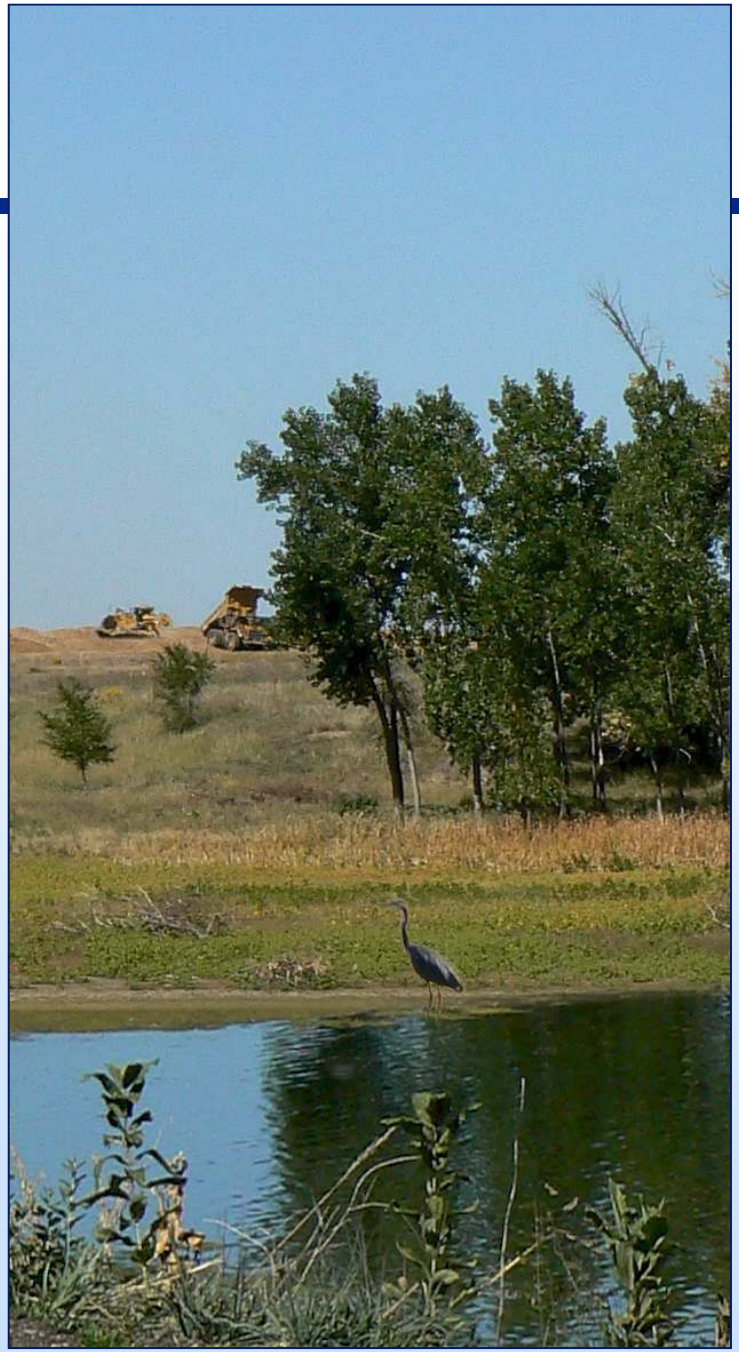


Give Me Refuge

Transforming the "most contaminated square mile on earth" into a premier urban wildlife refuge

Give Me Refuge

- Background of the Rocky Mountain Arsenal (RMA)
- Manufacturing and Disposal History
- Soil Remedy
- Operations and Maintenance
- Lessons Learned

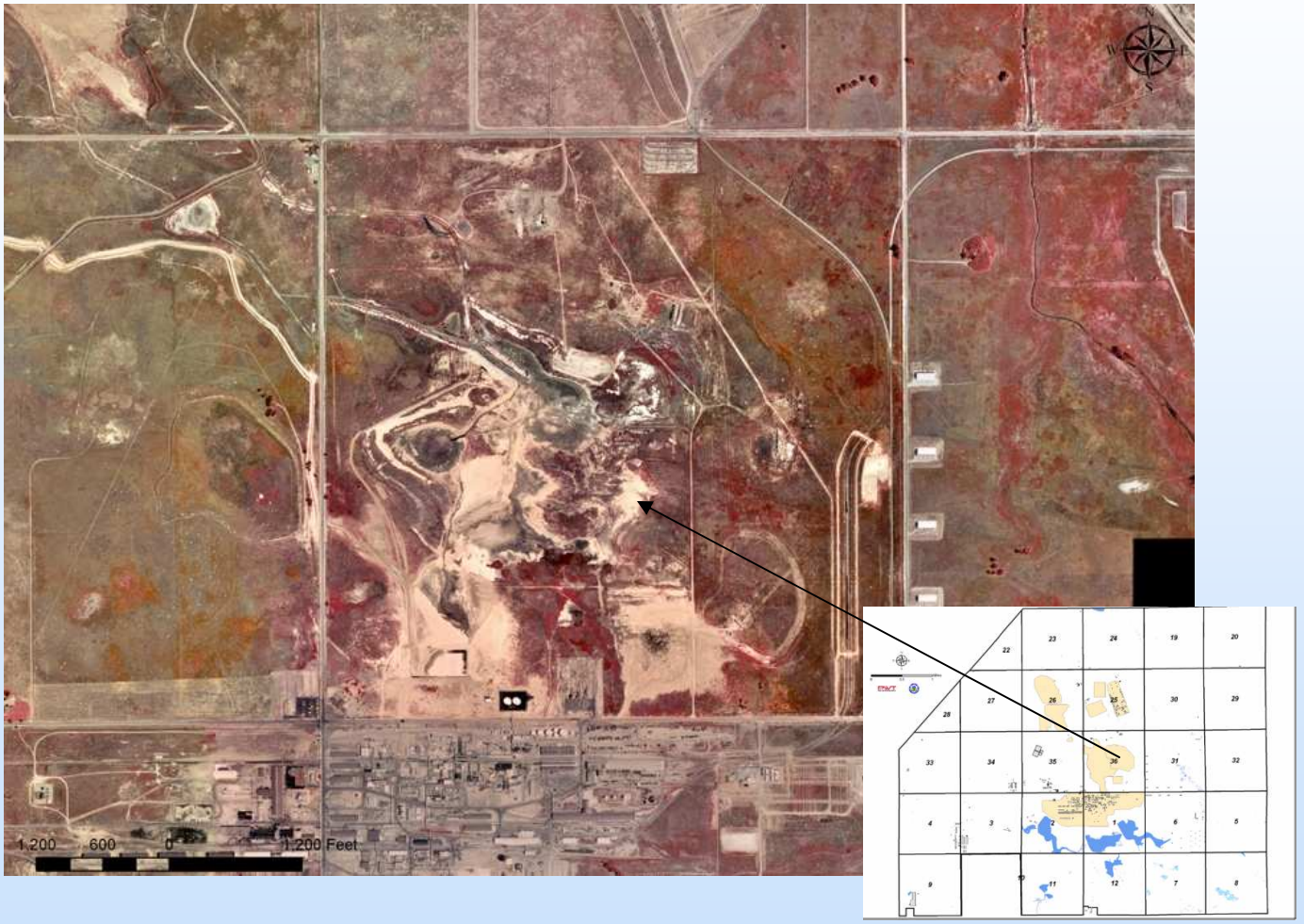
Give Me Refuge

Background:

- RMA location
- History, mission, & involved parties
- The CERCLA process

BACKGROUND

“The most contaminated square mile on earth”



Section 36 as it appeared in 1976 (U.S. Army aerial photograph)

BACKGROUND

Give Me Refuge

RMA is a nationwide clean-up success:

- **Winner of the 2007 Revitalization Award from EPA**

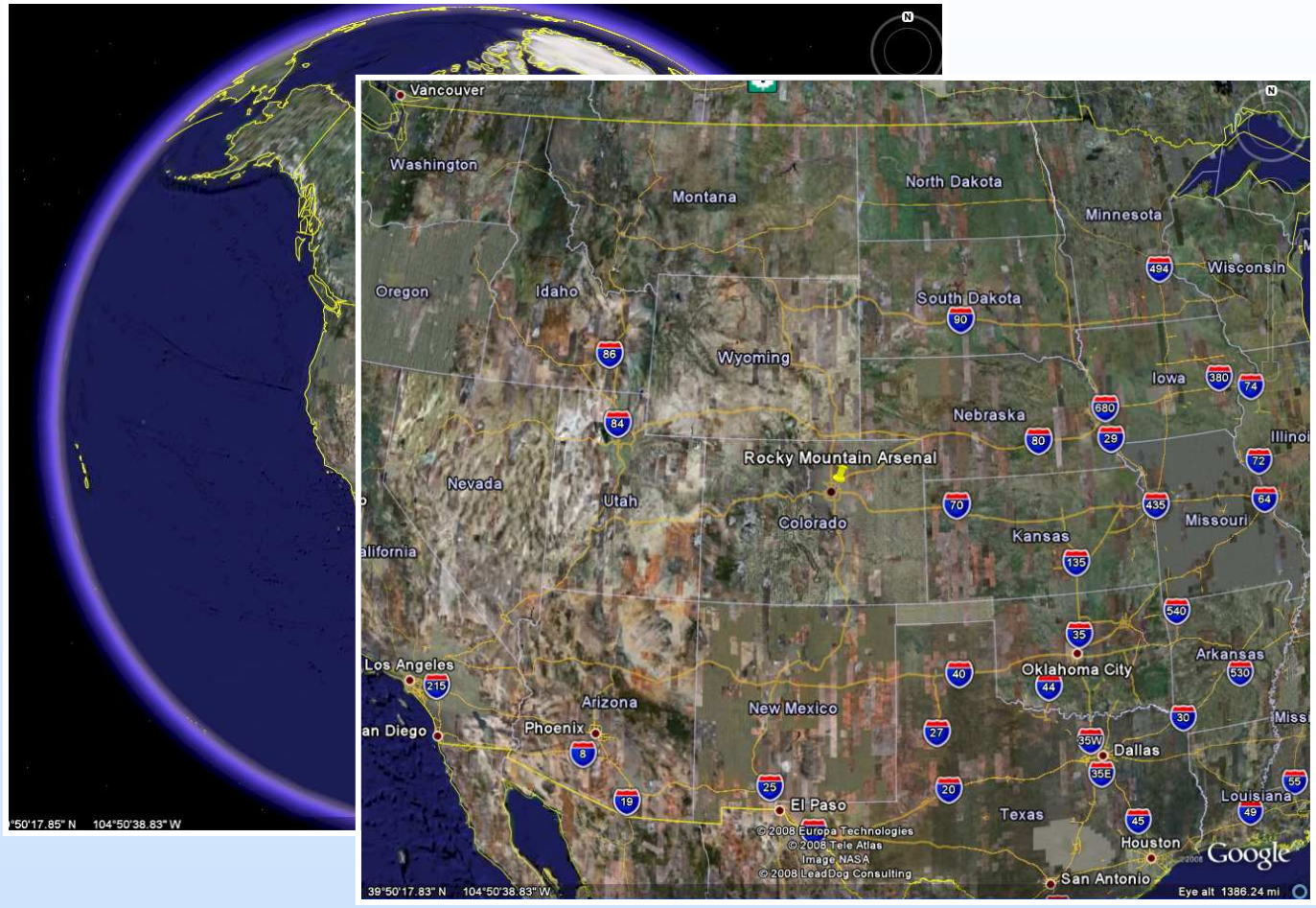
BACKGROUND

Give Me Refuge

Bison at the Rocky Mountain Arsenal.
Photograph by David Zalubowski

BACKGROUND

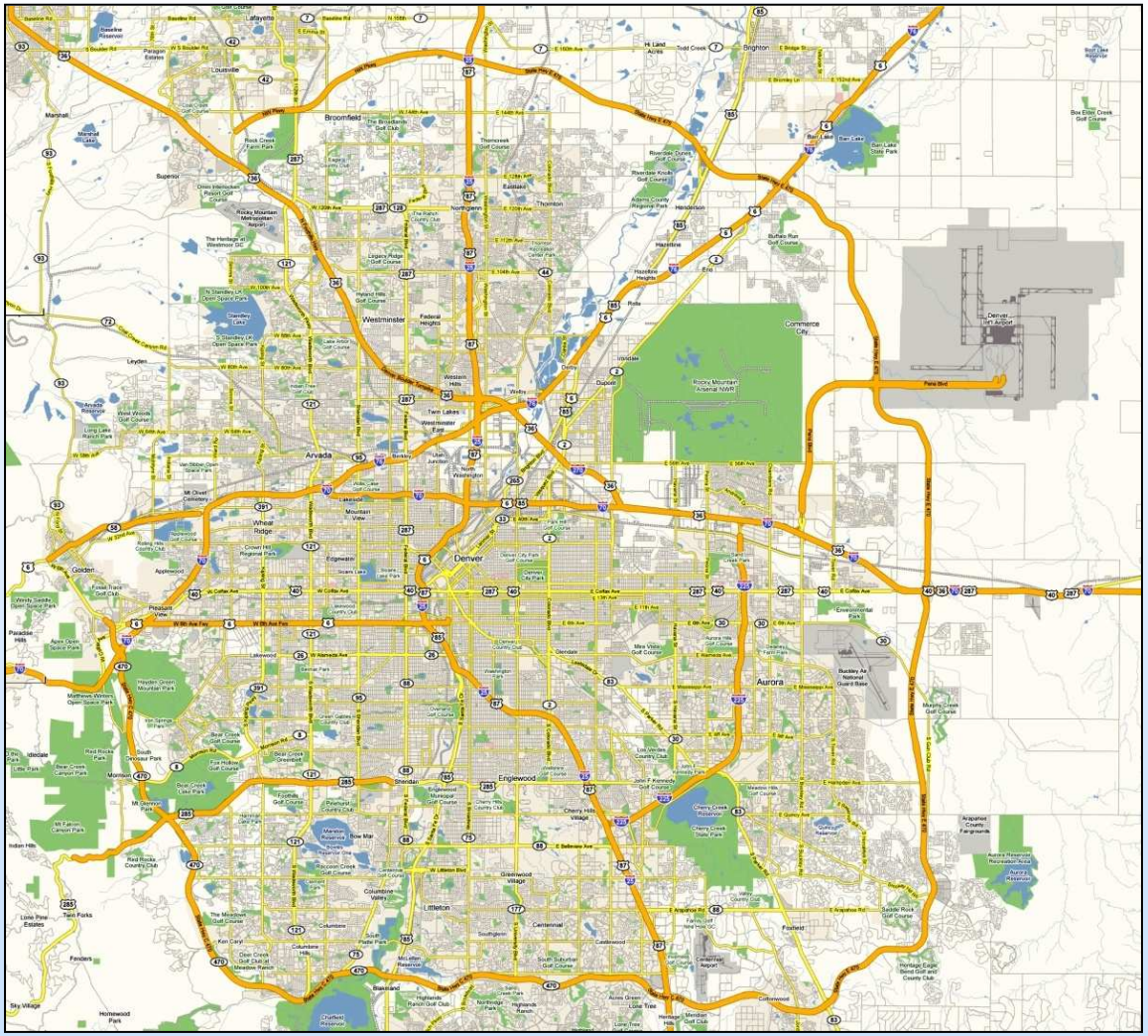
Location: Where in the world is RMA?



