MODIFICATIONS TO AN EXISTING WASTE CONTAINMENT STRUCTURE AT NIAGARA FALLS STORAGE SITE

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ABSTRACT

The Niagara Falls Storage Site (NFSS), located near Lewiston, New York, is an interim waste containment facility for low-level radioactive waste. The facility was completed in 1986 and is managed for the Department of Energy (DOE) by Bechtel National, Inc. (BNI) as part of the Formerly Utilized Sites Remedial Action Program (FUSRAP). The waste containment structure (WCS) at NFSS is approximately 297 m (975 ft) long and 137 m (450 ft) wide and reaches a maximum height of 10.4 m (34 ft). The peripheral slopes rise at an angle of 3:1 (h:v) for a width of about 16.8 m (55 ft), where the inclination decreases to 7.5%. The apex of the pile is higher at the south end, sloping about 1.2 m (4 ft) to the north. The interim layered cap consists of 0.9 m (3 ft) of clay overlain by 0.45 m (1.5 ft) of topsoil. The uppermost 15 cm (6 in.) of soil was loosely compacted to permit the development of a grass cover.

In the summer of 1991, approximately 2,677 m^3 (3,500 yd^3) of additional contaminated soil and material in temporary storage elsewhere at NFSS was incorporated into the WCS. To accommodate the waste, a portion of the cap roughly centered with the pile [including 0.45 m (1.5 ft) of topsoil and 0.6 m (2 ft) of clay cap] was removed from an area 99 m (325 ft) long and 58.5 m (192 ft) wide, leaving a minimum of 0.3 m (1 ft) of clay over the old waste as a radiation and radon barrier. The newly incorporated waste forms a layer 0.6 m (2 ft) thick, replacing the clay portion of the excavated cap. The waste is contained laterally by the old cap and sealed by a new cap, which also consists of 0.9 m (3 ft) of compacted clay and 0.45 m (1.5 ft) of topsoil. A transition zone about 6.1 m (20 ft) wide feathers the new cap to the old cap (see Fig. 3). Except for the uppermost 10.5 to 15.2 cm (4 to 6 in.) of vegetated topsoil, the excavated cap materials were stockpiled and reused in constructing the new cap. Additional material required to complete cap construction was imported from nearby sources. Hydroseeding, a technique involving wood pulp, water, seed, and sometimes fertilizer, was used to create the vegetative (grass) cover.

This paper describes in detail each phase of the basic operations: partial excavation of the cap, waste placement, and new cap construction. Additionally, it introduces concepts relating to excavation methods, measures to prevent cracking of the remaining original cap, daily protection of newly placed waste to prevent contamination of neighboring surfaces or rainwater, lateral drainage of precipitation, equipment distribution during construction, placement of storage drums and miscellaneous debris as part of the new waste, soils laboratory control prior to and during execution of the work, and compaction of the clay cap, with permeability outweighing shear strength or compressibility as the prime consideration.

INTRODUCTION

Waste material temporarily stored at three locations at NFSS has been consolidated by incorporation into the WCS. To create the space for approximately 2,677 m^3 (3,500 yd^3) of new waste, a rectangular area [99 by 58.5 m (325 ft by 192 ft)] of the original WCS cap was excavated, leaving a minimum of 0.3 m (1 ft) of clay cover over the old waste to control radiation and radon emanation. After placement of the waste at this new location, a layered clay/topsoil cap with characteristics similar to those of the original cap [0.9 m (3 ft) of clay and 0.45 m (1.5 ft) of topsoil] was constructed, and grass was planted to provide protection against erosion and moisture loss.

The work summarized above seems simple and straightforward. However, the successful execution of this task required exceptional attention to detail, as well as a great deal of engineering and construction experience, in both design and construction phases of the operation.

The paramount consideration was to prevent the escape of radiation, the emanation of radon gas, and the creation of paths that would facilitate the leaching of water into the WCS.

Clay-cap construction methodology has progressed significantly since the NFSS cap was completed in 1986. The newer method used in this waste consolidation effort allows compaction of the clay liner to densities lower than the typical 95% of maximum dry density specified in the previously used method, while continuing to satisfy the basic requirement of low permeability (1×10^{-7} cm/s). This method provides better agreement with realistic compaction efforts and density results obtained in the field and allows for a wider range of acceptable moisture content of the clay prior to compaction, thereby speeding construction work. The new methodology places as the prime consideration the permeability parameter instead of shear strength or compressibility (which are primary considerations in construction of highway embankments or structural fill applications). This "state-of-the-art" methodology was used in constructing the new portion of the NFSS cap.

