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Final Land Configuration for the Rocky Flats Environmental Technology Site

R. L. Stegen, J. M. Kapinos, J. P. Wehner, B. Snyder
Parsons
1700 Broadway, Suite 900, Denver, Colorado 80290
United States

R. W. Davis
Kaiser-Hill Company, LLC
9193 S. Jamaica, Englewood, Colorado 80112
United States

ABSTRACT

Closure of the Rocky Flats Environmental Technology Site (RFETS) has been completed. The future land use of the site is designated as a National Wildlife Refuge. A joint effort between Kaiser-Hill, Department of Energy, U.S. Fish and Wildlife Service, Environmental Protection Agency, State of Colorado, and other stakeholders was initiated to provide direction for developing the final land configuration. Through early identification of issues and developing mutually agreeable solutions, the final land configuration of the site was successfully completed.

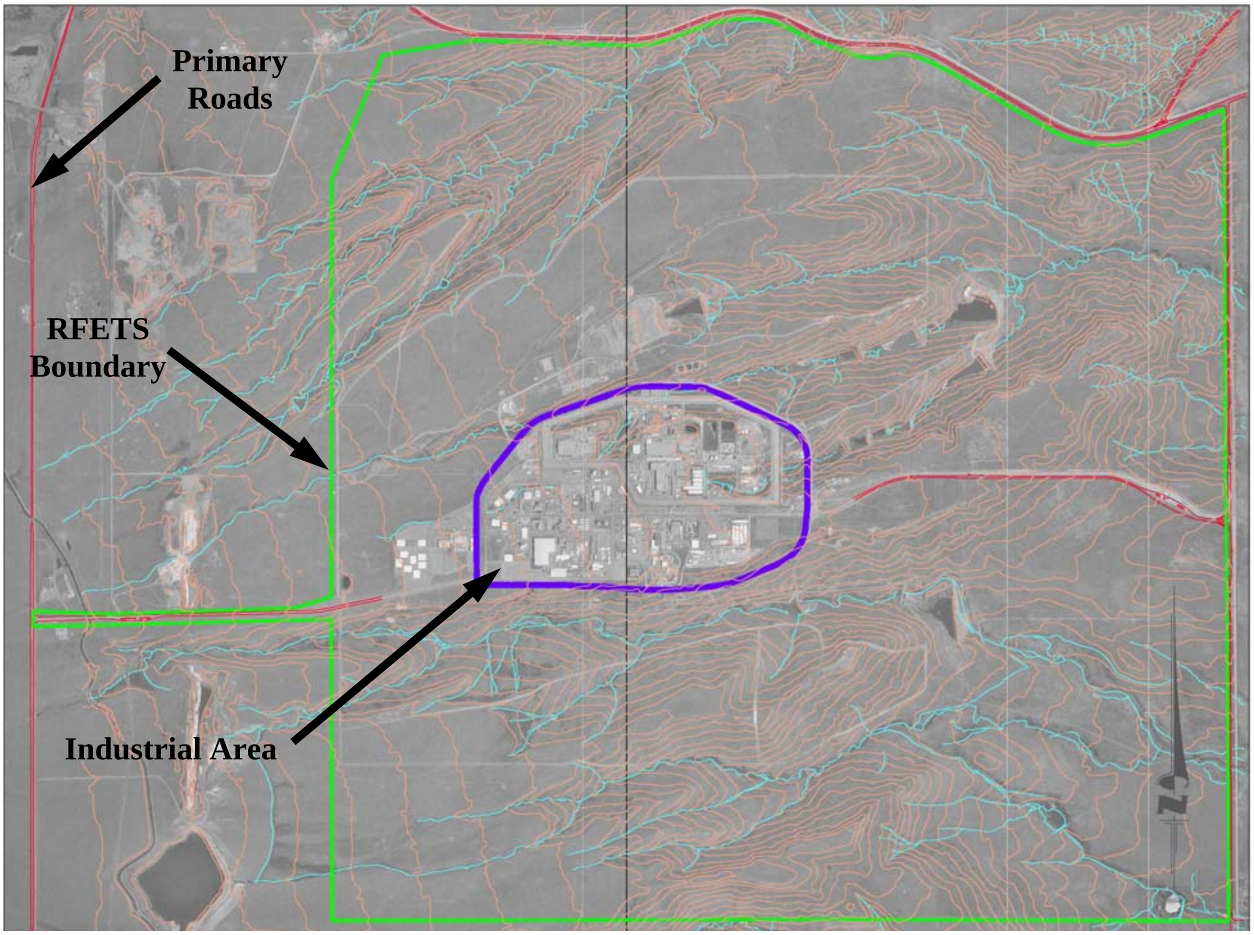
INTRODUCTION

From 1952 until 1989, uranium and plutonium triggers and other nuclear weapon components were manufactured at the RFETS located northwest of Denver, Colorado. Figure 1 provides a map showing the basic site features. The majority of the buildings and structures were located within a centralized Industrial Area that is approximately 162 hectares (400 acres). The Industrial Area is surrounded by a sparsely developed 2470-hectare (6,100acre) Buffer Zone. The Industrial Area was constructed on a relatively flat pediment that is notched by Walnut Creek to the north and Woman Creek to the south. The hillslopes between the Industrial Area and the creek channels range from 15 to 45 meters (50 to 150 feet) in height with a typical slope between 8 and 15 percent.

FINAL LAND USE

Many portions of the Buffer Zone have remained relatively undisturbed for the past 30 years, allowing a diverse natural habitat and associated wildlife to exist. The Buffer Zone contains a healthy expanse of grasslands, shrublands, and jurisdictional wetlands. The site vegetation includes a rare xeric tallgrass prairie community, which is believed to exist in fewer than 20 places globally. The largest remaining xeric tallgrass community in Colorado and perhaps North America is present at the site. The site provides suitable habitats for several high-interest resources including the Preble's meadow jumping mouse, a federally threatened species.

