IMPROVED DISPOSAL TRENCH IN A FRACTURED GEOLOGIC MEDIA AND IN A HUMID ENVIRONMENT

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ABSTRACT

The two related problems of trench cover subsidence and infiltration of water into disposal trenches have been the major cause of failure in past commercial burial operations in humid environments and has continued to defer the decommissioning of existing sites. This paper presents the design of an improved disposal trench which provides long term structural stability and the management of ground and surface water. Construction of the trench was started during the fall of 1985 for the burial of solidified evaporator concentrate waste which had accumulated at the Maxey Flats Disposal Site. The project was jointly funded by the Department of Energy and the Commonwealth of Kentucky. A major program objective was to demonstrate the transferability of the trench design to other sites located in humid environments and containing different waste forms.

INTRODUCTION

The control of ground and surface water is of primary importance in the design of a disposal trench since water is the primary vehicle for the movement of radionuclides out of the trench confines and off-site. Past disposal practices at commercial sites in humid environments have resulted in what is known as the bathtub effect, or the accumulation of infiltrating water into the trenches. This was due to the overall permeabilities of the surrounding geologic formations being lower than the permeabilities of the trench covers. The trenches eventually filled with water and overflowed, resulting in dissolved radionuclides being released from the trenches. Subsidence of the trench covers happened at most commercial sites and compounded the problem.

Subsidence occurred due to consolidation of the trench backfill material and to degradation of the waste containers. This lead to localized collapse of the trench covers. Precipitation collected in the subsidence areas, and thereby increased the amount of water that infiltrated into the trenches.[1] The design objectives of the improved disposal trench were therefore to provide long term structural support of the trench cover and to provide a means of minimizing the amount of infiltration into the trench.

Site Hydrology and Geology

Maxey Flats is located in a humid environment with an annual rainfall between 43 and 47 inches. When precipitation contacts the ground surface, it becomes one of three components of the water balance: runoff, evapotranspiration, or infiltration.

The largest component of the water balance is surface water runoff, which includes all storm water that does not infiltrate the surface or evaporate directly. At Maxey Flats, it is estimated that 50 percent or more of the precipitation can become surface runoff. The second component of the water balance is evapotranspiration. This includes direct evaporation into the atmosphere and transpiration by living plants. The amount of precipitation lost to evapotranspiration can be almost as much as the amount that becomes surface runoff. Therefore, only a small fraction of the precipitation infiltrates the soil. The infiltration rate or amount of surface water taken into the soil depends upon several factors. These include the texture, structure, depth, and nature of the soil cover; depth of root penetration; intensity and duration of the storm; and season of the year. The infiltration rate into undisturbed surface soil at Maxey Flats under a minimum soil cover and after thorough prior wetting ranges from zero to 0.05 inches per hour.

The site is underlain by several sedimentary rock formations with low water transmitting abilities. A geologic section of the Nancy Member of the site stratigraphy developed from near surface borings taken in the trench area is shown in Fig. 1. Most of the rock is shale except for the two sandstone marker beds. Because of the anisotropic nature of the subsurface media, it is difficult to model the flow of groundwater at Maxey Flats. The low primary permeabilities of the geologic layers beneath the site cause the principal groundwater movement to be along secondary openings, or fractures, in the rock. These fractures are more continuous in the lateral direction than in the vertical, which causes water to move laterally until a vertical fracture in the underlying rock is encountered. One result of this is that groundwater containing leachate from the trenches tends to flow on top of the lower sandstone marker bed.[2]

Design Requirements

At a disposal facility sited today, the trenches would be designed such that any water that had infiltrated into the trenches would drain rapidly through the trench floors and thereby lessen the contact time with the waste and reduce the amount of leachate produced. The problem with this concept were it applied at Maxey Flats is that the site is a demonstrated bathtub with permeabilities of the native soil

