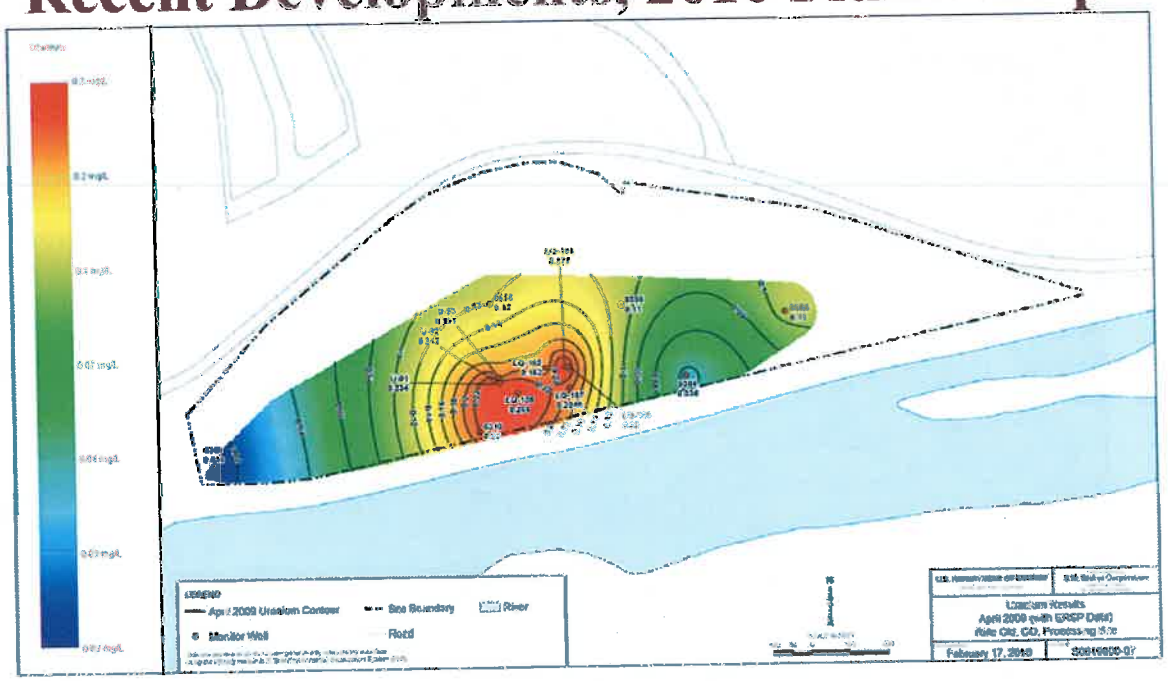


Recent Developments, 2010 Plume Map



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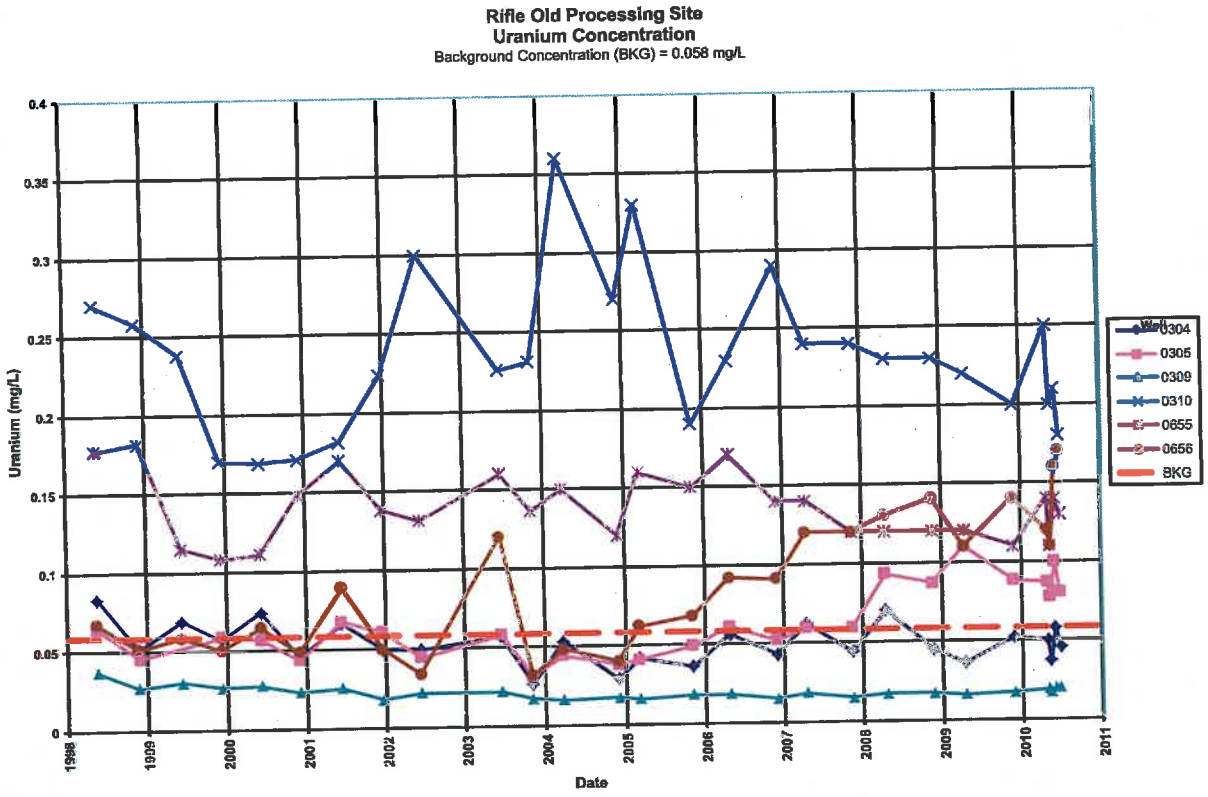
Time/Concentration Plots in Old Rifle Wells



Conclusions

- Site not flushing as predicted
- Site more complex than expected
- Additional characterization/new modeling effort?
- Revisit compliance strategy in light of low risk
- U.S. Office of Science adding insights to uranium sequestration, cycling
- Integrated Field-Research Challenge provides an outdoor lab
- Leverage funding for science and technology
- Future to expand to floodplain-wide analysis

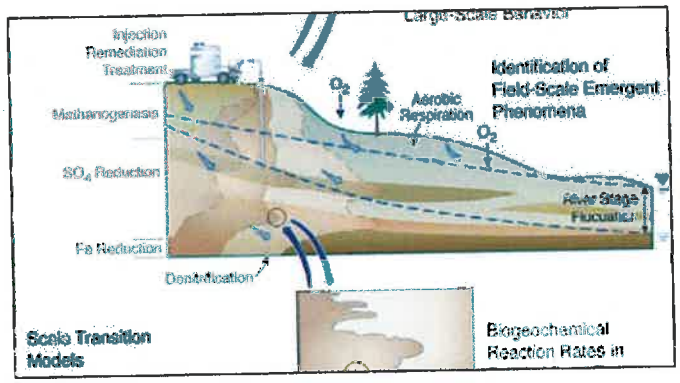
Rifle IFRC Site Visit

- Rifle Integrated Field Research Challenge (IFRC) site at the Old Rifle Processing Site conducts field scale experiments in biogeochemical and abiotic geochemical reactions