Federal Legislation was enacted in 2001 to designate the RFETS as a National Wildlife Refuge [1]. After certification of closure activities by the U.S. Environmental Protection Agency, the site will be transferred to the U.S. Fish and Wildlife Service for future management and preservation. Access to portions of the site subject to on-going environmental actions (e.g., passive groundwater collection and treatment systems) and institutional controls will be restricted. The Department of Energy (DOE) will retain primary jurisdiction over these areas for operation and maintenance, long-term stewardship, and monitoring.



Source: Photograph and topographical map from 1994. Contour interval: 20 feet.

Fig. 1. Site map for the Rocky Flats Environmental Technology Site

FINAL LAND CONFIGURATION

In October 2005, the Kaiser-Hill Company, LLC completed closure activities at the site. These closure activities included:

- Removing, stabilizing, and shipping special nuclear material;
- Decommissioning, dismantling, decontaminating, and demolishing building and structures;
- Remediating environmental concerns; and
- Constructing the final land configuration.

Planning the final land configuration for RFETS began in 2000 with the establishment of the Land Configuration Design Basis Project. The focus of this project was to develop the final topography for the 400-acre Industrial Area where the majority of the closure activities occurred. The project was a joint effort between Kaiser-Hill, Department of Energy, U.S. Fish and Wildlife Service, Environmental Protection Agency, State of Colorado, and other stakeholders. Parsons provided engineering services for the development and implementation of the final land configuration project. During the initial scoping tasks, it was concluded that returning the Industrial Area to pre-RFETS site development was not cost-effective, was not consistent with site closure, would not ensure long-term stability, and would be overly disruptive to existing sensitive ecological areas. The following design objectives were established for the post-closure configuration.

