5-18-2004

Uranium Mill Tailings Remediation Performed by the US DOE: An Overview

Paul Robinson

Southwest Research and Information Center

Uranium Mill Tailings Remediation Performed by the US DOE: An Overview

By
Paul Robinson
Research Director
Southwest Research and Information Center
Albuquerque, NM 87106 USA
www.sric.org

May 18, 2004

Table of Contents

Acknowledgements

The author acknowledges and appreciates the valuable contributions of his colleagues at Southwest Research and Information Center, the current and past employees and contractors at DOE's UMTRAP Office, and the many participants in the design and implementation of UMTRAP remediation projects.

He also acknowledges and appreciates the many families of the many men and women who have worked at uranium mills or and the families who lived near uranium mill tailings sites and who have lived with the health risk from those operations.

He also acknowledges and appreciates the many sources of information relied on in preparation of this Overview.

This Overview was funded by a grant from Citizens' Monitoring and Technical Assessment Fund.

Cover Photo

Aerial photograph of Shiprock, New Mexico uranium mill tailings pile and surrounding area, 2002. The view is looking toward the south and shows the San Juan River in the foreground, the covered Shiprock tailings pile in the left center and the Navajo community of Shiprock in the right hand portion of the image.

Source: Navajo Nation Abandoned Mine Land/Uranium Mill Tailings Remedial Action Program at: http://www.navajoaml.osmre.gov/UMTRA/NUcover.htm

Summary

This Overview summarizes key public policy, environmental impact and cost aspects of the Uranium Mill Tailings Remedial Action Program (UMTRAP). It has been prepared in order to make information about the first Unites States Department of Energy (DOE) long-term nuclear legacy waste management program more available to the public and decision-makers concerned about radioactive waste management and clean-up.

Uranium mill tailings are waste produced from the processing of ores mined for their uranium content. Uranium mills produce a refined product, uranium oxide – a uranium oxide, U3O8, commonly called "yellowcake" - and wastes, called tailings – a mixture of finely crushed, chemically treated ore and mill reagents. The tailings contain 85% of the original radioactivity (only uranium is removed), in most cases and almost all heavy metals associated with the ore. Uranium mill tailings, for almost exclusively in Western States, were produced at approximately 50 sites around the USA. Of those, 24 tailings sites are covered in DOE's UMTRAP program.

Uranium mill tailings have been undergoing a federally required clean-up program since 1978, considerably longer than other category of radioactive wastes under DOE authority. In carrying out its responsibilities pursuant to the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA 1978), DOE conducted an extensive research and development program before it begin to address waste containment and clean-up. This Overview of DOE's performance of its UMTRCA mandate 25-years later provides an introduction to the long-term environmental protection and cost effectiveness of the longest running DOE waste management program.

The report summarizes the history and scope of the UMTRAP effort, the current status of UMTRAP sites, on-going ground water remediation efforts, the cost of UMTRAP clean-up projects, estimates of future costs, DOE recognition of UMTRAP as a model program.

Uranium mill tailings were among the first hazardous nuclear weapons production legacy wastes to be created as their production go back to 1940s and the places were uranium was first mined and milled in the US. The first several decades of uranium mining and milling were conducted with little or no effort to control radioactive or non-radioactive emissions from uranium mill tailings. UMTRCA established clean up requirements for all US uranium mill tailings sites. The Act passed Congress in 1978 following disclosure of the use of tailings in homes and schools and other tailings-related pollution problems at a time when a uranium production "boom" to feed a new generation of nuclear power stations was projected.

The Act's purpose, as drafted by the US Congress is:

> "….to provide for the stabilization, disposal, and control in a safe and environmentally sound manner of … tailings in order to prevent or minimize radon diffusion into the environment and to prevent or minimize other environmental hazards from such tailings." and
>
> "to regulate mill tailings during uranium or thorium ore processing at active mill operations and after termination of such operations in order to stabilize and

> control such tailings in a safe and environmentally sound manner and to minimize or eliminate radiation health hazards to the public. (UMTRCA section 7901).

UMTRCA delegates DOE the responsibility for the remediation of the 22 uranium mill and mill tailings sites were all uranium produced before 1970 was purchased by the US Government for it nuclear weapons programs, as required by federal law. These sites are at:

Salt Lake City, Utah; Green River, Utah; Mexican Hat, Utah; Durango, Colorado; Grand Junction, Colorado; Rifle, Colorado (two sites)[New Rifle and Old Rifle]; Gunnison, Colorado; Naturita, Colorado; Maybell, Colorado; Slick Rock, Colorado (two sites) [New Slick Rock and Old Slick Rock]; Shiprock, New Mexico; Ambrosia Lake, New Mexico; Riverton, Wyoming; Converse County [Spook site], Wyoming; Lakeview, Oregon; Falls City, Texas; Tuba City, Arizona; Monument Valley, Arizona; Lowman, Idaho; and Canonsburg, Pennsylvania

Projected to cost $150 – 200 million in 1978, the UMTRAP program had cost approximately $2 billion dollars by the year 2000. In this Overview, the cost of remediation for each sites is presented as cost in $/ton; $/unit of radiation (Ra 226) in the tailings and $/pound of yellowcake produced at the site. When the uranium mills at the UMTRAP sites were operating, they sold their yellowcake for $8/pound, a price set by the sole legal uranium owner at the time, the US Government's Atomic Energy Commission (AEC).

As measured by cost per ton of tailings - and shown in Figure 1 – UMTRAP costs ranged from $18 at Mexican Hat and $19 at Monument Valley to $149 at Canonsburg and $122 at Lowman, Idaho and $123 at Naturita. The average (mean) cost of UMTRAP project activities is $73 per ton of tailings.

As measured by cost per Curie of Radium 226 contained in the tailings – as shown in Figure 2, remediation costs ranged from $21,600 at Ambrosia Lake and $30,268 at Mexican Hat to $1,536,167 at Lowman, Idaho and $1,092,810 at Naturita, Colorado to $1,536,167. The average (mean) cost of the UMTRAP project activities is $105,250 per Curie of Radium 226 contained in the tailings.

As measured by pound of yellowcake (U3O8) produced at the site – as shown in Figure 3, costs ranged from $3.07 at Ambrosia Lake and $3.34 at Shiprock to $50.47 at Lowman, Idaho and $97.27 at Lakeview, Oregon. The average (mean) cost of the UMTRAP project activities is $12.67 per pound of yellowcake produced, more than 50% more than the price paid for yellowcake when the tailings at the UMTRAP sites were produced.

While surface remediation of the UMTRAP sites is essentially complete, ground water contamination continues at most UMTRAP sites including three of the four sites on the Navajo Reservation and the Falls City, Texas site. Active ground water remediation continues at Monument Valley. Shiprock and Tuba City on the Navajo Reservation where contamination - including uranium, selenium, radium, cadmium, sulfate and nitrate - continues to exceed clean-up standards. At Shiprock, the peak uranium concentrations in contaminated ground water in the San Juan River floodplain reached 4.3 mg/l – more than 97 times the uranium MCL of 0.044 mg/l in 2001 (GWP, 2001). At Falls City, a pattern of increasing uranium concentrations continued in 2003 as uranium concentrations in ground water beneath the disposal cell reached 9 mg/l – more than 200 times the uranium MCL of 0.044 mg/l. (DOE 2003) Falls City is one of 12 UMTRAP sites for which DOE has sought NRC approval for Supplemental Standards, or Alternative Concentration Limits, in combination with Institutional Control on land use and water use, as a basis to reduce or eliminate the need to continue active ground water remediation efforts.

Following completion of UMTRAP remediation, DOE has projected costs for long-term surveillance and maintenance (LSTM) activities at UMTRAP sites for 70 years. DOE projections identify the cost of these multi-decade programs for future years and average years in future decades.

DOE projects annual costs at:

Year	Total Annual Cost
2000	\$2.271 million
2006	\$2.105 million
2050	\$1.227 million

Annual average long-term stewardship cost for future decades were projected as:

Decade	Average Annual Cost
Fiscal Years 2000-2010	\$2.325 million
Fiscal Years 2031-2040	\$1.219 million
Fiscal Years 2061-2070	\$1.219 million

These projected costs do not include active ground water remediation costs at sites not yet subject to Nuclear Regulatory Commission (NRC) - approved LSTM plans. Active ground water remediation costs anticipated to exceed \$50 million at Tuba City, Monument Valley and Shiprock through the year 2025.

This review of DOE's "first try" at a comprehensive radioactive waste clean-up program provides unique and important disposal cost and technology benchmarks for assessing the effectiveness of DOE clean-up methods and its capacity to demonstrate "long-term environmental stewardship" across its nuclear weapons complex.

Introduction

Uranium mill tailings present a radioactive waste challenge of uniquely large scale due to their content of radioactive and non-radioactive constituents, their large volume – the largest volume of any category of radioactive waste - and their high water content. Located at sites spread around the country, but mostly in the West, uranium mill tailings were the first radioactive waste to become focus of clean-up federal legislation following passage of the Uranium Mill Tailings Radiation Control Act (UMTRCA) in 1978.

The radioactive and hazardous nature of waste materials from the uranium mining and milling was poorly recognized during the first uranium boom, driven by the Cold War in the 1940s and 1950's. From the mid-1940s through 1966, the United States encouraged uranium exploration, mining and milling to produce raw material for nuclear weapons use. While technical literature was available on the health consequences of exposure to uranium and its decay products, including radium and radon, little of this information was communicated to workers or residents near uranium mining and milling communities. As early as 1952, a US Public Health Service – Colorado Department of Health joint report identified an excess of pulmonary fibrosis among Anglo and Indian millworkers compared with control groups. (FSA 1952 as cited in Dawson 1998, House 1998. See also Robinson, 1998, among other sources)

Among the earliest documents addressing the recognition of the radioactive and non-radioactive hazards of uranium mill tailings is "Waste Guide for the Uranium Milling Industry," US Public Health Service, Department of Health Education and Welfare 1962 (PHS 1962). The "Waste Guide" was prepared:

> "… for use by public health and water pollution control agencies. Mill operators and others in their efforts 1) evaluate the potential hazards associated with mill wastes, 2) to determine the effectiveness of existing mill waste control practices, 3) to estimate the effect of future mills on their local stream environment and locate mill sites so as to minimize such adverse effects and 4) to find more effective methods of waste control and treatment." (PHS 1962, p. 1)

The research that lead to "The Waste Guide" began in 1957, though US federal law did not formally recognize uranium mill tailings as a category of radioactive waste or require specific management plans for uranium mill tailings until 1978.

A substantial body of literature has been developed which addresses public and occupational health impacts of uranium mining and milling, including the evolution of knowledge about health impacts through the 1940s and 1950s. Useful sources include:

- "Uranium Miners Resources", in the Final Report of the Radiation Exposure Compensation Act Committee Submitted to the Human Radiation Interagency Working at: http://tis.eh.doe.gov/ohre/roadmap/uranium/ (DOE 1996)
- "Radiation Workers Justice Act of 1988," Hearing Immigration and Claims Subcommittee of Judiciary Committee of the House of Representatives, at: http://commdocs.house.gov/committees/judiciary/hju59930.000/hju59930_0f.htm (House 1998) among other sources.

UMTRAP and Uranium Mill Tailings Information Sources on the Internet

Extensive literature is available on the internet on environmental management aspects of uranium mill tailings, effects of uranium mine and mill wastes on health and communities, and other aspects of uranium production and use. This literature extends well beyond the scope of the UMTRAP program, and includes materials directly available on-line, citation to research available from governmental, private and academic sources.

Two particularly useful sources are:

- DOE Grand Junction office website at www.gjo.doe.gov - the home page for DOE's UMTRAP activities - and
- "WISE Uranium" (World Information Service on Energy Uranium Project) – an independent non-governmental organization compilation - at: http://www.antenna.nl/wise/uranium

Specific information on individual UMTRAP uranium mill tailings sites can be identified through either of these sources, or use of available search engines.

The primary sources for UMTRAP information is the agency responsible for the program. DOE's Grand Junction Office (GJO) homepage at www.gjo.doe.gov was updated to reflect the inclusion of the UMTRAP program in the DOE Office of Legacy Management – at: http://www.lm.doe.gov - in May 2004. The Legacy Management Program at the Grand Junction Office is the host for all current and planned DOE UMTRAP activities including groundwater remediation, long-term surveillance and maintenance, stakeholder involvement, and public relations. As currently structured, the Legacy Management Activities at GJO includes responsibility for long-term surveillance and monitoring for all DOE sites determined to have completed remediation efforts.

The site includes links to general information, legal requirements, newsletters, media releases and technical documents related to UMTRAP and all the UMTRAP sites. It is a source for recent information about those sites including 2003 Annual Inspection Reports (DOE 2003) and other activities conducted in response to ground water protection requirements and Long-term Surveillance and Maintenance Plans (LTSMP). Selected archival materials are available through searches on each of the UMTRAP sites and other Legacy Management sites as well as a selected portion of the voluminous technical literature generated by UMTRAP staff and contractors.

Mail and Email addresses are available at the GJO website. Written or phone contact with GJO can be directed to:

Stakeholder Relations
U.S. Department of Energy
Office of Legacy Management
2597 B 3/4 Road, Grand Junction, CO 81503
(970) 248–7727

The “Wise Uranium Project” website at: http://www.antenna.nl/wise/uranium provides an independent electronic library on uranium mining and milling, uranium’s role in the nuclear fuel cycle and associated social and environmental consequences. It includes information on the UMTRAP sites through links to DOE’s www.gjo.doe.gov site and other UMTRAP-related information, such as General Accounting Office reports, Congressional Hearing, and information from regulatory agencies and citizen organizations not posted by DOE.

The WISE Uranium Project extends well beyond UMTRAP and is international in scope. It provides links to information about uranium use, uranium mining, milling and processing facilities and uranium production-related health and public policy concerns around the world. The site provides both an easily accessed compilation of UMTRAP information and broad spectrum of materials from community-based and non-governmental organizations, uranium companies and trade associations, national state governments, international agencies, press sources and technical health-related and scientific literature world-wide.

An email address is available on the Wise Uranium Project homepage. Written or phone communications can be directed to:

WISE Uranium Project
Am Schwedenteich 4, 01477
Arnsdorf, Germany
Phone: +49-35200-20737

Characteristics of Uranium Mill Tailings and the Hazardous Materials They Contain

The processing of natural uranium to make nuclear weapons or reactor fuel begins with the mining and milling of uranium ore. As was true with other aspects of the Federal Government's nuclear weapons programs in its first several decades, control of uranium mining and milling wastes and their hazardous materials constituents was largely ignored during the government-sponsored uranium boom of the early Cold War years. The nuclear waste legacy of that boom is dozens of uranium mill tailings sites covering thousands of acres. Those sites are all in the West as wastes from the mining and milling operations were usually deposited as close a possible to the places where uranium ore was processed and those sites are in the West, with one exception - Canonsburg, PA..

Uranium mill tailings are waste products of the milling of natural uranium ore. Milling involves grinding, separating and concentrating natural uranium ore to produce uranium oxide – U3O8, called "yellowcake". The yellowcake produced at the mills is the source material - the raw material – processed to produce the enriched uranium components at the core of nuclear weapons and power reactors.

Uranium mill tailings are the largest volume radioactive waste produced in the nuclear fuel cycle. More than 200,000,000 tons of tailings have been produced by the year 2000 at more than 50 sites in the US. Approximately 25,000,000 tons, all generated before 1970 in the first uranium mining and milling boom, are found in the 24 sites addressed by the UMTRAP activities.

Uranium mill tailings accumulate rapidly as uranium ore is processed. Uranium ores mined in the US prior to 1970 occurred at a uranium concentration – ore grade - of approximately 0.1% natural uranium. To concentrate the uranium ore to produce yellowcake - typically 95% U3O8 (uranium oxide) with the appearance of a yellow powder - uranium mills would process 1000 tons of ore at 0.1% uranium for every one ton of yellowcake produced.

Waste liquids are an important component of uranium mill tailings and play a major role in the release of contaminants by seepage through tailings piles.. They including make up water and reagents discarded after use in the uranium mills discarded and are produced in volume similar to the volume of tailings. Uranium mill tailings are typically produced as a slurry containing approximately 50% solid and 50% liquid. While modern mills may use "state-of-the-art" tailings handling and disposal technologies, mills operating prior to 1970 general dumped tailings on land near the mill. The solid tailings were often piled up in mounds at the dumpsites with little or no site preparation or engineered containment systems. The liquid tailings were often collected in unlined ponds on top of the solid tailings or placed excavated unlined ponds near the mill. (PHS 1962)

Typical physical and chemical characteristics of uranium mill tailings are shown in the tables below. Uranium mill tailings made up of material that are about 50% sand grain size - called "sands" - and 50% clay-size - called "slimes." The waste ore and liquids in mill tailings contain most of the original radioactivity of the ore. Only uranium is removed from the ore by the milling process leaving approximately 85% of the original radioactivity in the ore and almost all of uranium’s decay products, including radium, thorium, radon, polonium and isotopes of radioactive lead remain in the tailings.

