APPENDIX A

DEPARTMENT OF ENERGY
RULISON END STATE VISION DOCUMENT
FINAL – JANUARY 2005

DOE/NV--950

U.S. DEPARTMENT OF ENERGY

Rulison Site
ENVIRONMENTAL MANAGEMENT
END STATE VISION
Final

Executive Summary

The Environmental Management End State Vision is to be used as the primary tool for communicating the individual site end state to the involved parties (e.g., U.S. Department of Energy [DOE], regulators, public stakeholders, Tribal Nations). The end state document is not a decisional document. If the DOE decides to seek changes to the current compliance agreements, decisions, or statutory/regulatory requirements, those changes will be made in accordance with applicable requirements (DOE/EM, 2003).

Restoration activities have been conducted on the surface of the Rulison Site; however, an investigation of subsurface contamination has not yet been completed. Therefore, the surface and subsurface end states are treated separately within this document.

The Rulison Site is in the northern part of Battlement Mesa in southern Garfield County, Colorado. Ranching, farming, and oil and gas production historically have provided the dominant commercial interests in this region of Colorado, but retirement homes and tourism have increased in recent years. The nearest town, Parachute, lies approximately 8 miles northwest of the site, and the largest town in the area, Rifle, lies 12 miles to the northeast.

The Rulison test was part of the Plowshare Program, which was designed to develop peaceful uses for nuclear explosives. One underground nuclear test was conducted at the Rulison Site in 1969 to study the ability of nuclear explosions to stimulate natural gas production from low permeability formations. No further tests were conducted at the Rulison Site.

Cleanup associated with the original deactivation of the Rulison Site in 1972 included removing equipment and materials not needed for potential gas production activities, extensive soil sampling, and removing contaminated soil. Cleanup associated with abandonment of the Rulison Site in 1976 included removing all equipment and materials, plugging and abandoning the emplacement and reentry wells, backfilling the mud pits, and removing soil contaminated with tritium. In 1996, the DOE/Nevada Operations Office (now the Nevada Site Office [NSO]) completed preliminary site characterization for the surface area of the Rulison Site. During these activities, the surface contamination was removed and additional water-quality monitoring wells were drilled. In 1998, the DOE/NSO completed surface closure of the site and submitted the *Rulison Site Surface Closure Report* (DOE/NV, 1998). The State of Colorado accepted the surface closure report with no surface restrictions (Johnston, 2003a). The site is currently privately owned and is used for livestock grazing and for recreation, including fishing.

The subsurface investigation has not yet begun at the Rulison Site. It is expected to involve numerical modeling of radionuclide transport in the gas phase. The objective will be to determine if the subsurface restriction zone is sufficiently protective in the event gas production wells are drilled adjacent to the site. Based on the historic use of the site and characterization conducted at similar sites, the contaminants of concern for the subsurface of the Rulison Site are expected to include radioactive fission products, plutonium, uranium, and tritium, with the gaseous radionuclides (tritium, carbon-14, and krypton-85) being the most mobile in the environment; however, the extent of the subsurface hazard has yet to be defined.

The subsurface contamination is being addressed by implementing an approach based on defining a contaminant boundary at the Rulison Site and monitoring subsurface resource development to ensure that gaseous radionuclides do not migrate past the existing restriction boundary. Migration to the existing restriction boundary, both under non-stressed and stressed (production) conditions, is being evaluated. If migration is found to be significant (which may be determined by a risk assessment), then the restriction zone will be enlarged. Drilling and subsurface resource extraction within the contaminant boundary will be prohibited, and resource (natural gas) production may also be limited for some region outside the boundary. This approach will be protective because, though it is not technologically feasible to remediate the contamination associated with an underground nuclear test, the use (withdrawal) of and exposure to contaminated natural gas will be precluded by implementation of institutional controls restricting the drilling of wells within the boundary. Resource development patterns in the area will be monitored to assess whether the boundary remains protective if resource extraction characteristics change through time, and samples of natural gas from nearby wells may be monitored for radionuclides. If radionuclides are ever found in nearby production wells, the radionuclide transport model will be re-evaluated to determine if the drilling restriction area and associated institutional controls need to be changed.

According to the Life-Cycle Baseline Revision 5, the DOE/NSO expects to complete closure of the Rulison Site subsurface in fiscal year 2011. The DOE/NSO assumes that monitoring will be performed for 100 years (2011 to 2111), and will refine existing subsurface intrusion restrictions as necessary, based on the outcome of the investigation and modeling efforts (DOE/EM, 2001). The end state for the subsurface of the Rulison Site will be to continue monitoring and maintenance of institutional controls indefinitely.

The end state has been achieved for the surface of the Rulison Site. The end state envisions leaving the Rulison Site in private ownership, as it now exists. The DOE will continue long-term stewardship activities for the subsurface contamination. The DOE has imposed deed restrictions on the site to prevent access to the test cavity, subsurface areas, and natural gas in perpetuity (DOE/EM, 2001). The U.S. Department of the Interior, Bureau of Land Management and the Colorado Oil and Gas Conservation Commission will exercise oversight of any wells located within three miles of the Rulison Site. This three-mile zone is sufficient to isolate contamination from potential receptors (IT, 1996).

The DOE/NSO developed a public participation plan for the Rulison Site Environmental Management End State Vision. The plan provided a draft copy of this document, an information sheet, and a letter soliciting feedback by July 1, 2004, to involved parties and stakeholders. All written comments that were submitted to the DOE/NSO received comment resolution.

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List of Acronyms and Abbreviations

bgs	Below ground surface
BLM	U.S. Department of the Interior, Bureau of Land Management
COC	Contaminant(s) of concern
CSM	Conceptual site model
DOE	U.S. Department of Energy
DOE/NSO	U.S. Department of Energy, Nevada Site Office
EM	U.S. Department of Energy, Environmental Management Program
EPA	U.S. Environmental Protection Agency
ft	Foot (feet)
ft^3	Cubic feet
FY	Fiscal year
LTHMP	Long-Term Hydrologic Monitoring Program
mi	Mile(s)
SGZ	Surface ground zero
TPH	Total petroleum hydrocarbons
USDA/FS	U.S. Department of Agriculture, Forest Service

1.0 Introduction

The Environmental Management End State Vision is to be used as the primary tool for communicating the individual site end state to the involved parties (e.g., U.S. Department of Energy [DOE], regulators, public stakeholders, Tribal Nations). The end state document is not a decisional document. If the DOE decides to seek changes to the current compliance agreements, decisions, or statutory/regulatory requirements, those changes will be made in accordance with applicable requirements (DOE/EM, 2003).

The environmental management end state vision juxtaposes land use with remediation requirements, establishing a conceptual completion goal (or end state) that is both realistic and protective of human health and the environment. The purpose of the vision is to identify where and how potentially harmful exposures to hazardous or radioactive contaminants might occur under projected future conditions, and to determine what actions will be necessary to minimize the potential for harm under those conditions. Consistent with the objectives of cleanup, the vision conceptualizes specific end state conditions that will minimize the potential for harm in the future.

The July 2003 DOE Policy 455.1, "Use of Risk-Based End States," requires DOE Environmental Management Program (EM) sites to define and document a risk-based end state vision that is acceptable to regulators and stakeholders, and then to revise clean-up program plans as necessary to achieve that end state in the most efficient manner (DOE, 2003). The policy is a formal mandate for EM sites to implement risk-based corrective action programs as described in numerous DOE and U.S. Environmental Protection Agency (EPA) publications, American Society of Testing and Materials Standard Guides, and National Research Council recommendations.

Environmental corrective action is an application of standard scientific, engineering, and mathematical principles, enabling steady progress in solving even very complex clean-up problems. The complexities of cleanup at a typical EM site are generally similar: multiple contaminants distributed in multiple environmental media, released over long periods of time and over large areas of land. Uncertainties in source(s), nature, extent, transport, and fate of contaminants are very large and can never be absolutely eliminated. Corrective action provides an objective means of managing uncertainties to the degree necessary and sufficient to make defensible decisions about effective clean-up actions.

The end state vision describes clean-up goals that would be protective under planned future uses. Proposed corrective actions based on risk and other factors associated with land use are presented, negotiated, and agreed to by the State of Colorado and DOE.

The DOE's risk-based end state initiative is fully consistent with the EPA's recent endorsement of systematic planning, which uses risk-based decision methods to ensure objectivity, defensibility, and cost-effectiveness in corrective action programs (EPA, 2001). The DOE Nevada Site Office (DOE/NSO) will collaborate with its stakeholders to revise the proposed environmental management end state vision, as needed, to define clear goals for completion of its EM-sponsored clean-up work.

The DOE/NSO developed a public participation plan for the Rulison Site End State Vision. The plan provided a draft copy of this document, an information sheet, and a letter soliciting feedback by July 1, 2004, to involved parties and stakeholders. All written comments that were submitted to the DOE/NSO received comment resolution.

Restoration activities have been conducted on the surface of the Rulison Site; however, an investigation of subsurface contamination has not yet been completed. Therefore, the surface and subsurface end states are treated separately within this document.

The Rulison Site is in the northern part of Battlement Mesa in southern Garfield County, Colorado. Battlement Mesa is in northwestern Colorado and consists of a high, basalt-capped mesa covered with aspen and pine trees in the upper elevations, and sagebrush and cedar in the lower elevations. High mountain ranges lie southeast and east of Battlement Mesa, and high plateaus lie southwest and west of the site. The Colorado River and Interstate Highway 70 are approximately 8 miles (mi) north of the Rulison Site, and have seen increasing commercial and population growth in recent years. Ranching, farming, and oil and gas production have historically provided the dominant commercial interests in this region of Colorado, but retirement homes and tourism have increased in recent years. The Rulison Site is privately owned and is used for livestock grazing and for recreation, including fishing. Parachute, the nearest town, lies 8 mi northwest of the site, and Rifle, the largest town in the area, lies 12 mi to the northeast.