- Support environmental restoration actions by ensuring that the final configuration would not adversely impact post-closure hydrology and hydrogeology.
- Provide long-term terrain and drainage channel stability by developing engineered channels for controlling storm water runoff.
- Facilitate site closure including building decommissioning and demolition while minimizing earthwork.
- Provide a post-closure setting compatible with national wildlife refuge uses.
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Environmental Restoration

Historical operations at RFETS resulted in the incidental dispersion of compounds into the environment. The principal compounds include plutonium, americium, uranium, volatile organic compounds (VOCs), and nitrate. Site-specific studies and published literature indicate that plutonium and americium are insoluble and strongly associated with soil particles [2]. Uranium, VOCs, and nitrate are detected in groundwater and have the potential to affect surface water via seeps and springs. Source materials and contaminated soil were removed and passive groundwater collection and treatment systems were installed as remedial actions to protect public health and the environment. During the development of the final land configuration, the post-closure hydraulic characteristics were evaluated to verify that the final grading and removal of impervious surfaces would not adversely impact the operation of ongoing remedial measures and would minimize soil erosion.

Long-Term Terrain Stability

A qualitative and semi-quantitative geomorphic evaluation was conducted to identify the dominant geomorphic processes at RFETS. The evaluation included literature reviews, historical aerial photograph comparison, predictive modeling, and site reconnaissance. This information was used to estimate the rates at which landform changes are occurring and identify provisions to ensure the long-term stability of the final land configuration.

The RFETS is located in the eastern Colorado Piedmont, which is an old erosional surface along the edge of the Front Range and is characterized by a dissected topography. The western half of the site is located on a relatively flat bench that gently slopes from west to east at approximately 2.5 percent and is capped with gravel from the Rocky Flats Alluvium. The surficial deposits of the Rocky Flats Alluvium located in the western portion of the site are characterized by clayey and sandy gravels up to 30 meters (100 feet) thick. Evaluation of the soil morphology indicates that the surface of the pediment has been stable for more than 1.3 million years. [3, 4, 5, 6]

The pediment is incised by several finger-like drainages that slope down to the rolling plains in the eastern portion of the site. Surficial deposits in the eastern portion of the site consist of colluvium that is 1 to 5 meter (3 to 15 feet) thick and terrace alluvium that is 3 to 6 meters (10 to 20 feet) thick. Incision of drainage channels result in topographical relief from 15 to 45 meters (50 to 150 feet) in the valleys along the eastern portions of the site. The valleys have been stripped (partially or completely) of the gravel capping to expose the underlying claystone bedrock of the Cretaceous Laramie and Arapahoe Formations. [3, 4, 7, 8, 9]

The hillsides slowly become steeper due to channel incision and headword advance. The resulting slopes between the flat pediment and drainage channels typically range between 8 and 15 percent. Mass movement (earthflows, slumps, and landslides) occur along the hillside to relieve stresses that build-up over time. Figure 2 shows an example location at RFETS where numerous old and recent landslides along the drainage valleys have occurred.