Each phase of the operation was meticulously studied and satisfactorily resolved. This allowed a smooth execution of the work within the relatively short period of favorable climatic conditions in this area just prior to the fall rainy season. Topics of major concern included:

- Controlling excavation depth
- Avoiding contamination of rainwater and providing for adequate drainage paths

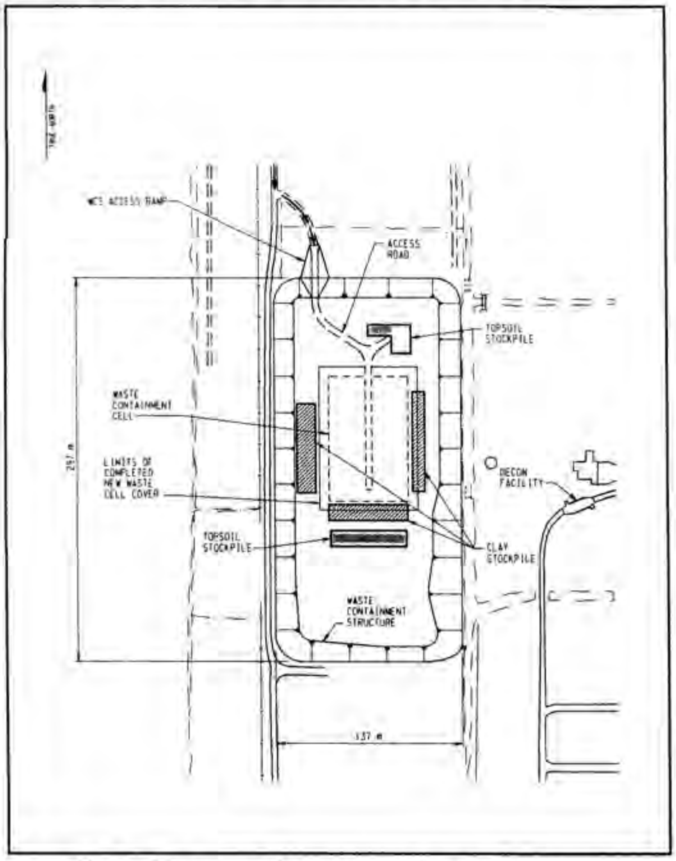

Fig. 1. Plan view of waste containment structure.

- Proper compaction of the new clay cap
- Health and safety considerations during execution of the work

These aspects will be discussed in this paper, together with supplementary operations required for the satisfactory completion of the task.

EXCAVATION WORK

Figure 1 shows the plan view of the WCS and the location of the excavated area (waste containment cell), which is closely centered with the pile to allow for runoff to the east and west, similar to the original configuration. The north/south placement facilitated access from the existing ramp, provided enough room for vehicle turnaround and for end and lateral stockpiling of excavated material, and provided an adequate gradient to channel drainage from south (higher) to north (lower) during construction, on either side of the excavation (east, west). Figure 2 shows a detail of the excavation plan, and Fig. 3 illustrates typical cross-sections and "feathering" of new and old caps.

The important features of the excavation are as follows:

- The provision of a central access road, at the end of which the new waste would be dumped into the excavation (see Fig. 1). As the placement of fill advanced from south to north, sections of the road were excavated so that the dumping area was always ahead of the fill (waste) placement areas. The excavated areas of the access road were eventually backfilled with a number of 208-L drums containing contaminated material.
- Two lateral berms, which were incorporated in the design to adequately contain the new waste as it was being placed. The berms served the additional purpose of channeling construction runoff, while preventing it from being contaminated, to collection sumps at the (lower) N-E and N-W corners of the excavation. The top elevation of these berms coincided with the surface of the new fill. To isolate the new waste, a 15.2-cm (6-in.) clay cover ("minicap") was placed over the fill at the end of each workday (or before a rainfall) to seal it against the berm, access road, and bottom of excavation.

The excavation to open the existing cap was carried out using two backhoes; the excavated material was trucked to designated stockpile areas. Using backhoes instead of small dozers that push the material to the sides of the pile provided several advantages including total control of the excavation depth, thicker excavation lifts [30.5 cm (12 in.)], and reduction in loss of clay moisture content.