Typical Physical and Chemical Characteristics of Uranium Mill Tailings (a)

Tailings component	Particle size (in micrometers - µm)	Chemical composition	Radioactivity characteristics
Sands	75 to 500	Silica Dioxide - SiO_2 - with <1 wt % complex silicates and metals oxides including aluminum, iron, magnesium, calcium, sodium, potassium, selenium, manganese, nickel, molybdenum, zinc, uranium, vanadium, lead, and arsenic	0.004 to 0.01 wt % uranium oxide – “yellowcake” -U_3O_8 (b) For acid leach mill tailings (c) – 26 to 100 picoCuries (pCi) Radium-226/gram; 70 to 600 picoCuries (pCi) Thorium-230/gram
Slimes	45 to 75	Small amounts of SiO_2, but mostly very complex clay-like silicates of Na, Ca, Mn, Mg, Al, and Fe; also metallic oxides	U_3O_8 and Radium 226 are almost twice the concentration present in the sands For Acid leach tailings: (c) 150 to 400 pCi ^{226}Ra/g; 70 to 600 pCi ^{230}Th/g
Liquids	(d)	Acid leaching: pH 1.2 to 2.0; Na^+, NH_4^+, $SO_4^{\ 2}$, Cl , and $PO_4^{\ 3}$; dissolved solids up to 1 wt %	Acid leach tailings liquids: 0.001 to 0.01% U; 20 to 7,500 pCi ^{226}Ra/liter; 2,000 to 22,000 pCi; ^{230}Th/liter
		Alkaline leaching: pH 10 to 10.5; $CO_3^{\ 2}$ and HCO_3 ; dissolved solids 10 wt %	Alkaline leach tailings liquids: 200 pCi ^{226}Ra/l; essentially no ^{230}Th (insoluble)

a Source: U.S. Nuclear Regulatory Commission, *Final Generic Environmental Impact Statement on Uranium Milling, Project M-25*, NUREG-0706, Washington, D.C. (September 1980) as cited at: http://web.em.doe.gov/idb97/tab53.html

b U_3O_8 content is higher for acid leaching than for alkaline leaching.

c Separate analyses of sands and slimes from the alkaline leaching process are not available. However, total ^{226}Ra and ^{230Th} contents of up to 600 pCi/g (of each) have been reported for the combined sands and slimes.

d Particle size does not apply. Up to 70% by volume of the liquid may be recycled. Recycle potential is greater in the alkaline leach mill process.

Uranium usually is found in nature as combination of three isotopes – uranium 234, uranium 235 and uranium 238, as summarized below. Yellow cake contains uranium as a combination of these “natural uranium” isotopes. Extensive processing is necessary to enrich, or increase, the concentration of uranium 235 – from 0.7% of the total uranium in "natural uranium" – for use in power reactors - requiring enrichment to 3 – 5% uranium 235 - or weapons manufacturing requiring enrichment to more than 95% uranium 235 - as it is the fissionable isotope of "natural uranium."

Uranium Isotopes Occurring in "Natural Uranium" (IEER 2000)

Isotope	Percent in natural uranium	No. of Protons	No. of Neutrons	Half-Life (in years)
Uranium-238	99.284	92	146	4.46 billion
Uranium-235	0.711	92	143	704 million
Uranium-234	0.0055	92	142	245,000

Uranium milling concentrates only uranium and leaves most of the uranium's radioactive decay products in the tailings. Because uranium 238 makes up more than 99% of "natural uranium," its decay products are source of most of the concern related to radioactive releases from uranium mill tailings. These decay products include very long half-life isotopes – such as radium 226 and thorium 230 - and very short half- life – radon 222 and its decay product, called "radon daughters" or "radon progeny" which have well documented health effects. (DOE 1996, House 1998). The uranium 238 decay chain, including half-life and type of radiation released during radioactive decay is summarized below.

URANIUM 238 DECAY CHAIN – Read from left to right. Arrows indicate decay (IEER 2000)

Uranium-238 ==> (half-life: 4.46 billion years) alpha decay	Thorium-234 ==> (half-life: 24.1 days) beta decay	Protactinium-234m ==> (half-life: 1.17 minutes) beta decay
Uranium-234 ==> (half-life: 245,000 years) alpha decay	Thorium-230 ==> (half-life: 75,400 years) alpha decay	Radium-226 ==> (half-life: 1,600 years) alpha decay
Radon-222 ==> (half-life: 3.82 days) alpha decay	Polonium-218 ==> (half-life: 3.11 minutes) alpha decay	Lead-214 ==> (half-life: 26.8 minutes) beta decay
Bismuth-214 ==> (half-life: 19.9 minutes) beta decay	Polonium-214 ==> (half-life: 163 microseconds) alpha decay	Lead-210 ==> (half-life: 22.3 years) beta decay
Bismuth-210 ==> (half-life: 5.01 days) beta decay	Polonium-210 ==> (half-life: 138 days) alpha decay	Lead-206 (stable)

From the perspective of potential health impacts the most important radioactive component of uranium mill tailings is radium, which decays to produce radon. Naturally occurring potentially hazardous substances associated with specific uranium ores and uranium mill tailings also frequently include heavy metals with significant associated health risks such as selenium, molybdenum, cadmium, arsenic, and lead. Potentially hazardous mill reagents remaining in tailings can include chloride, nitrate, ammonia and sulfate as well as organic compounds. (Landa 1980)

The liquid portion of the tailings has potential to seep through the solid tailings and carry radioactive and hazardous constituents into nearby soils, ground water and surface water. Radioactive and hazardous material releases through air or water pathways at uranium mill sites tailings sites during 1940s and 1950s provided the basis for the US government to initiate the first identified investigation of uranium mill tailings hazards in 1957. (PHS 1962)

The US Environmental Protection Agency (EPA) characterizes the exposure risks associated with uranium mill tailings as follows:

> "Uranium mill tailings can adversely affect public health. There are four principal ways (or exposure pathways) that the public can be exposed to the hazards from this waste.
>
> "The first is the diffusion of radon gas directly into indoor air if tailings are misused as a construction material or for backfill around buildings. When people breathe air containing radon, it increases their risk of developing lung cancer.
>
> "Second, radon gas can diffuse from the piles into the atmosphere where it can be inhaled and small particles can be blown from the piles where they can be inhaled or ingested.
>
> "Third, many of the radioactive decay products in tailings produce gamma radiation, which poses a health hazard to people in the immediate vicinity of tailings.
>
> "Finally, the dispersal of tailings by wind or water, or by leaching, can carry radioactive and other toxic materials to surface or ground water that may be used for drinking water." (EPA 2004)

The Agency for Toxic Substance and Disease Registry (ATSDR), part of the US Centers for Disease Control provides detailed information on health effects associated with the radioactive and non-radioactive hazardous constituents of uranium mill tailings through it toxicological profiles at: http://www.atsdr.cdc.gov/toxpro2.html. (ATSDR 2004)

UMTRAP Uranium Mill Tailings Sites Before and After Remediation

Prior to the passage of UMTRCA in 1978, the UMTRAP sites had been left as abandoned industrial sites with little if any effort to control tailings materials or the potential for wind-borne or water-borne releases from the sites. (DOE 2002a). Since that time, UMTRAP has conducted extensive remediation activities including reshaping of tailings facilities, building demolition, installing seepage controls, constructing erosion-resistant and radon-barrier covers, and in some cases completely removing and relocating of tailings to meet the standards established by UMTRCA and the agencies responsible for its enforcement.

The final disposal cells for UMTRAP uranium mill tailings sites have the appearance of enormous mounds 15 – 100 feet tall with low angle – 5:1 horizontal:vertical or less - side slopes covered with rock, soil and vegetation. Remediated tailings sites cover large areas of ground though they are considerable smaller than the site covered by the original mills, tailings facilities, and surrounding affected areas prior to remediation. Final UMTRAP disposal sites range from eight acres at Lowman, Idaho and 16 acres at Lakeview, Oregon to 127 acres at Falls City, Texas. Uranium mill sites covered 50 - 200 or more acres, in most cases. Lakeview, Oregon for example involved a 258 acres original mill site consolidated to a 16 acre disposal cell. The Riverton, Wyoming site is the only UMTRAP tailings pile disposed of below grade – or below the original land surface – as it has been remediated by disposal in an inactive open uranium mine at Gas Hills, Wyoming.

Due to their enormous size, UMTRAP sites can be seen as whole by aerial photographs. Aerial photographs of five UMTRAP sites showing their appearance before and after surface remediation are included as Appendix B in this Overview. These before and after picture demonstrate the shape contrast between the condition of the mill tailings site before remediation and after.

Additional images of these and other UMTRAP sites can be accessed though the www.gjo.doe.gov among other sources.

DOE's UMTRAP Project is a Unique and Significant Example of a Complete Radioactive Waste Management Program

For the public and policy-makers the dual challenges of:

1) establishing clean-up standards for radioactive wastes and
2) assuring that the responsibility for post-clean up monitoring and maintenance of waste sites is guaranteed for as long as needed

are fundamental concerns and have been the focus of political and social debate for decades.

The DOE UMTRAP project is the first large-scale program to conduct and complete remediation at nuclear legacy sites. The remediation efforts and the documents that detail them provide a unique, full-scale, multi-decade record of a radioactive and hazardous waste management program. The pattern of policy decisions, waste site clean up technologies used and their related costs provide valuable case studies and lessons learned for decision-makers and the public addressing nuclear waste legacy clean-up efforts in the US and around the world.

In 1978, the public policy concern for effective long-term control of radioactive wastes was stated as:

> "The development of a long-term waste management philosophy requires the acceptance of a basic set of management criteria. Our societies' approach has, as its basis tenet, that the present generation of waste managers should leave the wastes in such a manner that there is no foreseeable threat to future generations and future generations will not be involved in the care of the wastes.
>
> "Implied is that the future bleed rate of contaminants from waste management site should not exceed present regulatory levels, and not rely on continued monitoring to demonstrate that fact. Any acceptable long term solution must not rely solely on a social management system, but rather on management controlled by those basic geochemical and biochemical cycles which have been determining the flux rates of radionuclides through the open environment during the evolution of life on Earth." (Lush 1978, cited in Landa 1980)

Societal concerns about radioactive waste management have grown to become a prominent global issue in the decades since 1978. As DOE's UMTRAP effort has a 25-year track record, it provides among the first opportunities to assess the effectiveness of a radioactive waste programs designed to "leave the wastes in such a manner that there is no foreseeable threat to future generations and future generations will not involved in the care of the wastes." UMTRAP provides an example of how expensive that goal is to attain, and indeed whether it is truly attainable as the risks at the mill tailings sites have been isolated, or contained, rather than "eliminated."

The task of providing a permanent remedy to a radioactive waste problem is one of the specific objectives of The Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA 1978) .

The Act begins with the statement:

> "The Congress finds that uranium mill tailings located at active and inactive mill operations may pose a potential and significant radiation health hazard to the public, and that the protection of the public health, safety, and welfare and the regulation of interstate commerce require that every reasonable effort be made to provide for the stabilization, disposal, and control in a safe and environmentally sound manner of such tailings in order to prevent or minimize radon diffusion into the environment and to prevent or minimize other environmental hazards from such tailings."

Providing a comprehensive evaluation of the effectiveness of UMTRAP to meet this standard is a very complex task well beyond the scope of this Overview. It provides a summary of the UMTRAP program by providing a condensed description of the nature of the uranium mill tailings and their associated hazards, the applicable legal and regulatory framework, the completeness of ground water remediation efforts, remediation and long-term management costs, and sources of further information.

This material provides a basis for comparisons between UMTRAP standards, technologies and costs and other radioactive waste management activities in the US and other countries.

Uranium Mill Tailings Radiation Control Act (UMTRCA) and Associated Implementing Regulations

UMTRCA established clean up requirements for all US uranium mill tailings sites and defined uranium mill tailings as a radioactive waste, as "by-product material" within the scope of the Atomic Energy Act for the first time. As authorized by Congress and signed by President Jimmy Carter in 1978, the Act's purpose is:

> "….to provide for the stabilization, disposal, and control in a safe and environmentally sound manner of … tailings in order to prevent or minimize radon diffusion into the environment and to prevent or minimize other environmental hazards from such tailings,"
>
> "to provide in cooperation with the interested States, Indian tribes, and the persons who own or control inactive mill tailings sites, a program of assessment and remedial action at such sites, including, where appropriate, the reprocessing of tailings to extract residual uranium and other mineral values where practicable, in order to stabilize and control such tailings in a safe and environmentally sound manner and to minimize or eliminate radiation health hazards to the public, and
>
> "a program to regulate mill tailings during uranium or thorium ore processing at active mill operations and after termination of such operations in order to stabilize and control such tailings in a safe and environmentally sound manner and to minimize or eliminate radiation health hazards to the public. (Section 7901)

UMTRCA defines "residual radioactive material" as:

> "waste (which the Secretary [of DOE] determines to be radioactive) in the form of tailings resulting from the processing of ores for the extraction of uranium and other valuable constituents of the ores; and other waste (which the Secretary determines to be radioactive) at a processing site which relate to such processing, including any residual stock of unprocessed ores or low-grade materials."

The Act defines the term "tailings" as:

> "the remaining portion of a metal-bearing ore after some or all of such metal, such as uranium, has been extracted." (UMTRCA Section 7911)

UMTRCA provides for public participation in its implementation stating,

> "In carrying out the provisions of [the Act], including the designation of processing sites, establishing priorities for such sites, the selection of remedial actions, and the execution of cooperative agreements, the Secretary [of DOE], the Administrator [of EPA], and the [Nuclear Regulatory] Commission shall encourage public participation and, where appropriate, the Secretary shall hold public hearings relative to such matters in the States where processing sites and disposal sites are located." (UMTRCA Section 7921)

UMTRCA addressed uranium mill tailings produced from uranium acquired for use in manufacturing nuclear weapons in Title I of UMTRCA in which the responsibility Title I tailings, which became the UMTRAP sites, is delegated to DOE. The sites covered by Title I of the Act were the sites where uranium was produced before the end of 1970 solely for sale to the Atomic Energy Commission (AEC) as, beginning in the mid-1940s, the US

Government was the sole legal owner of uranium in the US. The AEC has been restructured since 1970 and the responsibilities derived from the AEC authorities are currently the responsibility of the Department of Energy.

Tailings produced after 1970 as a by-product of uranium commercially produced for use as nuclear reactor fuel were listed in Title II of UMTRCA. Responsibility for Title II tailings was delegated, primarily, to the companies that owned the Title II sites. Both Title I and Title II sites were subject to a regulatory system defined in UMTRCA that was adopted by the Nuclear Regulatory Commission to attain standards set by the US Environmental Protection Agency. When Title II sites and other nuclear waste legacy sites complete reclamation activities, most of the sites will have their ownership conveyed to DOE for long-term surveillance and maintenance, activities currently identified in DOE's Office of Legacy Management mission and function.

UMTRCA defines the sites under the responsibility of DOE include:

> "any site, including the mill, containing residual radioactive materials at which all or substantially all of the uranium was produced for sale to any Federal agency prior to January 1, 1971 under a contract with any Federal agency" and "any other real property or improvement thereon which (i) is in the vicinity of such site, and (ii) is determined by the Secretary [of DOE], in consultation with the Nuclear Regulatory Commission, to be contaminated with residual radioactive materials derived from such site." (UMTRCA Section 7911.6.A and 6.B)

These sites are include 22 locations:

> Salt Lake City, Utah; Green River, Utah; Mexican Hat, Utah; Durango, Colorado; Grand Junction, Colorado; Rifle, Colorado (two sites)[New Rifle and Old Rifle]; Gunnison, Colorado; Naturita, Colorado; Maybell, Colorado;
> Slick Rock, Colorado (two sites) [New Slick Rock and Old Slick Rock];
> Shiprock, New Mexico; Ambrosia Lake, New Mexico; Riverton, Wyoming
> Converse County [Spook site], Wyoming; Lakeview, Oregon; Falls City, Texas
> Tuba City, Arizona; Monument Valley, Arizona; Lowman, Idaho; and
> Canonsburg, Pennsylvania

The "other real property" outside the mill sites that were contaminated with tailings became known as "vicinity sites" and includes homes, fields, schools and other buildings or land contaminated with tailings removed from the Title I sites. More than 4000 homes, 16 schools and other locations were cleaned-up to standards set by EPA as part of the UMTRAP program. These sites were remediated to reduce or eliminate indoor concentrations of radon and radon decay products - radioisotopes created during the radioactive decay of uranium-238. The management of vicinity sites not a focus of this Overview though an extensive body of information is available in this portion of the DOE UMTRAP effort.