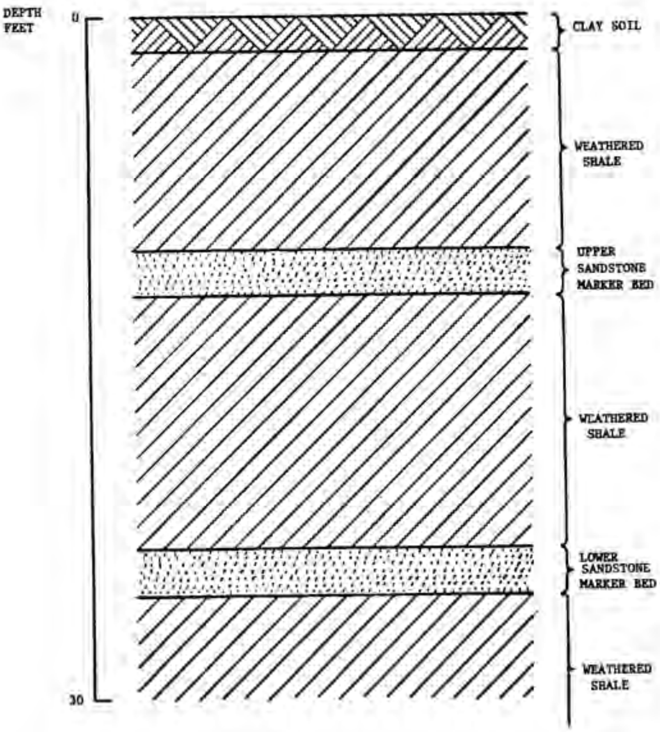

Fig. 1. Geologic Section of the Nancy Member Maxey Flats Site.

being as low as 10^{-8} cm/sec. [2] Any water that infiltrates into a Maxey Flats trench will stay there and be in contact with the waste for a long period of time. Therefore, the trench design must reduce the amount of infiltration to as low a level as possible. To accomplish this and the long term structural stability objective for the improved disposal trench sited at Maxey Flats, the following major design requirements were developed:

- o The support system for the trench cover would be independent of the waste containers.
- o The design life of the trench cover support system would be 300 years. This design life was selected since it is consistent with the waste form and stability requirements of 10 CFR 61.7.
- o The trench cover would be sloped and surface drains would be provided to convey surface water away from the disposal trench.
- o Water which infiltrates the trench cover would be diverted to a subsurface drainage system.
- o The trench design would prevent the lateral infiltration of groundwater into the trench.
- o The bottom of the trench would be located above the lower sandstone bed.
- o The trench floor would incorporate a hydraulic barrier to preclude leachate from surrounding trenches entering the bottom of the trench.
- o A performance monitoring program would be developed for the improved trench.
- o The trench design would provide for operational and radiological safety to site personnel, visitors, and the general public.

TRENCH DESIGN ELEMENTS

The design elements of the improved disposal trench consist of the trench floor, the trench sidewalls, the placement of waste and backfill, the trench cover support system, and the trench cover. The following sections will discuss how each of the above elements were designed to meet the program objectives and design requirements.

Trench Floor

The floor of the improved trench, as shown in Fig. 2, was excavated with a 1% slope running in two directions to promote drainage both during and after operation. The bottom of the trench was then layered with a mixture of gravel and dry granular sodium bentonite. The bentonite swells up to twelve times its dry volume upon contact with water and thus fills the void spaces between the gravel. The layer forms a barrier to the infiltration of water into the trench from below, so that monitoring of the trench cover and lateral infiltration barriers can be performed. It should be noted that the trench floor infiltration barrier was provided in the Maxey Flats trench to cope with the site specific problem of a potentially contaminated perched water table located just beneath the trench floor. At a different site, it would be desirable to have water that had infiltrated through the trench cover quickly exit the trench to minimize contact time with the waste. At such a site, a trench floor infiltration barrier would not be constructed.