The Rulison test was conducted under the Plowshare Program to evaluate the feasibility of using a nuclear device to stimulate natural gas production in low-permeability gas-producing geologic formations. On September 10, 1969, a 40-kiloton nuclear device was detonated at a depth of

8,426 feet (ft) below ground surface (bgs) in the R-E test hole. After the test, the R-EX pre-test exploration hole, located 300 ft southeast of the test hole, was redrilled to test gas production in the stimulation zone. Natural gas production testing was conducted in 1970 and 1971. Four separate production tests were conducted and 455 million cubic feet (ft^3) of gas were produced. In 1971, the production test well was shut-in. The R-E and R-EX drill holes were plugged and abandoned in 1976. Detailed descriptions of the site deactivation and abandonment activities are presented in the *Rulison Site Cleanup Report* (AEC, 1973) and the *Project Rulison Well Plugging and Site Abandonment Final Report* (ERDA, 1977).

The *Preliminary Site Characterization Report, Rulison Site, Colorado* (IT, 1996) documented the history and clean-up activities completed to that date, and made recommendations for the future of the Rulison Site. The *Rulison Site Surface Closure Report* (DOE/NV, 1998) was completed in 1998 and summarizes the clean-up activities that resulted in surface closure of the site. The State of Colorado accepted the surface closure report with no surface restrictions (Johnston, 2003b). The *Annual Water Sampling and Analysis, Calendar Year 2002* (EPA, 2002) summarizes groundwater quality monitoring completed by the EPA. The site characterization work plan for the Rulison Site subsurface will be based on the approach described in *Modeling Approach for Evaluating Radionuclide Transport in Nuclear-Stimulated Gas Reservoirs* (Cooper and Chapman, 2001). Upon construction of a dual-phase (liquid and gas) numerical flow and transport model, production stress will be applied to the modeled system to simulate gas development immediately beyond the current drilling restriction. The results will be analyzed to determine if the current restrictions are sufficiently protective. The present document summarizes results from these previous documents and addresses the current and future status and land use of the Rulison Site.

According to the Life-Cycle Baseline Revision 5, subsurface characterization of the Rulison Site will begin in fiscal year (FY) 2005, and subsurface closure of the Rulison Site is scheduled for completion in FY 2011.

1.1 Organization of the Report

The Rulison Site Environmental Management End State Vision is organized into five sections. Since the current state and end state are the same for the Rulison Site, only one map is presented for each subsection.

Section 1.0 introduces the site, including a brief discussion of past, present, and future site missions. This section also briefly discusses site hazards, the extent of environmental contamination, past remediation work, and any planned future clean-up work.

Section 2.0 describes the regional context end state. This section examines physical and surface interface and human and ecological land use in the regional context. A map showing the current state and the end state is also included for each subsection.

Section 3.0 describes the site-specific end state. This section examines physical and surface interface and human and ecological land use for the site and immediately adjacent lands. Legal ownership and demographics are also presented, and each subsection includes a map showing the current state and the end state.

Section 4.0 discusses specific site hazards including the nature of each hazard, potential impacts on human health and the environment, and any hazard mitigation identified. This section includes a current site-wide hazard map in addition to a current state/end state map for each specific hazard. A conceptual site model (CSM) is also included in this section. This model shows the current state/end state for each hazard. The CSM is used to show the known and potential contaminant pathways, potential receptors, and barriers that have been put in place to minimize exposure to contamination.

Section 5.0 provides references used to develop the Rulison Site Environmental Management End State Vision.

Attachment A provides a report table detailing that there are no variances between the end state vision and current remediation plans for this site.

1.2 Site Mission

The Rulison Site was active from 1968 to 1976. The site is located on Battlement Mesa in southern Garfield County, Colorado, approximately 8 mi southeast of the town of Parachute, and 12 mi southwest of Rifle. The Rulison test was part of the Plowshare Program, which was designed to develop peaceful uses for nuclear explosives. One underground nuclear test was conducted at the Rulison Site to evaluate the feasibility of using a nuclear device to stimulate natural gas production in low-permeability gas-producing geologic formations. The Rulison test involved a 40-kiloton nuclear device, which was detonated at a depth of 8,426 ft bgs in the R-E

test hole. The R-EX pre-test exploration hole, located 300 ft southeast of the test hole, was redrilled after the detonation to test gas production in the stimulation zone. Four separate production tests were conducted and 455 million ft^3 of gas were produced. In 1971, the production test well was shut-in. Site clean-up activities were conducted from 1972 to 1976. By 1976, all natural gas production wells at the Rulison Site had been plugged and abandoned.

The Rulison Site is currently under private ownership; however, the U.S. Government has acquired mineral interest as part of the oil shale reserve, and there are currently no mining claims. The deed has historic agreement language recognizing the oil and gas leases owned by Austral Oil Company, Inc., but these leases expired in 1972.

Surface contaminants at the Rulison Site included petroleum hydrocarbons associated with a drilling mud pit and surface contamination associated with decontamination of drilling equipment and fallout from gas flaring. All surface radioactive contamination was cleaned up in 1976 by excavating contaminated soil and transporting it to an off-site location (IT, 1996). Surface petroleum hydrocarbons were addressed in 1995.

Based on the historic use of the site and characterization conducted at similar sites, the contaminants of concern (COCs) for the subsurface of the Rulison Site are expected to include radioactive fission products, plutonium, uranium, and tritium, with the gaseous radionuclides (tritium, carbon-14, and krypton-85) being the most mobile in the environment. The DOE will retain long-term stewardship of the subsurface at the Rulison Site due to the presence of residual contamination (DOE/NV, 1998). Table 1.1 shows the representative source term for the Rulison Site.

Table 1.1 Representative Source Term for the Rulison Site

Mean radionuclide inventory for 76 nuclear tests detonated below or within 328 ft of the water table in Areas 19 and 20 at the Nevada Test Site. Values are decay corrected to January 1, 1994 (Smith, 2001). Unclassified site-specific mass estimates for the Rulison test are substituted where available from Reynolds (1971) and Smith (1971).

Radionuclide	Isotope Symbol	Half life ($t_{1/2}$; year)	Estimated Inventory (Ci)[a]
Tritium	H-3	1.23E+01	1.0E+04[b]
Carbon-14	C-14	5.73E+03	2.2E+00[c]
Aluminum-26	Al-26	7.30E+05	1.18E-04
Chlorine-36	Cl-36	3.01E+05	2.82E+00
Argon-39	Ar-39	2.69E+02	2.43E+01
Potassium-40	K-40	1.28E+09	6.17E+00
Calcium-41	Ca-41	1.03E+05	2.16E+01
Nickel-59	Ni-59	7.60E+04	5.25E-01
Nickel-63	Ni-63	1.00E+02	5.54E+01
Krypton-85	Kr-85	1.07E+01	1.11E+03[b]
Strontium-90	Sr-90	2.91E+01	1.57E+04
Zirconium-93	Zr-93	1.50E+06	5.49E-01
Niobium-93m	Nb-93m	1.61E+01	9.99E+01
Niobium-94	Nb-94	2.00E+04	2.28E+00
Technetium-99	Tc-99	2.13E+05	4.04E+00
Paladium-107	Pd-107	6.50E+06	2.07E-02
Cadmium-113m	Cd-113m	1.41E+01	1.53E+01
Tin-121m	Sn-121m	5.50E+01	5.67E+01
Tin-126	Sn-126	1.00E+05	6.47E-01
Iodine-129	I-129	1.57E+07	1.24E-02
Cesium-135	Cs-135	2.30E+06	4.17E-01
Cesium-137	Cs-137	3.02E+01	1.99E+04
Samarium-151	Sm-151	9.00E+01	7.51E+02
Europium-150	Eu-150	3.60E+01	1.46E+01
Europium-152	Eu-152	1.35E+01	4.33E+02
Europium-154	Eu-154	8.59E+00	2.04E+02
Holmium-166m	Hm-166m	1.20E+03	5.89E-01
Thorium-232	Th-232	1.40E+10	7.68E-04
Uranium-232	U-232	7.00E+01	3.36E+00
Uranium-233	U-233	1.59E+05	2.25E+00
Uranium-234	U-234	2.46E+05	1.62E+00
Uranium-235	U-235	7.04E+08	2.18E-02
Uranium-236	U-236	2.34E+07	6.22E-02
Uranium-238	U-238	4.47E+09	2.88E-02
Neptunium-237	Np-237	2.14E+06	4.80E-01
Plutonium-238	Pu-238	8.77E+01	9.42E+01
Plutonium-239	Pu-239	2.41E+04	2.54E+02
Plutonium-240	Pu-240	6.56E+03	8.16E+01
Plutonium-241	Pu-241	1.44E+01	1.18E+03
Plutonium-242	Pu-242	3.75E+05	4.42E-02
Americium-241	Am-241	4.33E+02	6.14E+01
Americium-243	Am-243	7.37E+03	2.36E-03
Curium-244	Cm-244	1.81E+01	3.91E+01

[a]Except where noted, value is from the mean unclassified radionuclide inventory for 76 nuclear tests detonated below or within 328 ft of the water table in Areas 19 and 20 of the Nevada Test Site.
[b]Value is an unclassified estimate for the Rulison test specifically, from Reynolds (1971).
[c]Value is an unclassified estimate for the Rulison test specifically, and is the total of gaseous species only, from Smith (1971).

1.3 Status of Clean-up Program

During the clean-up efforts at the Rulison Site, the device emplacement well and the drilling mud pits that were used to drill test wells were removed; however, some drilling fluids were left in a containment pond. The pond was left in place at the request of the landowner. Site characterization studies identified total petroleum hydrocarbons (TPH), benzene, ethylbenzene, toluene, xylenes, barium, chromium, and lead in the residual drilling mud left in the bottom of the containment pond (DOE/NV, 1998). Contaminated mud and pond sediment were excavated and removed to an off-site landfill. Closure of the pond and investigation of the surface ground zero (SGZ) were completed in 1995. The *Rulison Site Surface Closure Report* (DOE/NV, 1998) summarizes the clean-up activities that resulted in surface closure of the site. The State of Colorado accepted the surface closure plan with no surface restrictions (Johnston, 2003b). Therefore, the surface of the Rulison Site has achieved the end state.