- Studies sponsored by DOE Office of Science, Biological and Environmental Research through the Lawrence Berkeley National Laboratory, the Pacific Northwest National Laboratory, and numerous other institutions
- Links to more information and a list of numerous publications are found at:

http://ifcrifle.pnnl.gov/
http://ifrcrifle.org/
http://ifcrifle.pnnl.gov/publications/

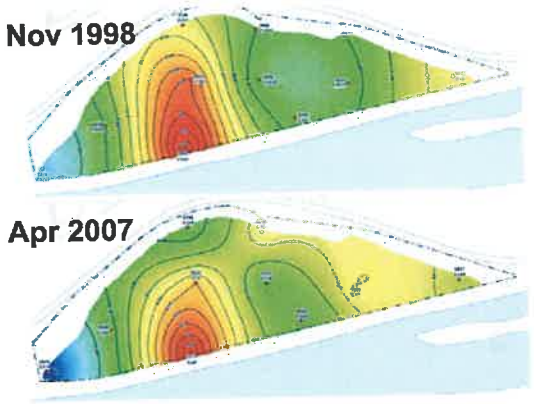
DOE-SC's Goal:

"…incorporate coupled biological, chemical and physical processes into decision making for environmental remediation and stewardship"



Project objective:

"…Gain a comprehensive and mechanistic understanding of the microbial factors and associated geochemistry controlling uranium mobility so that DOE can confidently remediate uranium plumes as well as support stewardship of uranium-contaminated sites."