Regulations were adopted by EPA and NRC to implement the authorities provided in UMTRCA. EPA adopted a set of performance standards applicable to uranium mill tailings. NRC adopted a set of design and review criteria for review and approval of uranium mill tailings remediation plans. The EPA standards, "Health and Environmental Protection

Standards for Uranium and Thorium Mill Tailings," (EPA 1983) are codified as 40 CFR 192 and available online at: http://www.gjo.doe.gov/lm/documents/cfr/Sec192.pdf.

NRC adopted "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material From Ores Processed Primarily for Their Source Material Content" (NRC 1985) codified at 10 CFR 40 Appendix A on line at: http://www.nrc.gov/reading-rm/doc-collections/cfr/part040/part040-appa.html.

These UMTRCA regulations, standards and criteria have served as guides and measuring points for UMTRAP and Title II clean up efforts since the early 1980s, and remain in force with only minor changes since that time. These US mill tailings remediation standards, regulations and criteria have also served a model for uranium mill tailings management requirements in other uranium producing countries and the International Atomic Energy Agency. "The Long-term Stabilisation of Uranium Mill Tailings: Final Report" (IAEA 2003) is among the most recent examples of the role of the US standards as an international model.

In general, these standards require:

- assessment of the environmental setting for the wastes including surface, geologic and hydrogeologic evaluations to determine site conditions and the extent of existing problems;
- development of remedial measures to minimize or eliminate surface and subsurface contamination, including ground water contamination, to specific numerical criteria; and
- demonstration that remedial measures will isolate wastes for up to 1000 years, but in no case less than 200 years, by measures designed to insure geotechnical stability, erosion resistance and containment of airborne and waterborne radionuclides and non-radioactive contaminants.

Appendix C provides a summary of the NRC 10CFR40 Appendix A Criteria adopted to implement EPA's 10CFR192 Standards. Appendix C including the list of "Maximum Contaminant Levels (MCLs) for Protection of Ground Water" from EPA's regulations that were incorporated into the NRC Appendix A Criteria without change.

The National Environmental Policy Act (NEPA) and its associated public involvement activities have been a fundamental part of the decision-making for key programmatic aspects of UMTRAP and all UMTRAP sites. In the 1980s and 1990s, NEPA-required studies, either Environmental Impact Statement or Environmental Assessments, were conducted for all UMTRAP sites. The most recent program-wide UMTRAP Environmental Impact Statement was part of the establishment of the UMTRAP Ground Water Project and took approximately six years, 1991 – 1997, to complete. The most recent UMTRAP Environmental Assessment was conducted in association with Ground Water Project activities at the Shiprock sites. (GWP 2001)

Summary of UMTRAP Performance After 25 Years of Effort

UMTRAP has been on the job for more than 20 years. During this period, nearly $2 billion worth of uranium mill tailings clean-up work has been conducted 24 project sites. Surface remediation work is almost complete – only one UMTRAP disposal site, at Grand Junction, Colorado, remains open, through year 2023, as a repository for future UMTRAP wastes. Ground water remediation is currently continuing at several sites and incorporates active and passive remediation processes. All sites are subject to long-term surveillance and maintenance programs currently projected to occur for at least 70 years.

The decades since passage of the Act have seen a wide array of programs developed and implemented around the world to address the hazards in uranium mill tailings, many of which echo requirements and methods developed to comply with UMTRCA. This Overview focuses on succinct portion of the uranium mill tailings legacy addressed by the DOE's Uranium Mill Tailings Remedial Action Program (UMTRAP) because of its implications for other radioactive waste management challenges facing communities and governmental agencies in the US and other countries.

While UMTRAP is approaching completion of the surface and ground water remediation portions of its responsibility, active ground water remediation at selected site is proposed to continue through year 2025 and a UMTRAP repository at Grand Junction will remain open for disposal through year 2023. Though the radioactive and non-radioactive hazards associated with include material with half-lives of more than 1,000 years and non-radioactive hazardous material that present a permanent source of risk, DOE has projected post-remediation activities only for a 50 – 70 year period. This period is very short compared to regulatory requirement to " be effective for 1,000 years, to the extent reasonably achievable, and in any case, for at least 200 years." (NRC 1985, Technical Criterion 6, as quoted in Appendix C of this Overview)

Post-remediation activities are the focus of Long-term Surveillance and Management Plans (LTSMP), the mechanisms DOE has established for all future oversight and environmental management of the UMTRAP sites and other remediated nuclear legacy sites. While DOE has projected a multi-decade series of long-term surveillance and maintenance measures, no financial guarantees, trust funds or endowed funds have been established to insure that all necessary long-term surveillance and maintenance activities will be conducted. (Robinson 2002)

While the UMTRAP sites have been managed as elements in a multi-site program, the individual sites themselves have unique characteristics that reflect site-specific ecological conditions and human activities, radioactive content and geochemical nature of the tailings and impacted soil and water, and geologic and hydrologic conditions.

Appendix A provides several tables that summarize key aspects of the UMTRAP sites. **TABLE 1 - Status of Department of Energy Uranium Mill Tailings Remedial Action Project (UMTRAP) Sites, 2002** presents a general summary of the UMTRAP sites. It provides a compilation identifying the location, tailings volume, tribal land involvement, status in DOE's Long-term Surveillance and Maintenance (LTSM) Program, and status of Groundwater Remediation and other Site Activities.

Table 1 lists all the original UMTRAP sites in Arizona, Colorado, Idaho, New Mexico, North Dakota, Oregon, Texas, Utah and Wyoming, and the site at Canonsburg, Pennsylvania. The Table reflects:

1) consolidation of the New Rifle and Old Rifle, Colorado sites into one site during remediation; and
2) revocation of the UMTRCA status of the two North Dakota sites – Belfield and Bowman, North Dakota – as a result of the State of North Dakota not providing the state funding required by UMTRCA for remediation by DOE.

The volume of uranium mill tailings at the UMTRAP sites ranged from a low of 150,000 tons (0.15 million tons) at the Lowman, Idaho site to 4,200,000 tons (4.2 million tons) at the Grand Junction, Colorado site, with the average UMTRAP tailings pile containing approximately 1,000,000 tons. (The North Dakota Sites – Belfield and Bowman – were the smallest of the original list at 50,000 tons (0.05 million tons) and 80,000 tons (0.08 million tons) respectively.)

Four of the UMTRAP sites lie on Tribal land – lands within the reservation of a Native American tribe. The four sites – Monument Valley, Arizona; Tuba City, Arizona; Shiprock, New Mexico; and Mexican Hat, Utah – are all found on the reservation of the Navajo Nation. DOE established a government-to-government relationship with the Navajo Nation to provide for remediation and long-term monitoring and maintenance of the four Navajo UMTRAP sites without requiring the Navajo Nation to relinquish ownership of the sites. The Navajo Nation portion of this program is administered by the Navajo Nation Department of Natural Resources, Abandoned Mine Land/UMTRA Department available online at: http://www.navajoaml.osmre.gov/UMTRA/NUcover.htm. (Navajo 2004)

Annual site inspection and monitoring reports - as recently as 2003 for most UMTRAP sites - and additional documentation on the sites, as well as access to information about all other sites managed for LTSM activities by DOE's Office of Legacy Management are accessible at: http://lts1.gjo.doe.gov/gjoreclog/gjoltssites.htm. (DOE 2004c)

As of 2003, 9 sites – Maybell, Colorado; Lowman, Idaho; Ambrosia Lake, New Mexico; Canonsburg, Pennsylvania; Falls City, Texas; Mexican Hat, Utah; Monticello, Utah; Salt Lake City, Utah; and Spook, Wyoming - had been fully transferred to the LTSM Program.

The remaining 12 sites are locations where ground water remediation activities are continuing or LSTM plans have not yet been approved by NRC, the licensing authority for all sites addressed by UMTRCA. Activities at these sites include active ground water remediation, passive ground water remediation, operation of the open portion of the Grand Junction disposal site, and/or DOE activities seeking to modify the EPA or NRC ground water standards –"attain supplemental standards" - to allow for determinations that site remediation is complete though water quality was not able to be cleaned-up to the level required by UMTRCA-derived standards.

These 12 sites include:

- Three sites - Monument Valley, Arizona; Tuba City, Arizona; and Shiprock, Arizona - undergoing active ground water remediation efforts. Active groundwater remediation is the use of specific technologies or methods to remove, treat or stabilize ground water contaminants at a site;

- Seven sites - Durango, Colorado; Gunnison, Colorado; Naturita, Colorado; Green River, Utah; New Rifle/Old Rifle (consolidated tailings site), Colorado; and Slick Rock, Colorado - undergoing passive ground water remediation. Passive remediation is monitoring natural processes, such the function of natural attenuation or evaporation, as means to stabilize or reduce ground water contamination in combination with institutional controls eliminating human or animal use of the affected ground water;

- One site – Riverton, Wyoming - has a LTSM plan pending before the NRC; and

- One site – Grand Junction, Colorado - where DOE proposes to leave the disposal site for Grand Junction tailings and vicinity site wastes - the Cheney Reservoir site - open for disposal of future UMTRAP waste through the year 2023 and is planning to seek NRC approval for LTSM plans at the remaining portions of the Grand Junction site.

Ground Water Remediation and UMTRAP

Ground water contamination exceeding the UMTRA standards adopted by EPA (MCLs) continues at most of the UMTRAP sites many years after the completion of surface remediation activities. Contamination at these sites is being address through either active or passive remediation approaches. Active ground water remediation continues at Tuba City, Monument Valley and Shiprock - three of the four UMTRAP sites on the Navajo Reservation. At 12 of the UMTRAP sites, noted on Appendix A - Table 1, DOE has sought NRC approval for Supplemental Standards, or Alternative Concentration Limits, and institutional controls on water use as a basis to reduce or eliminate active ground water remediation efforts. At the Falls City, Texas where Supplemental Standards and Institutional Controls have been adopted, uranium concentrations in ground water the disposal site continue to increase and four ground water monitoring wells exceed the MCL for uranium.

As the surface remediation portion of UMTRAP approached completion in the early 1990s, the need for additional long-term ground water remediation measures became apparent to agency staff and the public. Following completion of a prolonged Environmental Impact Statement process, a Ground Water Project – a second phase of UMTRAP was established. The Ground Water Project focused on two strategies to address continuing ground water remediation needs:

1) ***active ground water remediation***, in which specific remedial technologies were applied to reduce or remove ground water contamination, and
2) ***passive ground water remediation*** in which natural attention and institutional controls could be used to prevent spreading of groundwater contamination beyond UMTRAP site boundaries and use of contaminated ground water could be prevented.

Regulatory requirements for the Ground Water Project were established in 1995 as additions to EPA's "Uranium Mill Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," 40 CFR 192. (EPA 1983, the citation includes these1995 additions to the original regulations adopted in 1983). The 1995 amendments to the groundwater protection standards address the control of contaminants in the ground water at UMTRAP disposal sites, cleanup (restoration) of ground water at UMTRAP mill sites, and provide for applications of supplemental standards, where appropriate. The EPA Maximum Contaminant Limits (MCL) in 40 CFR 192 are listed in Appendix C.

In 1978 when UMTRCA was passed, ground water contamination was a major concern at uranium mill tailings sites. Prior to the efforts required by UMTRCA, no measures were required at any of the UMTRAP sites to control seepage of water through the tailings or dispersion of contaminants leached out of the tailings. Early efforts to address this problem included removal of liquids stored on top of tailings in unlined ponds and other surface and subsurface remediation measures to reduce the potential for ground water contamination plumes at the UMTRAP site to continue to spread.

Following surface remediation at UMTRAP sites in the 1980s and 1990s ground water contamination at concentration exceeding applicable standards continued at many sites. In 1993, eight UMTRAP sites - - Tuba City; Durango; Shiprock; Salt Lake City; Monument

Valley; Grand Junction; Gunnison; and Falls City - were still undergoing active ground water remediation due to ground water contaminants – typically uranium, selenium, cadmium, molybdenum, radium, arsenic, and/or nitrate – continuing to exceed applicable standards after completion of surface remediation. (Robinson 1995)

Since 1995, the DOE has sought to attain compliance with ground water standards of 40 CFR 192 through the Ground Water Project by applying a combination of active and passive remediation and a campaign seeking approval for alternative concentration limits, or "Supplemental Standards" in combination with Institutional Controls on site land use and water use. Supplemental Standards that have been sought, and in cases approved, as modifications of the 40 CFR 192 standards to allow approval of ground water remediation at contaminant levels higher than, or less stringent than, than the 40 CFR 192 requirements. Extensive active and passive remediation efforts have been conducted as part of the Ground Water Project's demonstration in support of Supplemental Standards before the NRC.

Ground water contamination and associated active remediation continues at three of the four Navajo UMTRAP sites. 2003 annual LSTM inspection reports and other sources identify the extent of continuing ground water contamination and associated active ground water remediation at Tuba City, Shiprock, and Monument Valley.

The Tuba City portion of the UMTRAP Annual Inspection and Monitoring Report (DOE 2003) section describes long-term ground water contamination at the site associated with four constituents – uranium, molybdenum, selenium and nitrate. DOE 2003 indicates that five of six monitoring wells exceed the uranium MCL and a peak uranium value at the site of nearly 0.7 mg/l – 16 times the uranium MCL of 0.044 mg/l. DOE identifies the continued contamination as a consequence of releases from historical uranium mill operations rather than releases following UMTRAP surface remediation efforts. Active ground water remediation efforts are anticipated at the Tuba City at the site through the year 2011. (DOE 2001, DOE 2002b) Aerial photographs of the Tuba City sites are included in Appendix B.

The Shiprock site is associated with contaminated groundwater affecting shallow alluvial in the San Juan River floodplain bordering the site and weathered and fractured bedrock on "Terraces" south and northwest of the former mill site. An aerial photograph of the Shiprock site is shown on the cover of this Overview. Earlier aerial photographs of the Shiprock site are included in Appendix B.

The spreading ground water contamination at Shiprock affects more than 500 million gallons of groundwater with elevated concentrations of with cadmium, nitrate, radium, selenium, uranium, and net gross alpha. The plume extends beyond the former mill site boundaries and covers an area about 1.6 miles long and about 0.75 miles wide. In 2000, peak uranium values in ground water affected by the Shiprock site reached:

- 4.3 mg/l – 97 times the uranium MCL of 0.044 mg/l - in the contaminated portions of the San Juan River floodplain and
- 3.06 mg/l – more than 47 times the uranium MCL - in contaminated ground water beneath the "terrace" northwest of the tailings site. (GWP 2001)

DOE plans to use active remediation measures to address contamination in affected "terrace" areas through at least the year 2012, and rely on natural flushing to address contaminated groundwater in the San Juan River floodplain. Natural flushing action is anticipated to clean the flood plain aquifer within a period of 75 years, after which the DOE will continue monitoring the aquifer in perpetuity to demonstrate the integrity of the disposal cell and its compliance with remediation standards. (DOE 2001, DOE 2002b)

In January 2004, the Navajo Nation Environmental Protection Agency expressed concern to the UMTRAP Ground Water Project regarding groundwater contaminant migrating from the Shiprock uranium mill tailings site to the northwest stating:

> "…The past six years of data indicate that the terrace plume is migrating to the northwest along the area between Shiprock High and 2nd Wash….
>
> "…This area has seen concentrations of nitrate, selenium, sulfate, and uranium steadily increase since 1998. The concentrations for each of these parameters now exceed the MCLs, benchmarks, and cleanup goals..."(NEPA 2004)

At the Monument Valley site, a plume of contaminated groundwater extends one mile to northeastward from site. Estimated to be up to one-half mile wide and to contain about 4.5 million gallons of groundwater, the plume is exceeds MCLS for nitrate, radium, uranium, and possibly net gross alpha radiation. Active remediation is planned for contaminants exceeding MCLs in the two uppermost bedrock aquifers and an alluvial/dune sand aquifer. (DOE 2001, DOE 2002b)

At Falls City, Texas, uranium concentrations in ground water at the disposal cell reached 9 mg/l – more than 200 times the uranium MCL of 0.044 mg/l – in 2003. The uranium concentration in ground water at the disposal cell has risen steadily from 3 mg/l in 1996. Uranium concentrations in three other ground water monitoring wells at Falls City also continue to exceed the uranium MCL, producing uranium concentrations in the 0.100 – 0.350 mg/l range. DOE 2003 indicates the increasing uranium concentrations may be a result of seepage from the disposal cell but does not present a current risk as the affected ground water is not currently being used.

Where Supplemental Standards have been sought or approved, DOE has determined that full attainment of the health based water quality standards of 40 CFR 192 cannot be attained at reasonable cost or as a result of sites specific geologic conditions.