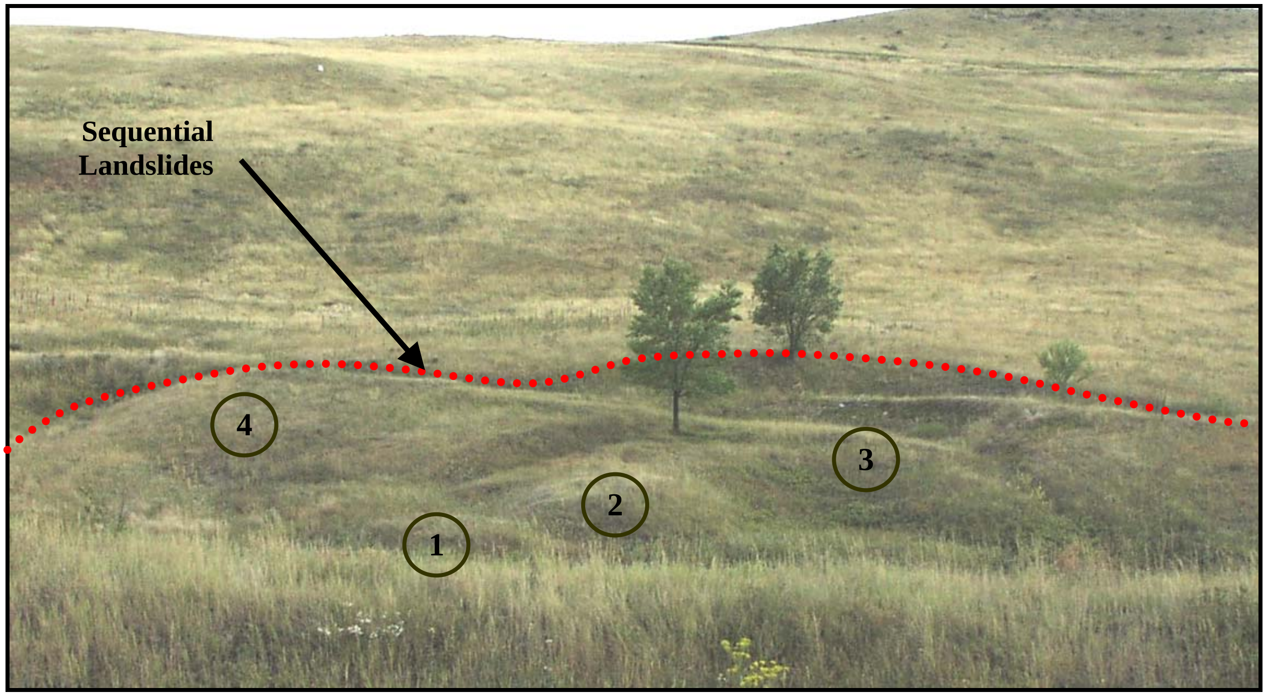

Fig. 2. Photograph of sequential landslide activity located below Buffer Zone road Looking south across Woman Creek west of Pond C-2 (18 September 2001).

The mass movements probably commenced about the middle Pleistocene (more than 150,000 years ago), shortly after the slopes were initially exposed [5, 10]. Most of the landslides are relatively young and shallow, on the order of 10 to 15 feet deep, with crescentic head scarps and lobate toes [6, 11]. The mass movement rate slows down as the landform progresses toward a stable slope angle and eventually stops moving when equilibrium is attained. This process causes a gradual widening of the stream valley. Factors that contribute to mass movements at RFETS include:

- Groundwater flow at the interface between the Rocky Flats Alluvium and bedrock (as evidenced by the seeps along the contact) causes an increase in soil pore pressure, reduces soil strength, and acts as a slip plane with the underlying claystone. The formations also typically contain expansive clays which tend to weaken the resistant forces between the bedrock and alluvium as their moisture content increases. [10]
- Slumps and landslides typically develop where the hillslope is greater than 12 percent.
- Slope stability is compromised in locations where the stream flow undercuts the toe of the slope.
- Soil saturated with infiltration or runoff are more likely to fail because of increases in soil mass.

Spatial analytical techniques were used to identify landscape changes between aerial photographs from 1937, 1951, and 1994. The 1937 and 1951 photographs were digitally scanned as gray-scale images and co-registered to 1994 digital image by aligning discernable geographic features common to each set of images. The total root mean squared error for the horizontal points used to co-register the three images was less than 1.5 foot. The images show that the landforms at RFETS have noticeably changed due to natural occurrence of mass movement and stream meander shifts over the 57 year period evaluated. Figure 3 shows fluvial development (stream meander, incision and bank instability) within the RFETS Buffer Zone.