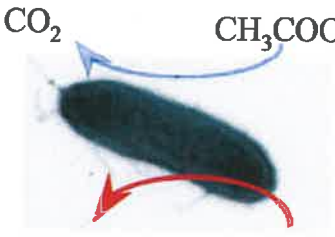


Key Features of the Rifle IFRC

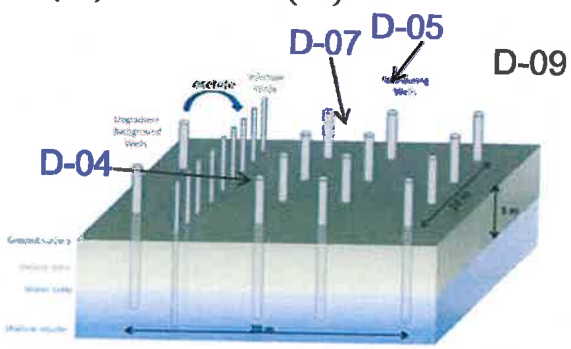
- Shallow, accessible alluvial aquifer
  - Low drilling costs
  - Large volume sediment samples available via backhoe
- Persistent plume that is not attenuating as predicted
- Low-permeability lower boundary
- Natural seasonal river-stage change
- Anaerobic to sub-oxic conditions
- Other variable redox elements (Mn, V, As, Se)
- Naturally bioreduced zones (sources/sinks for U)
- Low-hazard site
  - Samples ship as non-radioactive "environmental" samples
  - University access is straightforward
- Extensive background microbiological data
- Field scale biostimulation experiments replicable from one experimental plot to the next

Metal Reducing Bacteria

- Metal reducing bacteria catalyze reduction of U(VI) to U(IV) (insoluble) by coupling it with oxidation of electron donor (acetate in this case)
- Amendment with acetate stimulates growth of *Geobacter* which in turn precipitates uranium on soil particles as U(VI); extensive analysis of microbial populations enable tracking of this process (e.g. proteomics)
- Uranium concentration in a down-gradient well in response to acetate amendment to the subsurface. Periods of acetate amendment are shown in blue. Rebound of U is from upgradient U. U(IV) oxidizes slowly at the Rifle site.

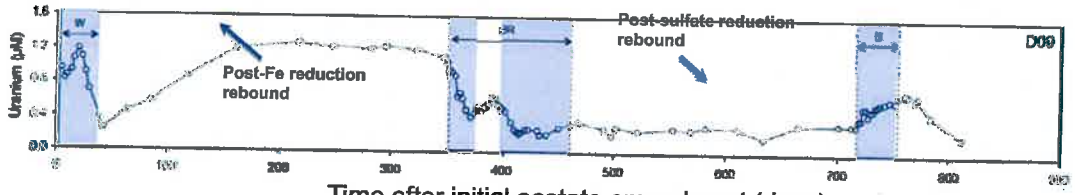


Geobacter uraniireducens, Isolated from the Rifle Site and a Member of the Subsurface Clade I *Geobacter*



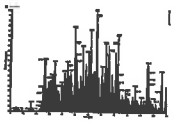
Periods of acetate amendment

Uranium concentration in well D-09 (Exp. Plot A) for >800 days

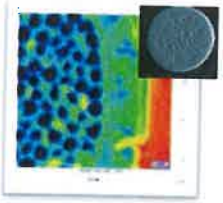


Principal Scientific Results

- Changed conceptual model for transition from Fe-reduction to sulfate reduction ("concurrent growth" vs. TEAP succession)
  - Based on successful proteomics sampling and analysis (Wilkins et al. 2009)
  - Slow growth of sulfate reducers (Williams et al. in prep, Chandler et al. submitted)
  - Persistence of Fe-reducers during dominance by sulfate reducers (Callister et al submitted; Williams et al. submitted)
  - Consistent with analysis of Postma and Jakobsen (1996)
  - Ramifications for other microbial ecosystems



- Discovered U(IV) in naturally occurring shallow organic-rich zones embedded in a sub-oxic aquifer (Campbell et al. in revision, Qafoku et al. 2009)
  - Non-roll front
  - Suggests we may need to re-think U speciation in organic-rich zones in shallow alluvial aquifers



- Demonstrated limited U(VI) reduction by abiotic Fe(II) at the field scale (Fox et al. in prep)
  - Modifying our view of Fe(II) transport, consumption, and reactivity in aquifers

- Discovered background input of uranium to the site at approximately twice the MCL.