Through May 2004, the www.gjo.doe.gov website provided information on the Ground Water Project activities at UMTRAP. After reformatting to reflect establishment of the Office of Legacy Management, Ground Water Project information is not readily available on the site.

Cost of UMTRAP Uranium Mill Tailings Remediation

Estimates of "inactive uranium mill tailings" -UMTRCA Title I - site remediation costs have risen steadily since 1978. By 1996, the General Accounting Office (GAO) projected that final UMTRAP costs would exceed \$2.4 billion dollars upon completion of all surface remediation, groundwater remediation and long-term surveillance and maintenance activities. That estimate is more than ten times the \$150 - \$200 million cost projected by DOE for Title I sites remediation during Congressional hearings prior to passage of UMTRCA in 1978. (GAO 1996)

Of this projected \$2.4 billion cost, GAO projected that the cost of completing surface remediation at all UMTRAP sites would reach \$2.0 billion, including administration and research and development costs. Ground water remediation costs alone were estimated to require an additional \$400 - \$600 million. In 1995, DOE projected groundwater remediation costs at \$80 - \$160 million per site where active remediation is needed to achieve background water quality conditions, rather than attaining maximum contaminant levels (MCLs); and \$14-24 million per site for passive remediation, where possible.

Comparisons among the cost data available for the individual sites are complicated by the unique characteristics of each site. Each UMTRAP project involves a unique site-specific geo-hydrological and ecological conditions, unique tailings characteristics, and unique social and political influences on decision-makers. To provide an overview of cost information, site specific and average cost figures are provided in tables and figures in Appendix A.

Appendix A **Table 2 – UMTRAP Sites – Cost of Remediation, 2002** presents DOE estimated costs for each site in terms of cost per ton of tailings, cost per pound of uranium produced, or cost per unit radiation contained in the tailings. (DOE 2002b) The costs per site vary widely - by several orders of magnitude - among the sites whether presented in cost per ton of tailings, cost per pound of uranium produced, or cost per unit radiation. Table 2 presents cost in terms of \$/ton, \$/unit radiation contained, and \$/pound of yellow cake produced to provide a means for comparing UMTRAP project costs to cost information related to other environmental remediation efforts. Appendix A Figures 1 – 6 to visually illustrate the site-by-site data in Table 2.

One point of comparison for his cost information is the price the US Government paid for yellowcake during the period that when the UMTRAP mill tailings were being generated. \$8.00/pound was the standard price the AEC paid for uranium oxide – yellowcake prior to 1970 when commercial ownership of uranium was made legal in the US. Without accounting for inflation, the \$12.67/pound average price for UMTRAP reclamation through 2000, as shown in Table 2, is more than 50% higher than the price paid for a pound of yellow cake produced at any one of the UMTRAP sites.

The data in Table 2 show that:

- As measured by cost per ton of tailings - and shown in Figure 1 - costs ranged from $18 at Mexican Hat and $19 at Monument Valley to $149 at Canonsburg and $122 at Lowman, Idaho and $123 at Naturita. The average (mean) cost of UMTRAP project activities is $73 per ton of tailings.

- As measured by cost per Curie of Radium 226 contained in the tailings – as shown in Figure 2 - remediation costs ranged from $21,600 at Ambrosia Lake and $30,268 at Mexican to $1,536,167 at Lowman, Idaho and $1,092,810 at Naturita, Colorado to $1,536,167. The average (mean) cost of the UMTRAP project activities is $105,250 per Curie of Radium 226 contained in the tailings.

- As measured by pound of yellowcake (U3O8) produced at the site – as shown in Figure 3 - costs ranged from $3.07 at Ambrosia Lake and $3.34 at Shiprock to $50.47 at Lowman, Idaho and $97.27 at Lakeview, Oregon. The average (mean) cost of the UMTRAP project activities is $12.67 per pound of yellowcake produced.

Figures 1 - 6 show the distribution of costs per site and the variation between cost per unit tailings, cost per unit radiation in the tailings and cost per pound of yellowcake produced from the site.

Figure 1 – **UMTRAP Mill Tailings Remediation Cost - $/Ton of Tailings** shows the wide variation in cost of remediation as calculated on the basis of tailings tonnage. Four sites – Canonsburg, Naturita, Lowman and Grand Junction - all exceed $120/ton. The remaining 13 sites for which data are available are all below the mean cost of $73/ton. Costs vary by a ratio of 8.5:1 between the highest and lowest cost sites.

Figure 2 – **UMTRAP Remediation Cost - $/Curie (based on Ra 226 content)** shows the wide variation in cost of remediation as calculated on the basis of radioactivity content of the tailings. Costs vary by a ratio of 71:1 between the highest and lowest cost sites.

Figure 3 – **UMTRAP Remediation Cost - $/U3O8 lb**. Shows the wide variation in cost of remediation as calculated on the basis of uranium produced at the site during mill operations. Costs vary by a ratio of 31.68:1 between the highest and lowest cost sites.

Figure 4 – **UMTRAP Remediation Cost - $/Ton and Cost - $/Curie (based on Ra 226 content)** shows that relatively high cost per ton sites do not consistently correlate with high cost per Curie Ra 226 sites. Two of three highest cost per ton sites, Lowman and Naturita, are among the three highest cost per Curie sites. The four lowest cost per ton sites, including Shiprock, Ambrosia Lake, Tuba City, and Mexican Hat are also among the four lowest cost per Curie sites.

Figure 5 – **UMTRAP Remediation Cost - $/Curie (based on Ra 226 content) and Cost - $/Ton** is a re-presentation of the data in Figure 4 to show the variability in cost per ton when cost per unit radiation is ordered from highest to lowest.

Figure 6 – **UMTRAP Remediation Cost - $/Ton and Cost - $/U3O8 lb.** shows the wide variation among cost when cost per ton of tailings is compared to cost per pound of yellowcake. This data shows that the uranium produced from the site is not a clear predictor of the cost per ton of tailings. This difference in relative cost may reflect difference in the concentration of uranium in the ore – the ore grade, among other site-by –site variations, for the UMTRAP sites.

Projected Cost of Long-Term Surveillance and Maintenance (LTSM) at UMTRAP Sites

Appendix A **Table 3 – UMTRAP Site Long-Term Stewardship (LTS) Cost, 2001** presents projected future LST (or LSTM) costs for the UMTRAP sites. This data show expenditures anticipated at UMTRAP sites through the year 2070, based on a range of underlying DOE assumptions including the relative complexity of the LTS activities planned for the sites and the potential for major site failures, repairs or "re-remediation" activities.

DOE calculated the long-term costs associated with the management of its nuclear waste legacy as both projected total costs per year for specific years and annual average cost for decades through the years 2070, based on the value of a dollar in the year 2000. For specific years, total long-term stewardship costs for all UMTRAP sites were projected as:

Year	Total Annual Cost
2001	$2.271 million
2006	$2.105 million
2051	$1.227 million

Annual average long-term stewardship cost for future decades were projected as:

Decade	Average Annual Cost
Fiscal Years 2000-2010	$2.325 million
Fiscal Years 2031-2040	$1.219 million
Fiscal Years 2061-2070	$1.219 million

These projected costs do not include active ground water remediation costs at sites not yet subject to NRC-approved LSTM plans. Active ground water remediation costs are anticipated to exceed $50 million at Tuba City, Monument Valley and Shiprock through the year 2025.

Since it was formed in December 2003, the DOE Office of Legacy Management has estimated budget needs for Long-term Surveillance and Maintenance activities for Fiscal Years 2005 – 2010. The Long-term Surveillance and Maintenance costs "within target" include, but are not limited, to UMTRAP site costs. These costs are projected as:

Office of Legacy Management
FY 2005 - FY 2010 Projection of Costs (Dollars in Thousands)
April 30, 2004

Source: DOE 2004a, "FY06-10 Program Plan, Office of Legacy Management, US Department of Energy, April 30, 2004" <http://www.gjo.doe.gov/LM/documents/LMProgramPlanFinal/noApp8.doc>

	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010
Long-Term Surveillance and Maintenance						
Within Target	10,574	10,498	10,575	10,691	10,790	11,007
Current Responsibilities – Additional Budget Transfer	0	200	220	220	220	100
Estimate for Additional Responsibilities	0	11,000	21,000	32,000	28,000	20,000
Total for LTS&M	10,574	21,698	31,795	42,911	39,010	31,107

DOE Policy Developments Related to Uranium Mill Tailings Since 2000

A 2002 reassessment of DOE's environmental management policies and programs identified UMTRAP as an example for future waste program. This analysis was part of an effort to restructure the policy direction and focus of DOE's programs to address the legacy of its nuclear programs following the election of the President George W. Bush in 2000.

The reassessment was a "Top-To-Bottom-Review" (TTBR) of DOE's Environmental Management programs (DOE 2002a). Whether the "Top-to-Bottom-Review" has provided a effective re-ordering of the program or just a mid-course reshuffling due to a change in Presidential Administrations cannot yet be determined. Either way, such a rethinking has been standard from administration to administration since the recognition of the enormous cost of long-term management of nuclear waste legacy in the late 1980s.

Among the core challenges of nuclear waste management addressed in the TTBR is need to demonstrate that all long-term stewardship (LTS) will be guaranteed to insure that nuclear legacy wastes remain where they finally disposed and cannot pose future risks. The TTBR identified DOE's Uranium Mill Tailings Remedial Action Program (UMTRAP) as a model because the program's "monitoring and surveillance [is] being performed under NRC license at 26 Title I sites for $5 million annually."

Critical aspects of waste site management such as attainment of closure and post-closure performance requirements and financial guarantees for post-closure activities remain major challenges at many of the DOE sites. DOE's TTBR identified the DOE's uranium mill tailings management program as a model for other waste sites without a supporting review of the effectiveness of the DOE UMTRAP program.

The TTBR recognizes that in 2002 DOE still suffered from both the "lack of a program strategy," and the lack of "a prescribed long-term stewardship process, [a condition] … resulting in uncertainty in the Environmental Management (EM) program and plans that are excessive and other than risk-based." The TTBR identified:

1) Lack of support for the range of LTS programs that have emerged to address these concerns within DOE in recent years;
2) Problems with recent agency management and performance practices; and
3) Past experience provides few positive models of effective long-term management to emulate.

Searching for a viable model applicable to LTS, DOE identifies the post-closure portion of the UMTRAP program. This recommendation is based on TTBR assertion that "mill tailings program's monitoring and surveillance [are] being performed under NRC license at 26 Title I sites for $5 million annually" without identifying any additional DOE or independent agency analysis.

The TTBR asserted that DOE needs to establish a LTS strategy and develop policy and guidance that will result in "consistent, predictable, risk-based implementation… in accordance with the goals of RCRA and CERCLA and should be rooted in the programmatic strategy for accelerated site closure." Calling "the UMTRCA process … a

model, [and] recognizing that risk should be used as an end-point determinant," the TTBR recommends that "policy should be formalized that assigns… responsibility [within DOE] for long-term stewardship once cleanup has been completed at DOE-owned sites."
(DOE 2002a)

Since the "Top-to-Bottom-Review" was completed, DOE has restructured its nuclear waste legacy management activities and established an Office of Legacy Management.

In May 2004 DOE updated its Grand Junction Office web site to reflect the inclusion of UMTRAP activities in the newly formed Office of Legacy Management. DOE describes the transition to Office of Legacy Management responsibility for UMTRAP sites as:

> " In December 2003, the U.S. Department of Energy (DOE) established the Office of Legacy Management to allow for optimum management of DOE's legacy responsibilities. The mission of the Office of Legacy Management is to effectively and efficiently manage the environmental and human legacy issues related to the U.S. Government's Cold War nuclear weapons program for current and future generations. Offices were established in Grand Junction, Colorado, Pittsburgh, Pennsylvania, Morgantown, West Virginia, and Washington, DC, to perform long-term site management, site transition support, records management, and other related tasks.
>
> "All activities formerly conducted under the Long-Term Surveillance and Maintenance Program have been incorporated into the Office of Legacy Management. In addition to site management activities, the Office of Legacy Management responsibilities include management of remedies involving ground water and surface water contaminated by former processing activities at sites regulated under Title I of the Uranium Mill Tailings Radiation Control Act." (DOE 2004b)

The website for the DOE Office of Legacy Management, is at www.LM.doe.gov and can be accessed through the DOE's Grand Junction Office home page at www.gjo.doe.gov.

The DOE Office of Legacy Management identifies its mission and functions as:

> "MISSION
>
> The mission of the Office of Legacy Management is to manage the Department's post-closure responsibilities and ensure the future protection of human health and the environment. This Office has control and custody for legacy land, structures, and facilities and is responsible for maintaining them at levels suitable for their long-term use.
>
> "FUNCTIONS
>
> - Protects human health and the environment through effective and efficient long-term surveillance and maintenance;
> - Preserves and protects legacy records and information;
> - Supports an effective and efficient work force structured to accomplish departmental missions;

- Implements Departmental policy concerning continuity of worker pension and medical benefits…;
- Manages and dispositions legacy land and assets, emphasizing safety, reuse, and disposition;
- Mitigates community impacts resulting from the cleanup of legacy waste and changing departmental missions; and
- Actively liaisons and coordinates all issues with appropriate Departmental elements consistent with their responsibilities." (DOE 2004b)

Specific responsibilities related to public involvement such as communications with stakeholder interests, public participation in policy development, and community education are not explicitly identified in the Office of Legacy Management mission or function.

Stakeholder involvement at Office of Legacy Management is not off to a confidence-building beginning. The Office of Legacy Management's cancelled its initial effort to engage members of the public and stakeholders at large in a "First National Stakeholders Workshop" in Las Vegas, scheduled for June 2004. Office of Legacy Management's notice regarding this cancellation provides no indication of the original agenda of the proposed workshop, no indication of the means to be used to identify stakeholders and balance representation among stakeholders, and no indication of when the conference might be rescheduled.

Future stakeholder involvement efforts at Office of Legacy Management can be anticipated though their form and function are unknown and mechanisms to establish authentic and diverse stakeholder involvement are not identified. The Office of Legacy Management notes, in its announcement of the cancellation of "First National Stakeholder Workshop" that, "it is our intent to continue to engage our key stakeholders on a local basis and in available forums." (DOE 2004b)

References

ATSDR 2004 Agency for Toxic Substances and Disease Registry, "Toxicological Profile Information Sheet," Centers for Disease Control, Atlanta, GA, 2004 at: http://www.atsdr.cdc.gov/toxpro2.html – provides links to toxicological profiles for specific radioactive and non-radioactive elements and compounds.

Dawson and Madsen 1998 Dawson, S. and Madsen, G., "Prepared Statement on Radiation Workers Justice Act of 1998," in House 1998, Hearing before the Subcommittee on Immigration and Claims of the Committee on the Judiciary House of Representatives, 105th Congress, Second Session on H. R. 3539, Washington, DC, USA, June 25, 1998 available at:

http://commdocs.house.gov/committees/judiciary/hju59930.000/hju59930_0f.htm

DOE 1996 DOE, "Uranium Miners Resources", in Final Report of the Radiation Exposure Compensation Act Committee Submitted to the Human Radiation Interagency Working Group, Office of Human Radiation Experiments, US Department of Energy, Washington, DC, 1996 available at: http://tis.eh.doe.gov/ohre/roadmap/uranium/

DOE 2001 DOE, "Report to Congress on Long-Term Stewardship," DOE, Office of Environmental Management DOE/EM-0593, January 19, 2001, Long-Term Surveillance and Maintenance Site Summaries in Volume II available at: http://www.em.doe.gov or http://lts.apps.em.doe.gov//center/ndaareport.html.

DOE 2002 DOE, "A Review of the Environmental Management Program Presented to the Assistant Secretary for Environmental Management by the Top-to-Bottom Review Team ("Top-to-Bottom Review")", DOE, Germantown, MD, February 4, 2002 at: http://web.em.doe.gov/ttbr.pdf

DOE 2002b DOE, "U.S. Uranium Production Facilities: UMTRAP Operating History and Remediation Cost as of 2000," DOE, Energy Information Administration, at: http://www.eia.doe.gov/cneaf/nuclear/page/umtra/title1map.html

DOE 2003 DOE, "2003 Annual Site Inspections and Monitoring Reports for Uranium Mill Tailings Radiation Control Act Title I Sites," DOE Long-term Surveillance and Maintenance Program, Office of Legacy Management, Grand Junction Office, Document Number – GJO-2003-528-TAC http://www.gjo.doe.gov/programs/ltsm/general/tech_doc/i-an-report/Yr2003/TitleIAnnualReport.pdf

DOE 2004a DOE, “FY06-10 Program Plan, Office of Legacy Management, US Department of Energy, April 30, 2004,” at: http://www.gjo.doe.gov/LM/documents/LMProgramPlanFinal/noApp8.doc

DOE 2004b DOE, Office of Legacy Management Website at: http://www.lm.doe.gov

DOE 2004c DOE, “Long-Term Surveillance and Maintenance Records,” including links for all UMTRAP and LSTM sites, DOE Office of Legacy Management, Grand Junction, Colorado, 2004 at: http://lts1.gjo.doe.gov/gjoreclog/gjoltssites.htm

EPA 1983 EPA, “Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," 40 CFR 192, initially promulgated at 48 FR 45946 – October 7, 1983 and amended in 1995, available online at: http://www.gjo.doe.gov/lm/documents/cfr/Sec192.pdf.

