GEOTECHNICAL AND WATER RESOURCE ASPECTS OF URANIUM MILL TAILINGS PILE RECLAMATION PROJECTS

by

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ABSTRACT

Design and construction work is currently in progress at more than twenty sites associated with the UMTRA Project - this involves final reclamation of the uranium mill tailings piles so that they are stable for at least 200 years and for up to 1000 years.

Remedial action construction plans for the tailings piles involve detailed consideration of the present and possible future ground-water and surface-water impacts of the pile. Since the stabilized pile is ultimately a major geotechnical structure, detailed consideration of the long-term resistance to erosion and containment of radioactive material is also required. A case history illustrates how the critical design criteria governing the remedial action activities at the various piles are applied to the pile at the Lakeview site to provide for long-term protection of the water resource and public health and safety.

INTRODUCTION

The U.S. Department of Energy (DOE) oversees the Uranium Mill Tailings Remedial Action (UMTRA) Project which involves remedial action work at 24 inactive uranium mill tailings piles in 10 states. The Uranium Mill Tailings Radiation Control Act of 1978, PL95-604, grants the Secretary of Energy authority and responsibility to perform such acts as are necessary to minimize health hazards and other environmental hazards from inactive uranium mill sites. Standards for the project were developed by the Environmental Protection Agency (EPA) and, following completion of the remedial action, the sites are licensed by the Nuclear Regulatory Commission (NRC). The primary standards for the remedial action work are that remedial action control shall be designed to:

- Be effective for up to 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.
- Provide reasonable assurance that the releases of radon-222 from radioactive material to the atmosphere will not exceed an average release rate of 20 picocuries per square meter per second ($pCi/m^2 s$), or increase the annual average concentration of radon-222 in air at or above any location outside of the disposal site by more than 0.5 picocurie per liter.

The EPA standards also require a detailed hydrogeological characterization of each site to define the presence and extent of ground-water contamination. If contaminants have been released from a tailings pile, the EPA standards call for a case-by-case assessment of the need for remedial or protective actions for aquifers. This assessment must be guided by state and Federal drinking water criteria, and is based on the technical feasibility, cost/benefit, availability of alternative water supplies, and the degree to which human exposure is likely to occur. As required, this approach has been followed for the twenty sites investigated to date.

A recent decision by the U.S. Court of Appeals, Tenth Circuit, dated September 3, 1985, has remanded the water protection portions of the EPA standards to EPA for further consideration. In summary, the court has ruled that the EPA must develop numerical standards for water quality of general application to all inactive sites, rather than allow for case-by-case considerations on the need for protective and remedial actions. Until the revised EPA water protection standards are promulgated, the DOE is following an interim plan which uses Federal and state primary drinking water standards as the basis for formulating appropriate and cost-effective remedial action plans to protect public health and safety.

To date construction work has begun at three of the tailings sites, Canonsburg, Pennsylvania, Salt Lake City, Utah, and Shiprock, New Mexico. Design of the remedial actions at the remaining piles is in progress. This paper describes in general terms and by way of a case history, the geotechnical, civil engineering, and ground-water resource aspects of the remedial actions.

DESIGN REQUIREMENTS

A remedial action plan for stabilization of an inactive uranium mill tailings pile must be consistent with:

- o EPA standards for cleaning up inactive uranium mill tailings piles.
- o NRC requirements for concurrence.
- o State-of-the-art engineering practice.
- o The requirements of other concurring parties, including states and tribes.

Remedial action designs for tailings stabilization usually include several engineered layers for the purpose of isolating the tailings from the environment. Fig. 1 shows the layout and a cross section of a typical stabilized pile. Once placed at an environmentally acceptable site, the tailings are covered with a radon and erosion barrier system. The radon barrier is usually compacted silt or clay or both; the thickness varies with the activity of the tailings from about 300 millimeters to three meters. The radon barrier serves two purposes: first, it reduces the emanation of radon gas from the tailings; and, second, it restricts infiltration of water into the tailings, and hence minimizes leaching of potential contaminants from the tailings to the ground water. If the base of a pile is subject to periodic wetting by a near-surface water table, the remedial action plan may include provision for a low-permeability natural soil layer to be placed under the pile, if necessary, to provide additional water resource protection.