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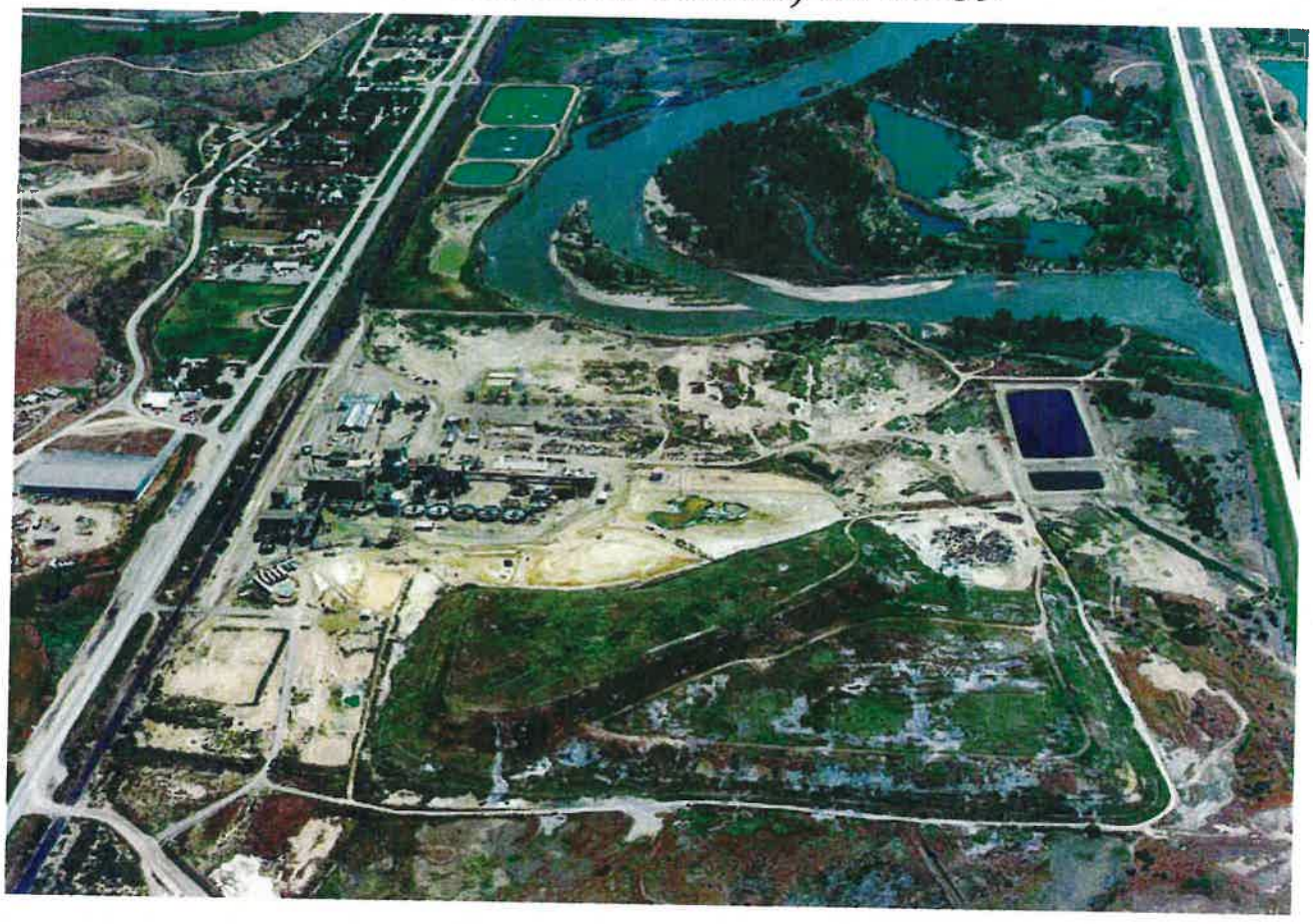