EPA 2004 EPA, “Uranium Mill Tailings: Radioactive Waste Disposal Environmental Perspective,” updated: May, 2004, at: http://www.epa.gov/radiation/docs/radwaste/umt.htm

FSA 1952 Federal Security Agency (Public Health Service, Division of Occupational Health) & Colorado State Department of Public Health. “An interim report of a health study of the uranium mines and mills,” Washington, DC: Office of Technical Services, 1952.

GAO 1996 General Accounting Office, Uranium Mill Tailings: Cleanup Continues but Future Costs are Uncertain, GAO/RCED-96-37, Washington, DC, 1996 at: http://www.gao.gov/archive/1996/rc96037.pdf

GWP 2001 Ground Water Project, “Environmental Assessment of Ground Water Compliance at the Shiprock Uranium Mill Tailings Pile Site – Draft,” DOE, UMTRAP, Grand Junction, CO, April, 2001, Document Number DOE/EA - 1388

House 1998 House of Representatives, “Radiation Workers Justice Act of 1988,” Hearing before the Subcommittee on Immigration and Claims of the Committee on the Judiciary House of Representatives, 105th Congress, Second Session on H.R. 3539, Washington, DC, USA, June 25, 1998 available at: http://commdocs.house.gov/committees/judiciary/hju59930.000/hju59930_0f.htm including: Dawson 1998 and Robinson 1998.

IAEA 2003 International Atomic Energy Agency (IAEA), “The Long-term Stabilisation of Uranium Mill Tailings: Final Report,” IAEA, Vienna, 2003. At:

http://www.iaea.org/programmes/ne/nefw/crp1/CRPL-TStabFinRepV31.pdf

IEER 2000 Institute for Energy and Environmental Research, "Uranium Its Uses and Hazards," Takoma Park, MD, August, 2000 at: http://www.ieer.org/fctsheet/uranium.html

Landa 1980 Landa, E., "Isolation of the Uranium Mill Tailings and Their Component Radionuclides from the Biosphere – Some Earth Science Perspectives," United States Geological Survey, Washington, DC, Circular 814, 1980.

Lush 1978 Lush, D., et al, "An assessment of the long-term interaction of uranium tailings with the natural environment" in Proceedings of a Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings, Albuquerque, NM July, 1978, OECD Nuclear Energy Agency, Paris, p. 373-398.

Navajo 2004 Navajo Abandoned Mine Land/UMTRA Department, "Navajo Uranium Mill Tailings Remedial Action Program," Division of Natural Resources, Window Rock, Arizona, Navajo Nation, available on line at: http://www.navajoaml.osmre.gov/UMTRA/NUcover.htm

NEPA 2004 Navajo Environmental Protection Agency, "Letter to UMTRAP Ground Water Project, Grand Junction Office," Window Rock, Arizona, Navajo Nation, cited at: http://www.antenna.nl/wise/uranium/udusat1.html.

NRC 1985 NRC, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material From Ores Processed Primarily for Their Source Material Content" codified at 10 CFR 40 Appendix A, initially promulgated at 50 FR 41862 - Oct. 16, 1985 and since amended, available on line at: http://www.nrc.gov/reading-rm/doc-collections/cfr/part040/part040-appa.html.

PHS 1962 Public Health Service, "Waste Guide for the Uranium Milling Industry," US Department of Health Education and Welfare, Public Health Service, Cincinnati, OH, 1962, Technical Report W62-12.

Robinson 1991 Robinson, P., Design Criteria and Standards for Uranium Mill Waste Management in the USA," in Proceedings of Conference on Geology and Tectonics of the Gera-Jachymov Fault Zone and its Relationship to Regional Uranium Resources, Gera, Thuringia, Germany, 4 - 6 August 1991

Robinson 1995 Robinson, P., "Groundwater Contamination at Uranium Mill Tailings Sites in the United States Reclaimed by the Department of Energy (DOE) Uranium Mill Tailings Remedial Action Project (UMTRAP): A Review of Seven Selected Sites" In Uranium Mining and

Hydrogeology: Proceedings of International Conference and Workshop, convened by Freiberg Mining Academy and Saxony Environment Ministry, Freiberg, Saxony, Germany, October 4-7, 1995

Robinson 1998 Robinson, P., "More Than Radon in the Uranium Dust: An Overview of the Basis for Uranium Miners and Millers Exposed to Non-Radioactive Hazards and Radioactive Hazards other than Radon Decay Products to be Included in US Radiation Exposure Compensation Act Program." Also at: http://www.sric.org/mining/docs/RECA.html

Robinson 2002 Robinson, P., "Is 'Trust Us, We're the Government' Really a Guarantee?: A Review of Financial Assurance Options for Long-Term Stewardship at the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, New Mexico, USA," prepared under contract to Citizen Action, Southwest Research and Information Center, Albuquerque, NM, June 18, 2002 available at: http://www.radfreenm.org/pages/robinson_full.htm

UMTRCA 1978 "Uranium Mill Tailings Radiation Control Act," as amended, Title 42 United States Code Chapter 88 (42USC88) at: http://www.nearctica.com/environ/elaw/42misc/tailing1.htm and http://www4.law.cornell.edu/uscode/42/7901.html.

APPENDIX A –TABLES AND FIGURES

TABLE 1 - Status of Department of Energy Uranium Mill Tailings Remedial Action Project (UMTRAP) Sites, 2003

Source: site specific files at <http://hsl.gjo.doe.gov/gjoreclog/gjoltsites.htm>

Site by site links available at <www.gjo.doe.gov> and <http://www.antenna.nl/wise/uranium>

Location/Name	State	Tailings Vol. (million tons)	Tribal Land	LTSM Plan Approved by NRC	Ground Water Remediation and Site Activity Status
Monument Valley	Arizona	1.3	X		Active ground water remediation continuing
Tuba City	Arizona	2	X		Active remediation continuing
Durango	Colorado	3.1			Active remediation continuing; Supplemental Stds. Adopted
Grand Junction	Colorado	4.2		Planned	Supplemental Stds; Disposal site open for waste until 2023
Gunnison	Colorado	1			Passive remediation on-going
Maybell	Colorado	3.9		Yes, Aug 2000	Completed 1996
Naturita	Colorado	0.7			Passive remediation; Supplemental Stds. Adopted
New Rifle	Colorado	3.8			Passive remediation; Supplemental Stds. Application
Old Rifle	Colorado	"			Passive remediation; Supplemental Stds. Application
Slick Rock	Colorado	0.8			Passive remediation;Supplemental Stds. Application
Lowman	Idaho	0.15		Yes	Completed 1996
Ambrosia Lake	New Mexico	3.3		Yes, Aug 2000	Completed 1998
Shiprock	New Mexico	3.4	X		Active and Passive remediation; Supplemental Stds. Application
Belfield	North Dakota	0.24		No longer DOE site	UMTRA status revoked; no state funding for cleanup
Bowman	North Dakota	"		No longer DOE site	UMTRA status revoked; no state funding for cleanup
Lakeview	Oregon	1.2			Passive remediation; Supplement Stds; NRC reviewing LTSM Plan
Canonsburg	Pennsylvania	0.32		Yes, Feb 2000	Completed Jan 2000
Falls City	Texas	6.7		Yes, Aug 2000	Completed 1998; Supplemental Stds. adopted
Green River	Utah	0.46			Passive remediation; Supplemental Stds. Application
Mexican Hat	Utah	3.1	X	Yes, Aug 2000	Completed 1998
Monticello	Utah	0.98		Yes, Oct 2001	Surface activities completed; groundwater strategy being evaluated
Salt Lake City	Utah	3.3		Yes, Aug 2000	Completed 2000; Supplemental Stds. Adopted
Riverton	Wyoming	2.2		Planned 2004	Completed 1998
Spook	Wyoming	0.38		Yes, Aug 2000	Completed 1997

TABLE 2 - UMTRAP SITES - COST OF REMEDIATION, 2000

From: "U.S. Uranium Production Facilities: UMTRAP Operating History and Remediation Cost as of 2000," (DOE, 2002) <http://www.eia.doe.gov/cneaf/nuclear/page/umtra/title1map.html>

	Uranium Ore Processed		Disposal Cell	Remediation Project Cost		
	Ore (Mt)	U3O8 Mlbs.	Volume (Mcy)	Total Cost	Cost/lb	Per Unit Radiation Avoided
			(A)	US$M	US$/U3O8lb	US$/Ci based on [Ra226]
Location/Name						
Monument Valley	1.1	0.77	0.93	24.13	31.43	(G)
Tuba City	0.8	4.7	1.63	34.14	7.27	36,322.34
Durango	1.61	7.85	2.53	67.62	8.61	48,298.57
Grand Junction	2.28	11.69	4.43	504.05	43.12	(E)
Gunnison	0.54	1.45	0.74	58.92	40.61	336,668.57
Maybell	1.76	4.03	3.5	63.53	15.75	139,621.98
Naturita	0.7	3.18	0.79	86.33	27.18	1,092,810.13
New Rifle/Old Rifle	2.7	16.54	3.76	119.17	7.2	43,522.64
Slick Rock	0.63	2.68	0.86	50.43	18.82	288,160.00
Lowman	0.20	0.37	0.13	18.43	50.47	1,536,166.67
Ambrosia Lake	3.05	13.02	5.2	39.96	3.07	21,600.54
Shiprock	1.53	7.42	2.8	24.77	3.34	33,116.31
Belfield	0.05	0.34	(C)	(C)	(C)	(C)
Bowman	0.08	0.61	(C)	(C)	(C)	(C)
Lakeview	0.13	0.34	0.94	33.33	97.27	793,452.38
Canonsburg	(D)	(D)	0.19	47.59	(D)	475,910
Falls City	2.72	8.66	5.8	56.25	6.49	44,051.68
Green River	0.18	0.83	0.38	23.63	28.44	787,766.67
Mexican Hat	2.20	11.38	3.48	54.48	4.79	30,267.78
Salt Lake City	1.69	9.57	2.8	94.17	9.84	60,751.61
Riverton	1.06	3.89	1.79	49.66	12.76	(G)
Spook	0.19	0.35	0.32	10.10	29.03	80,848.00
TOTALS AND AVERAGE	27.17	116.53	46.07	1,476,340	Average =12.67/lb	Aver per Ci Ra226 = 105,249.88

NOTES: A) ore tonnage x 1.6; (B) of 5.1 Mt tailings generated, 0.4 Mt backfilled in mines; (C) Combined Belfield and Bowman cost $10,239,000;
(D) Ore processing data for Canonsburg not available; (E) A Portion of Cell will remain open until as late as 2023;
(F) includes material from Rifle, Slick Rock and Belfield; (G) Material from Riverton moved to Gas Hills, WY

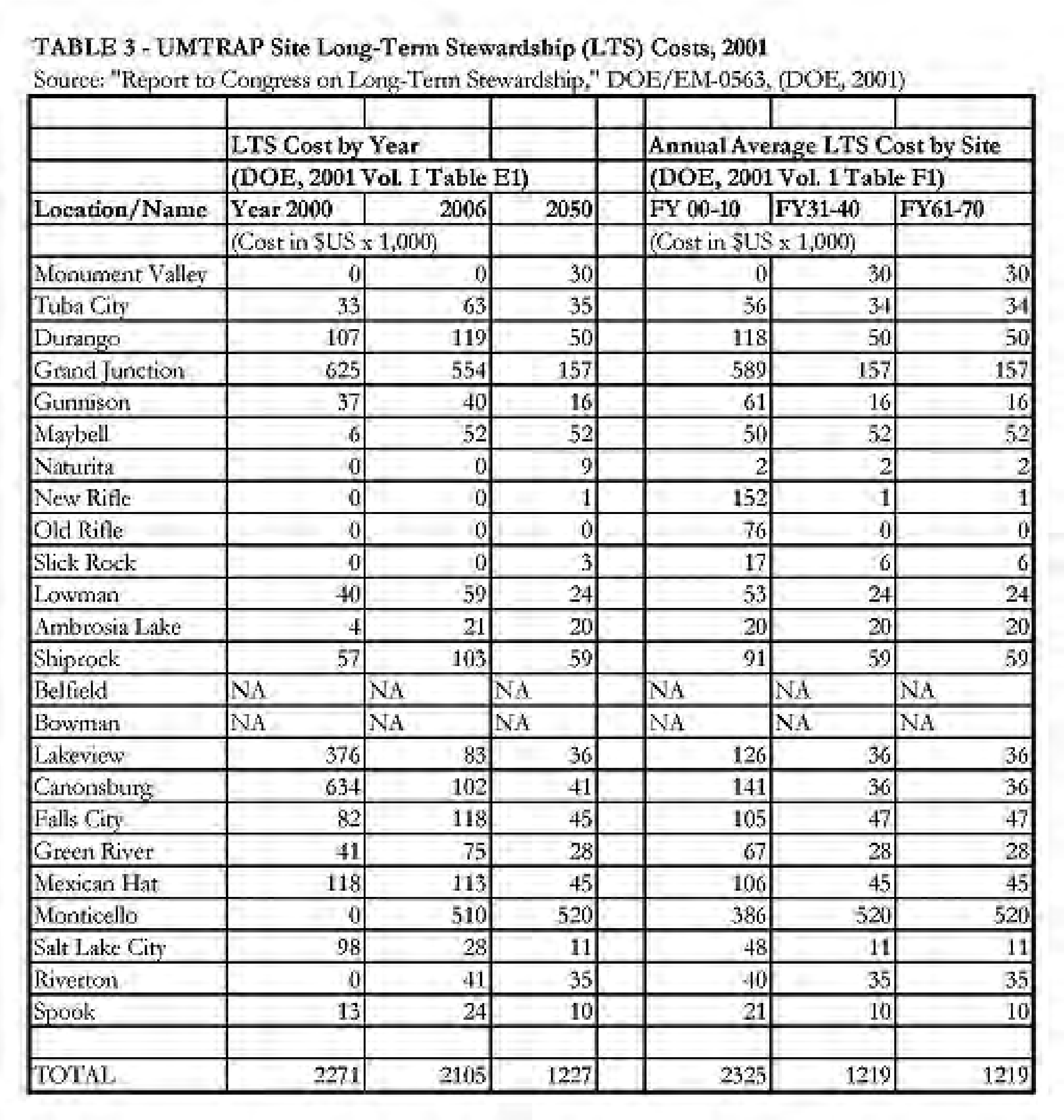


TABLE 3 - UMTRAP Site Long-Term Stewardship (LTS) Costs, 2001

Source: "Report to Congress on Long-Term Stewardship," DOE/EM-0563, (DOE, 2001)

	LTS Cost by Year				**Annual Average LTS Cost by Site**		
	(DOE, 2001 Vol. I Table E1)				**(DOE, 2001 Vol. 1 Table F1)**		
Location/Name	**Year 2000**	**2006**	**2050**		**FY 00-10**	**FY31-40**	**FY61-70**
	(Cost in $US x 1,000)				(Cost in $US x 1,000)		
Monument Valley	0	0	30		0	30	30
Tuba City	33	63	35		56	34	34
Durango	107	119	50		118	50	50
Grand Junction	625	554	157		589	157	157
Gunnison	37	40	16		61	16	16
Maybell	6	52	52		50	52	52
Naturita	0	0	9		2	2	2
New Rifle	0	0	1		152	1	1
Old Rifle	0	0	0		76	0	0
Slick Rock	0	0	3		17	6	6
Lowman	40	59	24		53	24	24
Ambrosia Lake	4	21	20		20	20	20
Shiprock	57	103	59		91	59	59
Belfield	NA	NA	NA		NA	NA	NA
Bowman	NA	NA	NA		NA	NA	NA
Lakeview	376	83	36		126	36	36
Canonsburg	634	102	41		141	36	36
Falls City	82	118	45		105	47	47
Green River	41	75	28		67	28	28
Mexican Hat	118	113	45		106	45	45
Monticello	0	510	520		386	520	520
Salt Lake City	98	28	11		48	11	11
Riverton	0	41	35		40	35	35
Spook	13	24	10		21	10	10
TOTAL	2271	2105	1227		2325	1219	1219