A monument has been placed at the Rulison Site SGZ to mark the test cavity (Johnston, 2003a). An assessment of the contamination potential to area aquifers was conducted in 1996. The results of the assessment indicated that radionuclides posed little threat to the aquifers (Earman et al., 1996). Seven groundwater-monitoring wells installed to monitor the potential migration of contaminants from the pond into the shallow groundwater were abandoned in 2001. The EPA monitors water quality in wells and springs in the vicinity of the Rulison Site on an annual basis as part of the Long-Term Hydrologic Monitoring Program (LTHMP) (EPA, 2002). The DOE/NSO has not completed characterization of the subsurface at the site, but does not plan to remove subsurface contamination in or around the test cavity due to the lack of feasible remediation technology. The DOE/NSO will develop subsurface models to define contaminant boundaries and refine the existing subsurface intrusion restrictions, if necessary. According to the Life-Cycle Baseline Revision 5, subsurface characterization of the Rulison Site will begin in FY 2005, and subsurface closure of the site is scheduled for completion in FY 2011. Post-closure monitoring will be conducted as agreed upon in the site closure report for the subsurface. The DOE/NSO assumes monitoring will be performed for 100 years (2011 to 2111) (DOE/EM, 2001).

The DOE/NSO assumes that current land use designations and subsurface intrusion restrictions will continue into the foreseeable future. However, the DOE/NSO will reevaluate and modify subsurface restrictions, as appropriate, as part of the assessment and/or corrective action activities (DOE/EM, 2001).

2.0 Regional Context End State Description

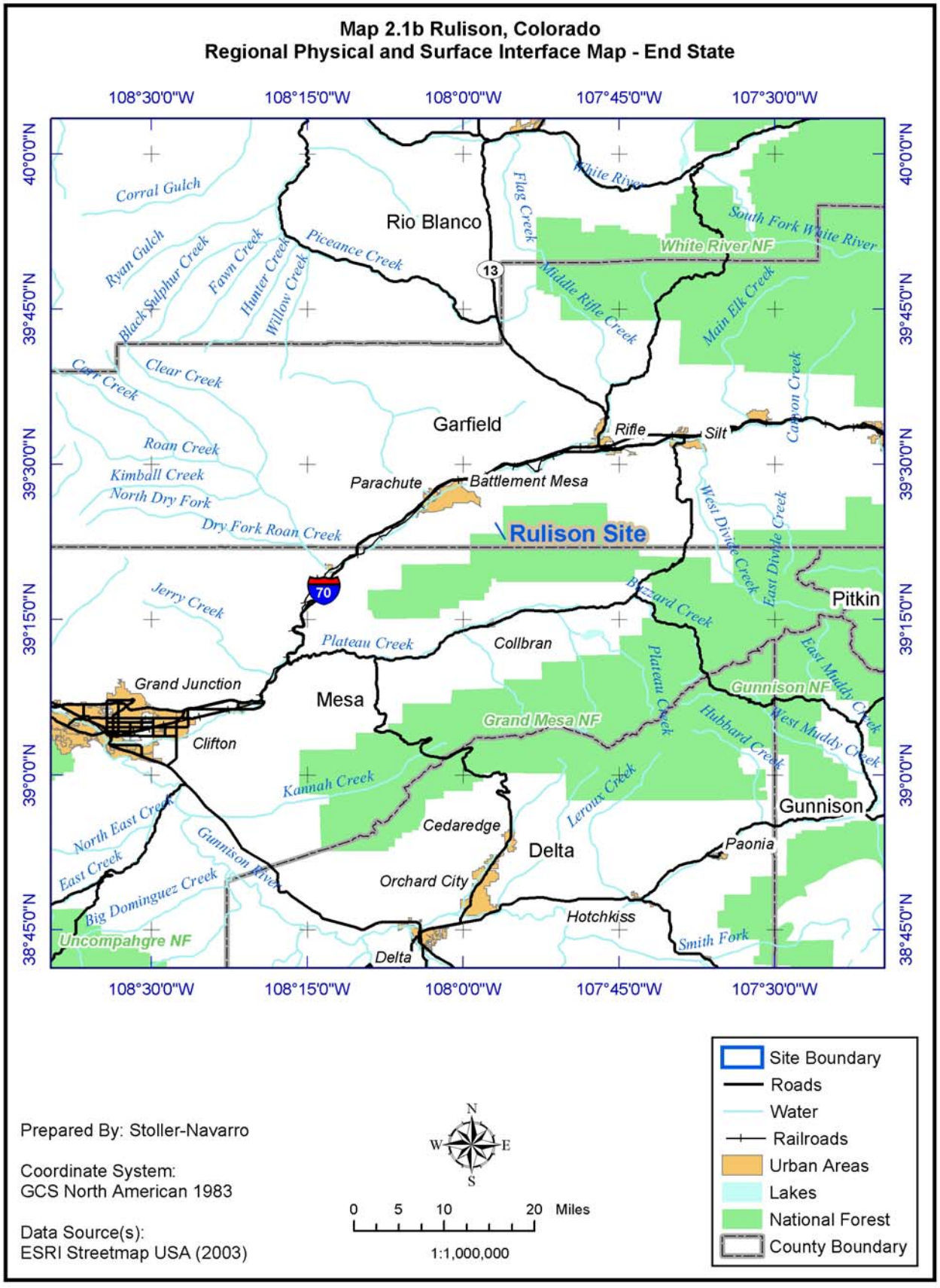
This section examines physical and surface interface and human and ecological land use in the regional context. This section also provides a discussion of current and planned future land use for the region surrounding the Rulison Site.

2.1 Regional Physical and Surface Interface

The Rulison Site is on the north slope of Battlement Mesa in southern Garfield County (Map 2.1b). The Colorado River Valley lies 8 mi north of the site. South of the site, the upper elevations of Battlement Mesa rise to over 10,000 ft. The east fork of Battlement Creek flows through the northern part of the site and discharges into the Colorado River. This region lies in a transition area between the glaciated high peaks of central Colorado and the arid canyon country of western Colorado. As such, the Battlement Mesa area contains characteristics of both regions.

Battlement Mesa is a basalt-capped highland that lies in the southern part of the Piceance Basin in northwestern Colorado. The Piceance Basin has produced oil and natural gas, coal-bed methane, and coal from the Tertiary Wasatch and Mesaverde Formations. The Piceance Creek structural basin is a large northwest-trending downwarp underlying northwestern Colorado. The Rulison Site is on the southwest limb of this basin such that beds penetrated by site boreholes dip gently northeastward. The basin contains about 27,000 ft of sedimentary rock. The Mancos Formation contains pro-deltaic marine mudstones and underlies the nuclear test horizon (Figure 2.0). The Rulison test was conducted in the Mesaverde Group, which is approximately 2,500 ft thick at the site. The Mesaverde Group is predominantly non-marine and consists of sandstone, shale, and coal deposited during the eastward advance of a large deltaic and coastal plain complex into a retreating sea. As a result, sandstone occurs in discontinuous lenses, many of which only extend for distances of a few thousand feet, interbedded with shale.

Above the Mesaverde Group is the Ohio Creek Formation. It is relatively thin in the area of the Rulison Site (37 to 76 ft thick) and is comprised of conglomerates, sandstones, and siltstones. Above this is an approximately 500-ft thick unnamed Paleocene-age formation between the Ohio Creek and Wasatch Formations. The Wasatch Formation (3,900 ft thick at the Rulison Site) contains clay, shale, and sandstone, with local occurrences of conglomerate, limestone, coal, and carbonaceous shale. Overlying the Wasatch is the Green River Formation, which is about 1,700 ft thick at the Rulison Site and is comprised of shale and marlstone, with minor amounts of sandstone, siltstone, and limestone. The Green River Formation is the primary formation of


Map 2.1b Rulison, Colorado
Regional Physical and Surface Interface Map - End State
108°30'0"W
108°15'0"W
108°0'0"W
107°45'0"W
107°30'0"W
40°0'0"N
39°45'0"N
39°30'0"N
39°15'0"N
39°0'0"N
38°45'0"N
Rio Blanco
Garfield
Mesa
Delta
Pitkin
Gunnison
Rifle
Silt
Parachute
Battlement Mesa
Collbran
Grand Junction
Clifton
Cedaredge
Orchard City
Paonia
Hotchkiss
Delta
Rulison Site
White River NF
Grand Mesa NF
Gunnison NF
Uncompahgre NF
Corral Gulch
Ryan Gulch
Black Sulphur Creek
Fawn Creek
Hunter Creek
Willow Creek
Piceance Creek
Flag Creek
White River
South Fork White River
Middle Rifle Creek
Main Elk Creek
Canyon Creek
Clear Creek
Carr Creek
Roan Creek
Kimball Creek
North Dry Fork
Dry Fork Roan Creek
West Divide Creek
East Divide Creek
Blizzard Creek
Jerry Creek
Plateau Creek
Kannah Creek
North East Creek
East Creek
Big Dominguez Creek
Gunnison River
Leroux Creek
Hubbard Creek
East Muddy Creek
West Muddy Creek
Smith Fork
13
70
Site Boundary
Roads
Water
Railroads
Urban Areas
Lakes
National Forest
County Boundary
Prepared By: Stoller-Navarro
Coordinate System:
GCS North American 1983
Data Source(s):
ESRI Streetmap USA (2003)
N
W
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0 5 10 20 Miles
1:1,000,000

interest for oil shale development in the region. Quaternary-age deposits of alluvium, mudflows, talus accumulations, and fan and pediment gravels top the geologic section.

Though the groundwater resources in the Piceance Basin are described as relatively large, yields are often sustained for only short periods and water quality can be marginal. As a result, alluvium is the source of groundwater in most stream valleys. Aquifers in the area of the Rulison Site are generally limited to alluvium and terrace deposits because the underlying formations are typically impermeable and produce little, if any, water. Water in the Mesaverde Group may be immobile. An inventory of wells and springs at the time of the Rulison test indicated only one well in the surrounding area that produced water from bedrock. This well is reported to be 764 ft deep, completed in the Green River Formation. Testing in Well R-EX indicated that no water was produced from any formation, though the investigation primarily focused on depths below 6,000 ft.