A filter is placed over the radon barrier to prevent piping of the radon barrier material into the larger voids of the erosion protection rock layer that is placed over the filter. The gradation of the rock of the erosion barrier is chosen so that the rock is able to resist the erosive forces that occur when water from the design precipitation event flows off or around the pile. An erosion barrier resistant to flow from this precipitation event will also resist wind erosion.

Channels or swales may be formed around the pile to direct flow of water from upstream areas around the pile. Depending on the grade and volume of water likely to flow in these swales or channels, they may or may not be lined with rock. The pile itself is shaped to shed water as efficiently as possible. The top surfaces are graded so that they are between two and four percent. The sides of the pile are graded to about one vertical to five horizontal (20 percent); this slope usually provides static and dynamic slope stability without requiring excessively large rock to resist erosion down the steeper sideslopes.

TECHNICAL APPROACH

In order to document the general approaches and design criteria to be adopted to prepare and implement a Remedial Action Plan (RAP), the DOE UMTRA Project Technical Assistance Contractor (TAC) has prepared the Technical Approach Document (TAD)[1]; and Technical Standard Operating Procedures (SOP) covering each project activity[2].

The TAD, compiled by DOE and the TAC, describes the technical approaches, methods, and the design criteria to be adopted to implement remedial action work that is consistent with the gen-