Figure 1 - UMTRAP Mill Tailings Remediation Cost - $/Ton of Tailings

Source: DOE, 2002b,
<http://www.eia.doe.gov/cneaf/nuclear/page/umtra/title1map.html>

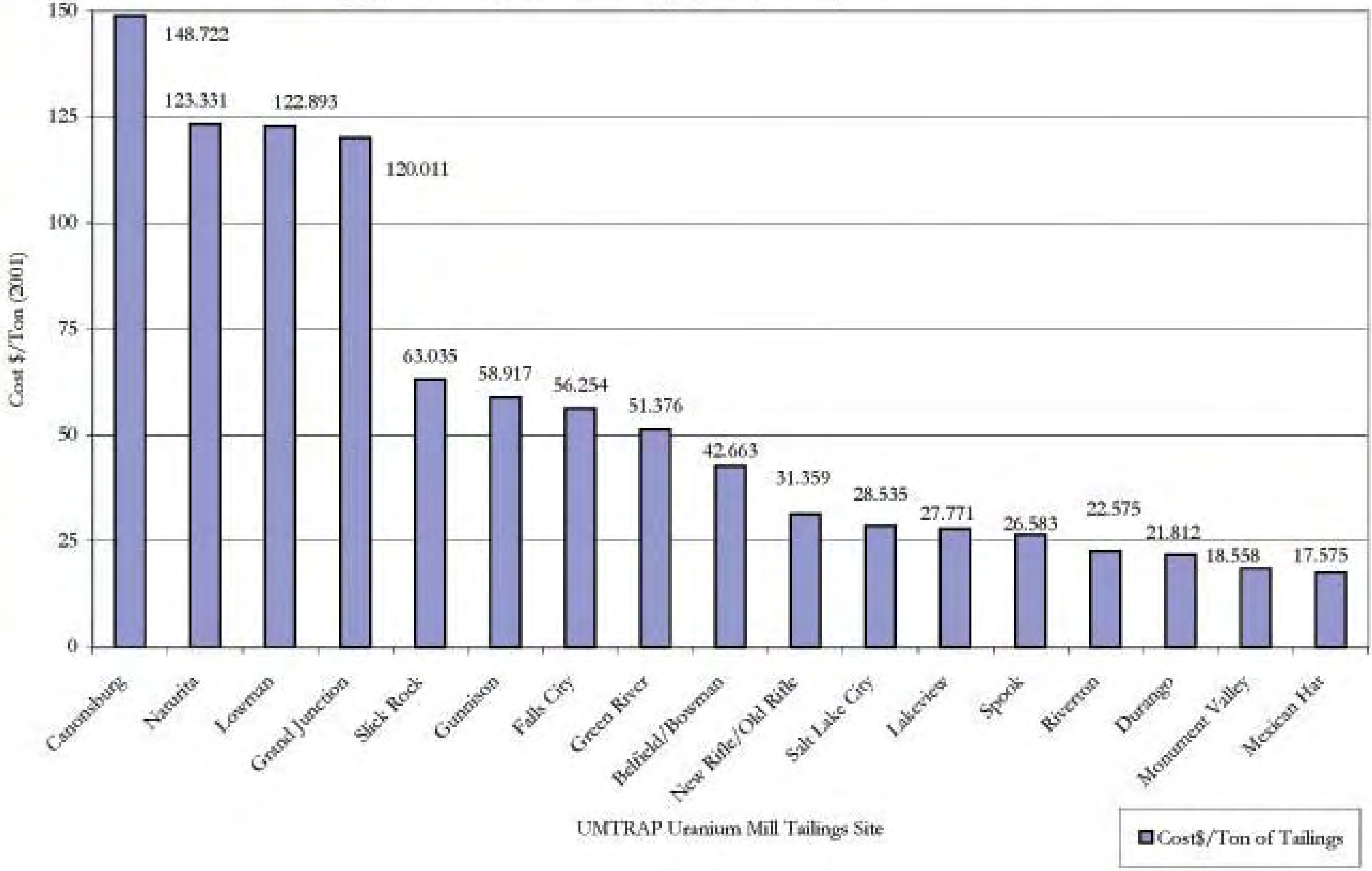


Figure 2 - UMTRAP Remediation Cost-$/Curie (based on Ra 226 content)

Source: DOE, 2002b, <http://www.eia.doe.gov/cneaf/nuclear/page/umtra/title1map.html>

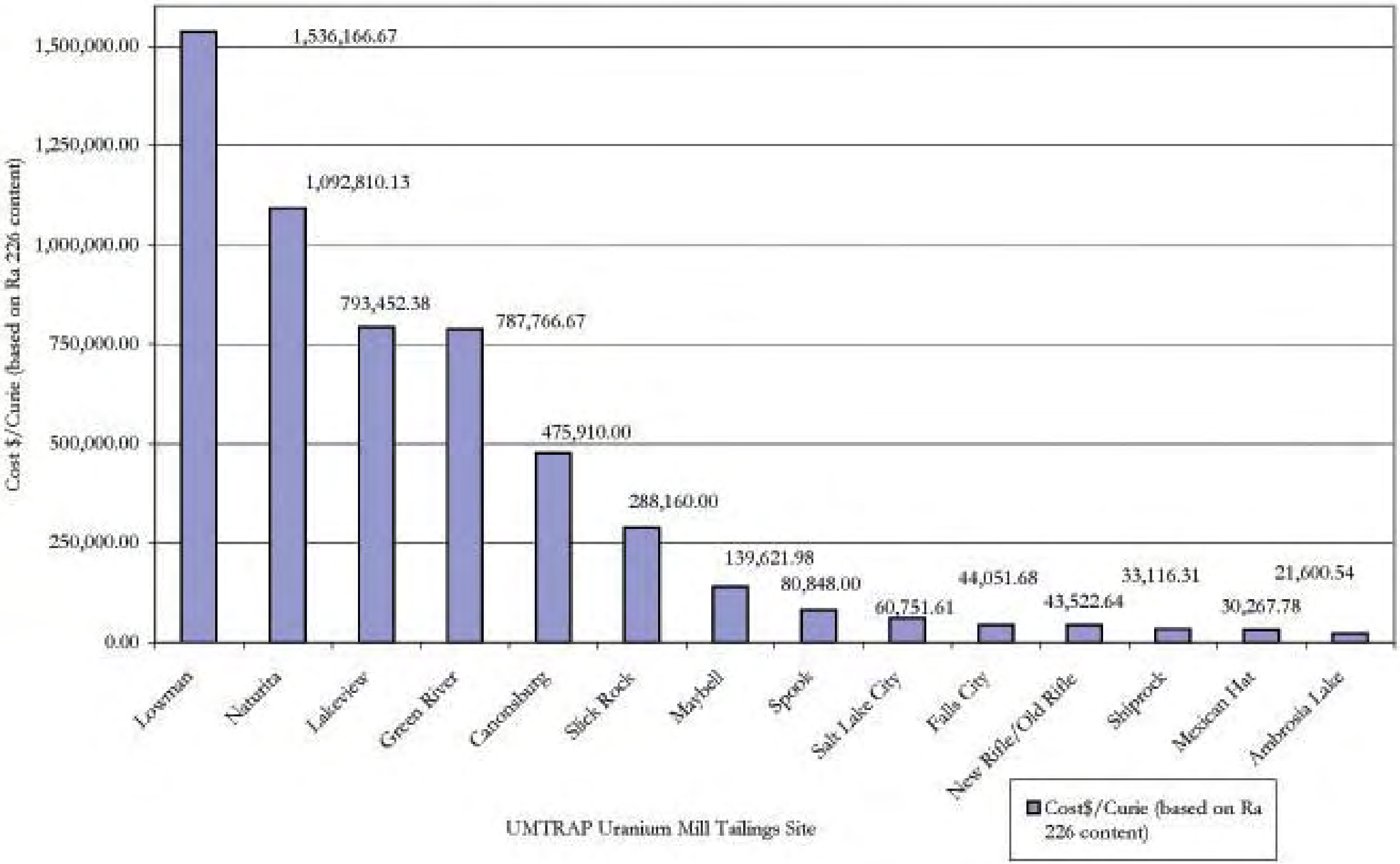


Figure 3 - UMTRAP Remediation Cost-$/U308 lb.

Source: DOE, 2000b,
<http://www.eia.doe.gov/cneaf/nuclear/page/umtra/title1map.html>

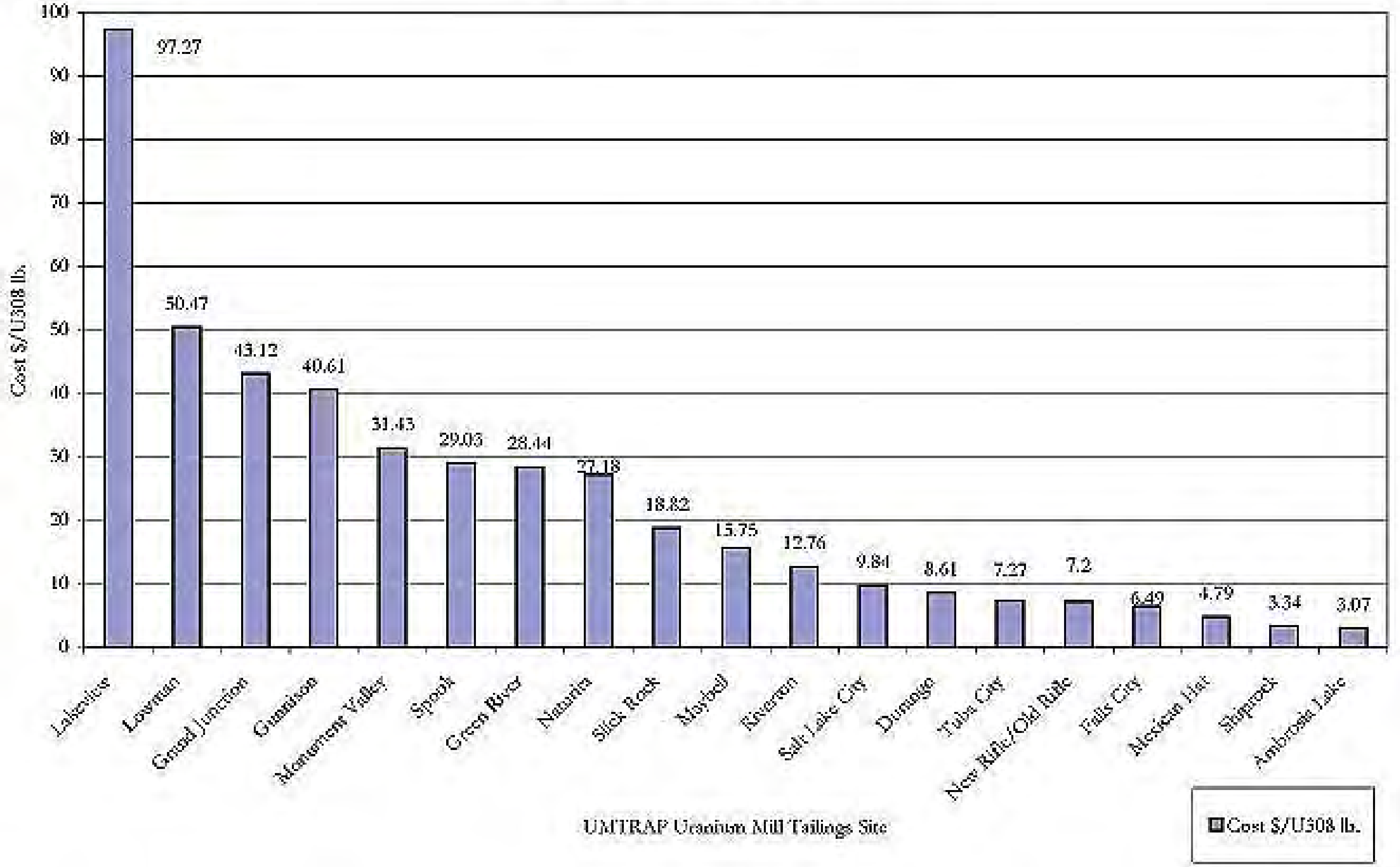
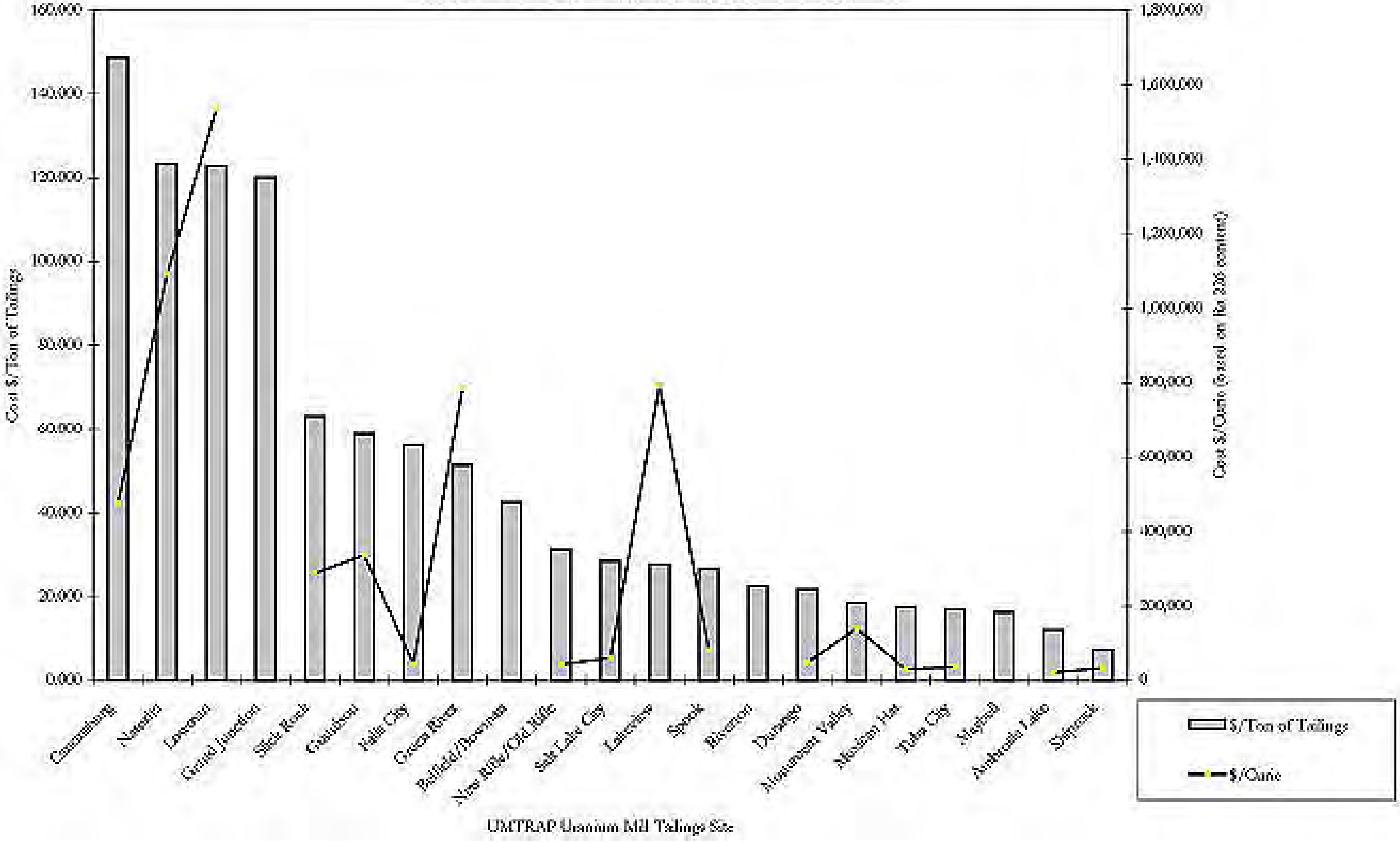


Fig.4 UMTRAP Remediation Cost-$/Ton and Cost-$/Curie (based on Ra 226 content)

Source: DOE, 2002b,
<http://www.eia.doe.gov/cneaf/nuclear/page/umtra/title1map.html>