STOCKPILING

The upper 15.2 cm (6 in.) of the 45.7 cm (18 in.) of topsoil that covered the original clay cap was used as fill in various areas at NFSS. The remaining 30.5 cm (12 in.) was stockpiled in equal parts at the north and south ends of the excavation. The excavated clay [53.3 cm (21 in.)] was stockpiled along the sides of the excavation and at the south end (between the topsoil stockpile and the excavation limit). The latter stockpile was used to construct the thin daily cover ("minicap") over placed waste. A minimum safe distance was specified between stockpile mounds and main cap lateral slopes; their maximum height was also limited. The surface of the stockpiles was smooth-steel-rolled to diminish soil moisture evaporation. In addition, the piles were irrigated frequently.

The new cap required 0.9 m (3 ft) of clay and 45.7 cm (18 in.) of topsoil; only 53.5 cm (21 in.) of clay and 30.5 cm (12 in.) of topsoil were stockpiled. The remaining material needed was trucked in from nearby sources and stockpiled near the base of the WCS, close to the access ramp.

CONTROL OF SHRINKAGE CRACKS IN CAP CLAY

The original excavation specifications called for removal of 45.7 cm (18 in.) of topsoil and 0.6 m (2 ft) of the 0.9-m (3-ft) clay cap, leaving 30.5 cm (12 in.) of original cap clay as a barrier to cover the old waste and control escape of radiation and emanation of radon gas.

However, during the excavation process, shrinkage cracks reaching depths of 30.5 cm (12 in.) or more developed quickly upon exposure of the clay surface to the warm air and sun. Unless timely moisture-protection measures were implemented, the development of such cracks could lead to the "opening" of the cap, despite the presence of the remaining 30.5 cm (12 in.) of protective clay. A satisfactory solution was achieved by excavating only 53.3 cm (21 in.) of the clay [instead of 61 cm (24 in.)] and discing (a farming technique by which a few inches of topsoil are loosened) 7.6 cm (3 in.) of the remaining clay. The loosened clay was then saturated with water, forming a spongelike cover over the remaining 30.5 cm (12 in.) of the original clay cap. Even on the hottest and driest days, this saturated layer remained moist for 24 hours.

Maintaining moisture in the stockpiles and preventing the development of shrinkage cracks in the clay required the institution of a strict irrigation program using various methods of water delivery to the surfaces. The results were very satisfactory.

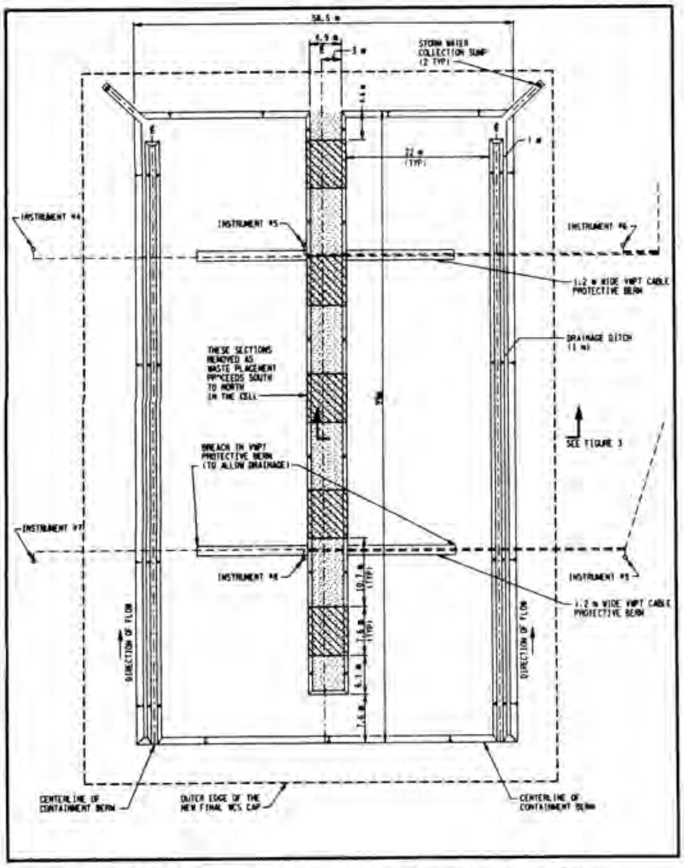

Fig. 2. Waste containment cell excavation plan.