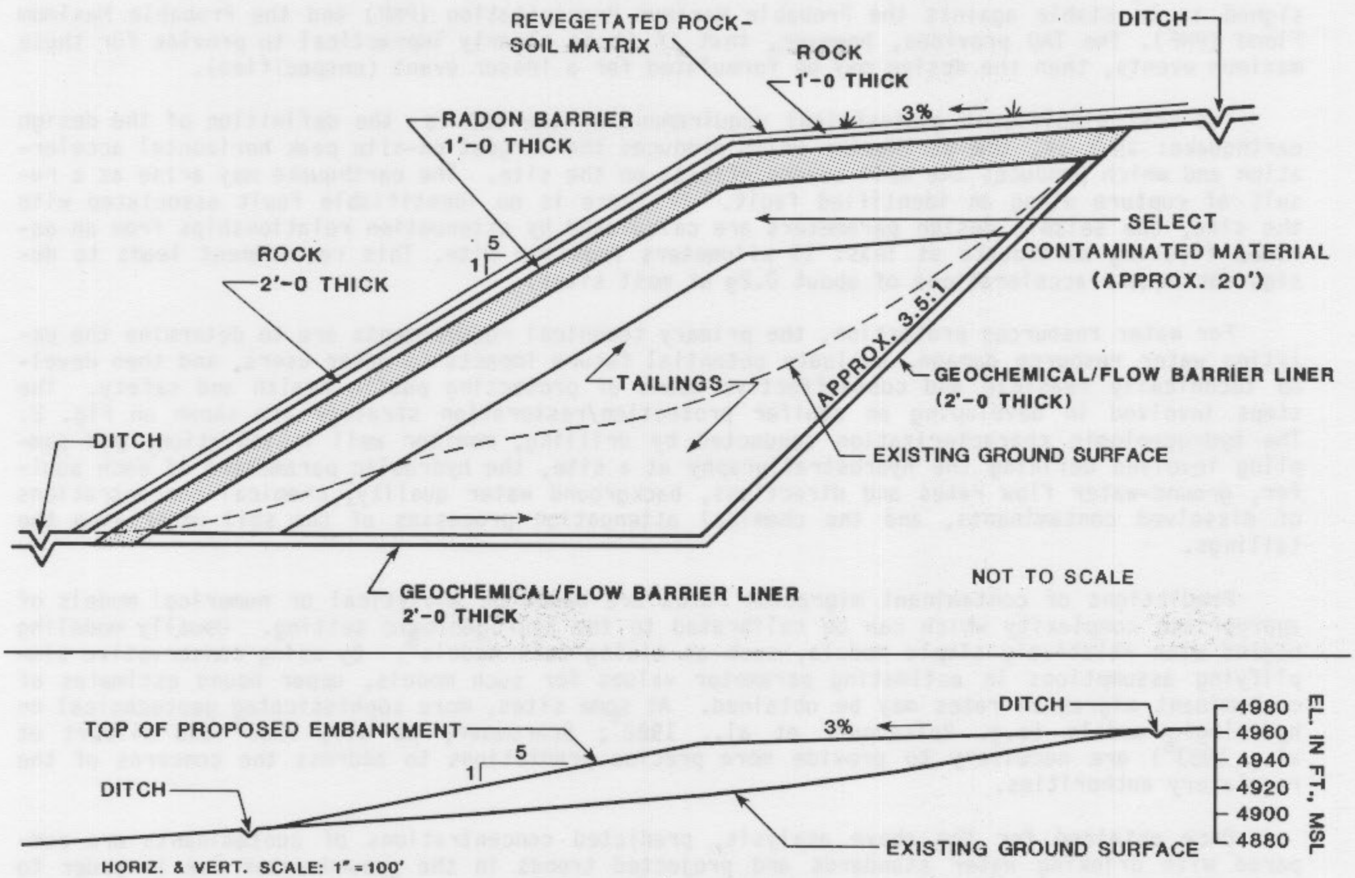

Fig. 1 Collins Ranch Disposal Site Typical Cross Section

eral standards applicable to the UMTRA Project and acceptable to the various concurring parties to the RAP. The four main sections of the TAD deal with surface water and erosion protection; geotechnical aspects; radon attenuation; and water resource protection. It is obviously not possible in a single paper to cover all aspects of pile design dealt with in the TAD. Accordingly, the following paragraphs discuss some highlights of the various sections.

With regard to erosion protection, the TAD notes that pile remedial action work will be designed to be stable against the Probable Maximum Precipitation (PMP) and the Probable Maximum Flood (PMF). The TAD provides, however, that if it is clearly impractical to provide for these maximum events, then the design may be formulated for a lesser event (unspecified).

The most significant geotechnical requirement of the TAD is the definition of the design earthquake: that is, the earthquake which produces the largest on-site peak horizontal acceleration and which produces the most severe effects on the site. The earthquake may arise as a result of rupture along an identified fault. If there is no identifiable fault associated with the site, the seismic design parameters are calculated by attenuation relationships from an assumed floating earthquake at least 15 kilometers from the site. This requirement leads to design earthquake accelerations of about 0.2g at most sites.

For water resources protection, the primary technical requirements are to determine the existing water resource damage, evaluate potential future impacts to water users, and then develop technically feasible and cost-effective means of protecting public health and safety. The steps involved in developing an aquifer protection/restoration strategy are shown on Fig. 2. The hydrogeologic characterization conducted by drilling, monitor well installation, and sampling involves defining the hydrostratigraphy at a site, the hydraulic parameters of each aquifer, ground-water flow rates and directions, background water quality, chemical concentrations of dissolved contaminants, and the chemical attenuation processes of the soil underlying the tailings.

Predictions of contaminant migration rates are based on analytical or numerical models of appropriate complexity which can be calibrated to the hydrogeologic setting. Usually modeling begins with relatively simple models, such as mixing cell models[3]. By using conservative simplifying assumptions in estimating parameter values for such models, upper bound estimates of contaminant migration rates may be obtained. At some sites, more sophisticated geotechnical or hydrologic models (e.g. Reisenauer et al., 1982[4]; Schroeder, et al., 1983[5] and Gilbert et al., 1983[6]) are necessary to provide more precise predictions to address the concerns of the regulatory authorities.

Once obtained for the above analysis, predicted concentrations of contaminants are compared with drinking water standards and projected trends in the ground-water use in order to assess the need and benefits of various design alternatives for aquifer protection/restoration. The cost of each design alternative is estimated. In general, the lowest cost alternative for dealing with the contamination in a potable aquifer is provision of alternative water supplies. When this strategy is combined with imposition of institutional controls to prohibit access to the contaminated ground water, public health and safety are adequately protected.

NRC CONCURRENCE

A Standard Review Plan was prepared by the NRC[7] in order to document the steps taken in reviewing an application for concurrence on a RAP. The document sets out the data the NRC requires in order to assess a plan, the criteria they use in evaluating a plan, and the issues they consider must be dealt with before they can concur in a RAP.

CASE HISTORY

The following section describes the remedial action at an UMTRA Project site, with particular attention to the geotechnical and ground-water aspects of the remedial action plan and the effect that the above-mentioned documents have had on the design[1].