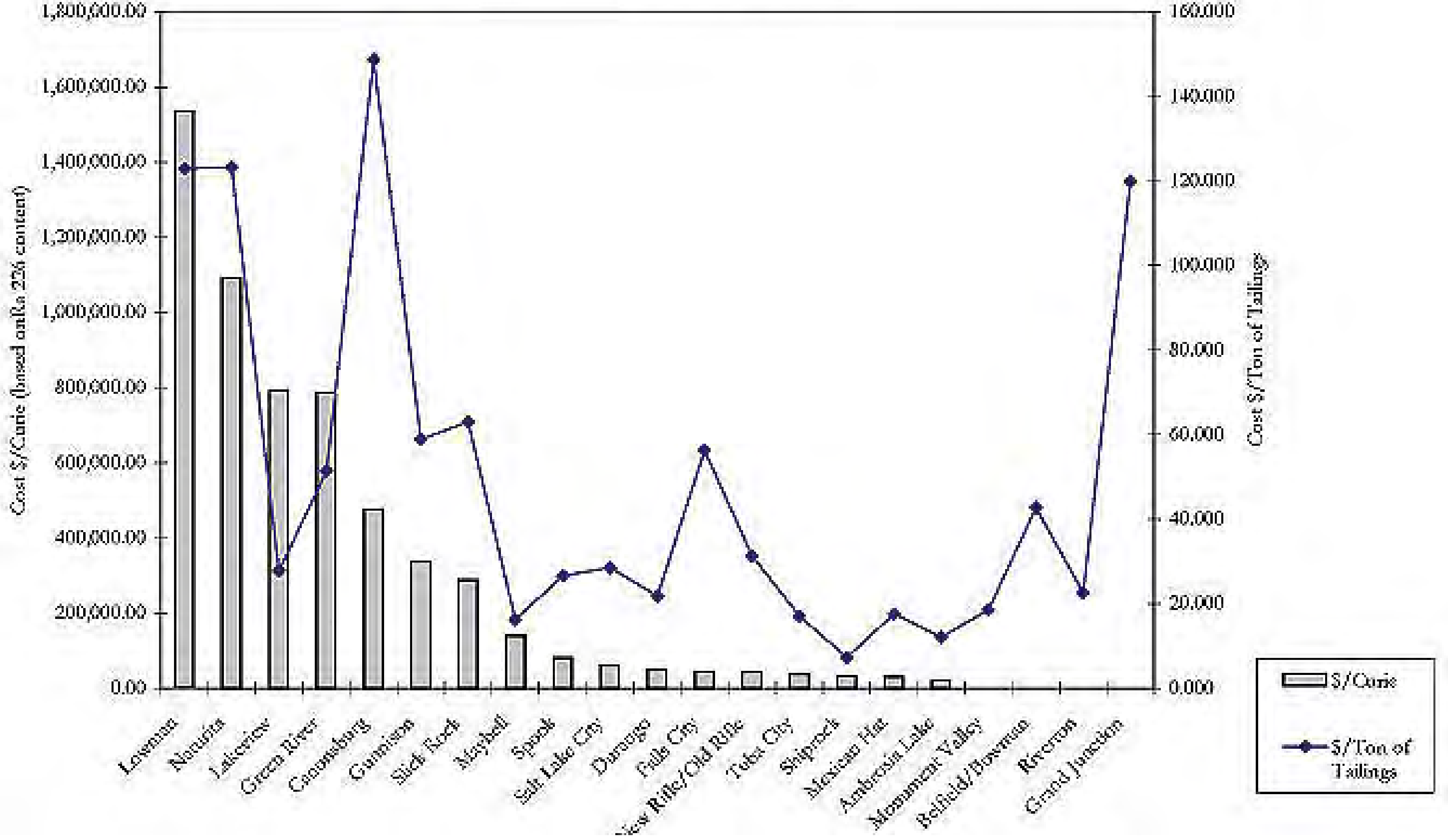


Figure 5 - UMTRAP Remediation Cost $/Curie (based on Ra 226 content) and Cost $/Ton

Source: DOE, 2002b,
<http://www.em.doe.gov/ovcal/nuclear/page/umtra/sitelist.html>

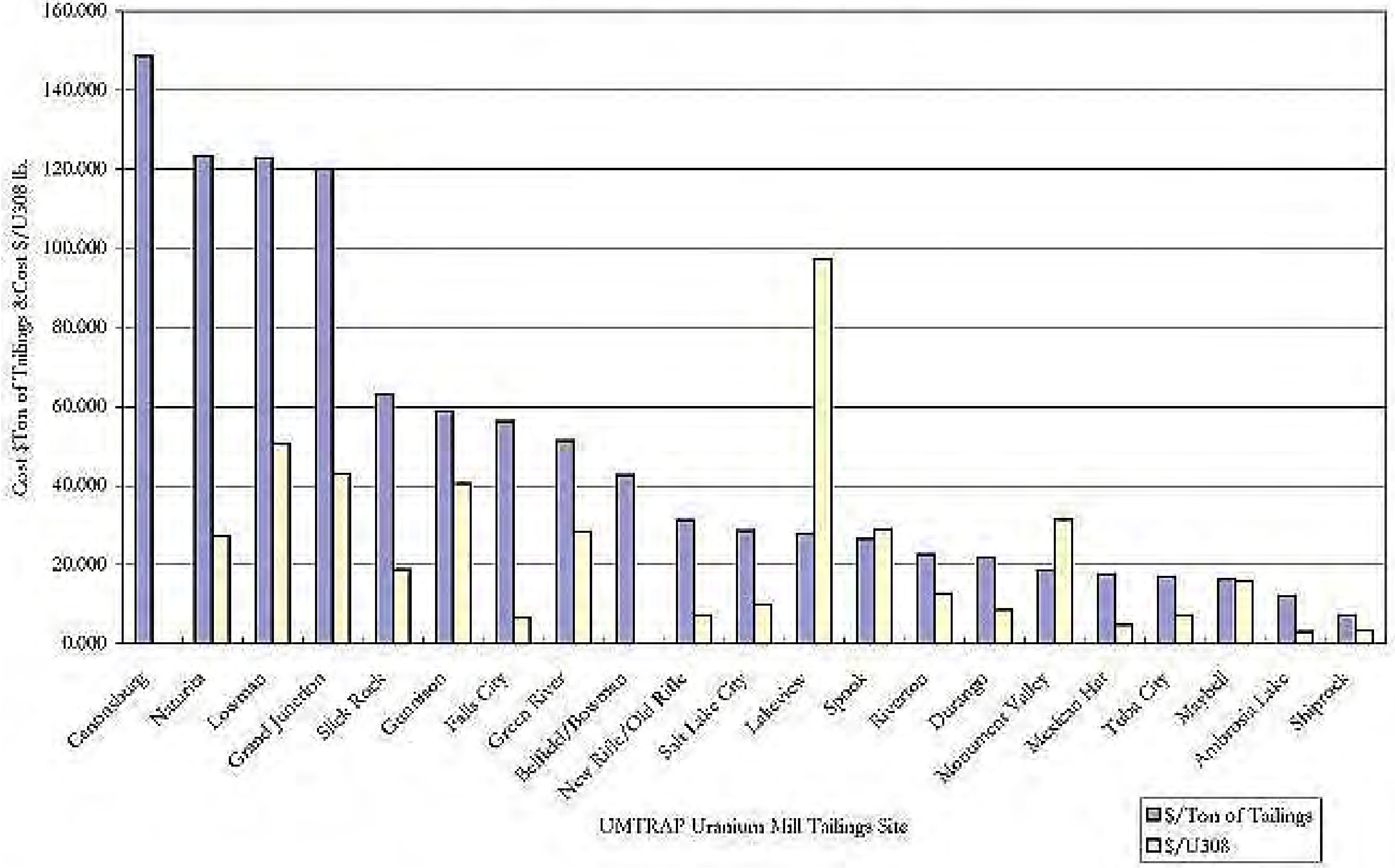


Figure 6 - UMTRAP Remediation Cost $/Ton of Tailings and Cost $/U308 lb.

Source: DOE, 2008,

<http://www.eia.doe.gov/cneaf/nuclear/page/Umtra/title1map.html>

APPENDIX B - UMTRAP SITE PHOTOGRAPHS
Source: DOE UMTRAP

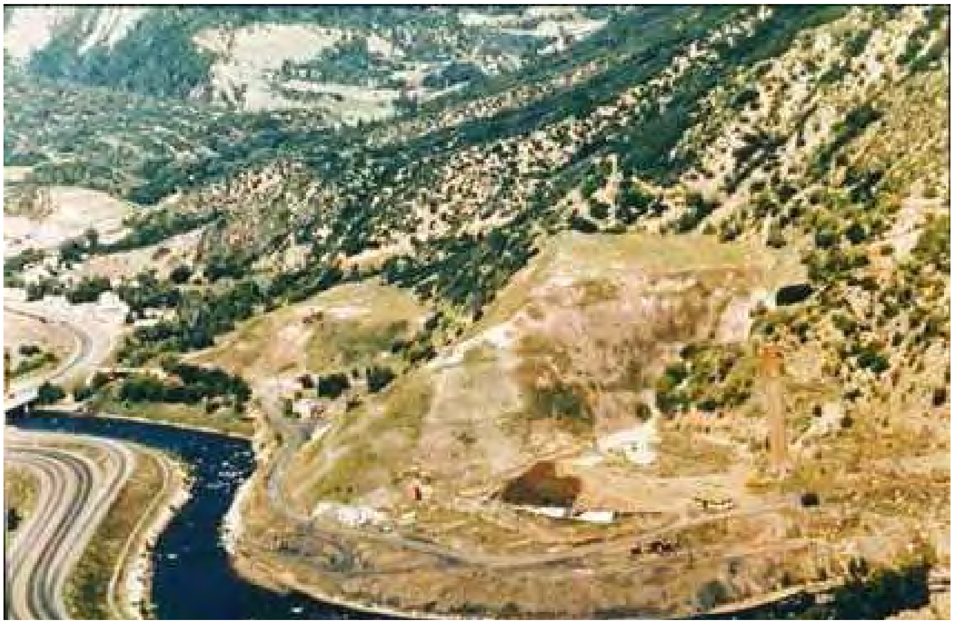


PHOTO 1 – Durango, CO Uranium Mill Tailings Site prior to remediation, 1986

PHOTO 2 – Durango, CO UMTRAP Site after removal of all tailings, residual contamination and covering with radon barrier, 1991.

PHOTO 3 – Durango, CO UMTRAP site remote disposal cell at Bodo Canyon, 1992
Source: Paul Robinson

PHOTO 4 – Durango, CO UMTRAP site remote disposal cell at Bodo Canyon, 1992
Source: Paul Robinson

PHOTO 5 – Falls City, TX UMTRAP Site prior to remediation, 1987

PHOTO 6 – Falls City, TX UMTRAP Site following surface remediation in place, 1994

PHOTO 7 – Gunnison, CO UMTRAP Site prior to remediation, 1985

PHOTO 8 – Gunnison, CO UMTRAP site following surface remediation in place, 1995

PHOTO 9 - Shiprock, NM UMTRAP Site prior to reclamation, 1985

PHOTO 10 – Shiprock, NM UMTRAP following surface remediation in place, 1995

PHOTO 11 – Tuba City, AZ UMTRAP site prior to remediation, 1985

PHOTO 12 – Tuba City, AZ UMTRAP site following surface remediation in place, 1990

PHOTO 13 – Salt Lake City, UT UMTRAP site following removal of tailings to remote site and surface remediation, 1993

APPENDIX C

Summary of
"Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material From Ores Processed Primarily for Their Source Material Content,"
US Nuclear Regulatory Commission, 10 CFR 40 Appendix A

From: Robinson 1991

To implement its statutory responsibility under UMTRCA, NRC developed an Appendix A to its regulations in section 40, of Chapter 10 of the Code of Federal Regulations, cited as 10 CFR 40, Appendix A. These criteria are divided into an Introduction and five parts - Technical Criteria (criterion 1 - 8), Financial Criteria (9 - 10), Site and Byproduct Material Ownership (11), Long-Term Surveillance (12), and Hazardous Constituents (13).

The Introduction clarifies that the criteria relate to "siting, operation, decontamination, decommissioning and reclamation of mills and tailings or waste systems and sites at which such mills and systems are located. ...[F]lexibility is provided in the criteria to allow achieving an optimum tailings disposal program on a site-specific basis. However, in such cases the objectives, technical alternatives and concerns which must be taken into account are identified. ...Applications for licenses must clearly demonstrate how the criteria have been addressed.

"The specifications [for reclamation plans] must be developed considering the full capacity of tailings or waste systems ....to accommodate increased capacities without degradation in long-term stability and other performance factors...[A]pplicants may propose alternatives to specific requirements ...The alternative plans may take into account local or regional conditions, including geology, topography, hydrology and meteorology. The Commission [may approve alternatives if they] achieve a level of stabilization and containment of the sites concerned, and a level of protection of public health, safety and the environment from radiological and nonradiological hazards associated with the sites, which is equivalent to, to the extent practicable, or more stringent than the level which would be achieved by the requirements of this Appendix and" applicable EPA rules. The applicable EPA rules are found at 40 CFR 192.

Technical Criterion 1 identifies the "general goal or broad objective in siting and design decisions is PERMANENT ISOLATION OF TAILINGS AND ASSOCIATED CONTAMINANTS BY MINIMIZING DISTURBANCE AND DISPERSION BY NATURAL FORCES AND TO DO SO WITHOUT ONGOING MAINTENANCE" (emphasis added). Site features to consider in "judging the adequacy of existing tailings sites [are]:

Remoteness from populated areas;

Hydrologic and other natural conditions as they contribute to continued immobilization and isolation of contaminants from ground-water sources; and

Potential for minimizing erosion, disturbance and dispersion by natural forces over the long term.

"In the selection of disposal sites, primary emphasis must be given to isolation of tailings... a matter having long-term impacts, as opposed to consideration only of short-term convenience or benefits, such as minimization of transportation or land acquisition costs. While isolation of tailings will a function of both site and engineering design, overriding consideration must be given to siting features given the long-term nature of tailings hazards.

"Tailings should be disposed of in a manner that no active maintenance is required to preserve conditions of the site."

Technical Criterion 2 recommends that disposal plans "avoid the proliferation of small disposal sites" by encouraging the use of existing large disposal sites.

Technical Criterion 3 identifies the "prime option" for disposal of tailings as placement below grade, either in mines or specially excavated pits. It recognizes that in some cases, "below grade disposal may not be the most environmentally sound approach, ... if ground-water ....is relatively close to the surface or not very well isolated by overlying soils and rock..." or where "bedrock may be sufficiently near the surface that blasting would be required to excavate a disposal pit at excessive cost, and more suitable alternative sites are not available."

"Where full below grade burial is not practicable, the size of retention structures and the size and steepness of slopes associated [with] exposed embankments must be minimized by excavation to the maximum extent reasonably achievable or appropriate given the geologic and hydrologic conditions at a site. It must be demonstrated that an above grade disposal program will provide reasonably equivalent isolation of the tailings from natural erosional forces."

Technical Criterion 4 identifies the site and design criteria applicable to disposal sites, whether above or below surface grade. These include:

"(a) Upstream rainfall catchment areas to be minimized to decrease erosion potential and the size of floods which could erode or washout sections of the tailings disposal area;

"(b) Topographic features should provide good wind protection;

"(c) Embankment and cover slopes must be relatively flat after final stabilization to minimize erosion potential and to provide conservative factors of safety assuring long-term stability. The broad objective should be to contour final slopes to grades which are as close as possible to those which would be provided if the tailings were disposed of below grade; this could, for example lead to slopes of about 10 horizontal to 1 vertical (10h:1v) or less steep. In general, slopes should not be steeper than 5h:1v. Where steeper slopes are proposed, reasons why a slope less steep than 5h:1v would be impracticable should be provided, and compensating factors and conditions which make such slope acceptable should be identified.

"(d) A full self-sustaining vegetative cover must be established or rock cover employed to reduce wind and water erosions to negligible levels." The NRC will consider relaxing this criteria due to arid climatic conditions or for areas of very gentle slope such as the top of the tailings facility.

For rock covers, factors to consider in cover design include measures "to avoid displacement by human or animal traffic; natural processes such as undercutting or piping; shape, size, composition and gradation of particles (except bedding material must be "cobble" size or greater); rock cover thickness and zoning; and steepness of underlying slopes.

"Individual rock fragments must be dense, sound, resistant to abrasion, and free from cracks, seams and other defects which tend to unduly increase their destruction by water and frost action. Rock covering of slopes may be unnecessary where top covers are very thick (on the order to 10m or greater); impoundment slopes are very gentle (on the order of 10h:1v or less); bulk materials have inherently favorable erosion resistance characteristics; and there is negligible drainage catchment area upstream of the pile and good wind protection" as described above.

"Furthermore, all impoundment surfaces must be contoured to avoid areas of concentrated surface runoff or abrupt or sharp changes in slope gradient....Areas toward which surface runoff might be directed must be well protected with substantial rock cover (rip rap). In addition to providing for stability of the impoundment itself, overall stability, erosion potential, and geomorphology of surrounding terrain must be evaluated to assure that there are not ongoing or potential processes, such as gully erosion, which would lead to impoundment instability.