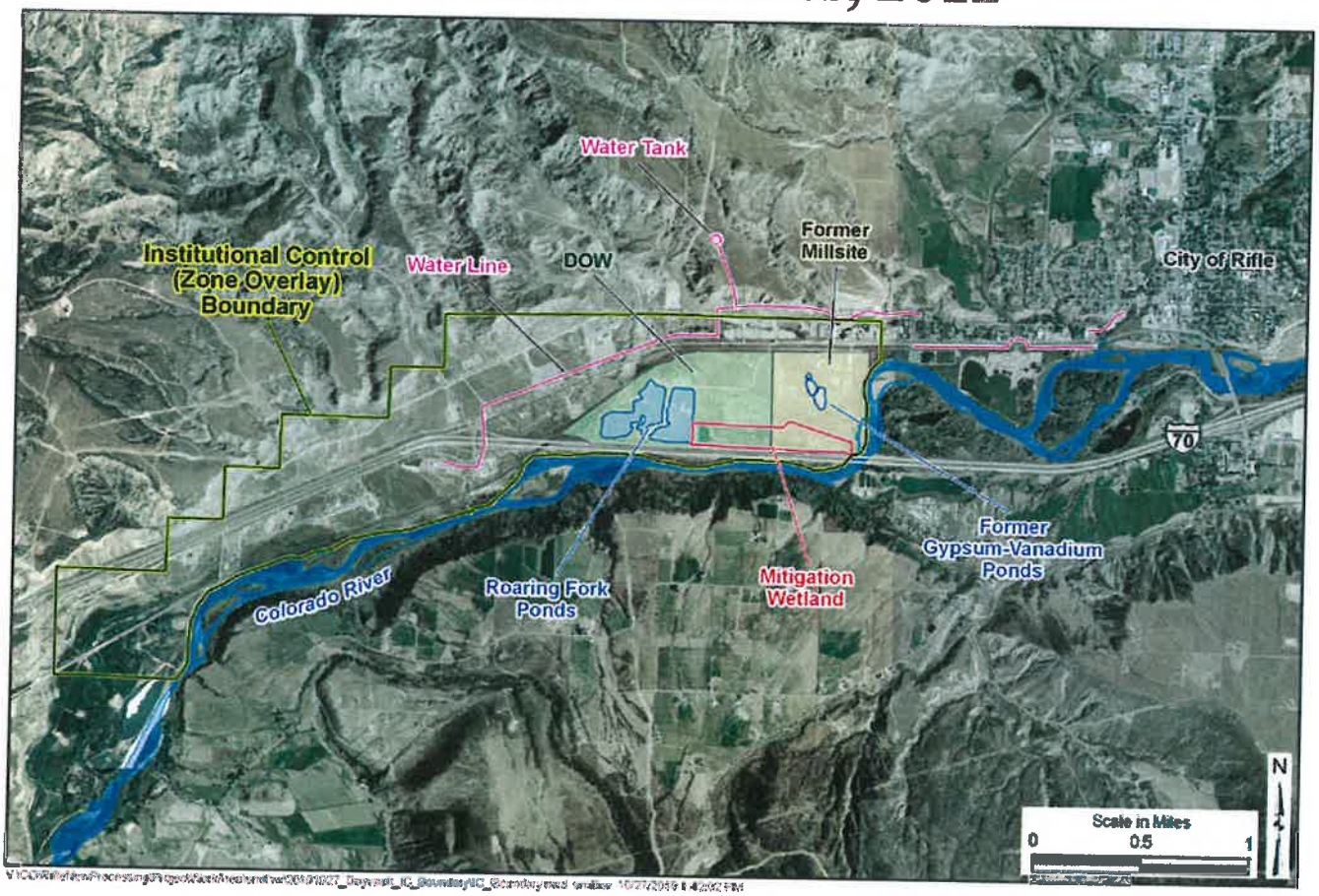
Pre-Remediation, c. 1989