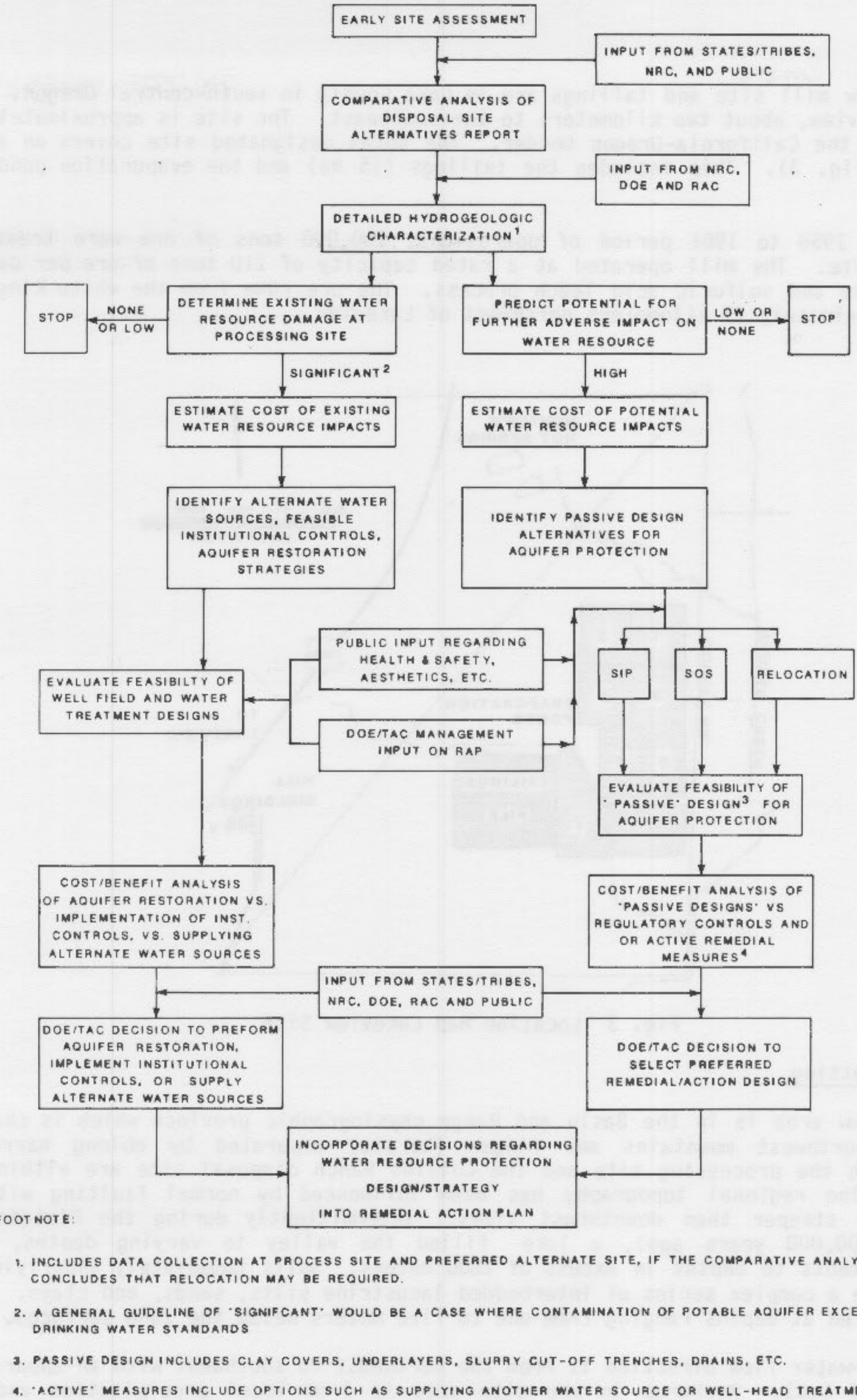

Fig. 2 TAC Approach for Identification of Aquifer Protection/Restoration Strategy

Lakeview, Oregon

The Lakeview mill site and tailings are in Lake County in south-central Oregon. The closest town is Lakeview, about two kilometers to the southeast. The site is approximately 25 kilometers north of the California-Oregon border. The total designated site covers an area of 120 hectares (ha) (Fig. 3). This includes the tailings (15 ha) and the evaporation ponds (approximately 30 ha).

During the 1958 to 1961 period of operations, 130,000 tons of ore were treated at the Lakeview mill site. The mill operated at a rated capacity of 210 tons of ore per day and used a sodium chlorate and sulfuric acid leach process. The ore came from the White King and Lucky Lass mines approximately 25 kilometers northwest of Lakeview.