Locator maps courtesy of Google Earth

BACKGROUND

Location: The greater Denver area

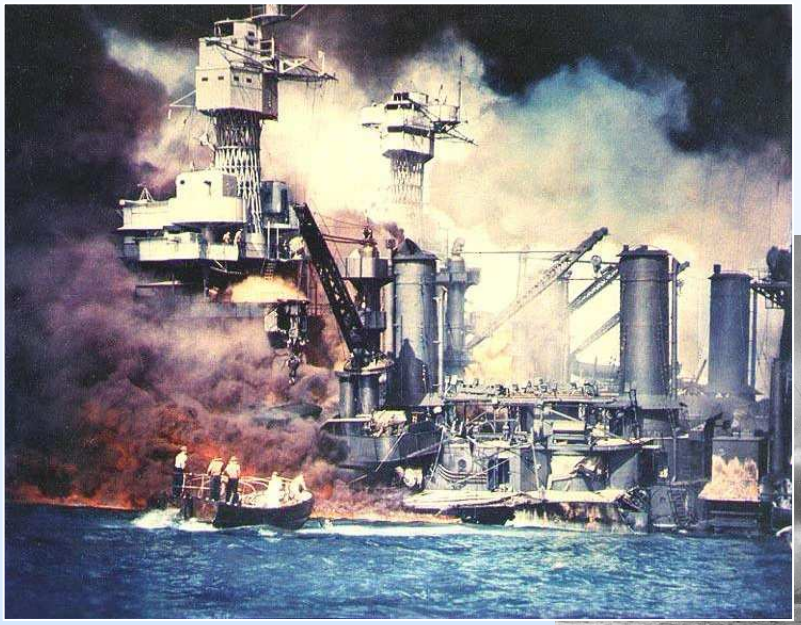


Locator map courtesy of Mapquest

RMA was originally about 27 square miles (69 km²)

History, mission, and involved parties

U.S. Army: World War II, Chemical Weapons Manufacturing at South Plants



USS West Virginia and USS California, Pearl Harbor, Hawaii, December 7, 1941
(Photographs from Wikipedia.com)

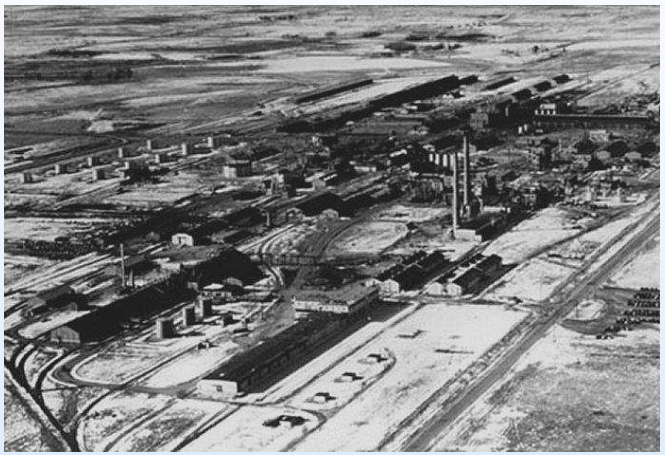
History, mission, and involved parties

US. Army: World War II, Chemical Weapons Manufacturing at South Plants

Construction of the first chemical weapons manufacturing facility at the Rocky Mountain Arsenal, 1942 (U.S. Army photograph)

History, mission, and involved parties

U.S. Army: World War II, Chemical Weapons Manufacturing at South Plants



Clockwise from top left: aerial photograph of South Plants in 1964 (globalsecurity.org photograph); weapons assembly (Denver Post photograph); deactivating fuses from cluster bombs (U.S. Army photograph); and workers assembling a napalm bomb in 1957 (U.S. Army photograph).

History, mission, and involved parties

Shell Chemical Corporation: pesticide manufacturing

South Plants (U.S. Army photograph)

History, mission, and involved parties

U.S. Fish and Wildlife Service: wildlife refuge

Clockwise from top left: Mule Deer (U.S. Army photograph), diverse waterfowl and coyote (EPA field oversight photographs).

History, mission, and involved parties

U.S. Fish and Wildlife Service: wildlife refuge

Bald eagles and many other animals live at RMA seasonally or year-round, or use it as a stopover on migration routes (EPA field oversight photograph)

Involved Parties at RMA

Three cleanup entities and three oversight agencies.

BACKGROUND

Involved Parties at RMA

The Success of the RMA Federal Facility Agreement (FFA)

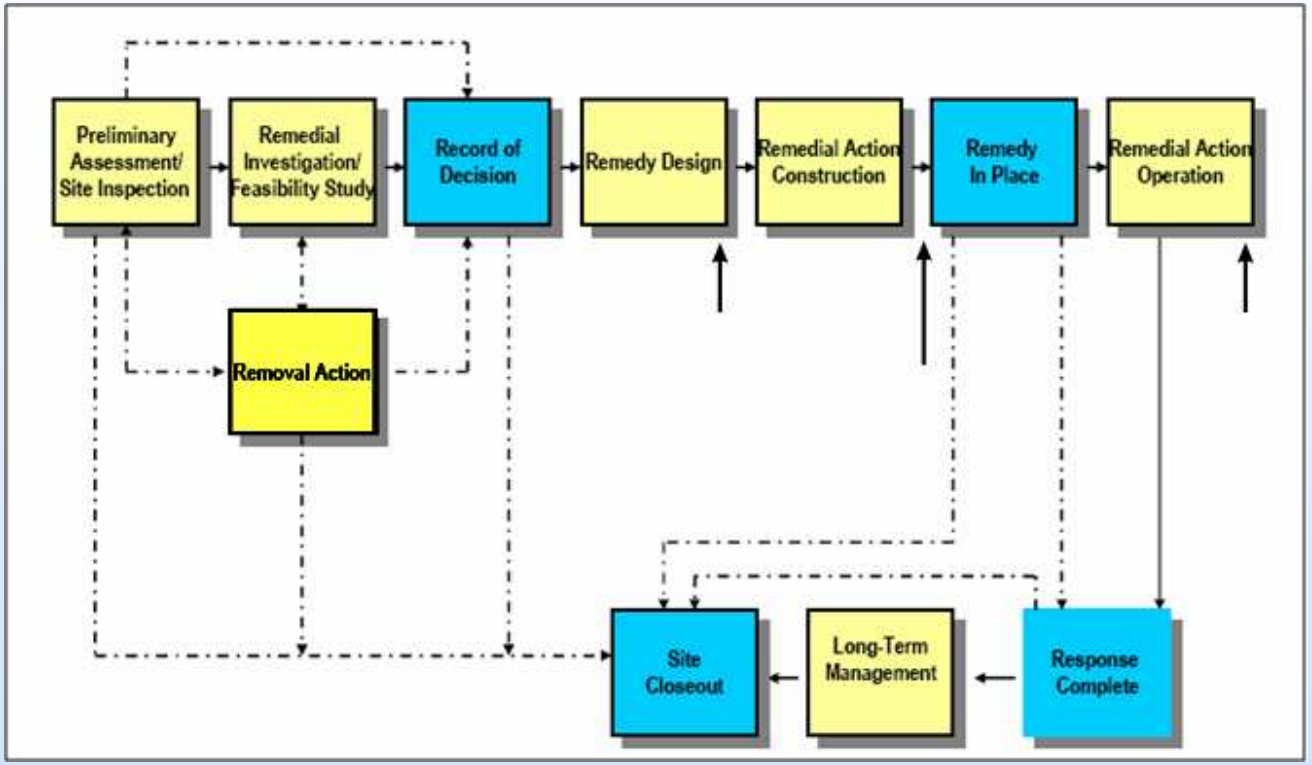
- The first multi-agency agreement with federal agencies in the country
- A template for other multi-agency agreements
- Specifies that EPA be reimbursed for oversight cost (there is only 1 other site in the US where this type of reimbursement takes place)

The FFA is unique

- Includes a private party (Shell)
- Proven to stand the test of time (almost 20 years to date)

The CERCLA process

Typical CERCLA process

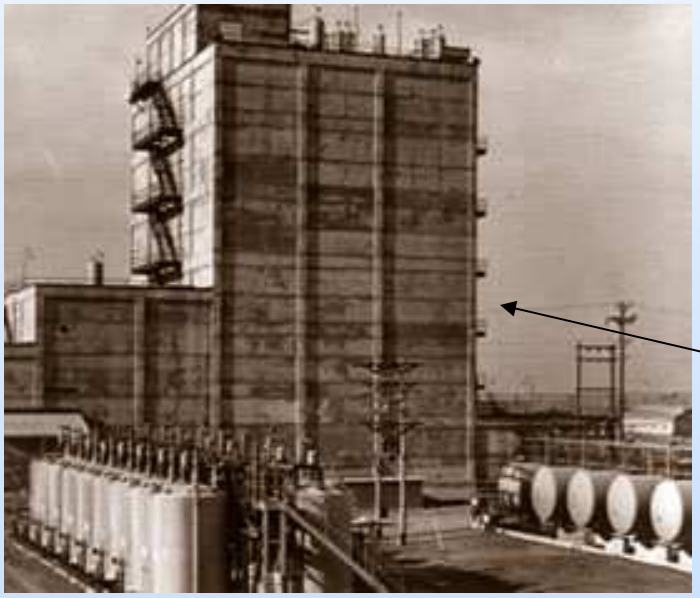


Manufacturing and Disposal History

Weapons production - 1940s and 1950s

U.S. Army: Korean Conflict, Chemical Weapons Manufacturing at North Plants

One ton containers of agent



North Plants (U.S. Army photographs)

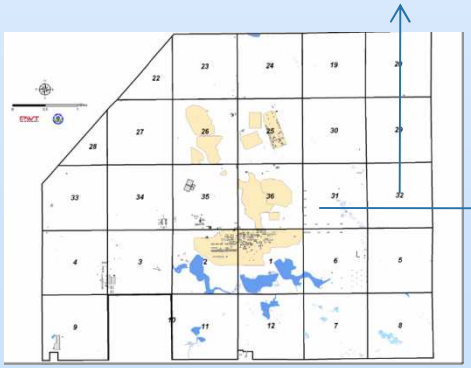
South Plants

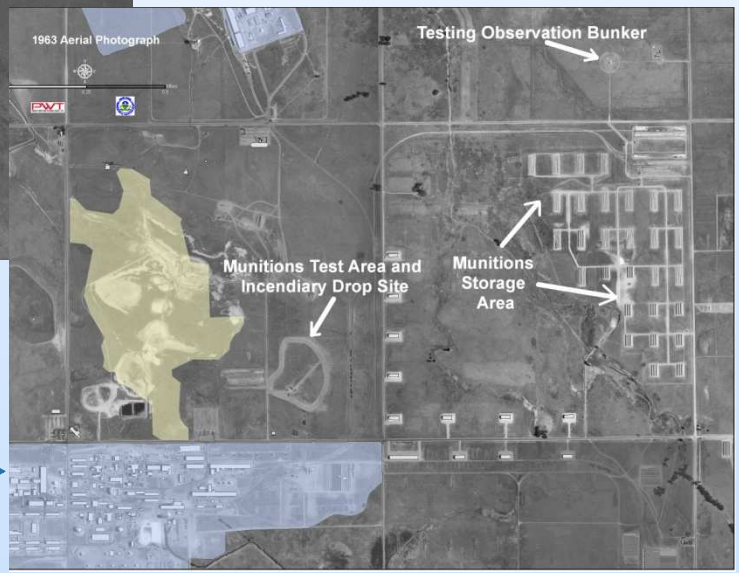
MANUFACTURING AND DISPOSAL HISTORY

Munitions storage, testing, and disposal

Burn pits

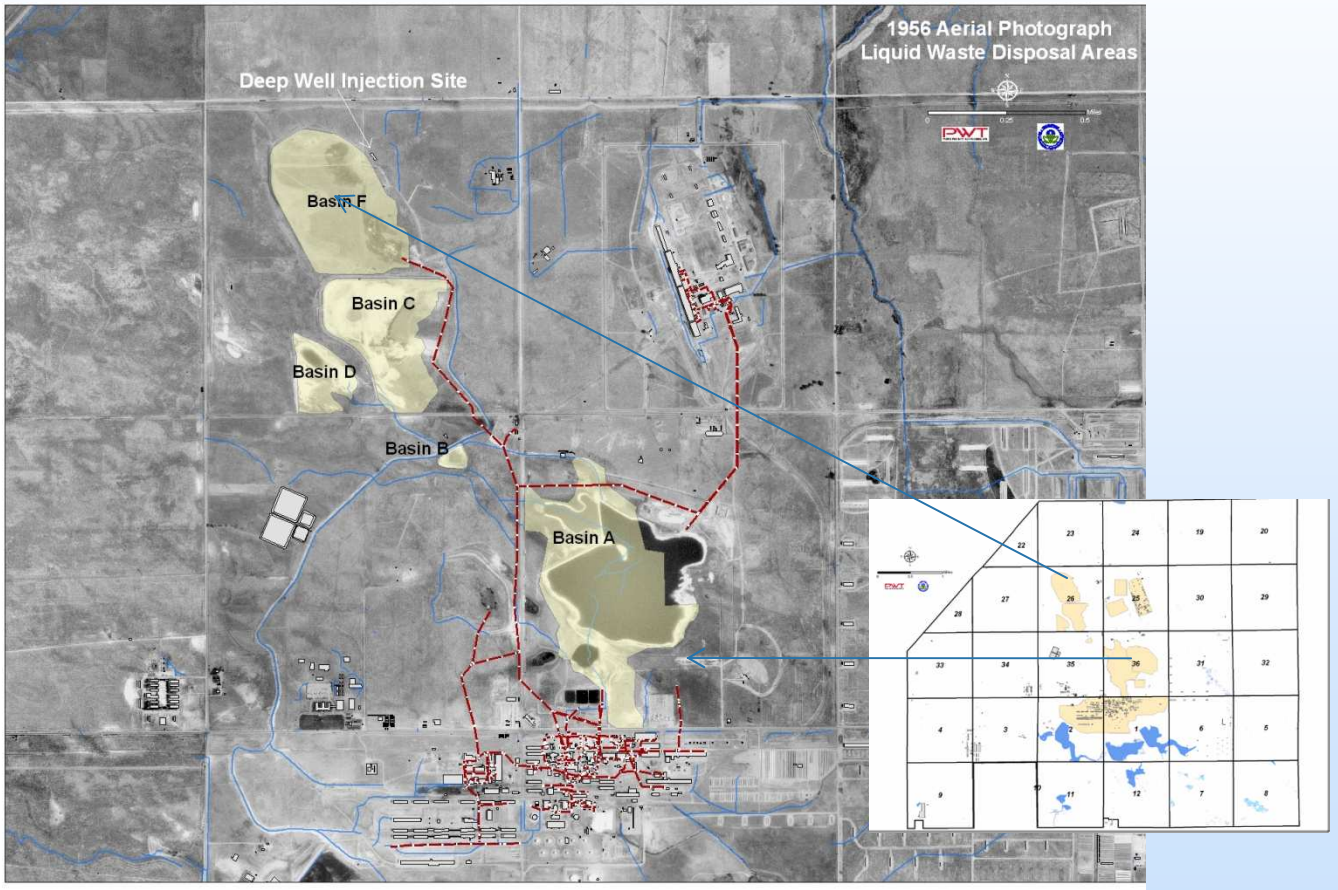
Active burn pit on the left and a recently used burn pit, center, in 1954 (left); munitions storage, testing, and disposal areas in 1963 (U.S. Army aerial photographs)





Liquid waste disposal

Disposal basins



Disposal basins for liquid waste in 1956

(U.S. Army aerial photograph, EPA/PWT map overlay)