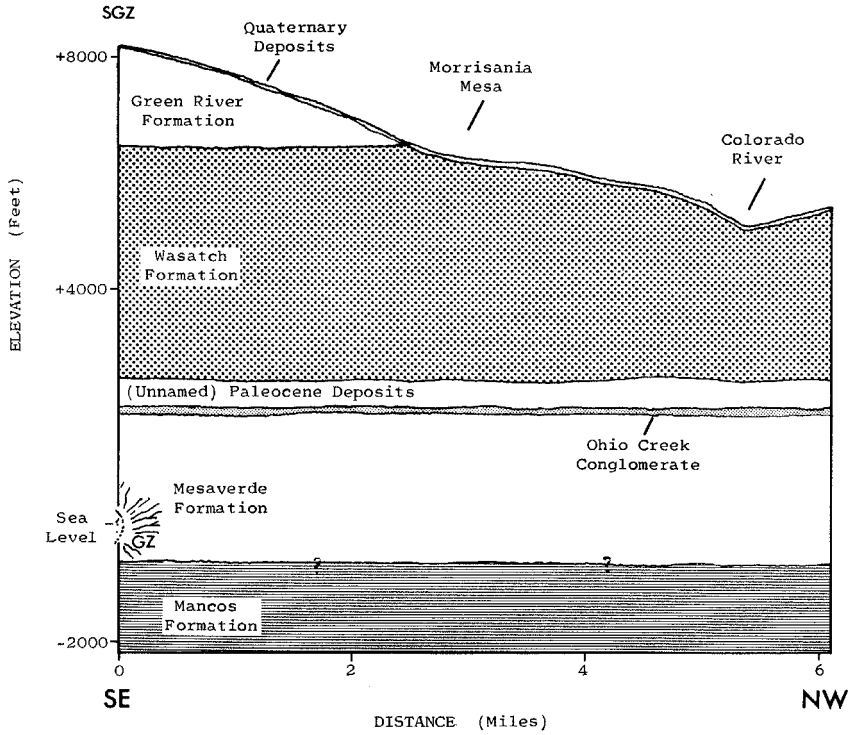


Figure 2.0

Diagrammatic Cross Section of the Rulison Site Along the Trend of Battlement Creek

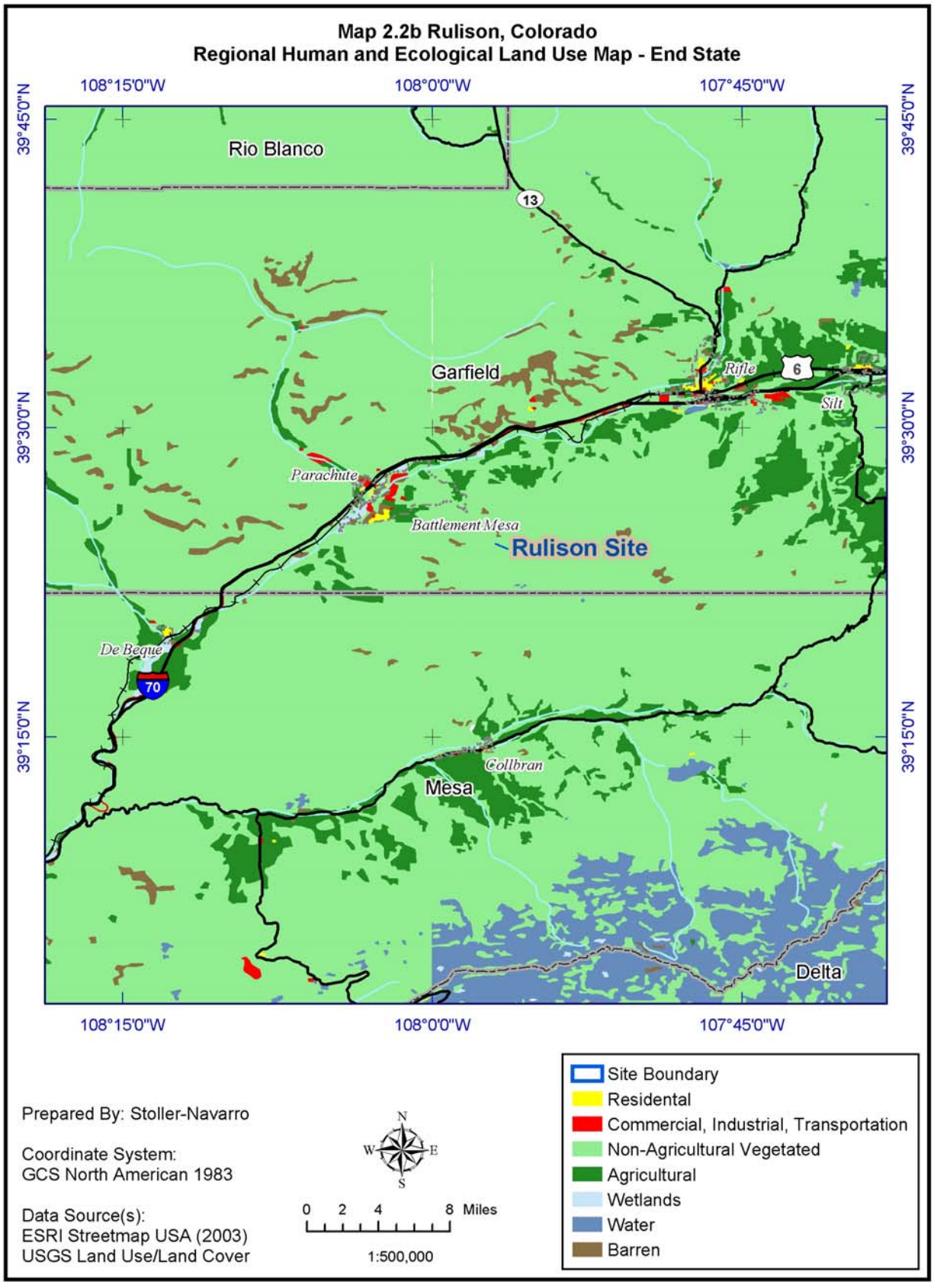
2.2 Human and Ecological Land Use

Human Land Use

Most of the land surrounding the Rulison Site is privately owned. The U.S. Department of the Interior, Bureau of Land Management (BLM) administers control over much of the federal land on Battlement Mesa, but higher elevations of the mesa are within the Grand Mesa National Forest, which is administered by the U. S. Department of Agriculture, Forest Service (USDA/FS). The Battlement Mesa region has been used for recreational purposes such as hunting and fishing, and for commercial purposes such as oil and gas production, grazing, and logging (Map 2.2b). Two natural gas production wells (Federal 28-95 and Federal 14-95) are located 2.7 mi from the Rulison Site SGZ; however, both are currently shut-in.

In recent years, the population of the Colorado River Valley has increased dramatically. The towns of Rifle and Parachute have expanded by as much as 40 percent in the past decade and a retirement community has been built on the lower slopes of Battlement Mesa. The encroaching development of summer homes and retirement residences in the region around the site can be expected to continue.

The small town of Parachute lies 8 mi northwest of the Rulison Site, and the larger town of Rifle lies 12 mi northeast. Grand Junction is the largest metropolitan area in the western half of Colorado, and it lies approximately 40 mi southwest of the site. The next largest community in the region is Glenwood Springs, approximately 35 mi east-northeast of the site.


Map 2.2b Rulison, Colorado
Regional Human and Ecological Land Use Map - End State
108°15'0"W
108°0'0"W
107°45'0"W
39°45'0"N
39°30'0"N
39°15'0"N
Rio Blanco
13
Garfield
Rifle
6
Silt
Parachute
Battlement Mesa
Rulison Site
De Beque
70
Collbran
Mesa
Delta
Prepared By: Stoller-Navarro
Coordinate System:
GCS North American 1983
Data Source(s):
ESRI Streetmap USA (2003)
USGS Land Use/Land Cover
N
W
E
S
0 2 4 8 Miles
1:500,000
Site Boundary
Residental
Commercial, Industrial, Transportation
Non-Agricultural Vegetated
Agricultural
Wetlands
Water
Barren

The future roles and responsibilities of the DOE, landowners, and other federal and state agencies are documented in Table 2.1 (Johnston, 2003b).

Table 2.1
DOE/NSO Land Status

Landlord	Surface Steward	Subsurface Steward	Withdrawal Order/Law	Specific Restriction Record	Oil/Gas Owner and Leases	Water Well Permits	Mineral Rights	Grazing Rights
Private Owner	Private Owner	**Current:** BLM and Colorado Oil and Gas Conservation Commission **Future:** DOE/Office of Legacy Management	**Surface:** General Land Office Order **Subsurface:** General Land Office Order	Glenwood Springs Resource Area Resource Management Plan and On-Site Plaque	Private Owner No Leases	Private Owner and DOE/NSO	U.S. Government	Private

As part of the LTHMP, the EPA regularly samples water from the Grand Valley municipal drinking water supply springs, water supply wells from five local ranches, and two sites in the vicinity of SGZ, including one test well and two surface discharge springs. No radioactive materials attributable to the Rulison test were detected in the samples collected in off-site areas between 2000 and 2002 (EPA, 2002).

Ecological Land Use

The area around the Rulison Site receives approximately 20 inches of rainfall per year and supports a variety of plants and animals. Forests, meadows, wetlands developed around beaver ponds, perennial streams, and creeks characterize the slopes of Battlement Mesa. The lower elevations support a community of sage, cedar, gambol oak, and mountain mahogany, which yields to firs, pines, and aspens in the higher elevations. The region supports deer, coyotes, raccoons, beavers, rabbits, chipmunks, marmots, and ground squirrels. A thriving bird community in the area includes eagles, doves, ravens, swallows, wrens, warblers, thrushes, sparrows, sandpipers, hummingbirds, robins, flickers, and sapsuckers. The flora and fauna currently found in the region surrounding the site are anticipated to continue as the species in the region for the foreseeable future (IT, 1996).

3.0 Site-Specific End State Description

This section examines physical and surface interface and human and ecological land use in the site-specific context. This section also provides a discussion of current and planned future land use for the site, legal ownership of the site and immediately adjacent lands, and demographics for the area.