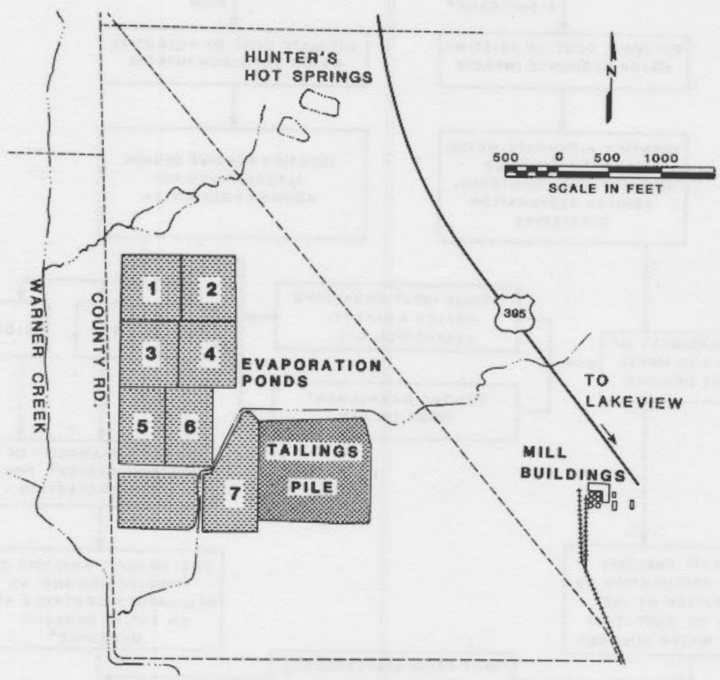

Fig. 3 Location Map Lakeview Site

Hydrogeologic Setting

The Lakeview area is in the Basin and Range physiographic province which is characterized by north to northwest mountains and ridges (horsts) separated by oblong narrow valleys (grabens). Both the processing site and the Collins Ranch disposal site are within the Goose Lake graben. The regional topography has been influenced by normal faulting with upthrust sides typically steeper than downthrust sides. Intermittently during the Pleistocene Epoch (10,000 to 1,000,000 years ago), a lake filled the valley to varying depths, depositing lacustrine sediments to depths in excess of 1800 meters. Soils immediately underlying the processing site are a complex series of interbedded lacustrine silts, sands, and clays. Ground water is encountered at depths ranging from one to five meters below the land surfaces.

The ground-water flow direction is from the northeast to southwest with an apparent hydraulic gradient of 0.01. Recharge in the site area is from local precipitation and snowmelt. Ground water discharges to surface drainages, springs, and wells in the area. There appears to be upward movement of ground water in the geothermal area north of the site. Differences in water levels of 600 millimeters to four meters between monitor well pairs indicate a small downward vertical hydraulic potential that decreases from northeast to southwest across the site.

A survey of domestic wells within 1.5 kilometers of the site showed only small differences in water level between shallow (30 meters deep) and 150-meter-deep wells. Therefore, strong vertical flow gradients outside the geothermal system are unlikely, and the entire sequence of sediments behaves as a single leaky system. Two aquifer tests were performed that indicated that restricted hydraulic interconnection exists between shallow (six meters) and deeper (20 meters) screened zones.

There are two chemically distinct types of upgradient water quality. The low temperature ground water exhibits a calcium-bicarbonate chemistry with total dissolved solids (TDS) of approximately 200 mg/l, whereas the geothermal ground water exhibits a sodium-sulfate chemistry with TDS of approximately 800 mg/l. Two contaminant plumes are migrating from the processing site. The main plume emanates from the southeast evaporation ponds and a lesser plume is migrating from the tailings pile. Extent of the plumes has been determined from sulfate or TDS concentrations. Elevated concentrations of radionuclides and most heavy metals are not appearing in the ground water, and are apparently attenuated in the subsoils beneath source areas of contamination. Differences in concentrations of elements between shallow and deep well pairs show that most of the contaminant migration has occurred in the shallow ground water, above 10 meters, and further attenuation of soluble species occurs as seepage moves downward into the deeper 25-meter zone.

Ground-water use downgradient of the site is generally sustained by pumping from zones greater than 25 meters deep. Available well records indicate there is no water usage from the shallow zone downgradient from the processing site. Therefore, because the contaminants have not endangered any downgradient water users and because the potential for future use is minimal due to marginal background water quality, provision of alternative water supplies for existing users or aquifer restoration at this site are not warranted.