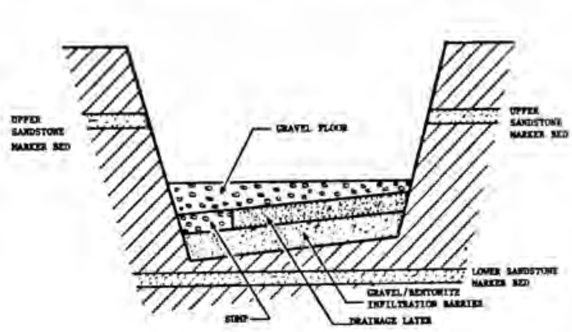

Fig. 2. Trench Floor.

Above the infiltration barrier, a gravel collection/monitoring sump was placed at the low end of the trench. A gravel drainage layer was then also placed above the infiltration barrier to allow any water that infiltrates down from the top of the trench to be collected in the sump. A layer of geotextile was placed above the gravel to act as a construction separator, and a final layer of gravel was spread over the geotextile and graded to form a level surface for the placement of waste containers and movement of operational equipment.

Trench Sidewalls

To intercept groundwater in the vadose zone from moving into the trench, upgradient drains which eventually terminate at the ground surface could have been constructed adjacent the trench. *Unfortunately*, this was not possible at Maxey Flats. The ground water is contaminated with radionuclides from other trenches, and the upgradient drain could have allowed the release of contaminated water from the site.

To solve the problem of groundwater movement into the trench from the side, a slurry wall constructed within the trench was selected as the most practical solution. The idea of constructing a slurry wall around a disposal trench is not new, but it requires a separate excavation around the trench with the bottom of the wall keyed into a strata of low permeability. The walls are generally costly to construct and require a crew experienced in their construction. A unique feature of the slurry wall designed for the improved trench is that it would be constructed within the disposal trench and utilize the waste containers as structural forms for the wall. As shown in Fig. 3, the waste containers were placed within the trench so that a space was left between the containers and the trench wall. Perforated pipes were then placed within the space. As each layer of waste was placed in the trench, the space was backfilled with clean, uniformly graded gravel. In that manner, a perimeter wall of gravel was formed around the trench interior. During the fall of 1985, the trench was filled with waste and backfilled.

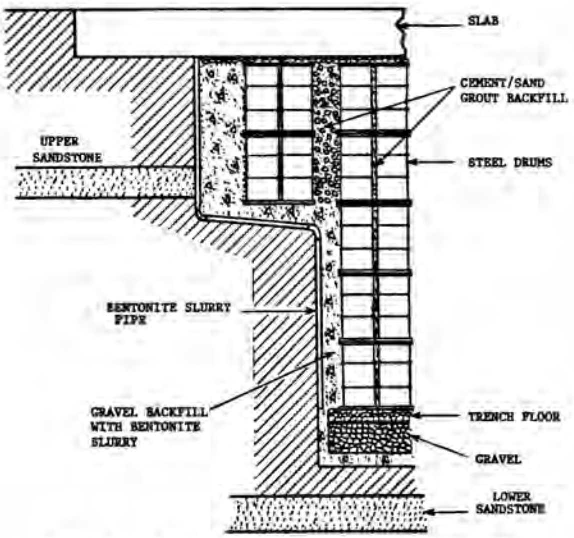

Fig. 3. Perimeter Infiltration Barrier.

In the spring of 1986, the gravel perimeter wall will be injected with a bentonite slurry through the perforated pipes. The bentonite will be injected to the bottom of the wall to displace the air in the gravel and prevent the formation of air pockets within the wall. In that manner, a bentonite slurry wall will be constructed around the perimeter of the disposal trench. The bentonite slurry has low permeability, approximately 10^{-8} cm/sec, [3] and will greatly reduce the infiltration of groundwater through the sides of the trench.

One problem associated with a slurry wall constructed in this fashion is that the waste containers are still providing lateral support to the wall. This is fine during construction, but it does not meet the 300 year design life requirement for the trench since the containers will degrade over that period of time. The bentonite slurry does not have sufficient gel strength to provide a free standing, structurally stable wall. Therefore, the wall must be supported in some manner over the design life of the trench. The answer for providing such support was found in the waste placement and backfill design of the trench.