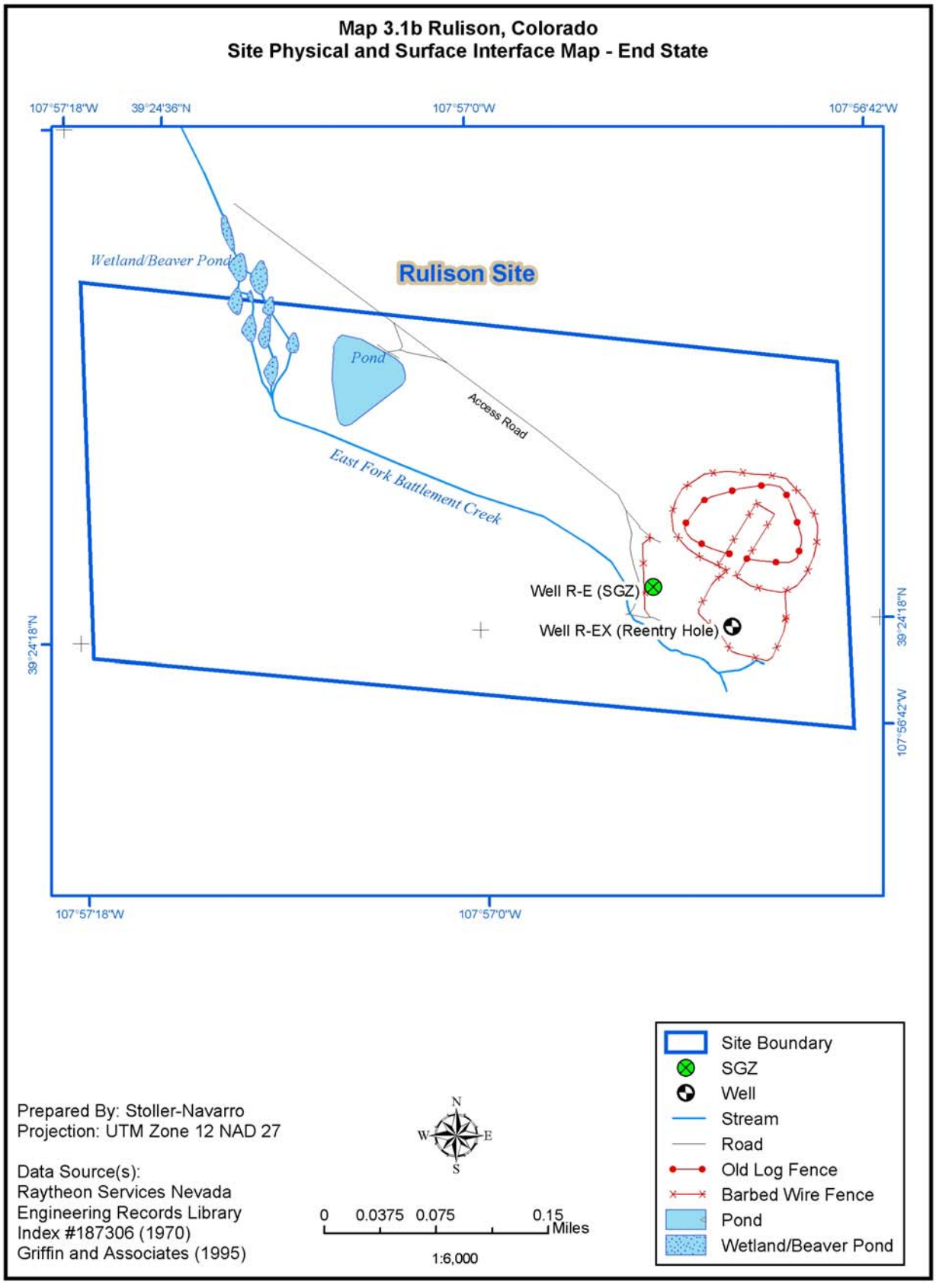
3.1 Physical and Surface Interface

The Rulison Site (Map 3.1b) is on the north slope of Battlement Mesa in upper Battlement Creek, at an elevation of 8,200 ft. The site encompasses the locations of the drilling mud pit and overflow pond, the emplacement drill hole, and the reentry drill hole. Both drill holes have been plugged and abandoned, and the mud pits have been reclaimed. The Rulison Site has received closure for surface contamination, and no further remediation is required (DOE/NV, 1998). The land surface of the Rulison Site is in its final end state.

Analysis of the potential for contamination of the aquifer in the area of the Rulison Site concluded that radionuclides from the Rulison test are totally contained within the Mesaverde Formation and pose no threat to groundwater supplies (Earman et al., 1996). The Rulison test device was placed at the base of the Mesa Verde Formation, at a depth of 8,426 ft bgs. Overlying the Mesa Verde Formation are the Fort Union, Wasatch, and Green River Formations. The Green River Formation crops out at the surface of the site and contains the shallow aquifers used by local water supply wells. Available data suggest that there is no hydraulic communication between water-saturated horizons in the Mesa Verde Formation and the aquifers in the Green River Formation (IT, 1996).

Subsurface contamination is being addressed by implementing an end state approach based on defining a contaminant boundary at the Rulison Site and monitoring subsurface resource development to ensure that gaseous radionuclides do not migrate past the contaminant boundary. The contaminant boundary will be defined on the basis of modeling the maximum extent to which gaseous radionuclides could migrate over 1,000 years. Drilling and subsurface resource extraction within the contaminant boundary will be prohibited, and resource (natural gas) production may also be limited for some region outside the boundary. This approach will be protective because, though it is not technologically feasible to remediate the contamination associated with an underground nuclear test, the use (withdrawal) of and exposure to contaminated natural gas will be precluded by implementation of institutional controls restricting

the drilling of wells within the boundary. Resource development patterns in the area will be monitored to assess whether the boundary remains protective if resource extraction characteristics change through time, and samples of natural gas from nearby wells may be monitored for radionuclides. If radionuclides are ever found in nearby production wells, the dual-phase radionuclide model will be re-evaluated to determine if the drilling restriction area and associated institutional controls need to be changed.


Map 3.1b Rulison, Colorado
Site Physical and Surface Interface Map - End State
107°57'18"W
39°24'36"N
107°57'0"W
107°56'42"W
Wetland/Beaver Pond
Rulison Site
Pond
Access Road
East Fork Battlement Creek
Well R-E (SGZ)
Well R-EX (Reentry Hole)
39°24'18"N
39°24'18"N
107°56'42"W
107°57'18"W
107°57'0"W
Site Boundary
SGZ
Well
Stream
Road
Old Log Fence
Barbed Wire Fence
Pond
Wetland/Beaver Pond
Prepared By: Stoller-Navarro
Projection: UTM Zone 12 NAD 27
Data Source(s):
Raytheon Services Nevada
Engineering Records Library
Index #187306 (1970)
Griffin and Associates (1995)
N
W
E
S
0 0.0375 0.075 0.15 Miles
1:6,000

3.2 Human and Ecological Land Use

Human Land Use

The Rulison Site is privately owned land surrounded by private land to the west, south, and east, and by BLM land to the north (Map 3.2b). A summer residence is located on the site, approximately 1,400 ft from the former drilling fluid overflow pond, which has subsequently been converted into a fishpond. The site is used for livestock grazing and for recreation, including fishing. There are currently no mining claims and no oil and gas leases on the site. Future use of the site is anticipated to remain the same (IT, 1996).

Subsurface use restrictions at the Rulison Site will remain in place in perpetuity. These restrictions, shown in Map 3.2b, are described on the permanent monument located at the SGZ on site. The restrictions are as follows:

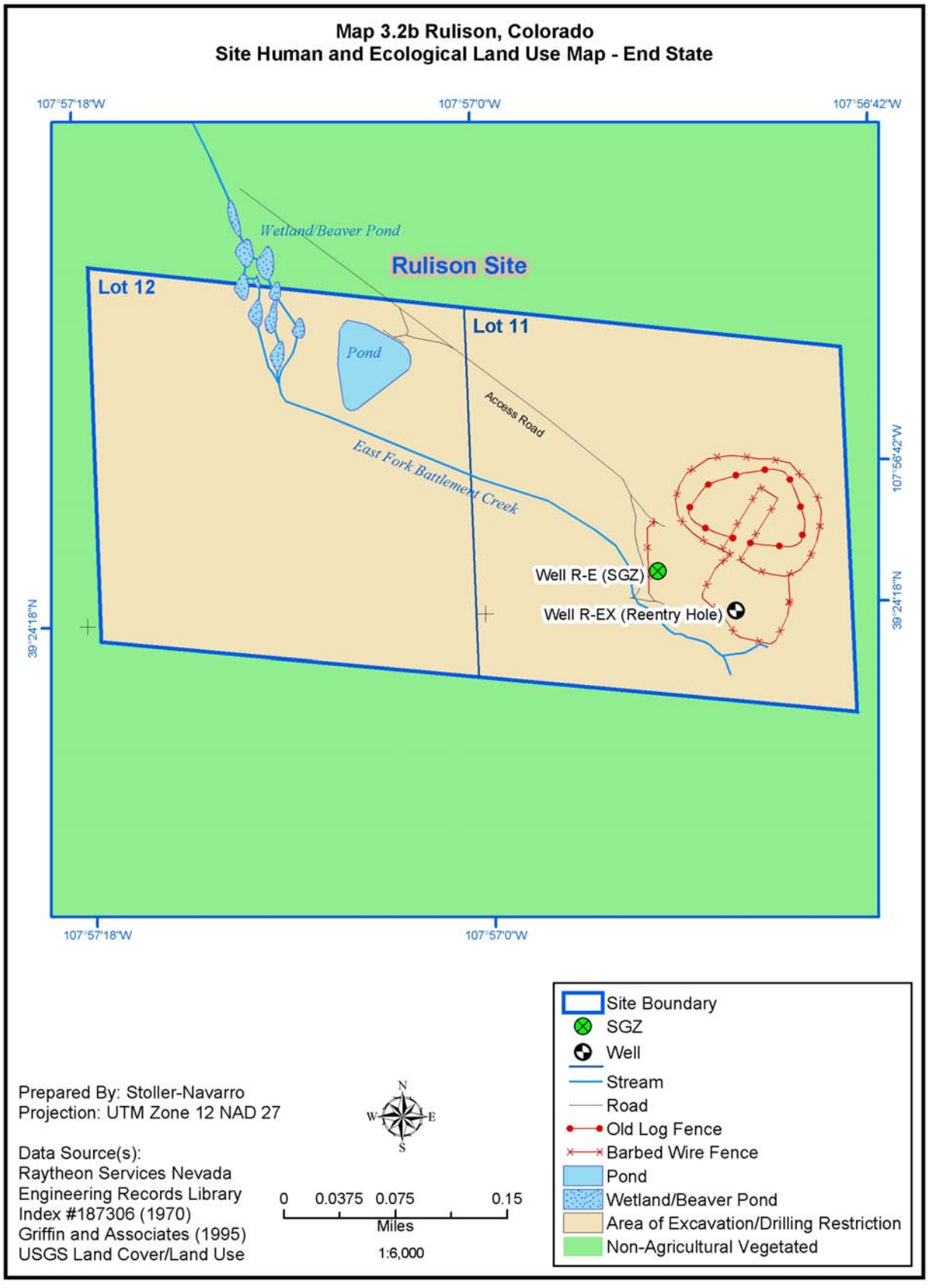
> "No excavation, drilling, and/or removal of subsurface materials to a depth of 12,450 ft is permitted within Lot 11, NE ¼ SW ¼ of Section 25, Township 7 South, Range 95 West, 6th Principal Meridian, Garfield County, Colorado, without U.S. Government permission. U.S. Atomic Energy Commission and the Department of the Interior" (Johnston, 2003a).