Interim Response Actions

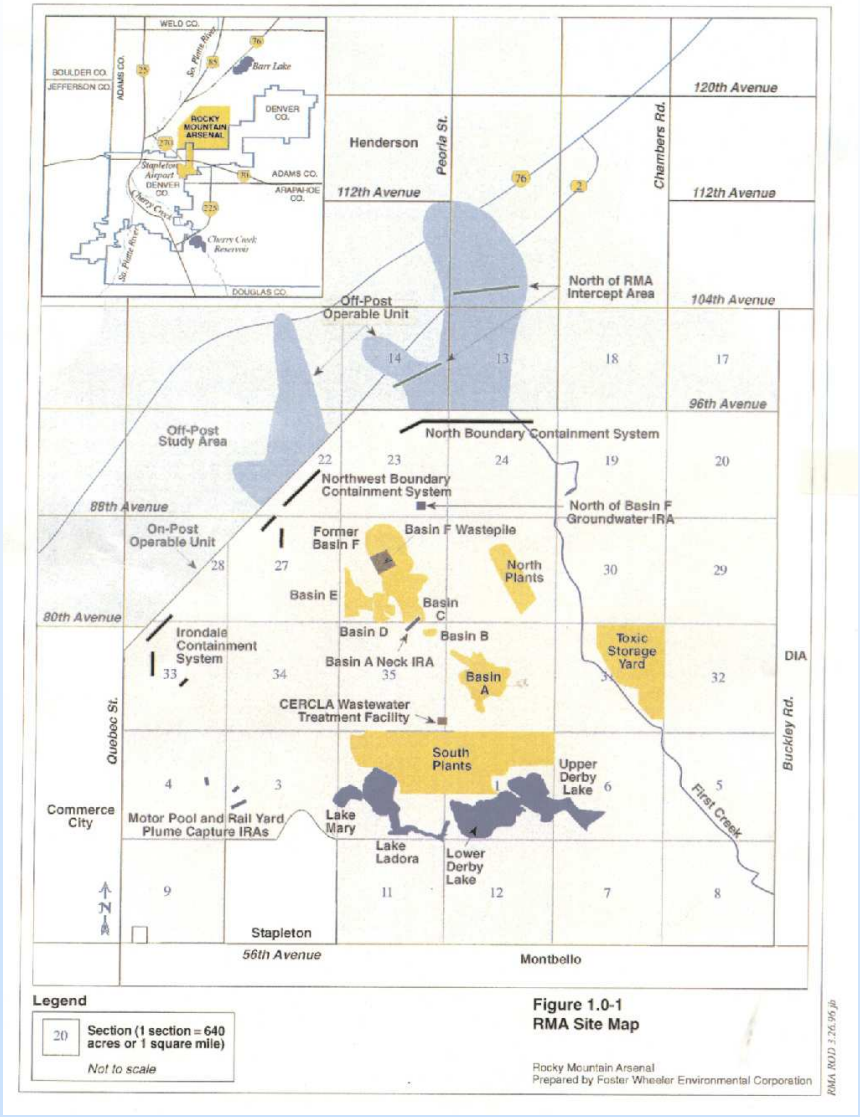
14 Interim Response Actions initiated in 1974

Asbestos abatement in South Plants (U.S. Army photograph)

MANUFACTURING AND DISPOSAL HISTORY

On-Post and Off-Post Records of Decision (RODs)

Site Map



Foster Wheeler Environmental Corp., 1996

Off-Post ROD

The Off-Post ROD addresses:

- Groundwater contamination north and northwest of RMA
- Continued operation and improvements to the IRA groundwater treatment systems
- Groundwater monitoring
- Tilling and revegetation of approximately 160 acres of land by the Army and Shell
- Institutional controls (HLA 1995)

MANUFACTURING AND DISPOSAL HISTORY

On-Post ROD

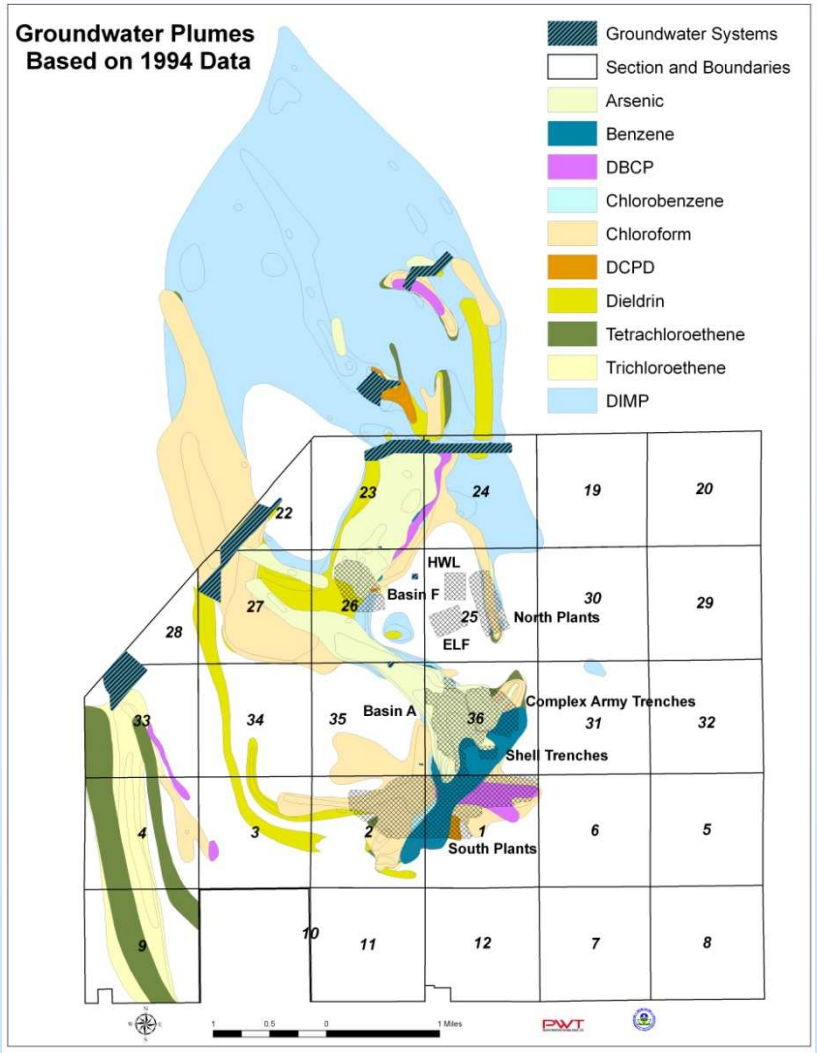
The On-Post ROD identifies:

- Approximately 3,000 acres of contaminated soil, 15 groundwater plumes, and 798 structures
- More than 600 chemicals were associated with activities at RMA and 27 chemicals of concern were identified as having potential risk to human health and the environment
- 31 cleanup projects were defined for soil, structures, and groundwater, including 88 phases of work
- Institutional controls (FWENC 1996)

MANUFACTURING AND DISPOSAL HISTORY

Groundwater contamination overview

General location of the on-post and off-post contaminated groundwater plumes at RMA



(EPA/PWT)

SOIL REMEDY

Give Me Refuge

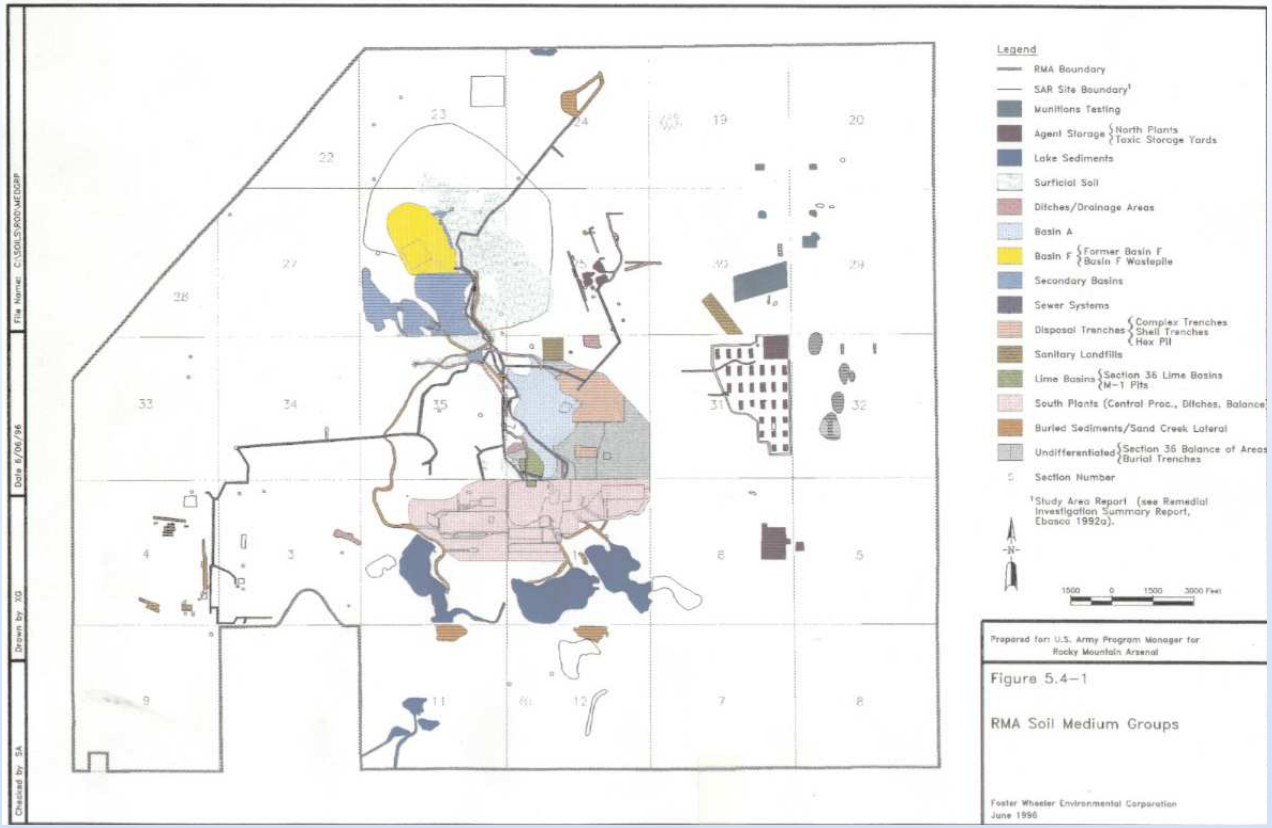
The Soil Remedy:

- Timeline of the remedy
- Wildlife – remedy/refuge interaction
- Innovative technologies
- Nuisance odor projects
- Munitions and agent
- Solidification/stabilization
- RCRA-Equivalent covers

SOIL REMEDY

Soil contamination overview

General location of contaminated soils

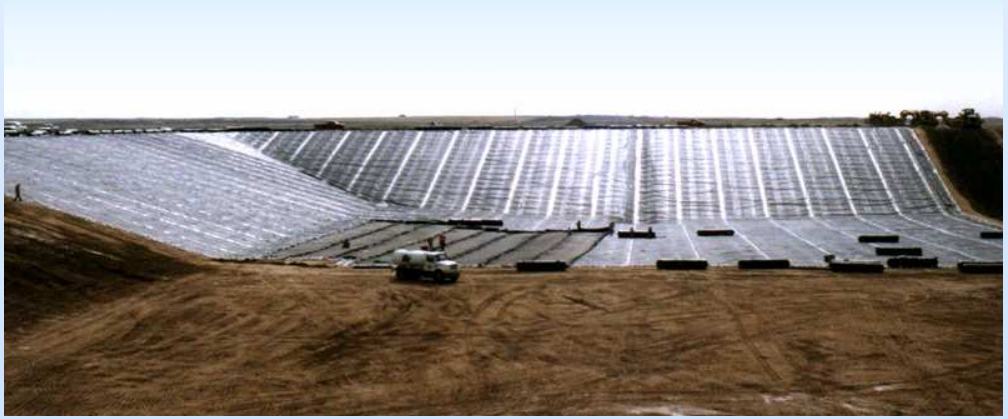


Foster Wheeler Environmental Corp., 1996

SOIL REMEDY

The soil remedy was considered "easy"

Excavate contaminated soil and place in on-site landfills

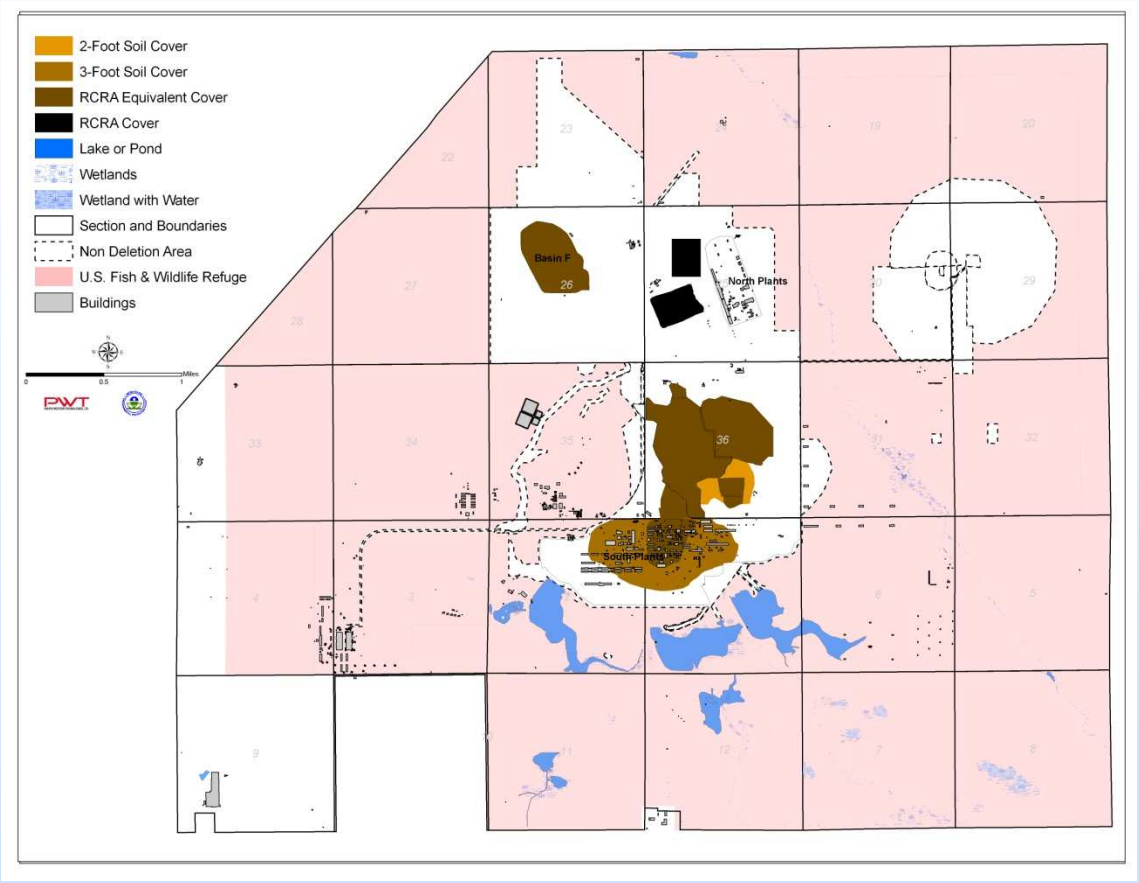


Soil remediation at the Rocky Mountain Arsenal (EPA field oversight photograph) and construction of the Hazardous Waste Landfill (Fiore and Sons photograph)