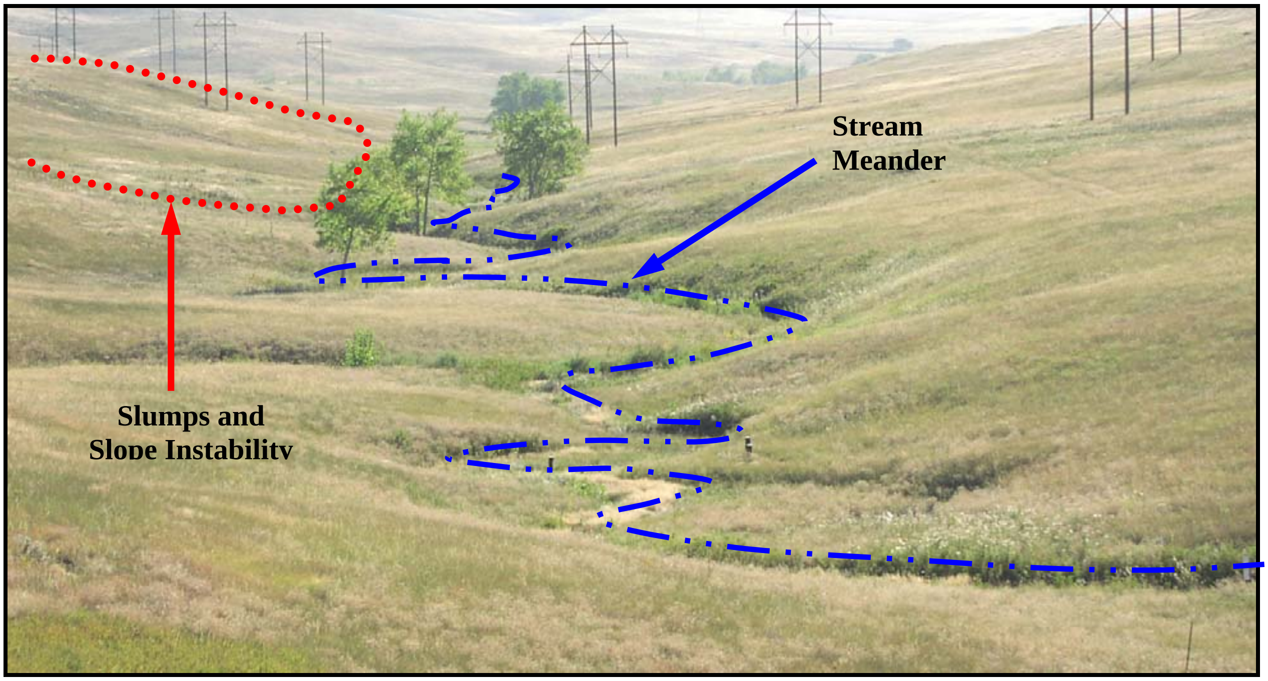

Fig. 3. Photograph of stream meander and slope instability
Looking east along No Name Gulch east of Present Landfill Pond (6 September 2001).

Surface soil erosion and deposition at RFETS was evaluated using the Water Erosion Prediction Project (WEPP) continuous simulation computer model. The WEPP results indicate that a single storm event with at least 0.7 inches of precipitation is needed to produce enough runoff to generate a significant loss of sediment from vegetated hill slopes. Based on storm frequencies over a 100-year period, the predicted average erosion rate is roughly 0.001 to 0.002 inches per year on a site-wide basis [12]. However, landslides and slumps that result in gully formation can cause significant localized soil erosion.

The conceptual model for the landforms at RFETS is based on long-term stability of the bench surfaces (pediments) and instability along the hillsides and in the valleys. The most significant geomorphic process occurring at RFETS is slope movement. The engineered design for the final land configuration was developed to obtain dynamic equilibrium (balance between the driving and resistive forces) where the geomorphic processes are significantly slowed. One of the most significant contributors to mass movement is grade slope. Where regrading of slopes was required, a maximum grade of 8H : 1V was used as the design basis. The maximum design grade (12.5 percent) provides a slope that is less susceptible to mass movement. Grading plans were also developed to promote controlled sheet flow down the hillsides to minimize concentration of surface water.

Long-Term Drainage Channel Stability

To provide a setting consistent with future land use and reduce long-term maintenance, it was decided that storm water culverts and other drainage structures should be removed. The native drainage system was extensively modified to construct the Industrial Area. Simple removal of the culverts and structures would create channels with high flow velocities and erosive characteristics. This accelerated erosion could destabilize adjacent hillsides after closure. As such, six engineered drainage channels were constructed as part of the final land configuration. The design of the engineering channels was primarily based on the criteria specified in *Urban Drainage and Flood Control District's Urban Storm Drainage Criteria Manual* [13, 14].