In addition to the restrictions placed within Lot 11, an arbitrary 3-mi limit for oil and gas drilling has been established by the State and BLM as referenced in the *Glenwood Springs Resource Area, Oil and Gas Leasing and Development Record of Decision and Resource Management Plan Amendment* (DOI, 1999). This 3-mi area is not a limitation; it is the zone within which any wells will be subjected to oversight measures established by the Colorado Oil and Gas Conservation Commission and review by the DOE for inclusion in a monitoring program. An actual risk-based restriction cannot be determined before completion of the subsurface characterization.

The DOE/NSO has developed a public participation plan for the Rulison Site RBES Vision. The plan provides a draft copy of this document, an information sheet, and a letter soliciting feedback by July 1, 2004, to involved parties and stakeholders. All written comments that are submitted to the DOE/NSO will receive comment resolution.

Ecological Land Use

Clean-up activities associated with abandonment of the Rulison Site resulted in the regrading and reclamation of the mud pit, and conversion of the drilling mud pond into a spring-fed fishpond. The access roads have been maintained for use by the private landowners, but native grasses and trees have reestablished themselves over most of the rest of the site. The area now contains forests of spruce, pine, and aspen, meadows of native grasses, willows, and alder, and a beaver pond wetland. No threatened or endangered species are known to exist at the Rulison Site.

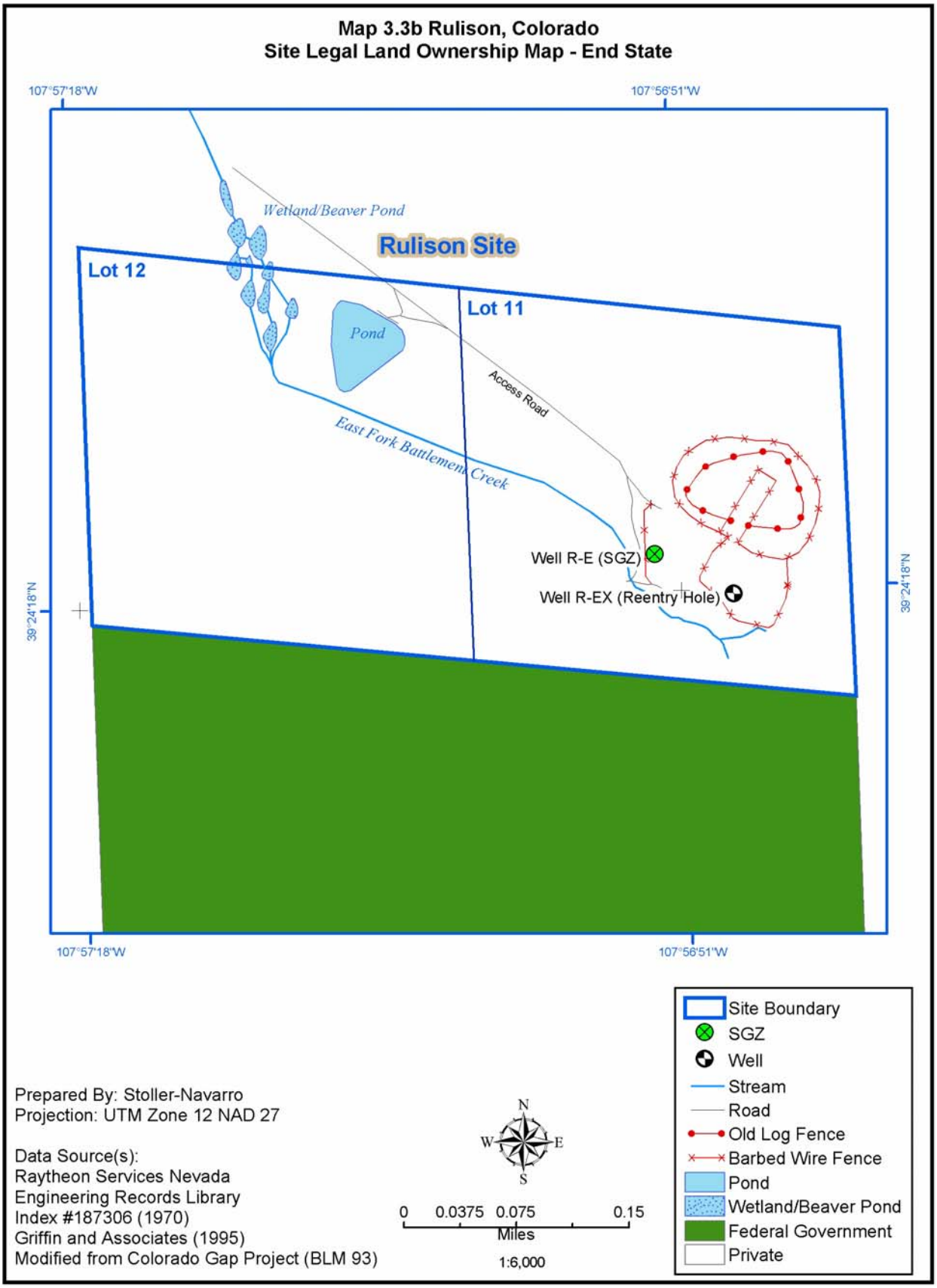

Map 3.2b Rulison, Colorado
Site Human and Ecological Land Use Map - End State
107°57'18"W
107°57'0"W
107°56'42"W
39°24'18"N
Wetland/Beaver Pond
Rulison Site
Lot 12
Lot 11
Pond
Access Road
East Fork Battlement Creek
Well R-E (SGZ)
Well R-EX (Reentry Hole)
Site Boundary
SGZ
Well
Stream
Road
Old Log Fence
Barbed Wire Fence
Pond
Wetland/Beaver Pond
Area of Excavation/Drilling Restriction
Non-Agricultural Vegetated
Prepared By: Stoller-Navarro
Projection: UTM Zone 12 NAD 27
Data Source(s):
Raytheon Services Nevada
Engineering Records Library
Index #187306 (1970)
Griffin and Associates (1995)
USGS Land Cover/Land Use
N
W
E
S
0 0.0375 0.075 0.15
Miles
1:6,000

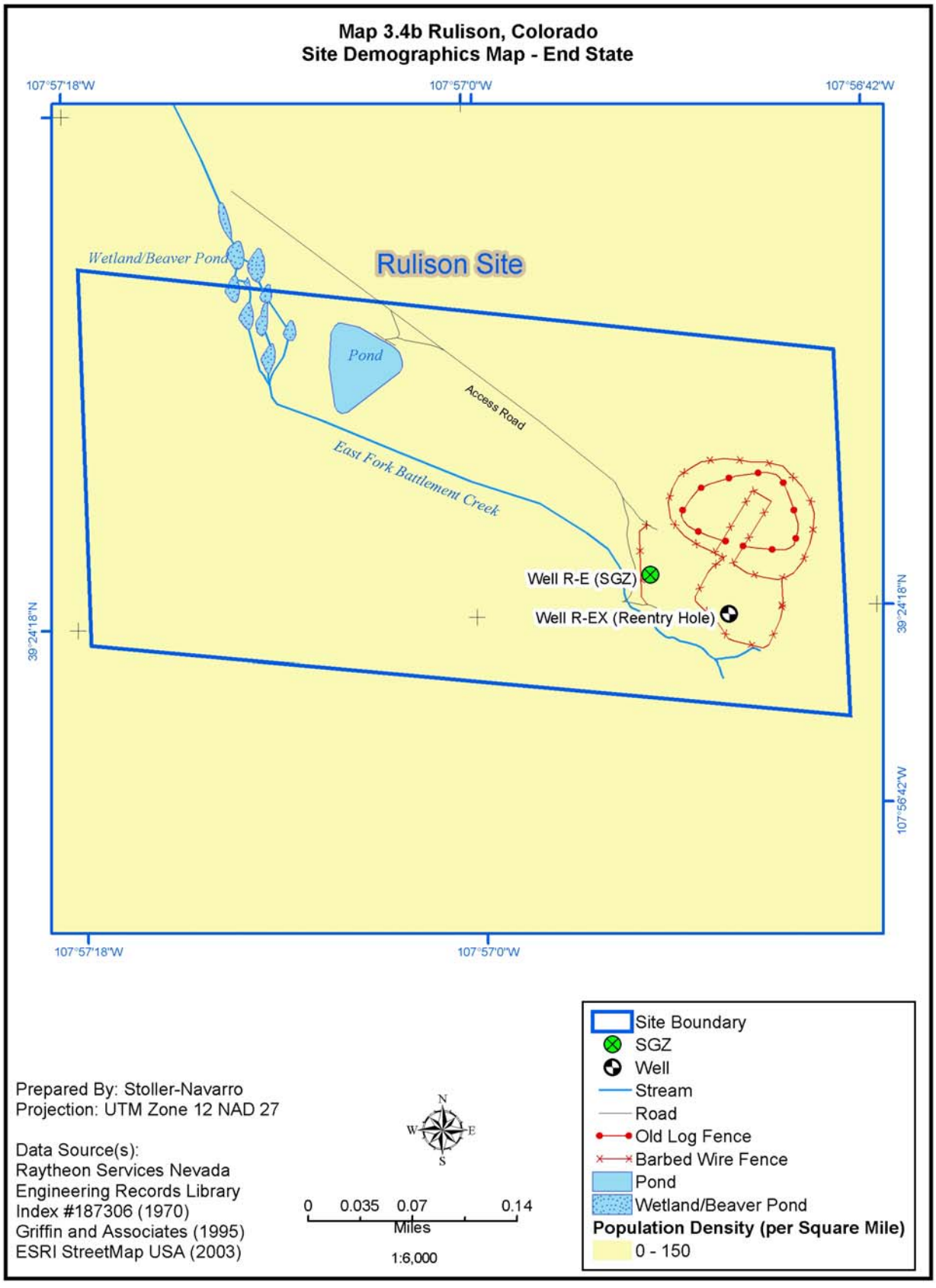
3.3 Site Context Legal Ownership

The Rulison Site is composed of Lots #11 and #12 in the north half of the south quarter of Section 25, Township 7 South, Range 95 West of the 6th Principal Meridian, Garfield County, Colorado (Map 3.3b). Both lots are privately owned, with Lot #11 belonging to Cary E. Weldon and Marcia and Wesley Kent, and Lot #12 belonging to Craig Hayward and Christy Hayward-Koeneke. Warranty Deed No. 463 states that all water, water rights, and ditch rights belong to Hayward. No subsurface restrictions are noted in the deed. Warranty Deed No. 463 applies to Lot #12, where there is no known risk. The mineral rights are owned by the U.S. Government and the entirety of Section 25 is withdrawn under General Land Office Order (June 3, 1919), Classification as Mineral Lands, so there are no mining claims in the section. The oil and gas lease owned by Austral Oil Company Inc. expired in 1972. There are current oil and gas leases on lots adjacent to the Rulison Site; however, no current drilling activity is associated with these leases (Johnston, 2003b). The BLM Glenwood Springs Resource Area Management Plan Amendment states, "Any wells located within three miles of Rulison will be subject to oversight measures established by the Colorado Oil and Gas Conservation Commission." The DOE has a Right of Entry Permit that has been signed by the landowners to access monitoring wells at the Rulison Site.