"(e) The impoundment may not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand.... The term "maximum credible earthquake" means that earthquake which would cause the maximum vibratory ground motion based upon an evaluation of earthquake potential considering regional and local geology and seismology and specific characteristics of local subsurface material.

"(f) The impoundment, where feasible, should be designed to incorporate features which promote deposition..."

Technical Criterion 5 incorporates the basic ground-water protection standards imposed by EPA which are applied using a lengthy set of specific criteria. In addition, ground-water monitoring criteria are required by Criterion 7A.

5A(1) provides that "the primary ground-water protection standard is a design standard for surface impoundments used to manage" mill tailings. Unless exempted under Criterion 5A(3), "surface impoundments (except existing portions) must have a liner that is designed, constructed, and installed to prevent migration of wastes out of the impoundment to adjacent subsurface soil, ground-water, or surface water... The liner may be constructed of materials that may allow wastes to migrate into the liner (but not into the adjacent subsurface soil, ground-water or surface water) during the active life of the facility.....For impoundments that will be closed with the liner material left in place, the liner must be constructed of material that can prevent wastes from migrating into the liner during the active life of the facility."

5A(2) specifies liner properties, such that it must be:

"(a) Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients..., physical contact with the waste or leachate to which they are exposed, climatic conditions, the stress of installation and stress of daily operation;

"(b) Placed upon a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression or uplift; and

"(c) Installed to cover all surrounding earth likely to be in contact with the wastes or leachate."

5A(3) allows an exemption from the liner requirement if the NRC "finds, based on a demonstration by the ... licensee, that alternate design and operating practices, including the closure plan, together with site characteristics will prevent the migration of any hazardous constituents into ground-water or surface water at any future time." Before granting an exemption the NRC shall consider:

(a) The nature and quantity of the waste;

(b) The proposed alternate design and operation;

(c) The hydrogeologic setting of the facility including the attenuation capacity and thickness of liners and soil present between the impoundment and ground-water or surface water; and

(d) All other factors which would influence the quality and mobility of the leachate produced and the potential for it to migrate to ground-water or surface water."

5A(4) requires that "surface impoundments must be designed, maintained, and operated to prevent overtopping resulting from normal and abnormal operations, overfilling, wind and wave actions, rainfall, or run-on; from malfunctions ... and human errors."

5A(5) requires that "when dikes are used to form surface impoundments, the dikes must be designed, constructed, and maintained with sufficient structural integrity to prevent massive failure of the dikes. In ensuring structural integrity, it must not be presumed that the liner system will function without leakage during the active life of the impoundment."

5B(1) specifies that tailings facilities shall be managed to conform with ground-water protection standards for the range of hazardous materials associated with the tailings. These hazardous materials must not exceed specific concentration limits in the uppermost aquifer beyond a specified point of compliance. The point of compliance is to be selected to "provided the earliest practicable warning that the impoundment is releasing hazardous constituents to the ground-water...The Commission shall identify hazardous constituents, establish concentration limits, set the compliance period, and adjust the point of compliance if needed to accord with developed data and site information as to the flow of ground-water or contaminants..."

5B(2) provides that a constituent becomes hazardous and subject to Criterion 5B(5) when it is:

(a) ...reasonably expected to be in or derived from the byproduct material;

(b) ... detected in the ground-water in the uppermost aquifer; and

(c) listed in Criterion 13 (a list of several hundred hazardous chemicals too lengthy to be included in this paper.)

5B(3) provides for the NRC to exclude detected hazardous constituents if it finds that the constituent, on a site specific basis, is not capable of posing a substantial present or potential hazard to human health or the environment. In making this determination the NRC shall consider, for ground-water and surface water contaminants, a specified set of nine water quality impact and use considerations.

5B(4) provides that in addition to the specified criteria in 5B(3), determinations of exemption for individual hazardous constituents by the NRC shall "consider any identification of underground sources of drinking water and exempted aquifers made by EPA."

5B(5) provides that, "at the point of compliance, the concentrations of a hazardous constituent must not exceed:

(a) The NRC approved background concentration of the constituent in ground-water;

(b) The respective value given in the table in 5C, if listed, and if the background level is below the value listed; or

(c) An alternate concentration limit established by the NRC."

5B(6) provides the basis for alternate concentration limits which may be proposed by licensees and the criteria for NRC consideration. These criteria are equivalent to the specified set of nine water quality impact use relationships for ground-water and surface water in 5B(3).

5C presents a table of:

MAXIMUM VALUES FOR GROUND-WATER PROTECTION

Constituent or property (milligrams per liter)	Maximum Concentration
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Lead	0.05
Mercury	0.002
Selenium	0.01
Silver	0.05
Endrin (pesticide)	0.0002
Lindane (pesticide)	0.004
Methoxychlor (pesticide)	0.1
Toxaphene (pesticide)	0.005
2,4-D (pesticide)	0.1
2,4,5,-TP Silvex (pesticide)	0.01
(in picocuries per liter)	
Combined radium 226 and radium 228	5.0
Gross alpha-particle activity	15.0

(excluding uranium and radon when applied to uranium mill tailings sites)

5D requires that if ground-water protection criteria are exceeded, "a corrective action program must be put into place as soon as is practicable, and in no event later that 18 months after the NRC finds that the standards have been exceeded. The licensee shall submit the proposed corrective action program and supporting rational for NRC approval prior to putting the program into operation, unless otherwise directed by the NRC. The objective of the program is to return hazardous constituent concentration levels in ground-water to the concentration levels set as standards. The ...program must address removing the hazardous constituents that have entered the ground-water at the point of compliance or treating them in place....The licensee shall continue corrective action to the extent necessary to achieve and maintain compliance with the ground-water protection standard", as determined by the NRC.

5E provides that, in developing and conducting ground-water protection programs, applicants shall consider:

(1) Well tested and properly installed liners using leakage detection systems to ensure detection of failures;

(2) Mill process design to provide maximum recycle of mill solutions and water conservation to reduce the net input of liquids into the tailings impoundment;

(3) Dewatering of tailings by adequately-sized process devices and/or in-situ drainage systems; and

(4) Neutralization to promote immobilization of hazardous constituents.

5F requires that "where ground-water impacts are occurring at an existing site due to seepage, action must be taken to alleviate conditions that lead to excessive seepage impacts and restore ground-water quality. The specific seepage control and ground-water protection method, or combination of methods must be worked out on a site specific basis. Technical specifications must be prepared to control installation of seepage control systems. A quality assurance, testing, and inspection program, which includes supervision by a qualified engineer or scientist, must be established to assure the specifications are met."

5G requires that tailings disposal system applications include the following supporting data:

"(1) The chemical and radioactive characteristics of the waste solutions;

"(2) The characteristics of the underlying soil and geologic formations particularly as they will control transport of contaminants and solutions. This includes detailed information concerning extent, thickness, uniformity, shape, and orientation of underlying strata. Hydraulic gradients and conductivities of the various formations must be determined. This information must be gathered from borings and field surveys methods taken within the proposed impoundment area and in surrounding areas where contaminants might migrate to ground water. The information gathered from boreholes must include both geologic and geophysical logs in sufficient number and degree of sophistication to allow determining significant discontinuities, fractures, and channeled deposits of high hydraulic conductivity. If field survey methods are used, they should be in addition to and calibrated with borehole logging. Hydrologic parameters such as permeability may not be determined on the basis of laboratory analysis of samples alone; a sufficient amount of field testing (e.g. pump tests) must be conducted to assure actual field properties are adequately understood. Testing must be conducted to allow estimating chemi-sorption attenuation properties of underlying soil and rock.

"(3) Location, extent, quality, capacity and current uses of any ground-water at and near the site."

5H requires that "steps must be taken during stockpiling of ore to minimize penetration of radionuclides into underlying soils; suitable methods include lining and/or compaction of ore storage areas."

Technical Criterion 6 addresses requirements for covering tailings. It requires that "in disposing of [tailings], licensees shall place an earthen cover over tailings or wastes at the end of milling operations and shall close the waste disposal area in accordance with a design which provides reasonable assurance of control of radiological hazards to:

(i) be effective for 1,000 years, to the extent reasonably achievable, and in any case, for at least 200 years; and

(ii) limit releases of radon-222 from uranium byproduct material ....to the atmosphere so as to not exceed an average release rate of 20 picocuries per square meter per second (20 pCi/m[2]/s) to the extent practicable throughout the effective design life determined pursuant to (i) above. In computing required tailings cover thicknesses, moisture in soils in excess of amounts found normally in similar circumstances may not be considered. Direct gamma exposure from tailings or waste should be reduced to background levels. The effects of any thin synthetic layer may not be taken into account in determining the calculated radon exhalation level. If non-soil materials are proposed as cover materials, it must be demonstrated that such materials will not crack or degrade by differential settlement, weathering, or other mechanisms over long-term time intervals.

"Near surface cover materials (i.e. within the top three meters) may not include waste or rock that contains elevated levels of radium; soils used for near surface cover must be essentially the same, as far as radioactivity is concerned, as that of surrounding surface soils. This is to ensure that surface radon exhalation is not significantly above background because of the cover material itself.

"The design requirements in this criterion for longevity and control of radon releases apply to any portion of a ... disposal site unless such portion contains a concentration of radium in land, averaged over 100 m[2], which as a result of byproduct material does not exceed the background level by more than: (i) 5 picocuries per gram of radium-226 .... averaged over the first 15 centimeters (cm) below the surface, and (ii) 15 pCi/g of radium-226 .... averaged over 15-cm thick layers more than 15 cm below the surface.

"The licensee shall also address the nonradiological hazards associated with the wastes in planning and implementing closure ...[and] ensure that disposal areas are closed in a manner that minimizes the need for future maintenance. To the extent necessary to prevent threats to human health and the environment, the licensee shall control, minimize, or eliminate post-closure escape of nonradiological hazardous constituents, leachate, contaminated rainwater, or waste decomposition products to the ground or surface or to the atmosphere."

Technical Criterion 7 provides a framework for development of monitoring systems for tailings management and control. It requires that "at least for one full year prior to any major site construction, a preoperational monitoring program must be conducted to provide complete baseline data on a milling site and its environs." These systems must be maintained and operated continuously "to measure or evaluate compliance with applicable standards and regulations; evaluate performance of control systems and procedures; to evaluate environmental impacts..., and detect potential long-term effects."

Criterion 7A requires the establishment of a ground-water monitoring system upon which "site specific ground-water protection standards in paragraph 5B(1)" can be based. The "detection monitoring system has two purposes. The initial purpose ... is to detect leakage of hazardous constituents from the disposal area so that the need to set ground-water protection standards is monitored. If leakage is detected, the second purpose ... is to generate data and information needed for the NRC to establish standards under Criterion 5B. The data and information must provide a sufficient basis to identify those hazardous constituents which require concentration limit standards and to enable NRC to set limits for those constituents and the compliance period...[and] to provide a basis for adjustments to the point of compliance..."

"In conjunction with a corrective action program, the licensee shall establish and implement a corrective action monitoring program...to demonstrate the effectiveness of corrective actions." Monitoring programs "may be based on existing ... programs to the extent the existing programs can meet the stated objective for the program."

Technical Criterion 8 outlines measures to ensure that "airborne effluent releases are reduced to levels as low as reasonably achievable...[primarily] by means of emission controls. Institutional controls, such as extending the site boundary and exclusion area may be employed to ensure that offsite exposure limits are met, but only after all practicable measures have been taken to control emissions at the source. Notwithstanding the existence of individual dose standards, strict control of emission is necessary to assure that population exposures are reduced to the maximum extend reasonably achievable and to avoid site contamination. The greatest potential sources of offsite radiation exposure (aside from radon exposure) are dusting from dry surfaces of the tailings...not covered by tailings solution and emissions from yellowcake drying and packaging operations...

"Checks must be made and logged hourly of all parameters (e.g. differential pressures and scrubber water flow rates) that determine the efficiency of yellowcake stack emission control equipment..."

"To control dusting from tailings, that portion not covered by standing liquids must be wetted or chemically stabilized to prevent or minimize blowing and dusting to the maximum extent reasonably achievable. This requirement may be relaxed if tailings are effectively sheltered from wind, such as may be the case where they are disposed of below grade...Consideration must be given in planning tailings disposal ...to methods which allow phased covering and reclamation ....because this will help in controlling particulate and radon emission during operation."

8A mandates that "daily inspections of tailings ...systems be conducted by a qualified engineer or scientist. The licensee shall retain the documentation for each daily inspection as a record for three years..." The NRC "must be immediately notified of any failure in a tailings...system that results in a release ...into an unrestricted area, or of any unusual condition (...not contemplated in the design...) that...could...lead to failure of the system and result in a release of tailings...into unrestricted areas."

Financial Criterion 9 provides for the establishment of "financial surety arrangements...by each mill operator prior to the commencement of operations to assure that sufficient funds will be available to carry out decontamination and decommissioning of the mill and site and for the reclamation of any tailings or waste disposal areas. The amount of funds...must be based on NRC-approved cost estimates in a NRC-approved plan for (1) decontamination and decommissioning ...and (2) reclamation of tailings and waste retention areas in accordance with technical criteria" 1 - 8.

"In establishing specific surety arrangements, the licensee's cost estimates must take into account total costs that would be incurred if an independent contractor were to perform the decommissioning and reclamation work...The licensee's surety mechanisms will be reviewed annually by the NRC to assure that sufficient funds would be available for completion of the reclamation plan if work had to be performed by an independent contractor...

"Regardless of whether reclamation is phased through the life of the operation or takes place at the end of the operations, an appropriate portion of surety liability must be retained until final compliance with the reclamation plan is determined."

"This will yield a surety that is sufficient at all times to cover costs of decommissioning and reclamation...The term of the surety...must be open ended, unless it can be demonstrated that another method would provide an equivalent level of assurance ...Proof of forfeiture must not be necessary to collect the surety so that in the event that the licensee could not provide an acceptable replacement surety within the required time, the surety shall be automatically collected prior to its expiration...Financial surety arrangements generally acceptable to the NRC are:

surety bonds;
cash deposits;
certificates of deposit;
deposits of government securities;
irrevocable letters or lines of credit; and
combinations of the above... as may be approved by the NRC.

"However, self-insurance, or any arrangement which essentially constitutes self-insurance (e.g. a contract with a State or Federal agency) will not satisfy the surety requirement...."

Financial Criterion 10 establishes a minimum charge to cover the costs of long-term surveillance. This minimum of $250,000 "must be paid by the mill operator to the general treasury of the United States or to an appropriate State agency prior to the termination of a...license. If site surveillance or control requirements at a particular site are determined ... to be significantly greater than those specified in Criterion 12 (e.g. if fencing is determined to be necessary) variance in funding requirements may be specified by the NRC. In any case, the total charge to cover the costs of long-term surveillance must be such that, with an assumed 1 percent annual real interest rate, the collected funds will yield interest in an amount sufficient to cover the annual cost of site surveillance. The total charge will be adjusted annually prior to the actual payment to recognize inflation..."

Site and Byproduct Material Ownership Criterion 11 requires that each license provide that ownership or "title to the byproduct material and land...which is used for disposal of any such byproduct material...must be transferred to the United States, or the State in which such land is located, at the option of the State. In view of the fact that physical isolation must be the primary means of long-term control, and Government land ownership is a desirable supplementary measure, ownership of certain severable subsurface rights (for example, mineral rights) may be determined to be unnecessary to protect public health and safety and the environment...In some rare cases, such as may occur with deep burial where no ongoing site surveillance will be required, surface land ownership transfer requirements may be waived...

"Material and land transferred to the United States or a State in accordance with this Criterion must be transferred without cost to the United States or State other than administrative and legal costs incurred in carrying out such transfer...

"The provisions of this part respecting transfer of title and custody to land and tailings and wastes do not apply in the case of lands held in trust by the United States for any Indian tribe or lands owned by such Indian tribe...In the case of such lands which are used for disposal of byproduct material...the licensee shall enter into arrangements with the NRC as may be appropriate to assure long-term surveillance of such lands by the United States."

Long-term Site Surveillance Criterion 12 requires that "the final disposition of tailings or wastes at milling sites should be such that ongoing active maintenance is not necessary to preserve isolation. As a minimum, annual site inspections must be conducted by the government agency retaining ultimate custody of the site...to confirm the integrity of the stabilized tailings ...and determine the need, if any, for maintenance or monitoring...The NRC may require more frequent site inspections, if, on the basis of a site specific evaluation, such a need appears necessary due to the features of a particular tailings or waste disposal system."

Hazardous Constituent Criterion 13 requires that the "secondary ground-water protection standards [provided for] by Criterion 5 are concentration limits for individual hazardous constituents." This Criterion is supplemented by a three page list of specific constituents which conforms to EPA's 40 CFR 192 list. However, "the NRC does not consider the ...list to be exhaustive and may determine other constituents may be hazardous on a case-by-case basis..."