Waste Placement and Backfill

The design requirement that the cover trench support system be independent of the containers eliminated the use of unstabilized earth as a trench backfill material. A cement grout was therefore selected as the backfill material. To be effective and to predict the structural strength of the grout backfill, the geometry of the cavities to be backfilled with grout must be controlled. This requirement precluded the random placement of the waste within the trench. Instead, the containers (55-gallon steel drums) were placed within the trench such that cells of drums were formed, and the spaces between the drums were filled with grout. The grout was formulated to be sufficiently fluid to flow between the drums, have a fairly fast set time and develop suitable compressive strength. Formulating a grout with a quick setting time also ensured that the grout would not completely penetrate the gravel perimeter wall and block the future injection of the bentonite slurry. The grouting was done in stages and care was taken to ensure that not too much grout was placed in any one area to avoid floating the drums. In that manner, grout columns and walls were formed within the trench. As shown in Fig. 4, several different arrangements of drums were tested in the Maxey Flats trench. Also, two Westinghouse hexagonal reinforced concrete modules (SUREPAKs™) were placed in the trench to observe their ability to control subsidence.

Besides the container arrangements shown in Fig. 4, the improved trench design can accommodate all of the different types of containers currently being buried at commercial disposal sites. These include steel drums, high integrity containers (HICs), liners, and low-specific activity (LSA) boxes. A typical configuration for the placement of these types of waste containers within a trench is shown in Fig. 5.

During commercial operation of the improved disposal trench, cells within an array of low activity containers can be left open for containers of high activity waste. The surrounding lower activity containers are used as shielding as shown in Fig. 5. A form can be placed around the high activity container so that after placement within the cell, the cell can be filled with grout to completely cover the high activity container. The grout then provides additional lateral and vertical shielding. During filling of the trench, the waste containers should be categorized so that high activity waste is placed in or near the bottom of the trench and only low activity waste containers form the top layers.

Trench Cover Support

With the system of grout columns and walls formed within the trench, subsidence of the cover can still occur between the grouted areas or in areas where grout did not penetrate. Also the drums can tilt or fall after placement creating voids within the waste mass. For these reasons, a slab is required over the waste. From a cost standpoint, the optimum slab material for the improved disposal trench is reinforced soil cement.

The reinforcement considered for the slab design were steel and prestressed high density polyethylene grids. Since the steel is on the tension side of the slab, cracks can develop in the slab and moisture can penetrate the cracks and attack the steel. For this

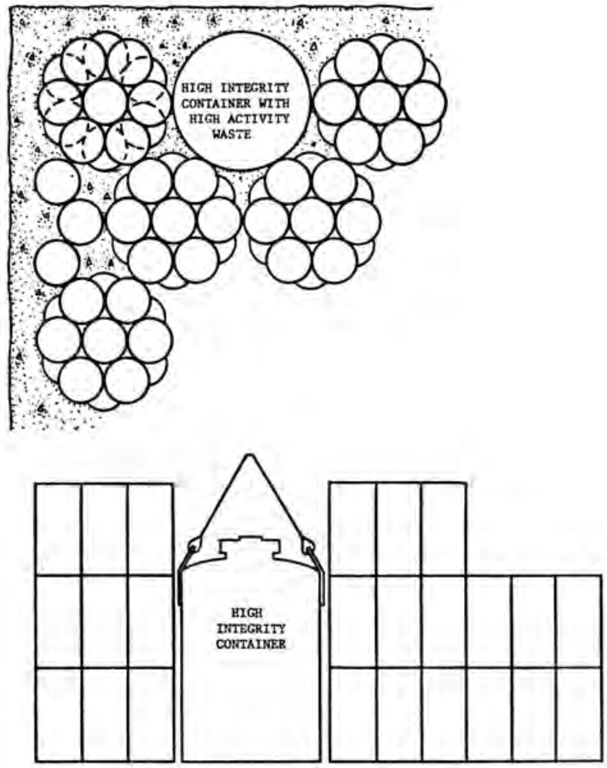

Fig. 5. Formation of Cells for High Activity Waste.