3.4 Site Context Demographics

The Rulison Site is in the southern part of Garfield County, in northwestern Colorado. The population of Garfield County, shown in Map 3.4b, was 43,791 in the 2000 census, which represented a 46 percent increase from 1990. Parachute, which lies 8 mi northwest of the Rulison Site, has a population of 1,006, and the population of Rifle, 12 mi to the northeast, is 6,784 (U.S. Census Bureau, 2000). Approximately 60 percent of the land in Garfield County is federally owned and administered by the BLM and USDA/FS. Farming, ranching, oil and gas production, and tourism dominate the local economy. The Rulison Site lies on Battlement Mesa, a region that has seen increasing real estate development for second homes and retirement homes. Because this area lies within the I-70 transportation corridor, this population growth trend is likely to continue in the future.


Map 3.3b Rulison, Colorado
Site Legal Land Ownership Map - End State
107°57'18"W
107°56'51"W
39°24'18"N
Wetland/Beaver Pond
Rulison Site
Lot 12
Lot 11
Pond
Access Road
East Fork Battlement Creek
Well R-E (SGZ)
Well R-EX (Reentry Hole)
Site Boundary
SGZ
Well
Stream
Road
Old Log Fence
Barbed Wire Fence
Pond
Wetland/Beaver Pond
Federal Government
Private
Prepared By: Stoller-Navarro
Projection: UTM Zone 12 NAD 27
Data Source(s):
Raytheon Services Nevada
Engineering Records Library
Index #187306 (1970)
Griffin and Associates (1995)
Modified from Colorado Gap Project (BLM 93)
N
W
E
S
0 0.0375 0.075 0.15
Miles
1:6,000


Map 3.4b Rulison, Colorado
Site Demographics Map - End State
107°57'18"W
107°57'0"W
107°56'42"W
39°24'18"N
Wetland/Beaver Pond
Rulison Site
Pond
Access Road
East Fork Battlement Creek
Well R-E (SGZ)
Well R-EX (Reentry Hole)
Prepared By: Stoller-Navarro
Projection: UTM Zone 12 NAD 27
Data Source(s):
Raytheon Services Nevada
Engineering Records Library
Index #187306 (1970)
Griffin and Associates (1995)
ESRI StreetMap USA (2003)
N
W
E
S
0 0.035 0.07 0.14
Miles
1:6,000
Site Boundary
SGZ
Well
Stream
Road
Old Log Fence
Barbed Wire Fence
Pond
Wetland/Beaver Pond
Population Density (per Square Mile)
0 - 150

4.0 Hazard Specific Discussion

Cleanup associated with the original deactivation of the Rulison Site in 1972 included removing all equipment and materials not needed for potential future gas production activities, excavating and removing radioactively contaminated soil, and characterizing the site's radiological condition by extensive soil sampling. Cleanup associated with abandonment of the Rulison Site in 1976 included removing all equipment and materials, plugging and abandoning emplacement and reentry wells, backfilling mud pits, and removing soil contaminated with tritium (IT, 1996).

A human health risk assessment was completed for the Rulison Site in FY 1996. The risk assessment evaluated materials that, if left in place, would require monitoring. Subsequent cleanup left the site in a state that poses no threat to human health or the environment (DOE/NV, 1998). The State of Colorado approved the surface closure with no restrictions and no further actions required (DOE/NV, 2000). The surface of the Rulison Site is in the end state.

The Rulison Site subsurface has not yet been characterized; however, natural gas is assumed to be the main contaminant migration pathway. Most contamination is believed to be isolated near the test cavity, approximately 8,400 ft bgs. Ongoing monitoring has confirmed that testing has not caused an increase in site radioactivity levels in surface or groundwater (DOE/NV, 2000). Subsurface intrusion restrictions are in place and will continue into the foreseeable future. The original shaft (R-E), and the reentry borehole (R-EX) were plugged and abandoned. Table 4.1 summarizes the hazards and risks associated with the site (DOE/NV, 2000). Restrictions are in place to prevent access to the test cavity, groundwater, and natural gas (DOE/NV, 2000).

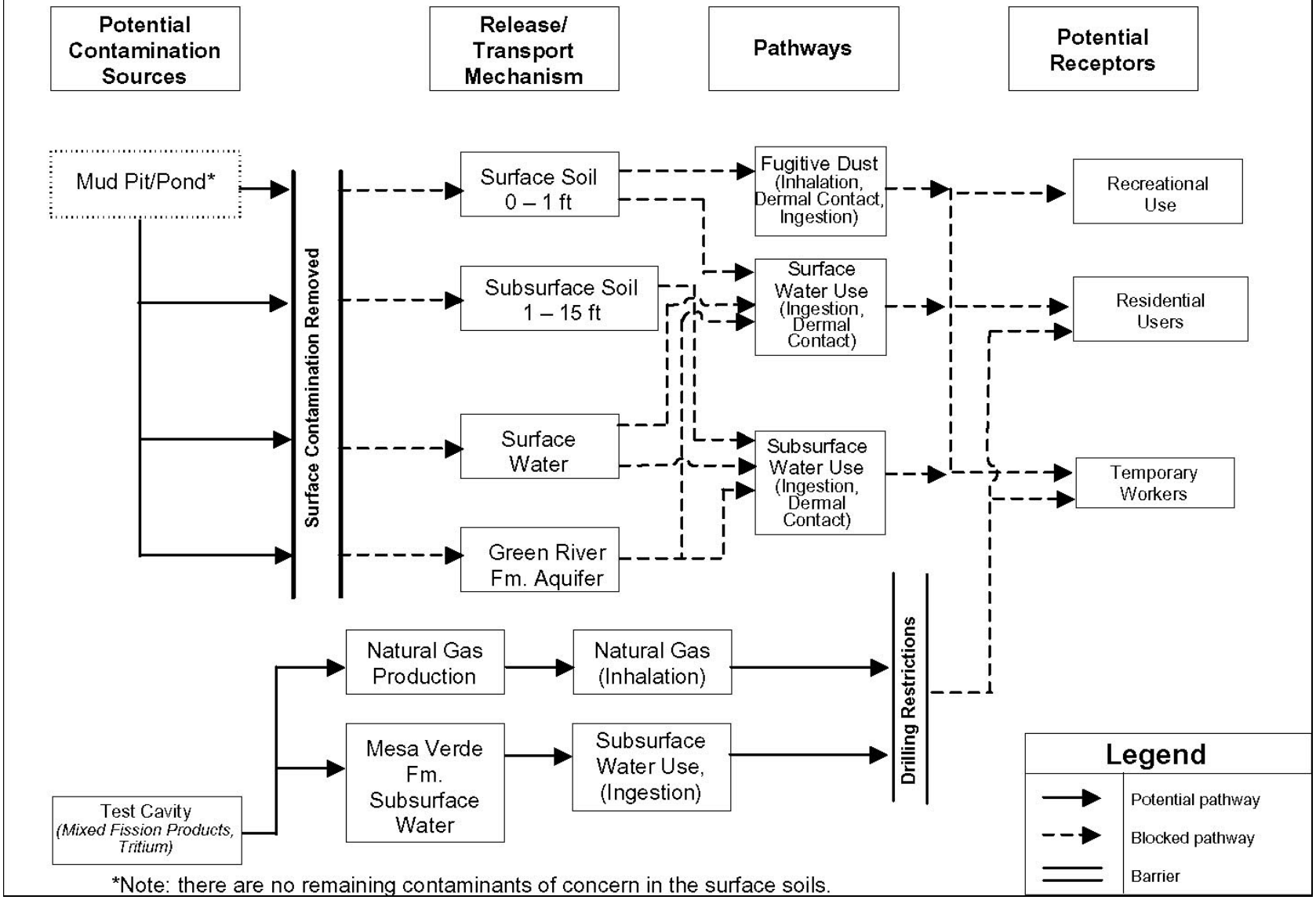
A CSM for the site is provided in Figure 4.0. The CSM illustrates the relationship between the identified potential sources of contamination, the mechanisms for release and migration away from the potential source, the pathways the contamination would follow once released, the exposure routes by which potential contamination would affect receptors, and the receptors that would be impacted by potential contamination.

Based on the results from the *Preliminary Site Characterization Report, Rulison Site, Colorado* (IT, 1996), additional clean-up activities and monitoring were completed in 1998. No surface source areas remain at the Rulison Site and the surface is in its end state. Descriptions of the subsurface hazard area and the surface area that received closure are provided in the following sections.