SOIL REMEDY

Soil remediation

General soil remediation and disposal areas

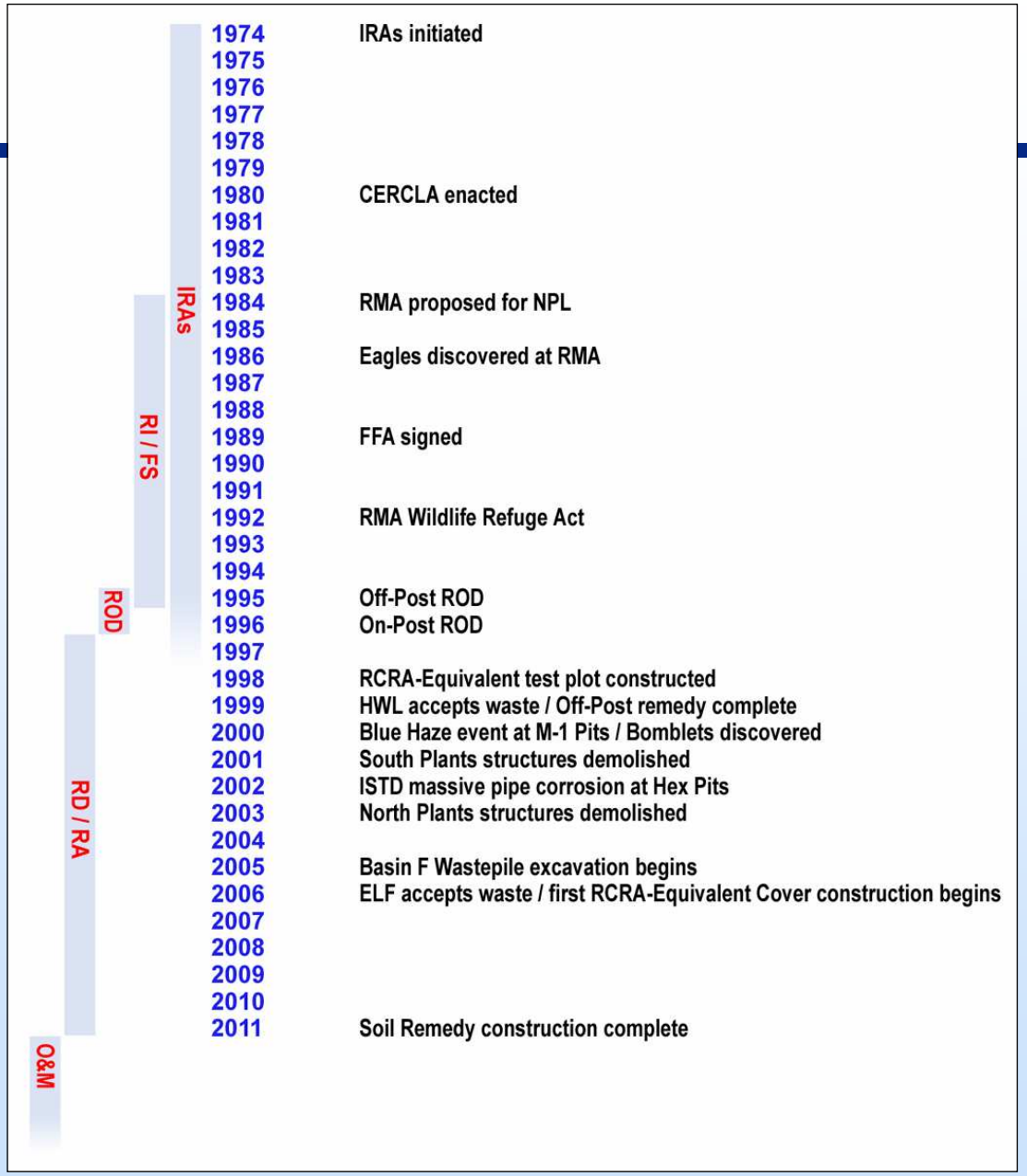


(EPA/PWT)

SOIL REMEDY

Timeline

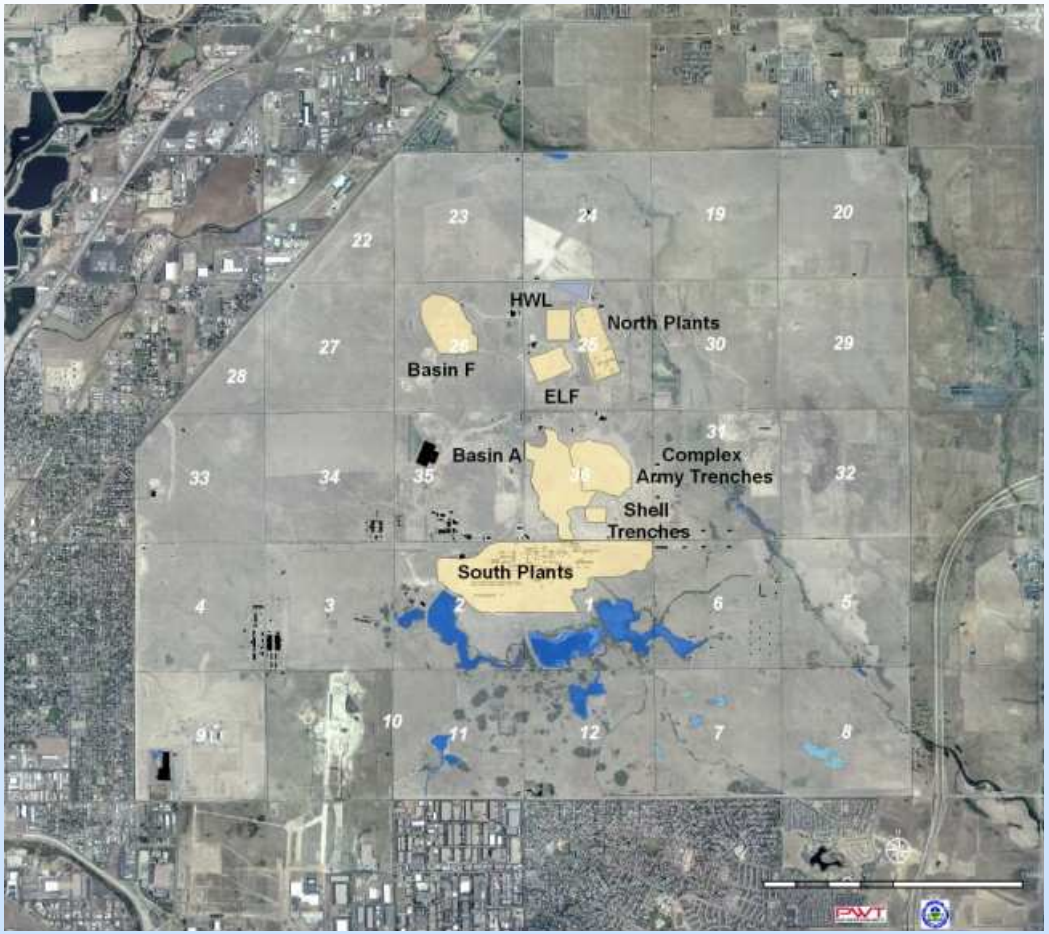
General timeline of the remedy at RMA



SOIL REMEDY

Wildlife – interaction with the remedy

Buffer Area, unique habitat



(U.S. Army aerial photograph, EPA/PWT map overlay)

Wildlife – interaction with the remedy

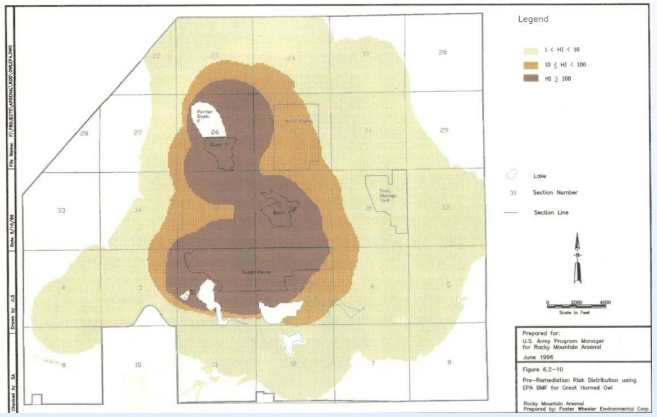
Buffer Area, unique habitat

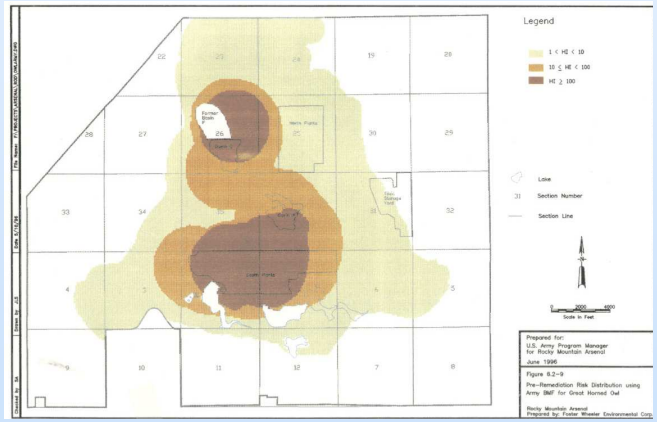
Clockwise from upper left: prairie dog, cormorants, (EPA field oversight photographs) mule deer (Aaron Rinker, USFWS), burrowing owls (EPA field oversight photograph)

SOIL REMEDY

Wildlife – interaction with the remedy

Different opinions regarding risk



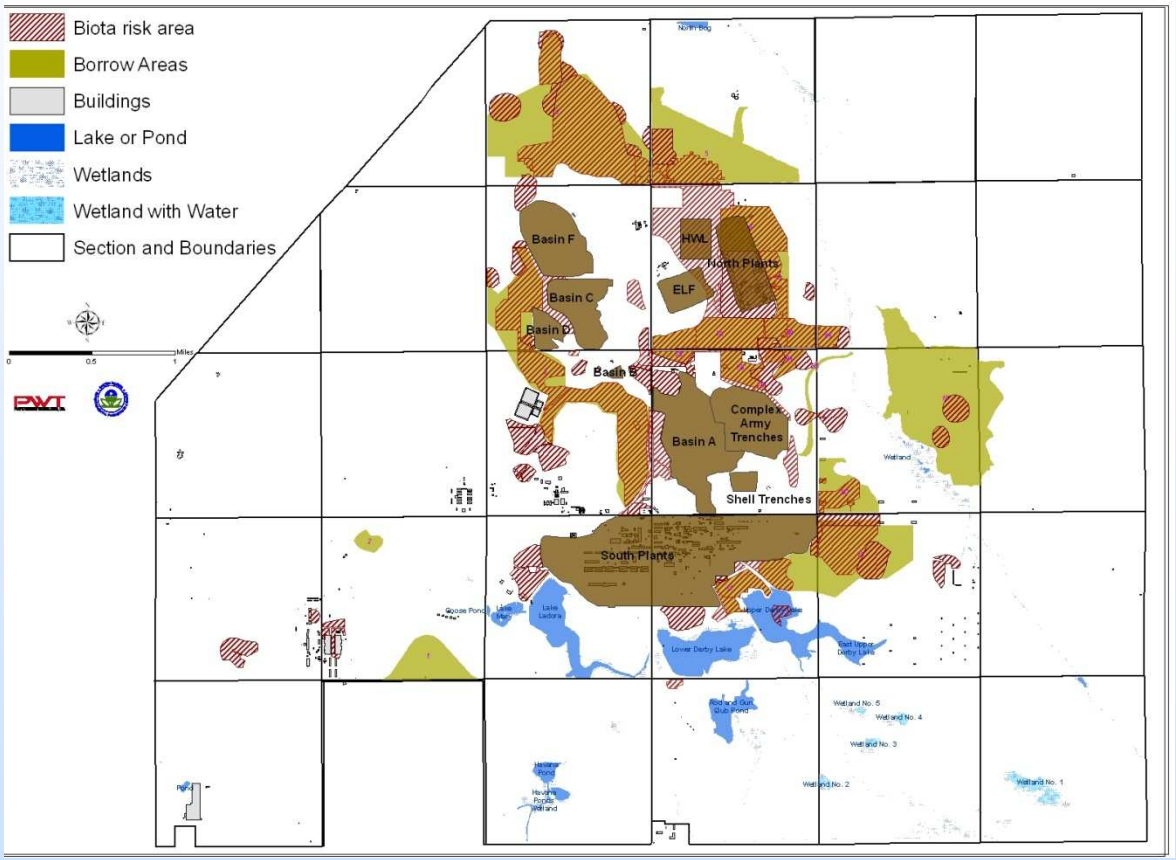


Great horned owl (EPA field oversight photograph). Modeled risk area for the great horned owl (FWENC 1996)

SOIL REMEDY

Wildlife – interaction with the remedy

The solution – use of borrow areas



Map of borrow areas and biota risk soil
(EPA/PWT)

Wildlife – interaction with the remedy

Biota risk considerations in the ROD

EPA field oversight photographs

SOIL REMEDY

Wildlife – interaction with the remedy

Continuous interaction between wildlife and the remedy

Sign identifies the Bald Eagle Management Area (EPA field oversight photograph)

Wildlife – interaction with the remedy

Continuous interaction between wildlife and the remedy

The remedy protects unique habitat when possible, including protecting large trees by not excavating around the dripline and leaving tree groves in place to preserve nesting habitat for raptors (U.S. Army photograph)

Wildlife – interaction with the remedy

Continuous interaction between wildlife and the remedy

Clockwise from top: coyote running across biota barrier during construction of RCRA-Equivalent covers; prairie dog and high voltage cable; mule deer by a structure before demolition; coyote on biota barrier (EPA field oversight photographs)

SOIL REMEDY

Wildlife – interaction with the remedy

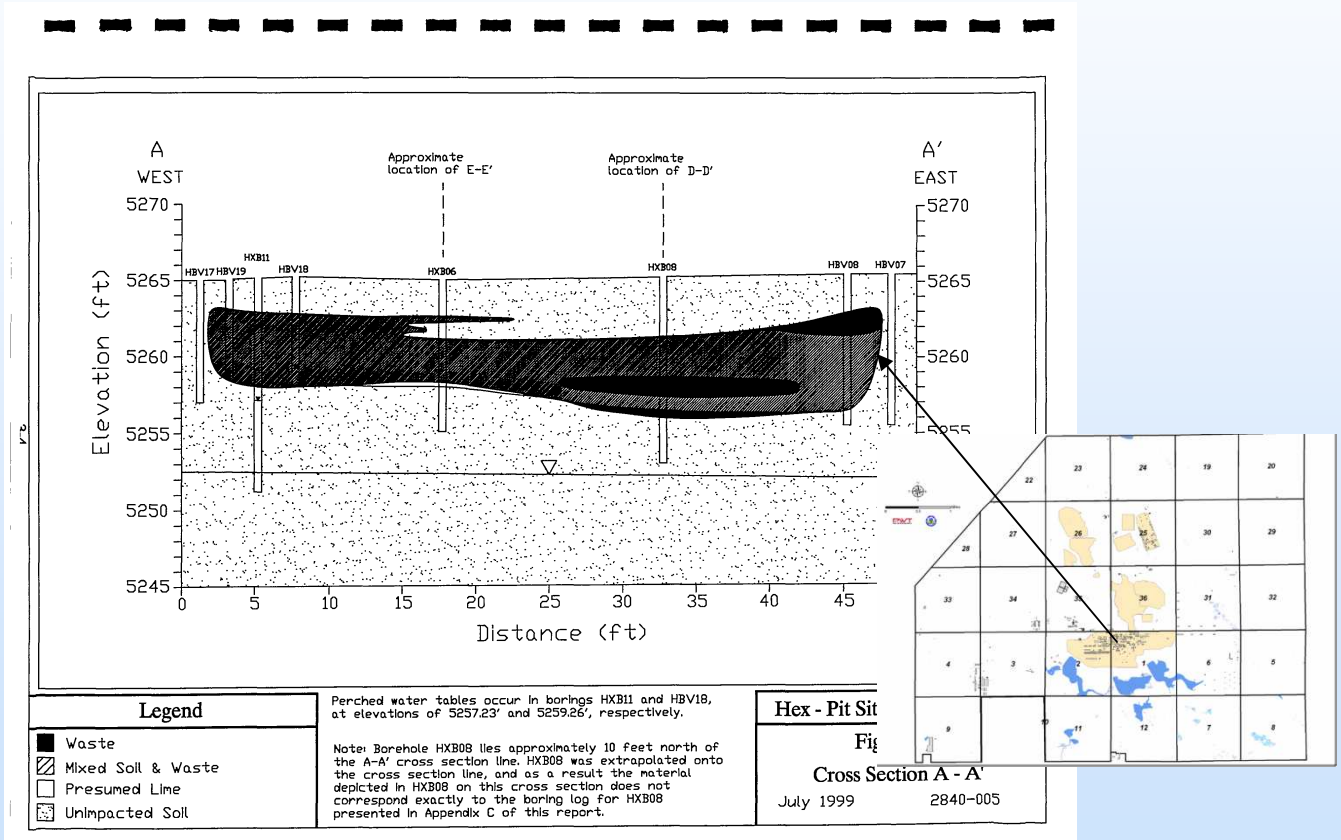
Wildlife hazards

Deer antler caught in a tractor tire
(EPA field oversight photograph)