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WASTE PLACEMENT

A small dozer (D-4) and a vibratory half-penetrating pad foot roller were kept in the excavation to move and compact the trucked-in waste. The material was placed and compacted in lifts to a final height not exceeding 0.6 m (2 ft) over the entire area designated for waste consolidation, except for the lateral drainage channels and the berms along the east and west sides of the waste containment cell. Waste placement began at the south end of the excavated area and progressed northward as the full height (thickness) of compacted waste was achieved. During daily operations, the layer of newly placed waste [0.6 m (2 ft) deep] was covered with a clay "minicap" (daily cover) that was 15.2 cm (6 in.) thick. The width of the layer of waste placed during a working day depended on the amount of waste that could be successfully placed to a height of 0.6 m (2 ft) with 15.2 cm (6 in.) of clay as daily cover.

Five types of waste were placed in the excavated enclosure:

- Contaminated heterogeneous soil.
- Sealed steel drums containing various soil-like and resinous/bituminous materials. To diminish void space, the drums were opened and top-filled with dry sand before they were placed in the pile. The drums were laid sideways in excavated areas of the access road, and dry sand was vibrated around and on top of the drums to ensure that it would fill any voids around them.
- Pile cover material. The plastic covers of the temporary piles where most of the waste had been stored were cut into strips that were rolled tightly in small rolls and placed randomly within the waste.
- Several thousand plastic sample jars. These were placed in a designated area and covered with dry sand, which was vibrated while being placed and compacted.
- Miscellaneous debris including such items as plastic containers and piping, pieces of tanks, wood segments, and bags filled with contaminated clothing. These materials were placed in one of the breaches

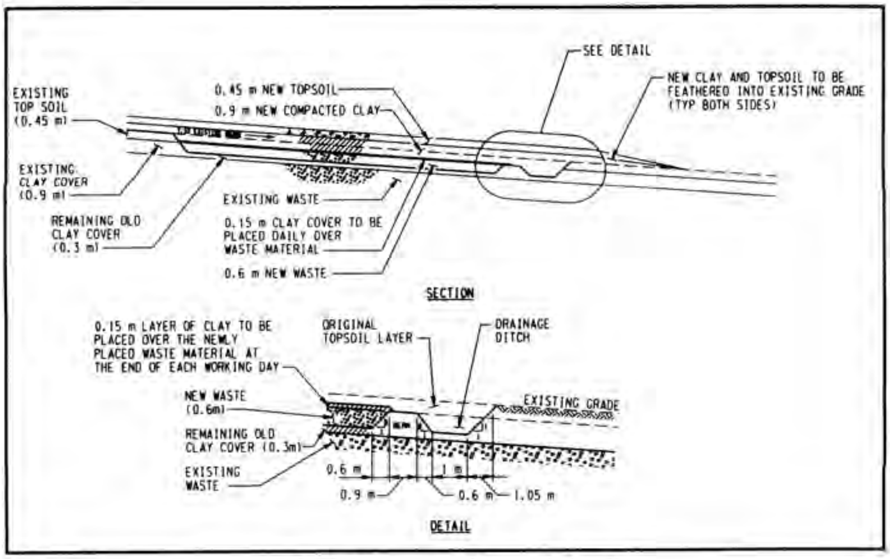

Fig. 3. Cross-section and detail.

of the access road and submerged in a very wet mix of one part cement to 12 parts sand.

CAP CONSTRUCTION

A laboratory soil testing program was established to determine the characteristics of clay materials used in construction of the clay liner. Extensive field testing was also carried out during construction. Bulk samples of the old cap clay, the new source cap clay, and the topsoil were tested in the laboratory to determine index properties and to establish permeability/moisture/density relationships at three different compactive efforts: Reduced, Standard, and Modified Proctor (ASTM D-698, ASTM D-1557, and USBR 5610). Following the procedures recommended by Daniel and Benson (1), an "acceptable zone" was determined for both types of clay. Other factors (such as workability, method of moisture conditioning of the clay, potential mixing of clay types, and type of equipment used) also were considered in determining the moisture content boundaries of this zone. The maximum permeability was established at 1×10^{-7} cm/s. Field tests were carried out using a nuclear device that measured moisture content and percent compaction (ASTM D-2922 and 3017), and correlation tests were conducted using the sand cone density method (ASTM D-1556) with "Speedy," a moisture-content tester that mixes calcium carbide with soil samples (ASTM D-4944).