The open channels were designed with adequate flow capacity, armoring, and bank stabilization to retard stream incision, limit headward advance and resist erosive forces. Peak flows for each drainage channel were calculated using the rational method and the U.S. Army Corps of Engineer's HEC-RAS program was used to model channel hydraulics. A 100-year storm event with a minimum 1-foot freeboard allowance was used as the basis of design. The flow velocity was calculated based of the channel slope and sectional dimensions. The design of the channel was adjusted to prevent occurrence of critical erosive velocities based on channel soil type. The channel bends were designed with long radius curves and super elevation of the outside bank to preclude undercutting and overtopping. When required, the super elevated banks were armored with rip-rap.

Grass lining was used for sections of the drainage channels where the velocity was less than 1.5 meters per second (5 feet per second) which is less than the minimum flow velocity required to cause erosion of the RFETS. Grass-lined channels were typically located on the pediment where the slope is gentle (0.2 to 0.6%). Riprap-lined channels were specified when the calculated velocity was greater than 1.5 meters per second (5 feet per second). Rip-rap lined channels were typically required along the hill slopes between the pediment and valley. Natural-looking rip-rap materials were selected. Smaller sized rip-rap (typically less than 12 inches) was mixed with soil, covered with an additional 15 centimeters (6 inches) of soil and vegetated to blend in with the surrounding landscape. The soil filled rip-rap also provides a more conducive habitat for the Preble's meadow jumping mouse (Preble's mouse), a threatened species that lives along the drainage channels at RFETS.

Building Demolition

The Industrial Area was primarily constructed on the flat portions of the pediment. However, the native soil materials have been extensively altered with the substantial quantity of fill material that was imported into the area for foundations and other uses. Many production facilities were constructed with large underground areas resulting in excess material that was used as fill soil in other portions of the site.

Non-contaminated structures were allowed to remain after closure provided that a minimum depth of earthen soil was placed over the structure. Demolition and grading plans were developed for major building structures to identify the specific elevations to which subsurface component removal was required. Grading plans were developed to promote sheet flow and to direct runoff to the engineered channels. Positive drainage was also provided to minimize subsurface infiltration into the areas where the major production facilities were located. Temporary erosion control measures were erected to minimize entry of sediment into the surface water. Disturbed areas were stabilized and re-vegetated with native short- and mid-grass plant communities, which are becoming increasingly rare along the Front Range.

Cut and fill volumes were calculated based on the initial 1994 baseline topography and the proposed final grading. The topography comparison was performed using AutoCAD® Land Development Desktop Software. Hand calculations were also performed to determine the amount of soil required to fill subsurface building features and to provide replacement soils for foundation components that were required to be removed. An on-site excavation borrow area was established and designed to provide the fill soil required to close the Industrial Area buildings.

Support National Wildlife Refuge

Increasing growth and development in Colorado has reduced the amount of open space and vistas with a striking Front Range mountain backdrop. The Rocky Flats National Wildlife Refuge will provide habitat for many wildlife species, including a number of threatened and endangered species. The site contains rare xeric tall grass prairie plant communities and provides habitat for the threatened Preble's meadow jumping mouse. These high-value resource areas are associated with the valleys, springs, drainage channels and riparian corridors that are typically found within the Buffer Zone. Provisions to minimize ecological disturbance and enhance these habitats were factored into the final land configuration.

Two new, self-sustaining wetland areas were designed and constructed as part of the engineered drainage channels. The wetlands are located on upland terraces and provide approximately 2.5 acres of willow shrub and wet meadow complexes. The wetlands were developed to serve three primary functions: (1) provide replacement habitat for the Preble's meadow jumping mouse, (2) provide quality riparian and wetland habitat for other high-interest wildlife species in the refuge, and (3) filter suspended sediments from normal stream flow and storm water runoff.

CONCLUSION

The selected approach to the final land configuration included developing engineered channels for controlling storm water runoff, minimizing earthwork, constructing wetland areas to enhance ecological habitats, blending restored areas into the natural land formations, using native plants for re-vegetation, and ensuring that the final configuration would not adversely impact post-closure hydrology and hydrogeology. Through early identification of issues and developing engineering solutions with all stakeholders, the final land configuration of the site was successfully completed.

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