SOIL REMEDY

Innovative technologies – Hex Pits

Typical section through the Hex Pits showing the tar-like layers



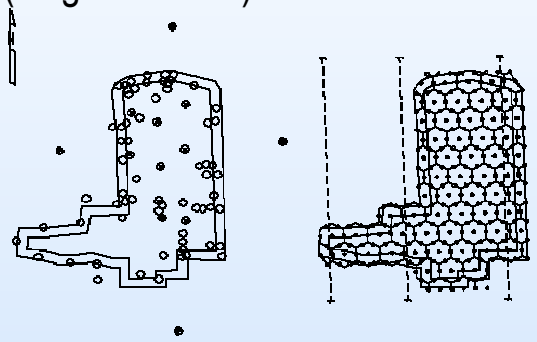
(ENSR 1999, Hex Pit Characterization Report)

SOIL REMEDY

Innovative technologies – Hex Pits

Heater well installation

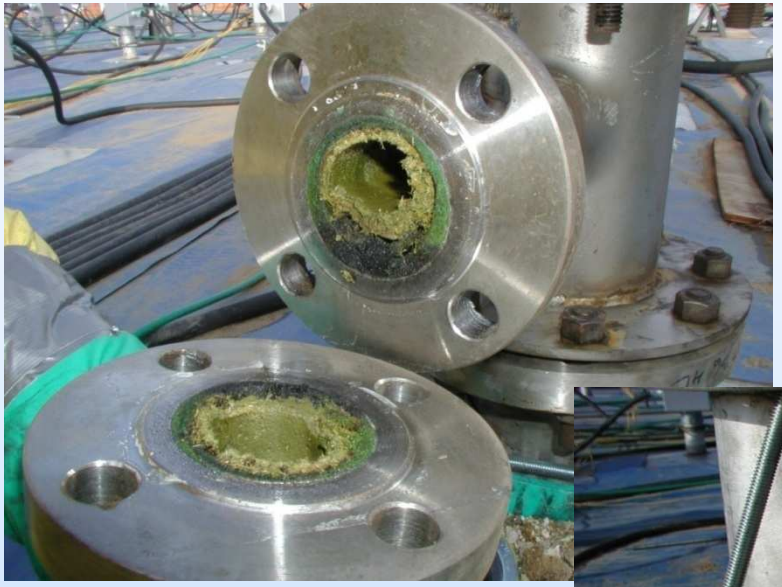
Plan view of the Hex Pits and array of heater and heater vacuum wells (diagram below)



Installation of heater only (top photo) and heater-vacuum wells (right) for In Situ Thermal Destruction at the Hex Pits (U.S. Army photographs)

Innovative technologies – Hex Pits

Corroded piping at the Hex Pit Remediation Project



U.S. Army photographs

SOIL REMEDY

Innovative technologies – Hex Pits

Lessons learned from the Hex Pit Project

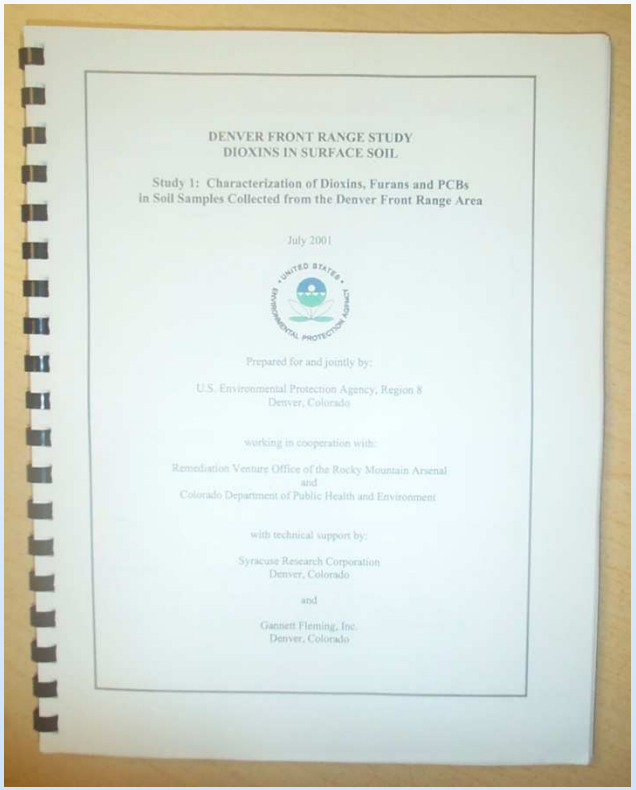
- Do not assume that *in-situ* neutralization of acids will occur, especially in the case of highly chlorinated NAPL or situations in which the waste resides as a neat *solid* material that has not penetrated into a porous matrix
- Be conservative to ensure captured vapors remain in the vapor state

SOIL REMEDY

Innovative technologies – EPA dioxin study

Study of dioxin presence along the Denver front range

- Five different types of land use categories were considered in the Denver front range:
  - Residential
  - Agricultural
  - Open space
  - Commercial
  - Industrial



SOIL REMEDY

Innovative technologies – EPA dioxin study

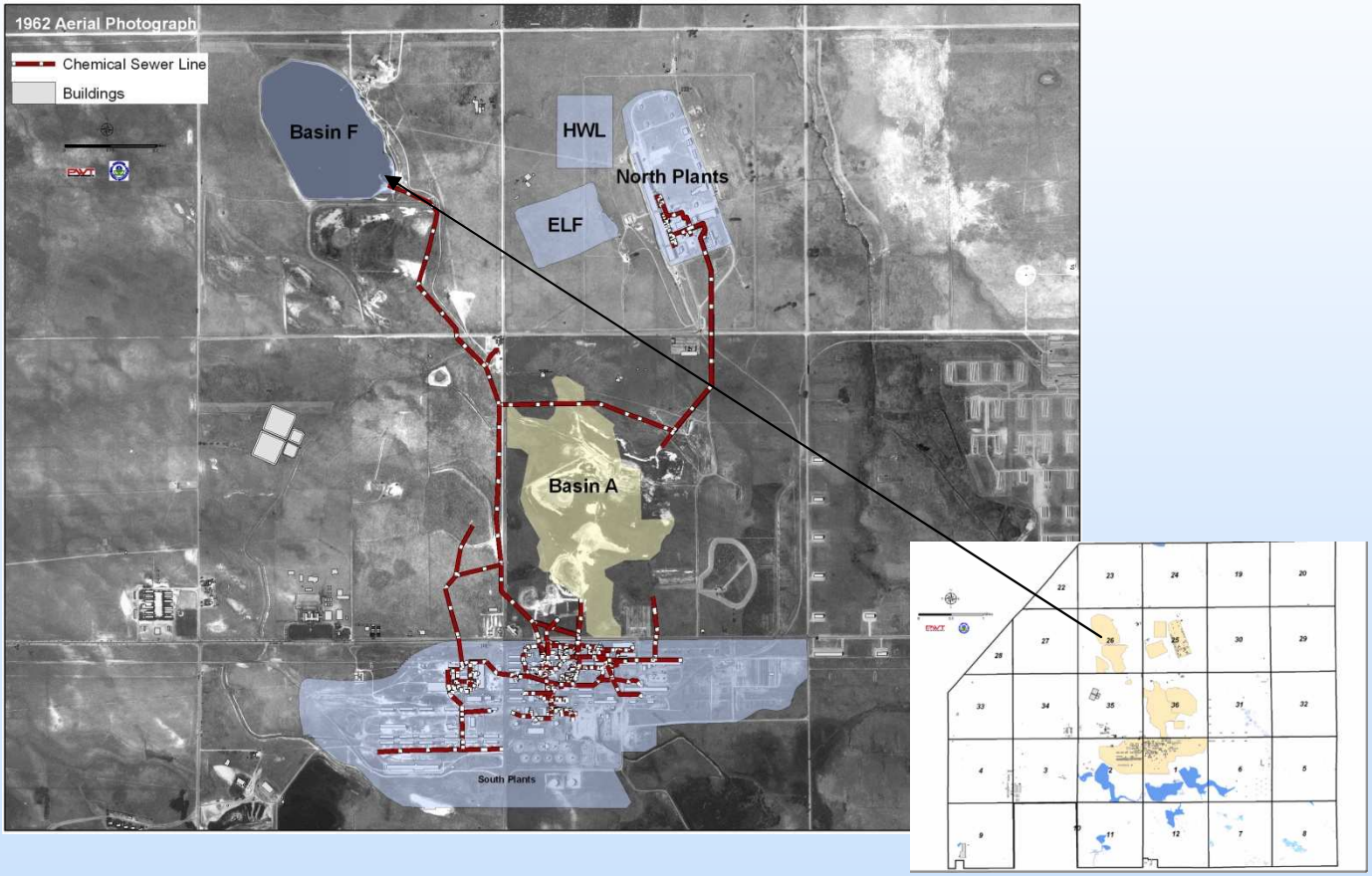
Conclusions

- Important baseline study of dioxin in the environment
- No exceedances of human health levels were detected throughout the front range
- Dioxin study an important factor in transfer of RMA land to Commerce City for development

SOIL REMEDY

Nuisance odors - Introduction

Basin F: liquid disposal for North Plants and South Plants



Map of Basin F, North Plants, South Plants and chemical sewer locations
(U.S. Army aerial photograph, EPA/PWT map overlay)

SOIL REMEDY

Nuisance odors - Introduction

Air monitoring during implementation

Air monitoring station for chemical emissions at RMA (EPA field oversight photograph)

Nuisance odors - Introduction

Remediation challenges with highly odorous soil

Geomembrane odor testing (EPA field oversight photographs)

SOIL REMEDY

Nuisance odors – M-1 Pits, blue haze incident

M-1 Pits – soil solidification and stabilization

(EPA field oversight photograph)

SOIL REMEDY

Nuisance odors – M-1 Pits, blue haze incident

Poor air dispersion – still and stagnant air

Warm Air

Cold Air

November 2002 (Photograph by B. Burkhart)

SOIL REMEDY

Nuisance odors – M-1 Pits, blue haze incident

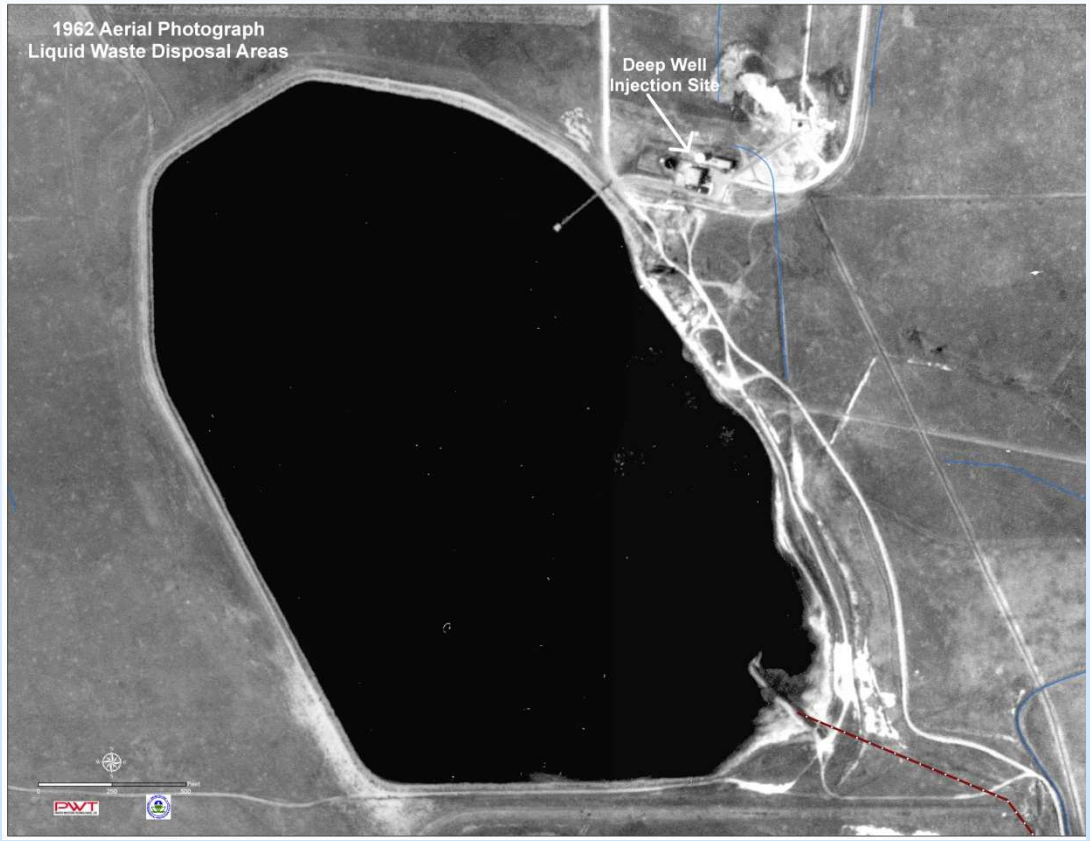
Lessons learned/successes from the M-1 Pits project

- Favorable meteorological conditions were important for reducing odors. Set up a go/no-go decision based on atmospheric stability classifications
- Stockpiling odorous soil overnight was discontinued
- Minimizing disturbance/mixing of the soil greatly helped reduce odors
- Limiting the area of an open excavation helped reduce odors

SOIL REMEDY

Nuisance odors – Basin F Wastepile

Basin F – the most controversial site at RMA

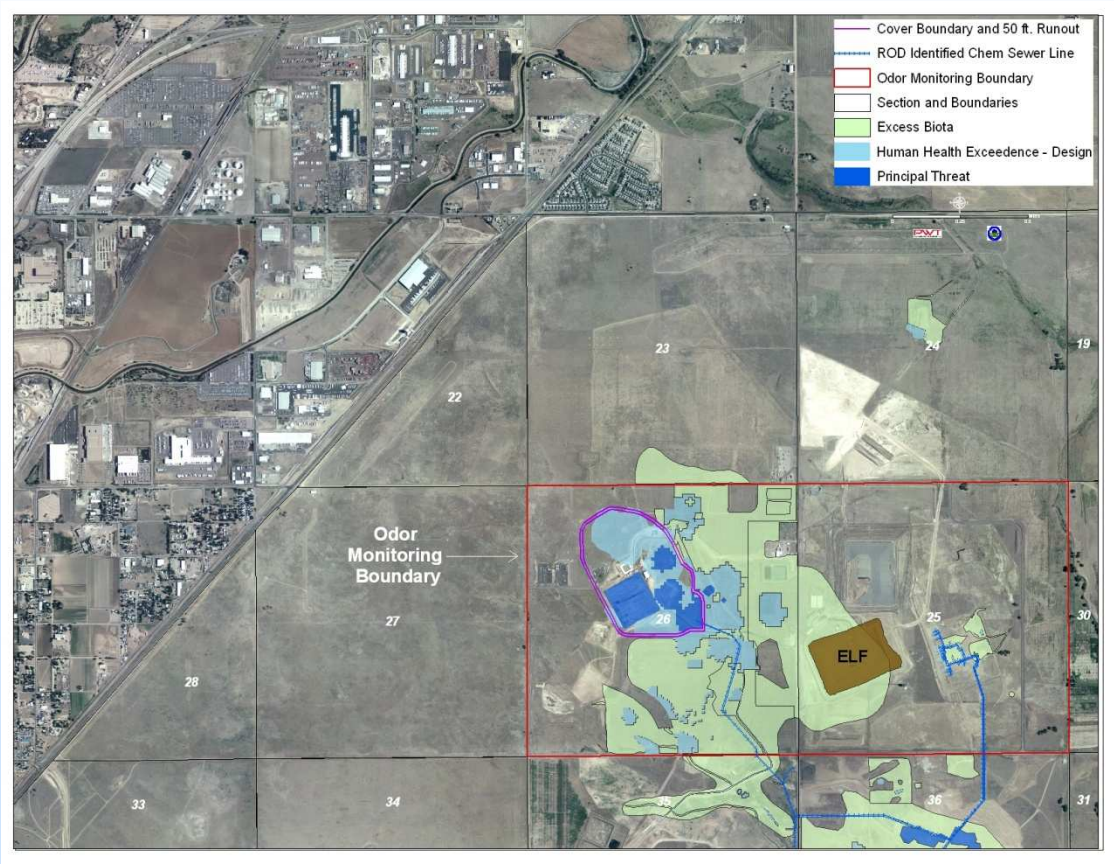


Basin F liquid waste disposal evaporation pond and deep well injection site (U.S. Army aerial photograph, EPA/PWT map overlay)