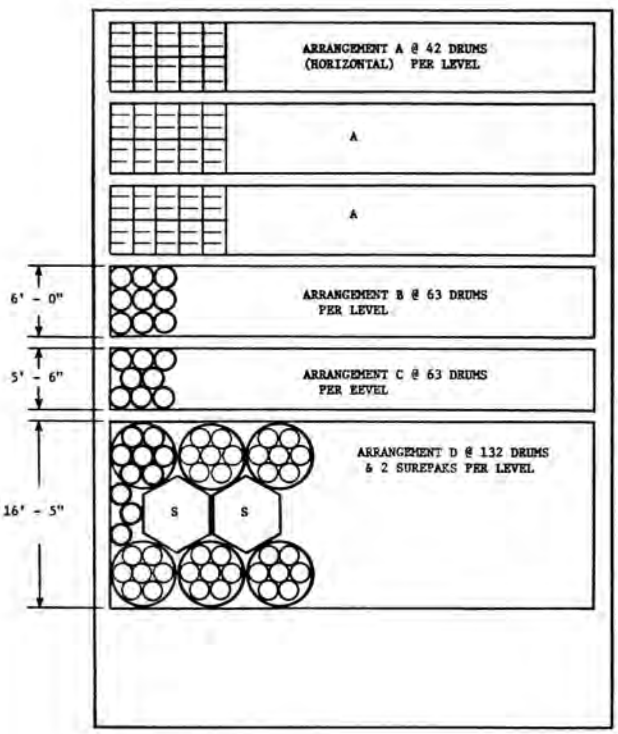

Fig. 4. Arrangement of Drums in the Maxey Flats Trench.

reason, standard steel rebar might not remain functional for the full design life of the trench. The rebar can be epoxy coated or fabricated from stainless steel for improved life. Epoxy coated rebar requires special care in handling to ensure that the coating is not scratched or damaged, and both it and stainless steel bar are expensive. Polyethylene grids are less costly than epoxy coated or stainless steel rebar, and polyethylene is resistant to chemical attack. Polyethylene is more ductile than steel and subject to greater creep. The initial deformation of polyethylene is high, but after several years the deformation becomes constant under constant load.[4] Due to its lower cost and resistance to chemical attack, polyethylene reinforcement grids were selected.

Soil cement is prepared by mixing the native soil with generally 5 to 10 percent Portland cement. The soil cement is mixed at optimum moisture content in a portable concrete batch plant. It is then spread over the waste and compacted at close to the maximum Proctor density. The slab is formed by first placing a layer of soil cement over the waste to provide shielding and then alternate layers of reinforcement and soil cement are placed to build up the required thickness of the slab.

A soil cement slab would be the optimum choice at a commercial disposal site where equipment to batch and mix the material could be a permanent part of the disposal site equipment. Unfortunately, it is not feasible to obtain this equipment on a one time basis for use on a small demonstration trench at Maxey Flats. For this reason, a slab formed from commercially available ready mix concrete reinforced with polyethylene grids will be placed over the improved disposal trench during the spring of 1986.