Table 4.1
Rulison Site Hazards and Risks

Material Category	Nature of Hazard	Nature of Potential Risk	Status of Current Management	Planned Risk Reduction Control	Anticipated Risk Reduction Progress	End-State Disposition and Risk
Deep (>8,000 ft bgs) natural gas, groundwater and test cavity	Groundwater and natural gas in the immediate vicinity of the test cavity are contaminated with radionuclides. Migratory potential of the contaminants via natural gas from the test cavity is being modeled. Additional subsurface characterization will be used for model refinement and validation.	Migratory potential of radionuclides in natural gas and groundwater is minimal. Existing monitoring data from surrounding wells have not indicated radionuclide contamination. If contaminant migration is verified, the most probable exposure scenarios would be via inhalation of, ingestion of, and dermal contact with natural gas.	Site subsurface characterization and groundwater modeling activities are ongoing. Natural gas modeling activities are ongoing. Site subsurface access is restricted.	Subsurface restrictions and institutional controls are in place and maintained. The subsurface risk-based compliance boundary will be refined based on subsurface modeling results. A refined long-term monitoring program will be implemented, if required and if technically feasible.	Currently, there is no feasible or cost effective corrective action technology to address test cavities and associated subsurface contamination that will prevent risk.	Subsurface restrictions and institutional controls will be maintained and long-term hydrologic monitoring will be implemented, based on the groundwater and natural gas modeling results.
Surface soil	TPH-contaminated material from the mud pits has been excavated and removed.	None	The site surface is in its end state. The site surface has been closed with regulatory agency approval.	None	None	Surface institutional controls are no longer required.

Figure 4.0 - Rulison Site Conceptual Site Model - Current State and End State



4.1 Surface Source Area 1

The Rulison Site sampling identified TPH, benzene, ethyl benzene, toluene, total xylenes, barium, chromium, and lead in the residual drilling mud left in the bottom of the containment pond. Contaminated mud, pond sediment, and soil from a location adjacent to the pond were excavated and removed to an off-site landfill. Subsequent sampling revealed no further contaminated soil in or around the pond. Closure of the pond and investigation of the SGZ area were completed in 1995 (DOE/NV, 1996). Seven groundwater-monitoring wells were installed to monitor the potential migration of contaminants from the pond into the shallow groundwater. These monitoring wells were abandoned in 2001.

The EPA monitors water quality in wells and springs in the vicinity of the Rulison Site on an annual basis. No radioactive contamination associated with the Rulison test has been detected in samples taken from the Grand Valley municipal drinking water system, water supply wells from five local ranches, and a spring and three wells on the test site (EPA, 2002).

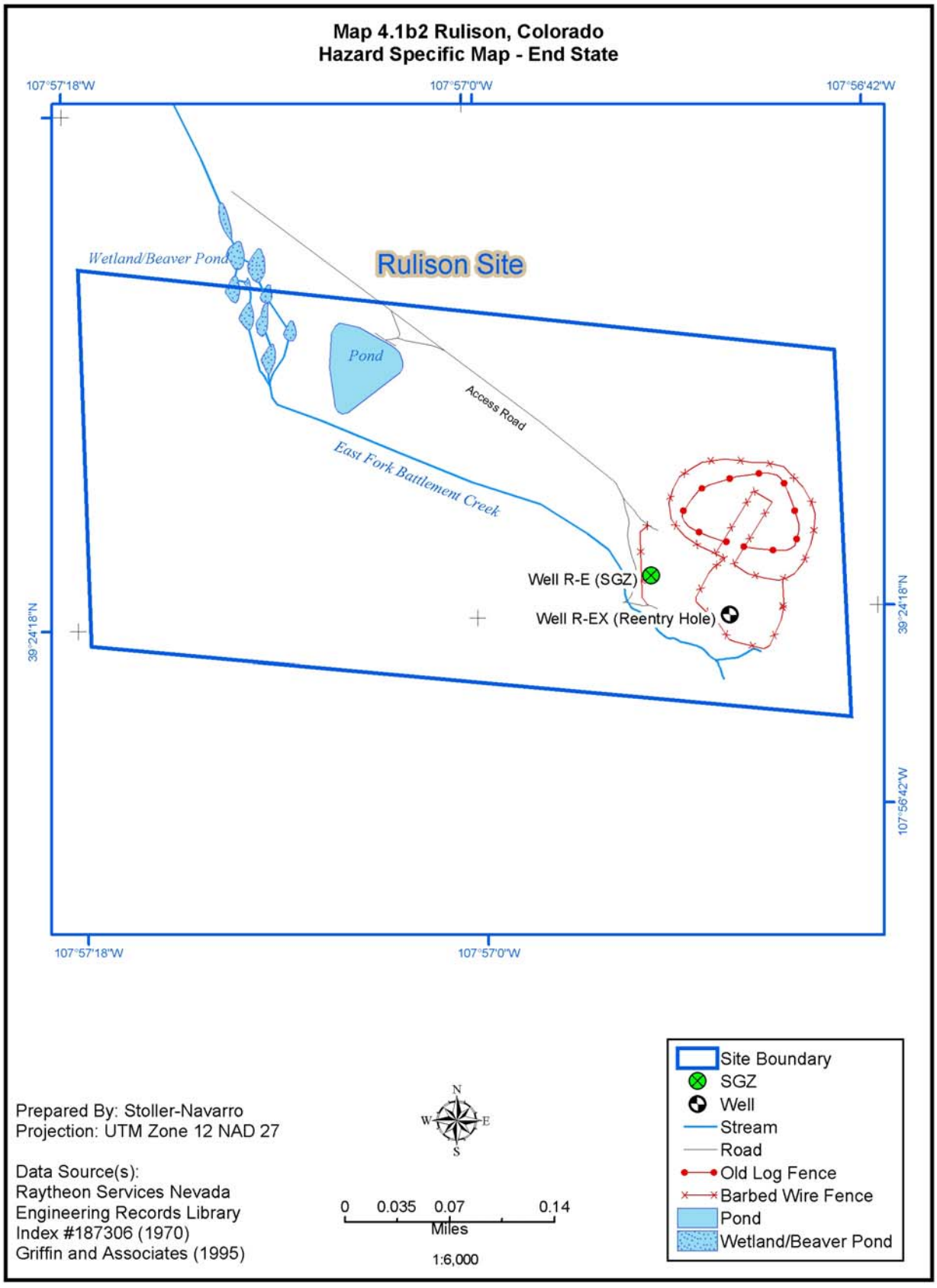
4.2 Subsurface Source Area 1

The Rulison Site contains a plugged emplacement hole and a plugged re-entry test hole. The nuclear device was placed in low permeability sandstone at a depth of 8,426 ft bgs. Emplacement was accomplished by drilling a vertical hole to a depth of 8,426 ft, lowering the device down hole, and plugging the hole to the surface. The test created an underground cavity that immediately collapsed to form a breccia-filled chimney, but this chimney did not reach the surface. The pre-test exploration hole was re-drilled into the test cavity for gas production tests. During subsurface nuclear testing, a number of fission by-products and other materials were released into the area immediately adjacent to the point of detonation. The radioactive by-products generated include original radioactive material that did not undergo fission, fission products, and activation products produced by the high neutron flux. Other materials that may have been released include lead from shielding material, synthetic materials used in control cables, and materials used in the emplacement borehole.

Clean-up associated with subsurface contamination included removing all equipment and materials and plugging and abandoning the emplacement and reentry wells (Map 4.1b2). The DOE/NSO does not plan to remediate the subsurface contamination because of the lack of feasible technologies for removing radioactive contamination from subsurface cavities formed by

underground nuclear tests. Water samples collected from municipal water supplies, local ranches, and springs and wells located on the test site indicate that no radionuclides attributable to the Rulison test have migrated into drinking water supplies (EPA, 2002).

Subsurface characterization at the Rulison Site will begin in FY 2005. Based on the historic use of the site and characterization conducted at similar sites, COCs for the subsurface are expected to include plutonium, tritium, and mixed fission products, with gaseous radionuclides (tritium, carbon-14, and krypton-85) being the most mobile in the environment. At the present time, the hazard extent has not been defined; however, the DOE/NSO will continue to investigate and model subsurface contamination (DOE/EM, 2001). According to the Life-Cycle Baseline Revision 5, subsurface closure of the Rulison Site is scheduled for completion in FY 2011.


Map 4.1b2 Rulison, Colorado
Hazard Specific Map - End State
107°57'18"W
107°57'0"W
107°56'42"W
39°24'18"N
Wetland/Beaver Pond
Rulison Site
Pond
Access Road
East Fork Battlement Creek
Well R-E (SGZ)
Well R-EX (Reentry Hole)
Site Boundary
SGZ
Well
Stream
Road
Old Log Fence
Barbed Wire Fence
Pond
Wetland/Beaver Pond
Prepared By: Stoller-Navarro
Projection: UTM Zone 12 NAD 27
Data Source(s):
Raytheon Services Nevada
Engineering Records Library
Index #187306 (1970)
Griffin and Associates (1995)
N
W
E
S
0 0.035 0.07 0.14
Miles
1:6,000

5.0 References

AEC, see U.S. Atomic Energy Commission.

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DOE/EM, see U.S. Department of Energy, Office of Environmental Management.

DOE/NV, see U.S. Department of Energy, Nevada Operations Office.

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Attachment A – Discussion of Variances

The following variance report table is provided in accordance with Appendix D of the Environmental Management End State Vision Development Guidance dated September 11, 2003. The table below does not identify any variances, but does provide information clarifying why there are no perceived differences between the various plans and agreements governing activities at the site. There are no negative impacts in terms of scope, cost, schedule, and risk, and no known barriers to achieving the end state. Based on the above noted belief, the next steps are identified for future activities associated with the Rulison Site. There are no maps provided, as there are no differences between the end state based on the current requirements and the end state based on the end state vision. The maps within the main body of the end state document sufficiently identify pertinent information related to the Rulison Site.

Rulison Site Variance Report				
ID No.	**Description of Variances**	**Impacts (in Terms of Scope, Cost, Schedule and Risk)**	**Barriers in Achieving the End State**	**Recommendations**
N/A	There are no known variances between the end state, the current Offsites baseline, the DOE/NSO Performance Management Plan, and/or regulatory agreements.	Clean-up decisions made for the Rulison Site are consistent with planned future use as residential, privately owned land. The State of Colorado and the private landowner have agreed to the clean closure of the surface, and understand issues associated with the residual contamination in the subsurface. The State and the private owner have not expressed opposition to future subsurface characterization activities and have not proposed alternative plans.	None at this time.	Support completion of future subsurface plans and documents and prepare the necessary long-term stewardship information for transfer of the management responsibility of the site subsurface to the Office of Legacy Management.