SOIL REMEDY

Nuisance odors – Basin F Wastepile

Monitoring and controlling odors during implementation



Basin F, as illustrated with a purple outline, is close to residential neighborhoods

(U.S. Army aerial photograph, EPA/PWT map overlay)

Nuisance odors – Basin F Wastepile

Odor controls used during excavation of the wastepile

Clockwise from top left: placement of short-duration foam odor control; short-term odor control at Basin F HHE excavation; long-duration odor control foam; geomembrane used as odor control (EPA field oversight photographs)

SOIL REMEDY

Nuisance odors – Basin F Wastepile

Lessons learned and successes from the Basin F Wastepile Remediation Project

- No complaints from the community were received
- Full-time odor monitoring to assess/confirm odors in the community was successful
- Slow start was successful
- It was possible to implement the project without a full enclosure
- Use of onsite meteorological towers and daily forecasting was successful in making go/no-go decisions
- Limiting the area of disturbance was successful
- Odor control using foam was not always effective because it breaks down in the rain, is difficult to apply in the wind, and won't adhere to steep slopes

SOIL REMEDY

Basin F Wastepile - Aside: Liner Excavation

Wastepile Liner System – a double lined facility:

- Compacted soil subgrade
- 60-mil HDPE as a secondary liner
- 200-mil HDPE geonet (leak detection)
- 60-mil HDPE primary liner
- 200-mil HDPE geonet (leachate collection)
- 12-oz geotextile
- 36 inches of soil as a protective cushion layer

SOIL REMEDY

Basin F Wastepile - Aside: Liner Excavation

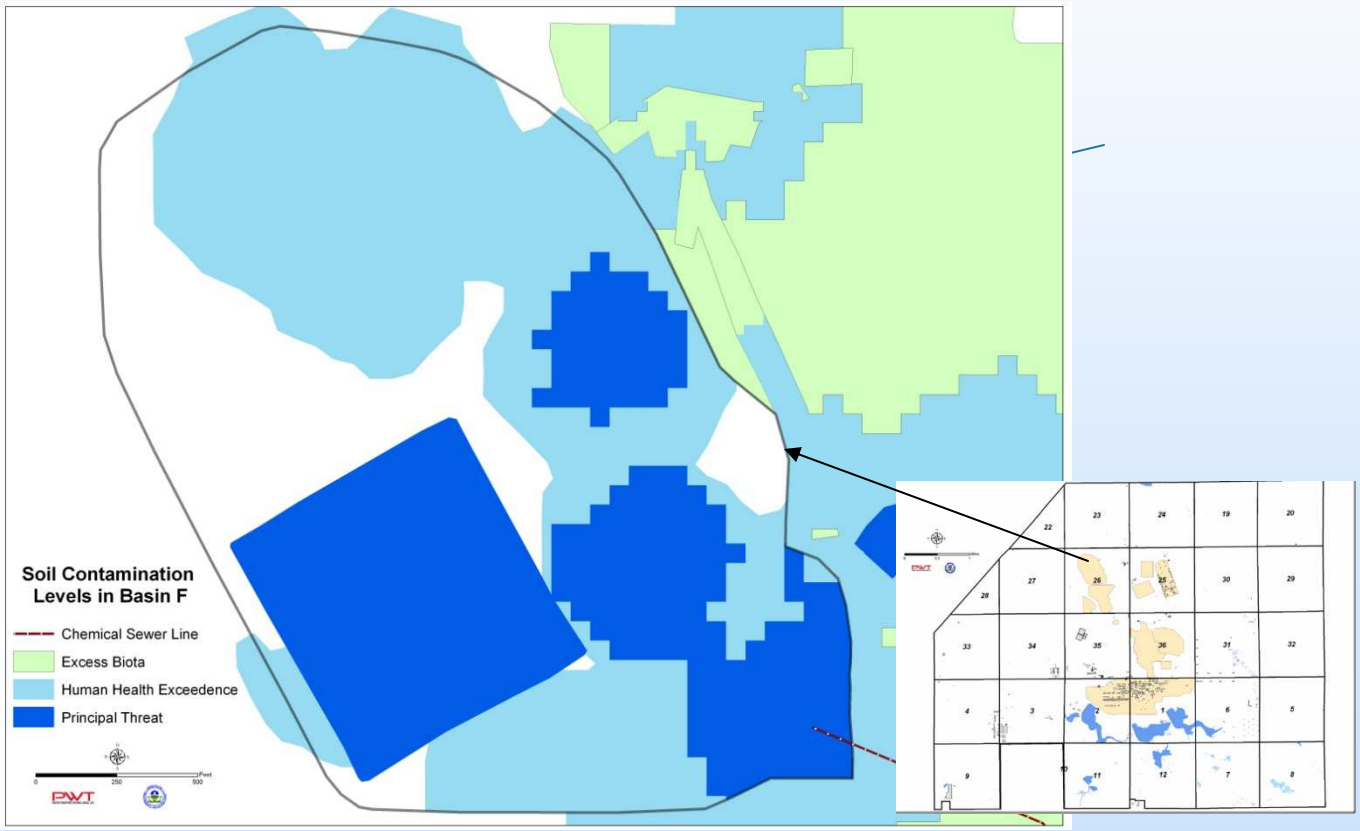
Excavation of the double liner system

Removal of one of the Wastepile sumps and liner material (EPA field oversight photographs)

SOIL REMEDY

Solidification / stabilization

Former Basin F



Map of different soil contamination levels, Basin F
(EPA/PWT)

SOIL REMEDY

Solidification / stabilization

Basin F Solidification/Stabilization Treatability Study Summary :

- Key contaminants were pesticides
- Cement-based mixes with activated charcoal and contaminated soil were evaluated first and met the performance criteria
- Additional concern that the contaminants should be chemical stabilized, not just physically stabilized, however, special reagents, such as hydrogen peroxide and manganese dioxide, did not perform well in the mixes and hydrogen peroxide created safety concerns

SOIL REMEDY

Solidification / stabilization

Basin F Solidification/Stabilization Treatability Study Summary:

- *Final Former Basin F Solidification Treatability Study Report,* Tetra Tech FW, Inc. 2006
- Key contaminants were pesticides
- Cement-based mixes with activated carbon were evaluated most successful – 98% reduction in contaminants in the leachate

* Additional concern that the contaminants should be chemical stabilized, not just physically stabilized.

* However, special reagents, such as hydrogen peroxide and manganese dioxide, did not perform well in the mixes and hydrogen peroxide created safety concerns.

* Stabilization changed to excavation to accommodate problems at another RMA project.

SOIL REMEDY

Finding unexpected munitions & chemical agent

Remediation of North Plants

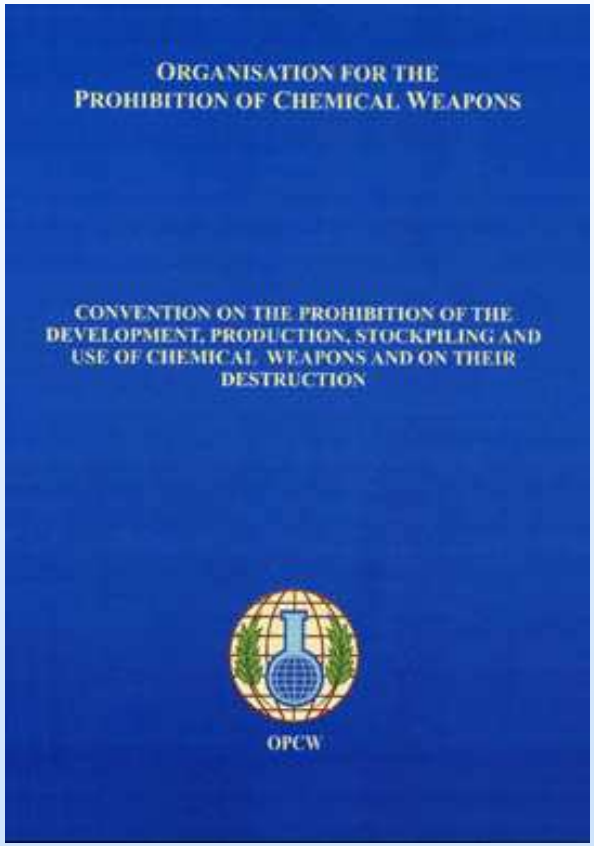
North Plants Weapons Manufacturing Facility, top (globalsecurity.org); building demolition of North Plants (EPA field oversight photograph)

SOIL REMEDY

Finding unexpected munitions & chemical agent

Remediation of North Plants – Chemical Weapons Convention Treaty

(US Chemical Weapons Convention website)



Finding unexpected munitions & chemical agent

Munitions debris

Recovered munitions debris from a former munitions testing area (EPA field oversight photograph)

SOIL REMEDY

U.S. Army Photograph

Finding unexpected munitions & chemical agent

Sarin bomblets

Left, a Sarin bomblet showing relative size (USFWS photograph). Below, Sarin bomblet recovered from a debris pile at the RMA (U.S. Army photograph)

SOIL REMEDY

Finding unexpected munitions & chemical agent

Sarin bomblet destruction

The Explosive Destruction System
(B.L. Haroldsen, J.H. Stofleth, and T.J. Shepodd)

SOIL REMEDY

Finding unexpected munitions & chemical agent

Other actions initiated from the bomblet discoveries:

- RMA Emergency Response Integrated Contingency Plan was revised
- Visitor Access Plan and public notification procedures were revised
- A comprehensive year-long evaluation of each square mile of RMA was conducted for potential ordnance and chemical warfare hazards

SOIL REMEDY

Finding unexpected munitions & chemical agent

Lessons learned / successes from the bomblet issue

- **Never say Never**

  AND

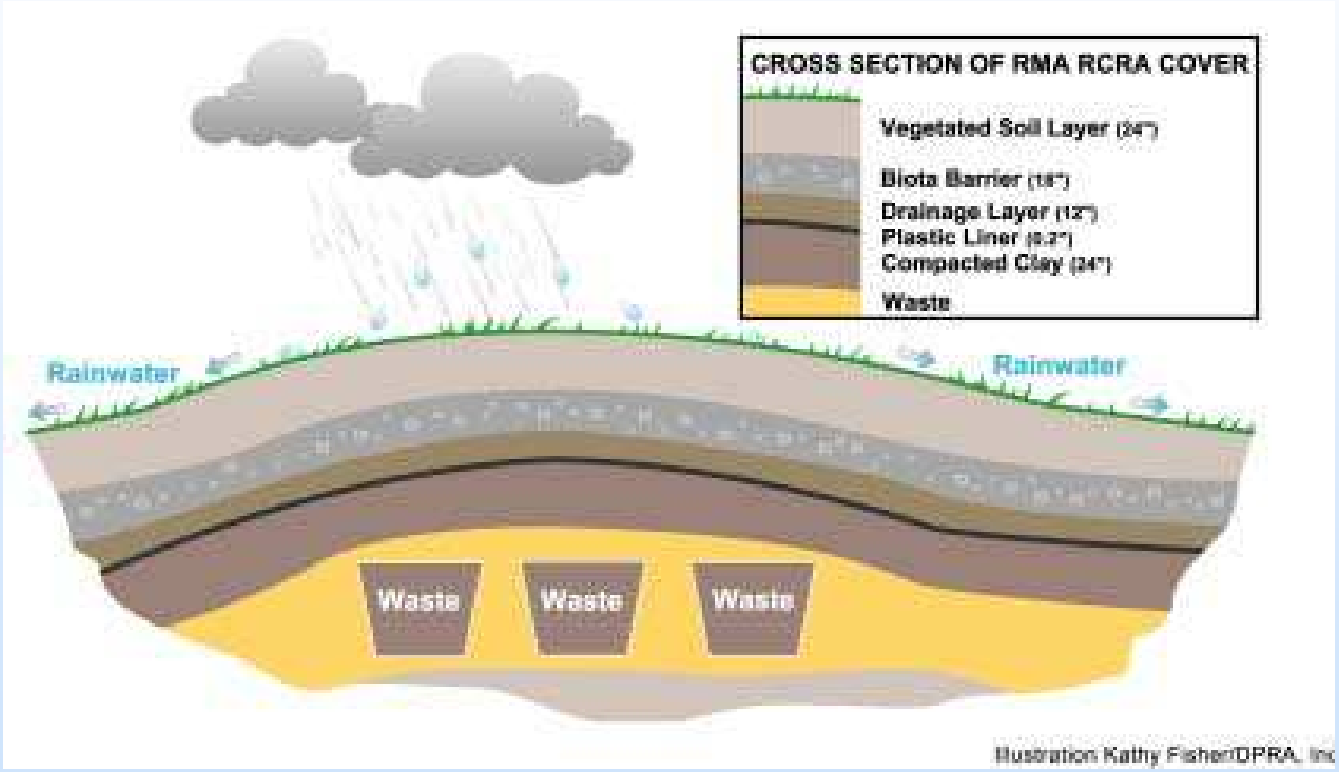
- **Expect the Unexpected**

SOIL REMEDY

RCRA-Equivalent Covers

Innovative technology for waste containment

RMA RCRA Cover using clay and geosynthetics



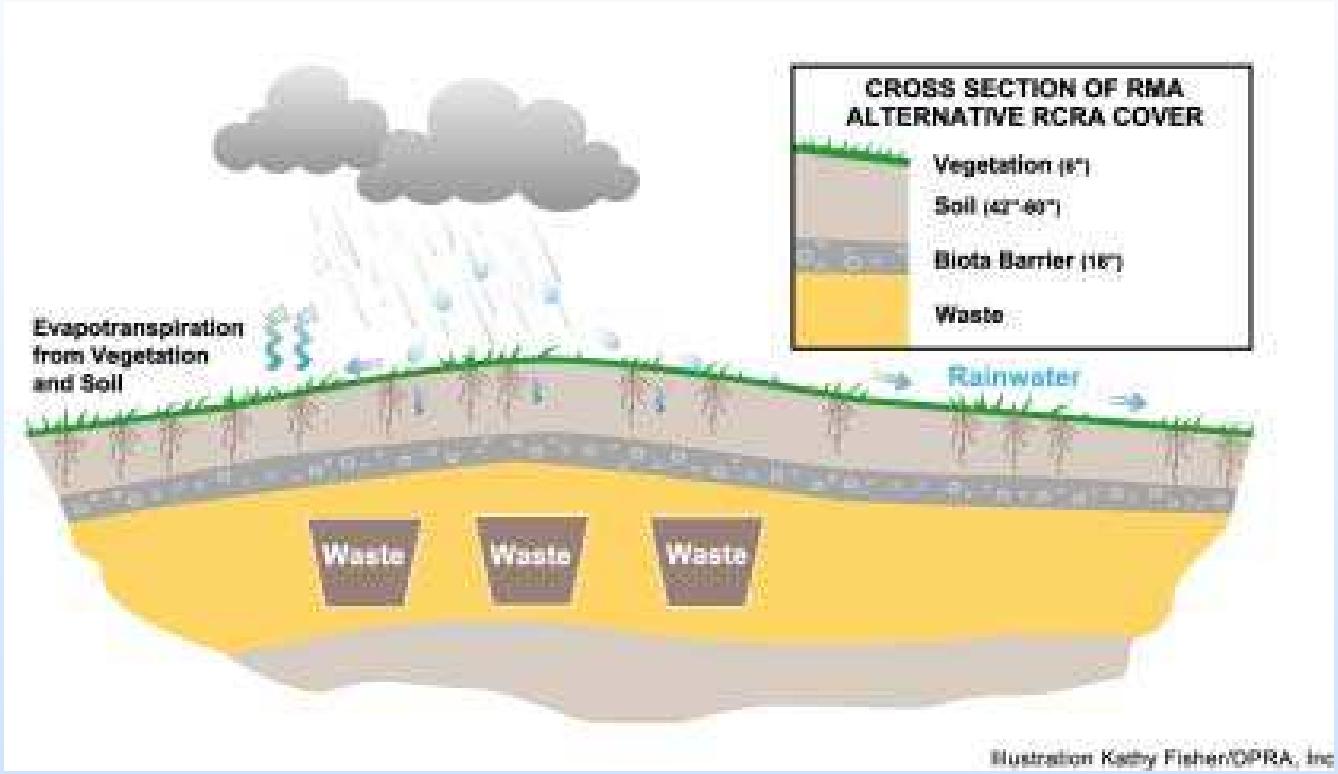
(ITRC, Technology Overview Using Case Studies of Alternative Landfill Technologies and Associated Regulatory Topics, March 2003)