During Remediation, c. 1992

Post Remediation, c. 1995

New Rifle Features, 2012



New Rifle Institutional Controls

Quitclaim Deed Restrictions on Site Proper

- No subsurface disturbance or access to groundwater without prior written approval by Colorado Department of Public Health and Environment and U.S. Department of Energy (a no-dig area for vanadium also prescribed)
- No use of groundwater for any purpose

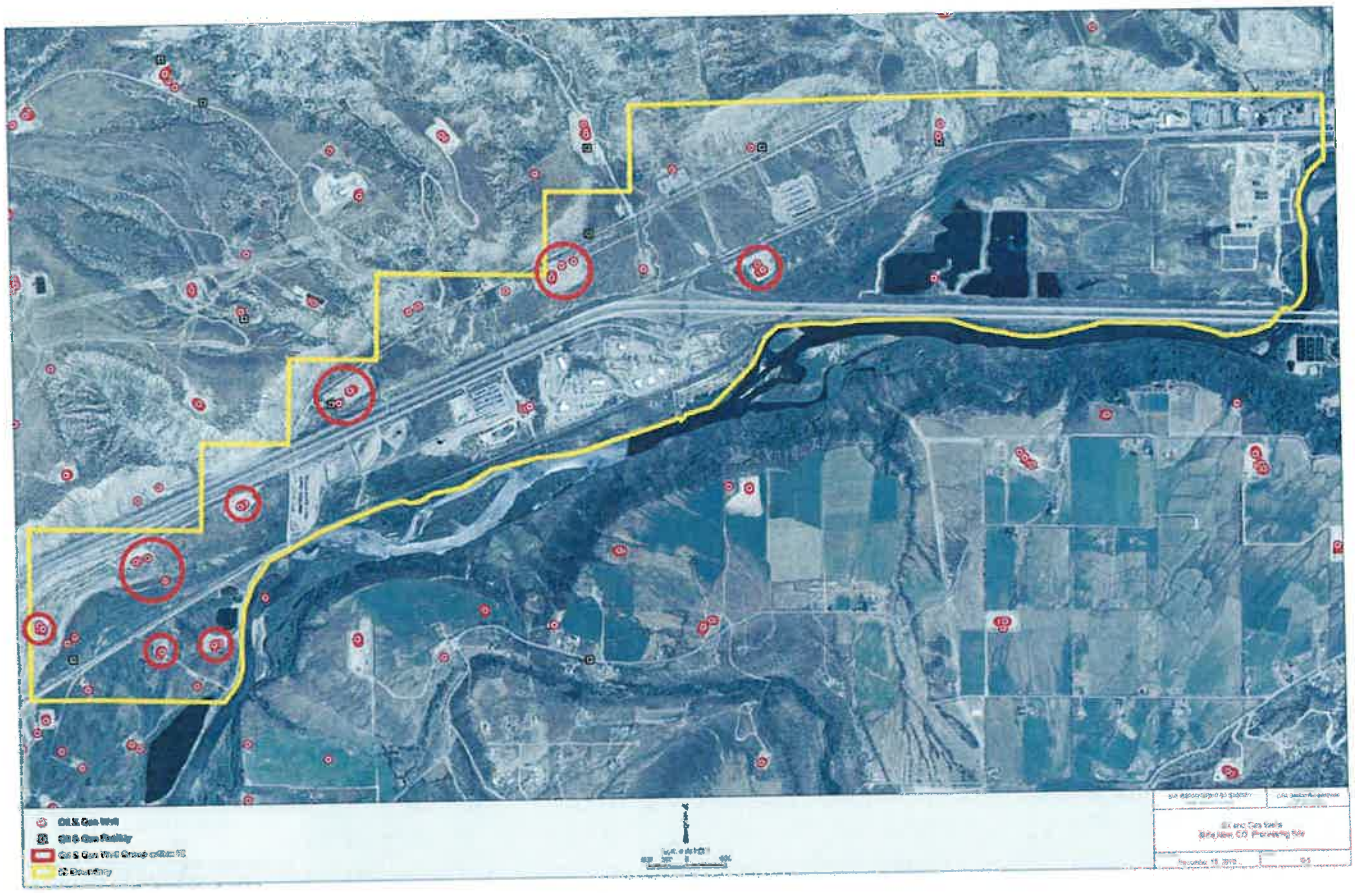
Zone Overlay with Expanded Institutional Controls Boundary

- Restricts groundwater for potable use
- Provides funding for municipal waterline

Environmental Covenant

- Restricts livestock access to former gravel pit ponds (elevated uranium, molybdenum, nitrate in E pond)

New Rifle Zone Overlay: IC and Gas Drilling Activity



New Rifle Reuse