The processing site is in a Geothermal Resource Area. The geothermal activity is associated with the seismotectonic setting of the area. Geothermal anomalies have been observed in the form of geysers, the closest of which is Hunters Hot Springs, 0.6 kilometer north of the site. Water temperatures of 60°C and 41°C in two monitor wells immediately north of the evaporation ponds and a 100-millimeter blowhole opening through snow on the southeast raffinate pond observed on January 27, 1984, also are indications of geothermal activities in the area.

South-central Oregon is in an area of moderate to high seismic risk. In addition to the ground motion experienced from a seismic event, a potential for surface rupture exists directly under the processing site due to the short distance (less than 0.8 kilometer) from the Fremont Mountain fault zone. There exists potential for solutioning of the siliceous cap rock or alteration by seismic events to produce venting directly beneath the tailings pile[8]. These potential geologic hazards do not exist at the proposed relocation site, Collins Ranch. Therefore, by moving the tailings and contaminated material to the Collins Ranch site, these potential hazards can be avoided and the EPA longevity requirements can be met.

Proposed Alternate Disposal Site

The tailings will be moved from the processing site to the disposal site at Collins Ranch which is approximately 10 kilometers northwest of the Lakeview tailings site. Soils underlying Collins Ranch are interfingered and layered silty sands, sandy silts, and surficial lenses of high plasticity clays. These materials, encountered to a depth of 40 meters, form the slopes of Augur Hill, and are a remnant pediment of outwash deposits from the nearby Fremont Mountains. Ground water was encountered in five of the nine boreholes completed as monitor wells. The four remaining on-site observation well borings did not encounter ground water within the stratigraphic interval penetrated. Four shallow wells (seven to eight meters) in the valley, just west of the site boundary when measured in December, 1984, showed water-table conditions with depths to ground water from 1.5 to six meters. One 25-meter well drilled on the disposal site near the course of a broad drainage channel on the southwest slope of Augur Hill showed ground water beneath the proposed boundary of the disposal site is presently about 10 meters deep. This depth increases moving up the slope of Augur Hill. Ground water beneath the site moves from northwest to south-southwest under a hydraulic gradient of 0.018. The ground-water flow direction is opposite the topographic slope indicating most recharge is from the Fremont Mountains to the west, rather than the small areal drainage divide immediately above the proposed disposal site.

The potential for ground-water contamination at the Collins Ranch disposal site appears to be minimal. The proposed design plan and natural site attributes should buffer the existing ground water from future contamination. To determine seasonal fluctuations in ground-water levels beneath the site, water levels will be monitored.

The average background gamma radiation exposure rate in the Lakeview region from both terrestrial and cosmic sources, measured at one meter above the ground, is 11 microrentgens per hour (microR/hr) with a range of eight to 19 microR/hr. Cosmic rays (radiation from the sun and other sources external to the earth) contribute approximately 5.3 microR/hr (48 percent) to the 11 microR/hr background gamma exposure rate in the Lakeview area.

Radon emissions from the tailings exceed the EPA standard of 20 pCi/m^{2}s by approximately eight times; however, the 600-millimeter earthen cover decreases the radon emissions by half. The radiation standards for buildings and open lands are exceeded in approximately six vicinity properties and 40 hectares of evaporation pond or windblown contaminated areas on and around the site.

Proposed Remedial Action

The principal feature of the design concept is the relocation of approximately 600,000 cubic meters of tailings and contaminated materials to the Collins Ranch disposal site. The proposed final pile is shown in Fig. 4. The contaminated materials will be consolidated into a