Trench Cover

After the slab has been placed and allowed to set, the top of the slab will be backfilled with native soil to form the contour of the trench cover. The design of a trench cover is highly dependent upon the site location. Factors such as rainfall, frost depth, physical and chemical characteristics of the native soil, and types of native plants and animal species will influence the cover design. The cover chosen for the Maxey Flats site, shown in Fig. 6, is representative for an improved cover design in a humid environment. It may differ from the cover designed

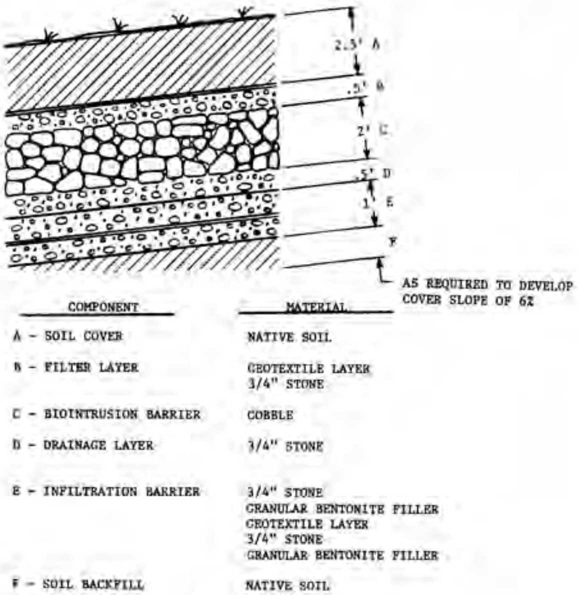

Fig. 6. Trench Cover.

for another site, but its basic functionality should be the same. The cover consists of four functional layers: an infiltration barrier, a drainage layer, a biointrusion barrier, and a soil cover.

The infiltration barrier will be composed of crushed stone with bentonite spread on top. The bentonite will fill the void spaces between the stones once it has been hydrated and provides a barrier with a permeability on the order of 10^{-8} cm/sec. In a humid environment, the soil moisture content should be sufficient to keep the bentonite hydrated and prevent the infiltration barrier from drying out and cracking. If during drought conditions the bentonite were to dehydrate, it will rehydrate and swell upon contact with moisture. [3]

Above the infiltration barrier, a drainage layer consisting of six (6) inches of stone will be placed. Water collected by this layer will flow to a subsurface drain at the sides of the waste trench.

The biointrusion barrier will be placed above the drainage layer. Current research work on the effectiveness of biointrusion barriers is being performed at Los Alamos National Laboratory. [5] The work is being performed in an arid environment using indigenous plant and animal species, but the general methodology of providing a barrier to plant roots and burrowing animals should be transferable to a humid site. Since no data is available to date on biointrusion in a humid environment, the Los Alamos data was used to design the biointrusion barrier. The barrier will be formed by a two (2) foot thick layer of cobble. The cobble layer is prevented from silting up with soil from the uppermost layer by an intervening six (6) inch thick layer of crushed stone. The soil layer is thirty (30) inches thick, and therefore the total effective depth for biointrusion is sixty (60) inches.

The thirty (30) inch soil layer is sufficiently thick to provide freeze/ thaw protection to the filter and barrier layers and to store water for the vegetation. The soil will be fertilized and a vegetative cover consisting of Kentucky 31 Fescue established to control erosion of the soil layer.

SUMMARY AND CONCLUSIONS

The demonstration program for an improved trench being constructed at the Maxey Flats Site offers several innovative solutions to the problems of trench cover subsidence and the infiltration of water into a trench. These solutions include the construction of a perimeter slurry wall within the trench, the use of the waste containers as forms for the formation of cement grout columns and walls which support the trench cover, and the construction of infiltration barriers composed of gravel and granular bentonite. A monitoring program was developed for the trench to test the performance of these solutions. Sodium Bromide and Sodium Iodide will be used as tracers to indicate the presence of leachate and for the performance of the trench cover infiltration barrier, respectively. To determine runoff and infiltration rates for the trench cover, a complete water balance of the trench area will be made. Also, elevation markers will be placed on the trench cover to determine and detect subsidence. Construction of the trench was started during the fall of 1985. Prior to terminating construction activities for the winter, all of the waste was placed in the trench, the perimeter gravel wall was completed, and the trench was backfilled with the cement grout. During the spring of 1986, construction of the trench will be completed, and performance monitoring will commence. To date, no major construction difficulties have been encountered and it appears that the design can be successfully implemented.

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