SOIL REMEDY

RCRA-Equivalent Covers

Innovative technology for waste containment

RCRA-Equivalent Cover



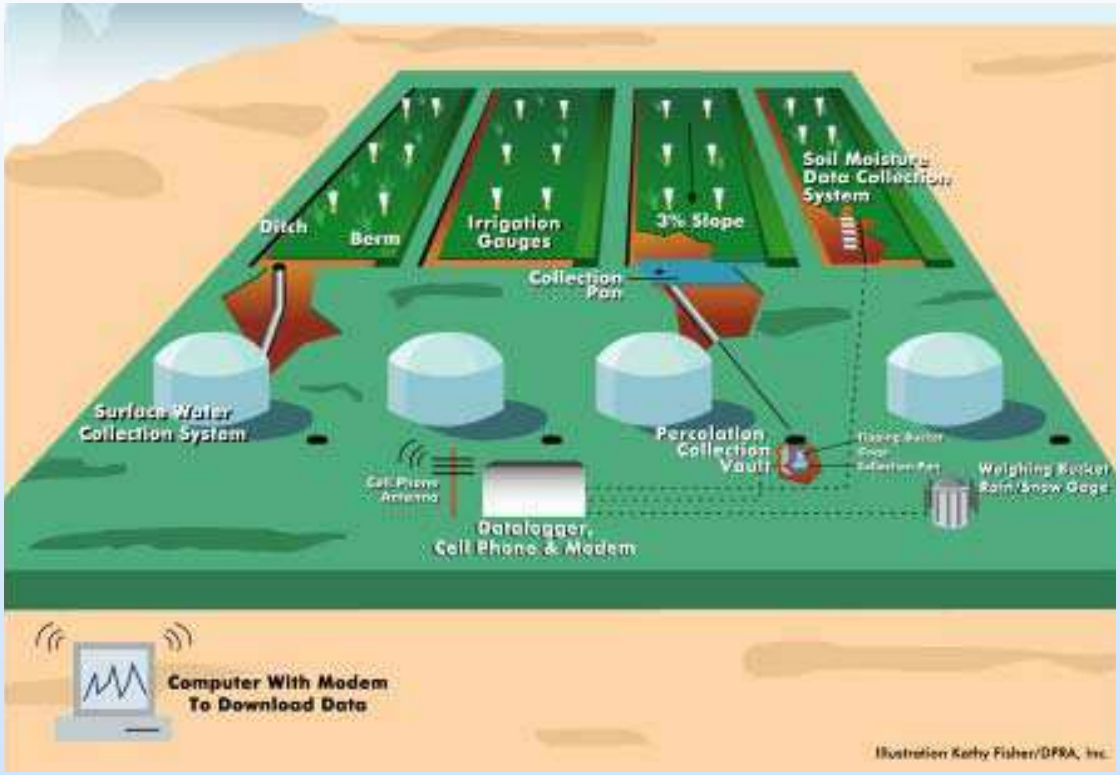
(ITRC, Technology Overview Using Case Studies of Alternative Landfill Technologies and Associated Regulatory Topics, March 2003)

SOIL REMEDY

RCRA-Equivalent Covers

Innovative technology for waste containment

Test Plot Demonstration



RCRA-Equivalent Cover Test Plot Demonstration at RMA.
(ITRC, Technology Overview Using Case Studies of Alternative Landfill Technologies and Associated Regulatory Topics, March 2003)

SOIL REMEDY

RCRA-Equivalent Covers

Innovative technology for waste containment

Development of the 1.3 mm/year compliance standard for percolation:

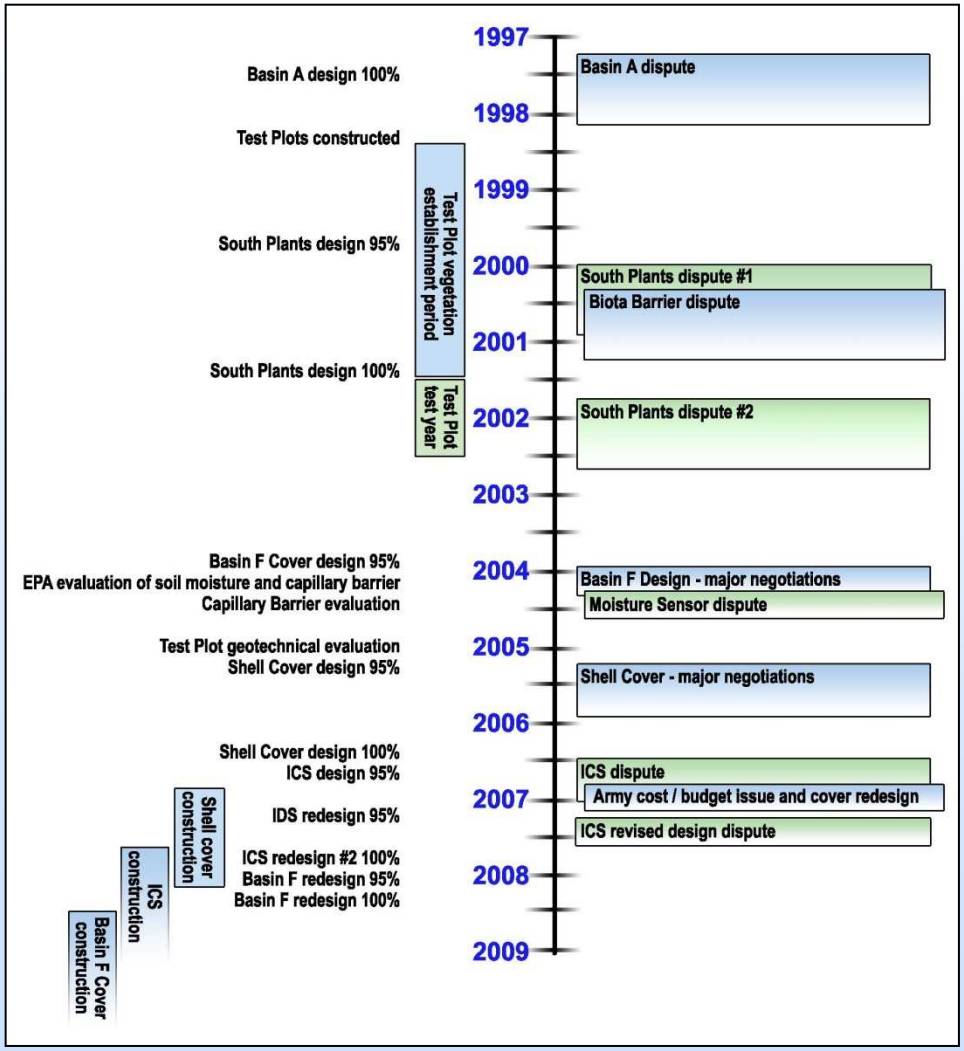
- Based on a 8-year study conducted in Germany between 1988 and 1995
- Percolation through a Subtitle C composite liner system was measured in 2 landfills
- The average percolation was determined to be 1.3 mm/year. (Melchior 1997).

SOIL REMEDY

RCRA-Equivalent Covers

Innovative technology for waste containment

Timeline of the negotiation process.



SOIL REMEDY

RCRA-Equivalent Covers

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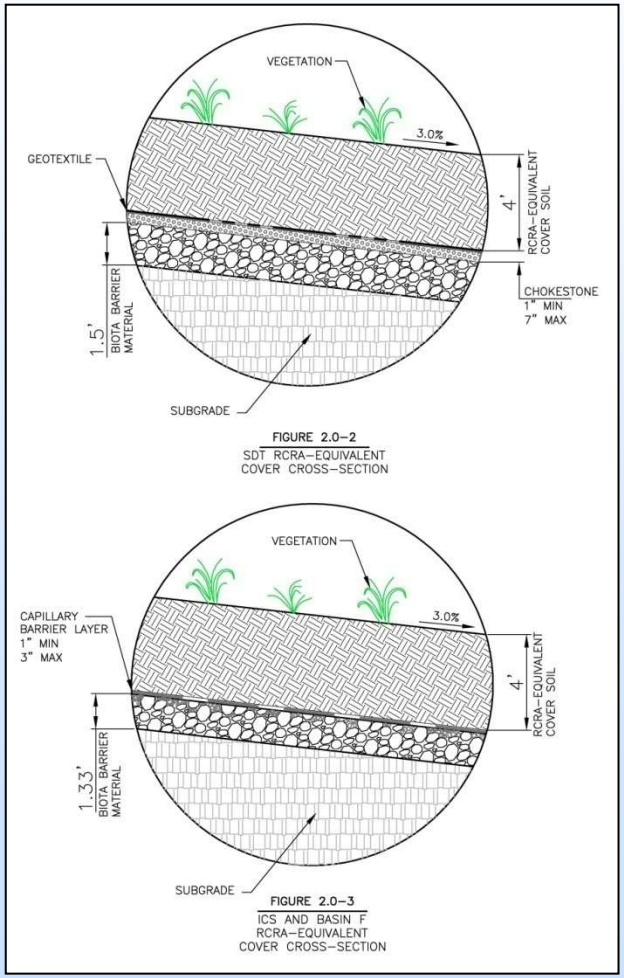
As-built RCRA-Equivalent Cover Sections

Cross section through the Shell RCRA-Equivalent Cover. 18 inches of BBM is overlain with a geotextile and 4 feet of soil (EPA field oversight photograph). Cross section of RCRA-E Covers (TetraTech EC 2008)



RCRA-Equivalent Covers

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Biota Barrier

16 inches of biota barrier material. Stockpile of crushed concrete from the demolition of the old Stapleton International Airport, being loaded for cover construction (EPA field oversight photographs)

SOIL REMEDY

RCRA-Equivalent Covers

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Capillary Barrier

Capillary barrier layer (orange geotextile) on the Shell Cover. Placement of capillary barrier material (squeegee - a clean, washed gravel material) on the Integrated Cover System (EPA field oversight photographs)

RCRA-Equivalent Covers

Innovative technology for waste containment

4-foot thick soil layer

Placement of a single lift of acceptable soil for the RCRA-Equivalent Cover. A low ground pressure dozer is the only equipment allowed on the top of the cover to avoid over compaction (EPA field oversight photograph)

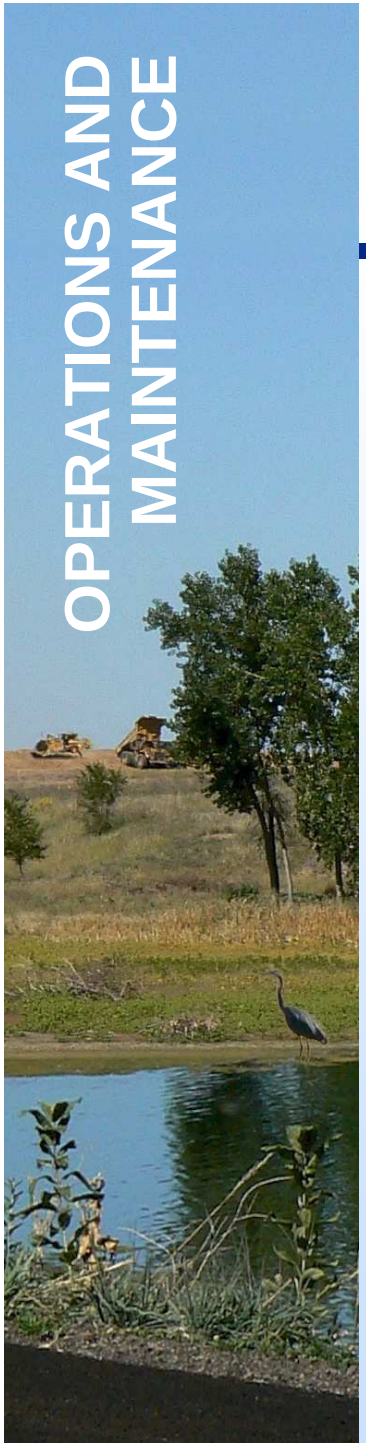
SOIL REMEDY

RCRA-Equivalent Covers

Innovative technology for waste containment

Vegetation designed for evapotranspiration

Cross section of the Shell RCRA-Equivalent Cover. Progress of vegetation after one growing season. (EPA field oversight photograph)