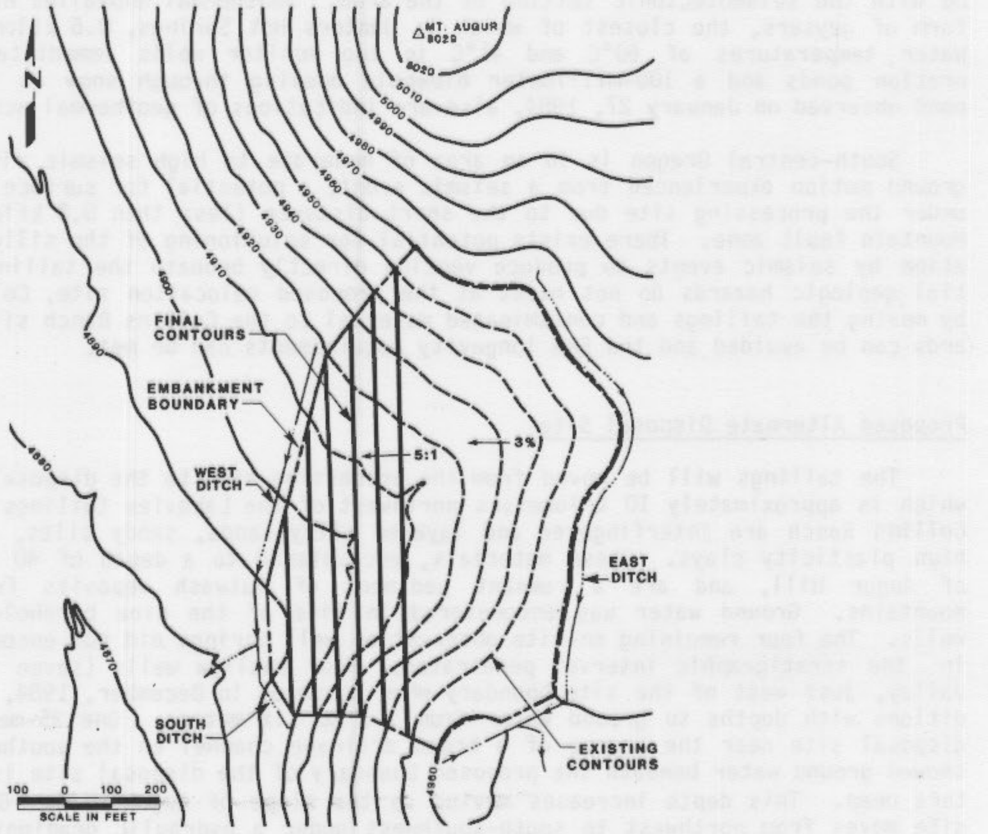

Fig. 4 Proposed Final Pile, Collins Ranch Site

pile constructed with 20 percent sideslopes and four percent topslopes partially below grade, and covered with protective layers consisting of a compacted clay layer to reduce radon emissions to acceptable levels and reduce infiltration, a rock erosion protection layer on the sideslopes, and a rock-soil matrix to support vegetation and protect against erosion on the topslopes.

Approximately 300 millimeters of soil for the radon barrier will be excavated from the pile area. An additional 400,000 cubic meters of soil will be excavated from the disposal site for processing site backfill. A compacted low-permeability clay layer approximately 600 millimeters thick will be constructed as a base for the tailings. The low-permeability layer will be constructed from select materials excavated from the site. The tailings and highly contaminated material will be placed and compacted first, then the less contaminated material will be placed and compacted, and an earthen cover placed. The pile will be capped on the top with a rock-soil matrix. The sideslopes will be protected with a rock cover. The rock has been designed to counter erosion by wind and water, and to impede inadvertent disturbance by man or animals. The rock-soil matrix is specified to minimize plant root intrusion, while at the same time facilitating revegetation of the surface. Plant root intrusion will primarily be impeded by the compacted (95 to 100 percent maximum density by ASTM D698) radon barrier.

Compliance with UMTRA Project Procedures, Criteria, and Standards

The design for the remedial action described above has been carried out in accordance with the various documents described in the early sections of this paper. The design system of layers at the Lakeview site is very similar to the generic design cross section given in Fig. 1, except that a rock-soil matrix is to be used on the top surface. The climate at the site is such that long-term vegetation is a viable option. As vegetation usually serves to reduce the quantity of water flowing through the pile, this option has been adopted for the Lakeview site.

The rock of the rock-soil matrix will prevent significant erosion of the cover. The 50-percent size of the rock is such that it will not be moved even if flow from the Probable Maximum Precipitation flows across the pile surface. Hence the criteria regarding the long-term integrity of the pile are met.

The low-permeability natural soil layer is placed under the pile to provide additional ground-water resource protection. This layer is placed in order to restrict migration of potential chemical contaminants from the base of the tailings. Geochemical properties of this layer which reduce the migration of solute species, including adsorption and neutralization. The hydraulic conductivity of the radon barrier will be low (less than 10^{-7} cm/sec) hence infiltration through this barrier is impeded.