The procedure outlined by Daniel and Benson (1) was chosen over the method traditionally used for compacting clay fills because the primary consideration in the construction of this clay liner was permeability rather than shear strength or compressibility. The wider range of allowable moisture content in the clay during compaction permitted the work to proceed faster and with fewer delays. The fill was placed in loose lifts that were 20.3 cm (8 in.) thick and were compacted to 15.2 cm (6 in.). After acceptable compaction was achieved using a half-penetrating pad foot roller, the surface was sealed using a smooth vibratory drum. Before placement of the next lift, the surface was scarified and moistened to effect adequate inter-layer bonding between lifts.

The new cap was extended beyond the limits of the excavation to create a "feathering" zone [6.1 m (20 ft) wide] as transition between new and old caps. At no point within the limits of the excavation where new waste was placed is the thickness of the clay liner less than 0.9 m (3 ft). The minimum combined thickness of the liner and underlying old waste is also 0.9 m (3 ft).

TOPSOIL AND GRASS COVER

The topsoil was placed in two lifts [28 cm (11 in.) loose thickness; 23 cm (9 in.) compacted thickness] and was compacted to a lower density than the clay liner, thereby allowing *sufficient* accumulation of irrigation water to sustain a satisfactory grass cover. Final grading to the lines and grades established to create uniform slopes and a pleasing blend with the old cap was accomplished during topsoil placement. A hydroseeding method was used to place a mulch and seed mix. Proper fertilization and irrigation are also part of the program being carried out to establish and maintain a satisfactory grass cover.

HEALTH AND SAFETY

The work described was carried out in accordance with the Site-Specific Health and Safety Plan (HSP). Workers were trained accordingly, received Bechtel-approved physical examinations, and participated in a bioassay program.

Site activities were monitored for radiation and chemical exposures. This monitoring included use of direct reading instruments for organic vapors and ionizing radiation. To determine whether radon was migrating through the remainder of the cap after excavation, 24-hour radon flux detectors were used. Additionally, radon was assessed with direct reading instruments. No leaks were detected, indicating that no breach had occurred in the original cap. Sediment barriers were constructed using filter fabric, thereby limiting the amount of sediment leaving work areas during construction operations. Detailed specifications were adhered to for inspection of vehicles used for transport of contaminated waste, loading of material, and unloading operations. All vehicles and machinery in contact with the waste were radiologically monitored, decontaminated, and released when the work was completed.

CONCLUSIONS

Incorporating contaminated material that had been temporarily stored elsewhere at NFSS into the WCS served several important purposes:

- Reducing maintenance costs
- Eliminating sources of possible further contamination
- Freeing land areas for other uses

The decision to consolidate these wastes within the existing WCS was bold; certain implicit risks are associated with excavation that penetrates an existing clay liner. However, assuming that the work is carried out properly, the benefits are obvious.

From the outset, the conceptual designs were oriented toward eliminating potential risks. Aspects such as the method of excavation of the cap, delivery of the waste to its new location, protection of the waste from the elements prior to cap construction, and provision of drainage paths that avoid contamination of rainwater were analyzed with the following basic considerations in mind:

- Avoiding paths into or out of the old cap
- Preventing contaminant dispersion during and after waste placement
- Ensuring the safety of those involved in execution of the work

The final design was thorough and permitted straightforward execution of the work without delays. Strict control was necessary during construction, and field changes that were adopted involved improvements based on availability of equipment, local conditions, or characteristics of the materials. For example, as a result of the unexpected proliferation of shrinkage cracks in the remaining original cap during excavation, several moisture-retaining methods were field-tested, leading to a very satisfactory solution: 7.6-cm (3-in.) discing and saturation of a protective, loose clay layer.

The design and execution of the work were an unqualified success but required exhaustive planning and execution controls. This type of work by nature requires precisely such an approach, which is based on extensive engineering and construction experience and careful attention to detail.

REFERENCE

1. DANIEL, D. E. and BENSON, C. H., "Water Content - Density Criteria for Compacted Soil Liners," Journal of Geotechnical Engineering, American Society of Civil Engineers, Vol. 116, No. 12, p. 1811-1830 (December 1990).