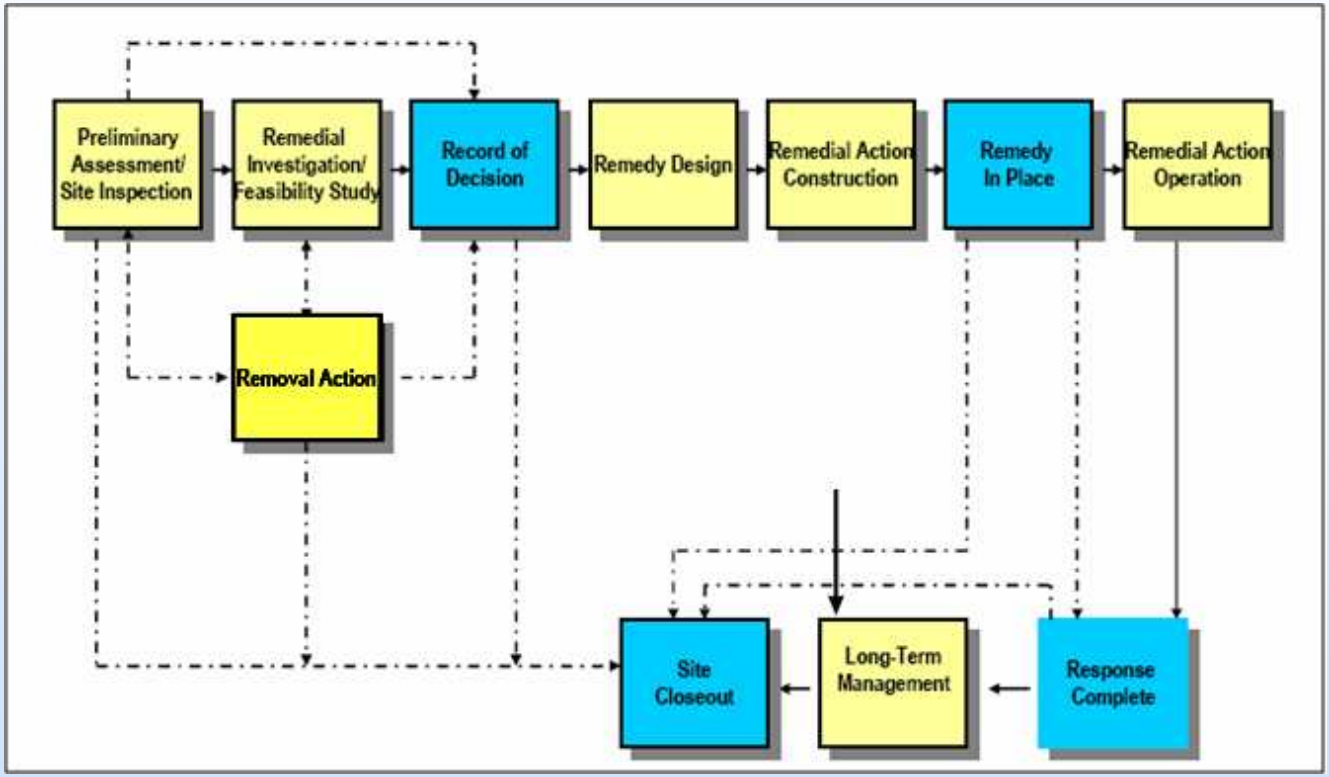
Give Me Refuge

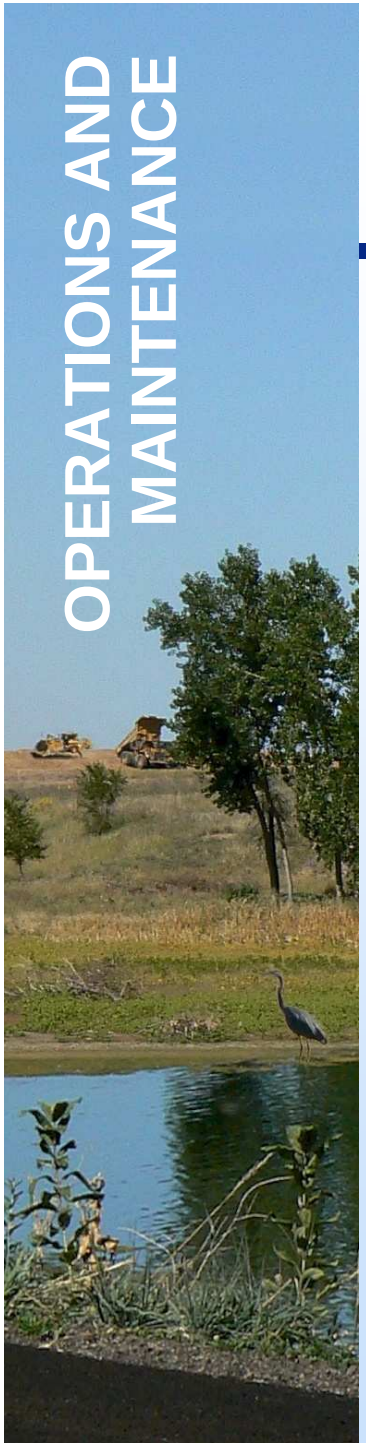
Operations and Maintenance

OPERATIONS AND MAINTENANCE

Long-term maintenance of covers

Typical CERCLA process

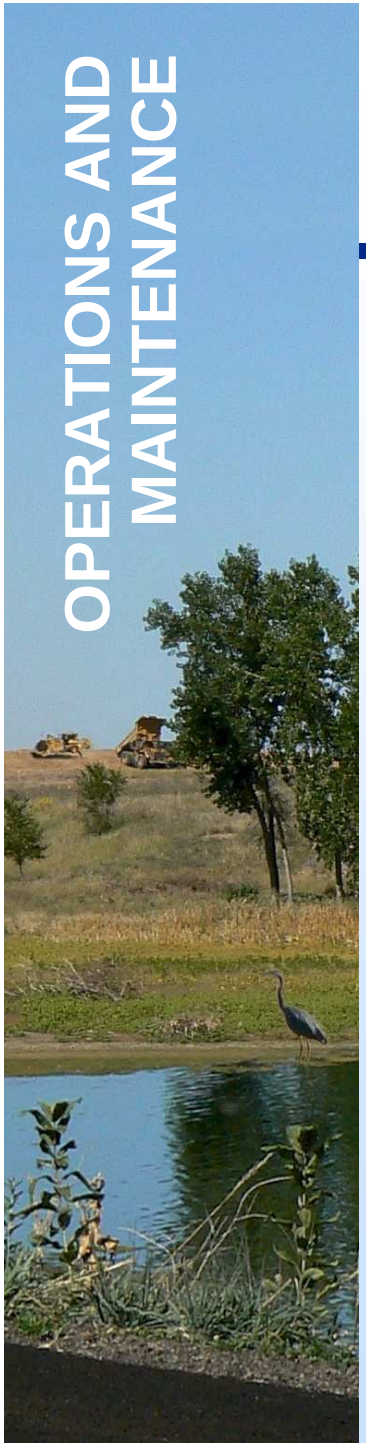




Long-term maintenance of covers

Compliance Standards for the RCRA-Equivalent and Soil Covers at RMA:

- Percolation (RCRA-Equivalent covers only): less than or equal to 1.3 mm/year of water measured in the lysimeters over a rolling 12-month evaluation.
- Cover thickness (all covers): a minimum of 42-inch thick soil cover layer above the capillary barrier material for RCRA-Equivalent Covers, a minimum of 36 inches of soil for 3-foot covers, and a minimum of 24 inches of soil for 2-foot covers.
- Vegetation standard (RCRA-Equivalent covers only):
  - Total live vegetation not less than 25 percent in any single year
  - Two-year running average value for total ground cover not less than 50 percent
  - Three-year running average value for total ground cover not less than 67 percent.

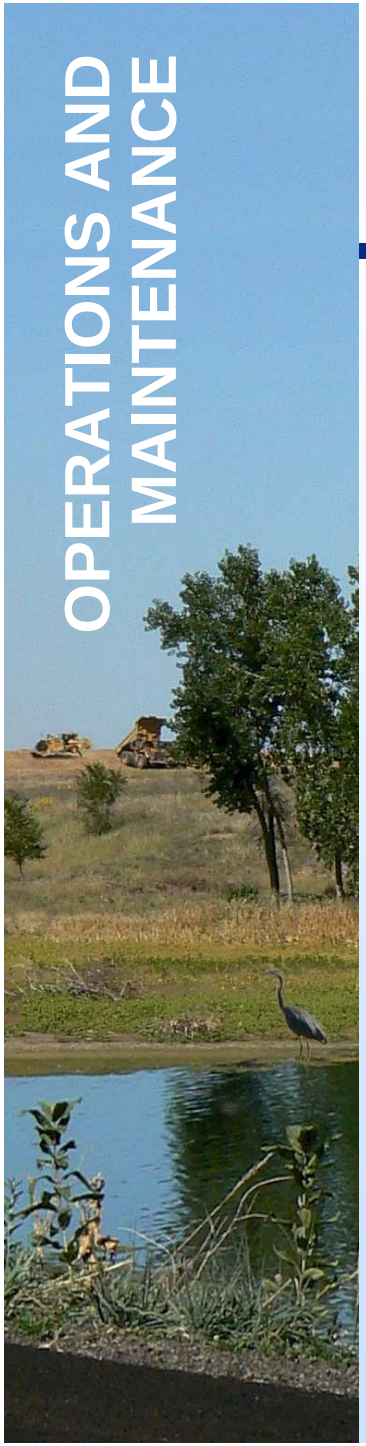


Long-term maintenance of covers

Routine maintenance activities - example

SOP	Item	Inspection Frequency	Routine Maintenance Activities for Localized and First-Time Occurrences*
001	Erosion Control	Monthly and after significant storm events Semiannually	Apply soil as necessary to fill rills followed by revegetation. Establish temporary erosion controls, such as straw logs and/or silt fencing or other appropriate measures as necessary.
001	Ponding	Monthly and after significant storm events Semiannually	Apply soil as necessary to fill small areas of localized differential settlement in lightly compacted layers and contour to provide proper drainage and revegetation.
001	Trails or Tire Marks	Monthly and after significant storm events Semiannually	Change ATV traffic patterns. Trails will be repaired and/or deterrents may be placed to mitigate wildlife travel routes across the covers if trails continually reform.
001 / 002	Noxious/ Undesirable Vegetation Control	Monthly and after significant storm events Semiannually Annually	Refer to Table 7.0-2 for weed control options.
001 / 002	Vegetation Management	Monthly and after significant storm events Semiannually Annually	Localized areas of vegetation loss (greater than 100 square-feet, but less than 11,000 square-feet) will be reseeded, amended and mulched. Fertilizer or amendment may be applied to promote growth of existing vegetation.
001/ 002	Pest/Insect Invasion	Monthly and after significant storm events Semiannually Annually	Evidence of localized pest/insect infestation will be treated in accordance with best management practices, depending on the type of pest, size of area, and intensity of infestation.
001	Surface Water Drainage Controls	Monthly and after significant storm events Semiannually	Concrete-lined drainage channels will be cleaned of accumulated sediment and/or debris. Significant cracks in the concrete (but smaller than those identified in Table 8.1-1) will be repaired. Vegetated drainage channels will be manually cleaned of debris and any eroded portions will be repaired by replacement and compaction with soil and revegetated.

(Tetra Tech EC 2008)



Long-term maintenance of covers

Non-routine action trigger levels - example

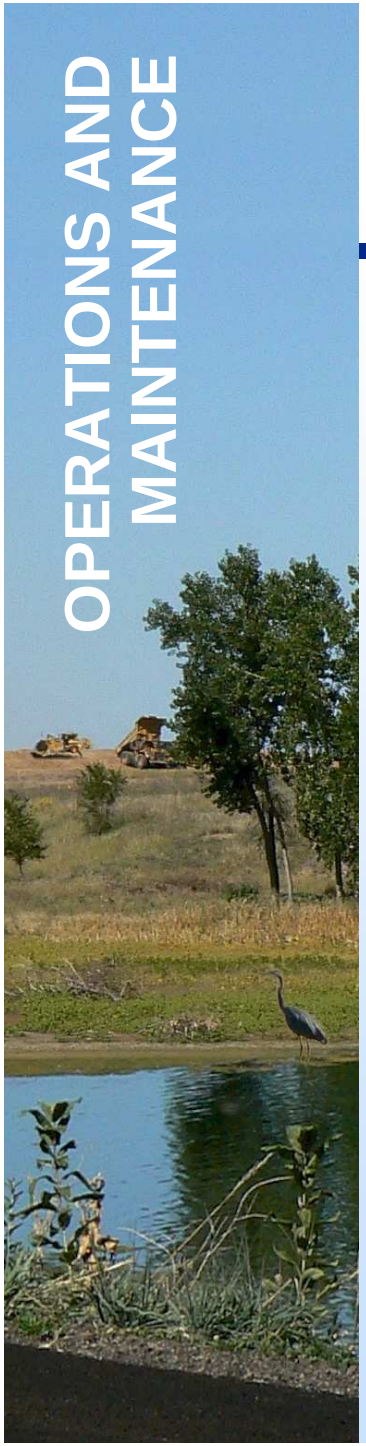
SOP	Item	Inspection Frequency	Type of Problem	Non-Routine Trigger Level (Consultation Required)
001	General Cover Conditions	Monthly and after significant storm events Semiannually	Erosion and differential settlement	Identification of reoccurring or wide-spread rills or gullies, sheet erosion or plant pedastaling, depressions/ ponding, sedimentation, or differential settlement.
			Poor vegetation	Area greater than 11,000-square feet with poor vigor, disease, pest/insect infestation, grazing, burns, discoloration, or bare ground.
			Weeds present (Refer to weed list in Appendix C)	Identification of reoccurring or wide-spread weeds. (Refer to weed management methods in Table 7.0-2)
			Animal Burrows	Identification of reoccurring or wide-spread animal burrows of any size.
			Surface salts and/or surface crusting	Area greater than 11,000-square feet.
			Structural integrity	Evidence of seepage, differential settlement, cracking, subsidence, sliding, or creep.
			Human intrusion or vandalism	Evidence of damage to the covers such as unplanned excavation, drilling, grading, damage to engineering or access controls.
001	Surface Water Drainage Controls	Monthly and after significant storm events Semiannually	Erosion, obstructions to flow, deterioration, excessive sedimentation, and inadequate vegetation conditions in grass channels/swales. Cracks or concrete degradation in concrete lined channels/swales that may impact drainage, undercutting, subsidence.	Identification of reoccurring or wide-spread maintenance problems due to erosion, ponding or settlement, and chronic low vegetation cover in the drainage swales. Repair requires excavation or other type of intrusive construction where there is a subsurface liner.
001	Cover Soil Thickness	Semiannually	Cover thickness loss	For RCRA-Equivalent and 3-foot covers, soil loss or settlement greater than 3 inches as measured from the top of one or more erosion/settlement monuments. For the 2-foot cover, evidence of soil loss on adjacent RCRA-Equivalent cover slopes or conditions indicating sheet erosion.

(Tetra Tech EC 2008)

Long-term maintenance of covers

Bison – should they graze on the covers?

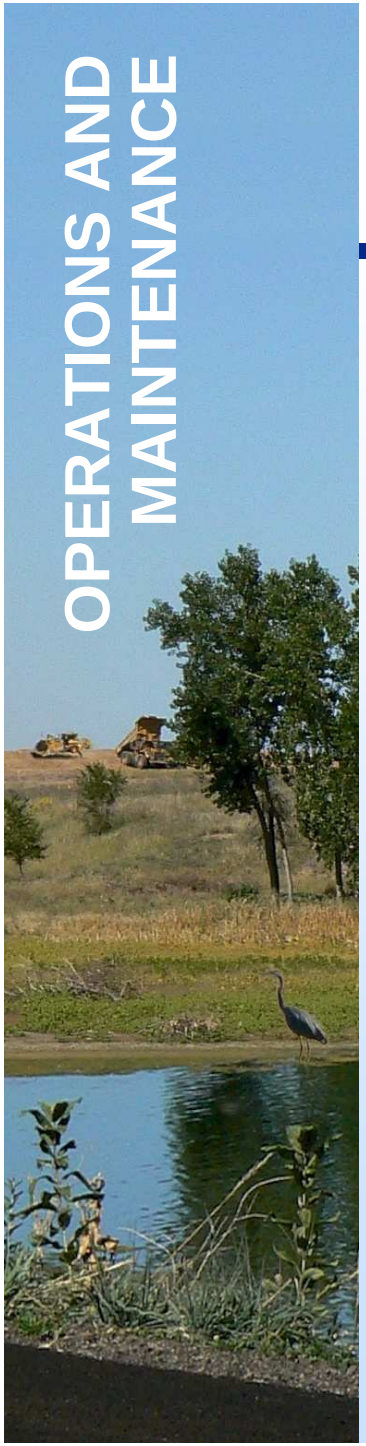
Bison in the Bison Pilot Area (EPA field oversight photographs)



Long-term maintenance of covers

Designing covers for grazing

Cover construction on the Hazardous Waste Landfill with 20% to 33% side slopes (top); 3% side slopes on the RCRA-Equivalent cover – undergoing revegetation (right) (EPA field oversight photographs)



Long-term maintenance of covers

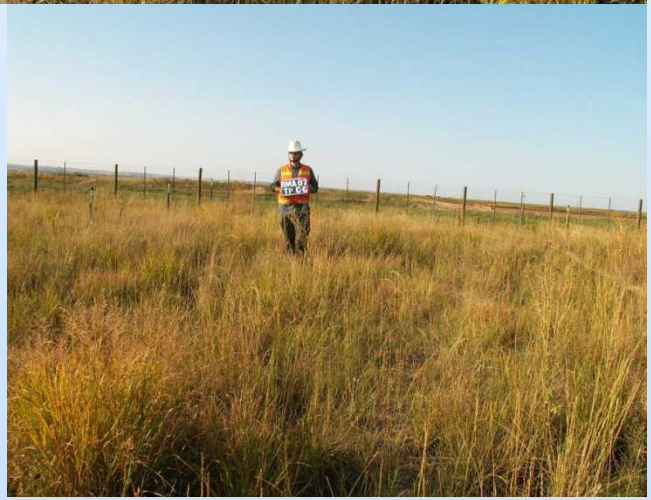
Structures on RCRA Subtitle C Covers

Clockwise from left: articulated concrete blocks drainage channel, power supply and manhole vents, and instrumentation on the Hazardous Waste Landfill cover. (EPA field oversight photographs)

OPERATIONS AND MAINTENANCE

Long-term maintenance of covers

How long should the grass grow?



Grass seedling just after germination (top), in progress (top right), well developed vegetation 10 years after seeding (right).

EPA field oversight photographs)

Conclusion and Lessons Learned

CONCLUSION AND LESSONS LEARNED

Lessons Learned

- **Share a mutual goal**
- **ASSUME that a mutually acceptable solution is possible**

CONCLUSION AND LESSONS LEARNED

The Arsenal's legacy

(EPA field oversight photograph)

The Arsenal's legacy

U.S. Army photograph

For more information, contact :
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