The thickness of cover material required to limit radon flux to below EPA standards (20 pCi/m^2s) is calculated using the computer code RAECOM[9]. The mathematical model implemented in RAECOM describes one-dimensional steady-state radon diffusion through a two-phase multilayer system of porous media, representing the tailings pile and its cover. Multiple layers of tailings and cover are allowed, with differences in physical, radiological, and diffusional properties represented by layer-specific input parameters (such as thickness, porosity, and the like). Details are contained in the TAD[1].

The pile as shown in Fig. 4 has flat slopes (5 horizontal to 1 vertical). The main reason is that at such a slope the velocity of water flowing off the pile from extreme precipitation events is not so high that it is impractical to provide rock of reasonable size which resists erosion. In addition, such flat slopes are stable against slope failure for both static and dynamic conditions.

The tailings as placed in the pile will be compacted to 90 percent of their maximum density (as determined by ASTM D698). At this density, settlement by consolidation of the tailings is small and the potential deformation of the cover is not large enough to cause either cover (radon barrier) cracking or a surface topography that will lead to concentration of flow off the pile. The shape and layout of the pile have been designed to blend into the natural topography and to make as much use as possible of natural features to control runoff.

The pile will, at completion of construction, be surrounded by a series of granite monuments which will serve to designate the site. No fence will be erected. Following remedial action, regular surveillance and maintenance will be done[8].

CONCLUSION

The UMTRA Project provides for effecting remedial action work at a large number of inactive uranium tailings piles, in a diversity of climates and states. Remedial work has to be concurred in by the states or tribes in whose area the pile is situated. The EPA and the NRC have to review and also concur in the planned remedial action. As described in this paper, a number of documents have been produced to date to record and describe the design standards, criteria, and methods to be adopted in formulating remedial action plans. The acceptance of these documents by affected parties has considerably facilitated the process of reaching concurrence on the details of remedial action.

As illustrated by the case history of the Lakeview Remedial Action Plan, implementing criteria and requirements from the various project design documents leads to a practical stabilization plan for the tailings, and one which will protect the environment and preclude unacceptable changes of ground-water quality.

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ENVIROCHEM CONTROL AND ELIMINATION
OF OFF-SITE MIGRATION OF CONTAMINATED WATER

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ABSTRACT

Under the Authority of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), U.S. Environmental Protection Agency's Region V Emergency Response Section conducted an Immediate Removal Action at the Environmental Conservation and Chemical Corporation (Envirochem) located in Boone County, Indiana. Contaminated water emanating from under a concrete pad, previously used as a drum storage area, was migrating off site and entering a tributary that led to the Eagle River Reservoir, a water supply reservoir for the City of Indianapolis, Indiana, approximately 10 miles downstream.

Source(s) of the run-off water was unknown, although it was surmised that it may have been attributed to either surface water recharge immediately upgradient of the pad or ground water recharge from the shallow artesian aquifer. A cleanup approach was recommended which would determine the source of the water, and subsequently identify appropriate mitigative measures to prevent the off site migration of contaminants.

Discussion will be presented which summarizes the chain of events related to the site and outlines the three major proposed phases of the removal action. Phase I addresses surface water run-off control, installation of an extraction well and piezometers, and excavation of a water collection sump. Specific discussions will include the implementation of the removal action, where installation of the piezometers, pump well and sump well successfully defined the source and quantity of water beneath the concrete pad. Additional discussion will detail the removal of the contaminated water and the elimination of the source. Finally, discussion will be presented detailing the cost savings of approximately $700,000 utilizing the specific, step-wise approach of defining and controlling the water run-off implemented at the Envirochem site.

SITE LOCATION, HISTORY AND INITIAL SITUATION

Environmental Conservation and Chemical Corporation (Envirochem) is located in Boone County, 905 South U.S. 421, near Zionsville, Indiana, about ten miles northwest of Indianapolis (Figure 1). The site occupies 6.5 acres within the 168 acre Northside Sanitary Landfill, an operational solid waste disposal facility which was included on the National Priorities List published in September 1983.

The Envirochem facility is bounded on the south and east by the landfill. An unnamed ditch separates the two facilities along the east boundary of the site. The site is bounded on the north and west by several residences, located within one-half mile of the facility. The Eagle River Reservoir, a water supply reservoir for the City of Indianapolis, is in the same drainage basin as the site, approximately ten miles downstream.

Envirochem began operations in August of 1977. The company was engaged in the recovery/reclamation/brokering of primary solvents, oils, and other wastes received from industrial clients. Two problems developed during the facility operation: 1. The inability of the company to