INTERNAL MONITORING SYSTEM FOR RADIOACTIVE WASTE DISPOSAL

J. A. Blanke and B. C. McConnel
Bechtel National Inc.
Oak Ridge, Tennessee 37830

ABSTRACT

The U.S. Department of Energy (DOE), with Bechtel National, Inc. as the project management contractor, is responsible for the Niagara Falls Storage Site (NFSS) interim waste containment facility in Lewiston, New York. The NFSS contains approximately 190,000 m3 of low-level radioactive waste resulting from the remediation of approximately 600 hectares of the U.S. Army's former Lake Ontario Ordnance Works. The remedial action for the site and vicinity properties was performed as part of DOE's Formerly Utilized Site Remedial Action Program and Surplus Facilities Management Program.

The NFSS adapted off-the-shelf instrumentation to show that the design features are functioning, and develops confidence that long-term stability, without constant surveillance, is feasible.

BACKGROUND

The Niagara Falls Storage Site (NFSS) is an interim storage site for low-level radioactive waste located on a 77-hectare site near Lewiston, New York. Development of the NFSS is part of the Surplus Facilities Management Program (SFMP) and Formerly Utilized Sites Remedial Action Program (FUSRAP), two remedial action programs administered by the U.S. Department of Energy (DOE). The DOE Oak Ridge Operations Office, Technical Services Division, manages FUSRAP and selected SFMP projects and oversees the work of the Project Management Contractor (PMC), Bechtel National, Inc. (BNI), responsible for implementing project activities. As PMC, BNI acts as DOE's representative in the planning, management, and implementation of these activities.

Several papers have been written on the details of the storage facility (Refs. 1, 2, 3, 4, and 5). This paper focuses on how the internal monitoring system provides verification that the containment system is functioning properly and how the monitoring system will provide an early indication of weakness in the containment system. An explanation of some basic features of the containment structure are necessary to understand what the monitoring system is expected to accomplish, and a short description of the total monitoring program is needed to understand how the internal monitoring complements the overall monitoring program.

Containment System

The waste containment facility at the NFSS has been constructed to store radioactively contaminated material excavated from the site and properties in the vicinity (Fig. 1). A design favoring minimal maintenance was used in constructing the facility. The service life of the present interim facility is 25 to 50 years; however, with modifications, the facility could be upgraded to a service life of 200 to 1,000 years, thereby permitting long-term disposal of the waste.

The waste containment area at the NFSS measures approximately 325 meters long by 165 meters wide and covers roughly 4 hectares. A natural layer of gray, lacustrine clay forms the bottom of the containment facility; a cutoff wall keyed into the gray clay unit and a clay dike atop the cutoff wall form the perimeter of the cell. The facility is closed by an engineered, multilayered cover that extends beyond the perimeter dike. Fig. 1 shows the short-term cap configuration that has been constructed and the planned modification for long-term use. Additional information is available in Refs. 1, 2, 3, 4, and 5).

Monitoring Systems

An environmental monitoring program has been devised for this facility to provide qualitative and quantitative evaluation of the impact of the facility on the local environment. The primary components of the program include sampling and analysis of groundwater, air, sediment, and surface water for parameters that are known to be present or are indicative of materials stored within the facility. In addition, gamma radiation will be measured at selected locations around the perimeter of the facility. While the program provides confidence to DOE that the health and safety of the public are ensured, an additional program, "performance monitoring," was developed to monitor the performance of the containment facility itself and to verify that the elements of the containment facility are functioning properly.

The performance monitoring program was developed for this facility to provide early detection of trends that could indicate weaknesses developing in the containment structure so that corrective action can be taken before the integrity of the structure is compromised. Typically, surface monitoring is all that is used for such a facility, but this type of monitoring provides only limited information on the behavior of the structure. Surface monitoring includes topographic surveys based on a predetermined grid, walkover surveys, and aerial photography to detect vegetative stress or other changes not evident at ground level. Consequently, the performance monitoring program,

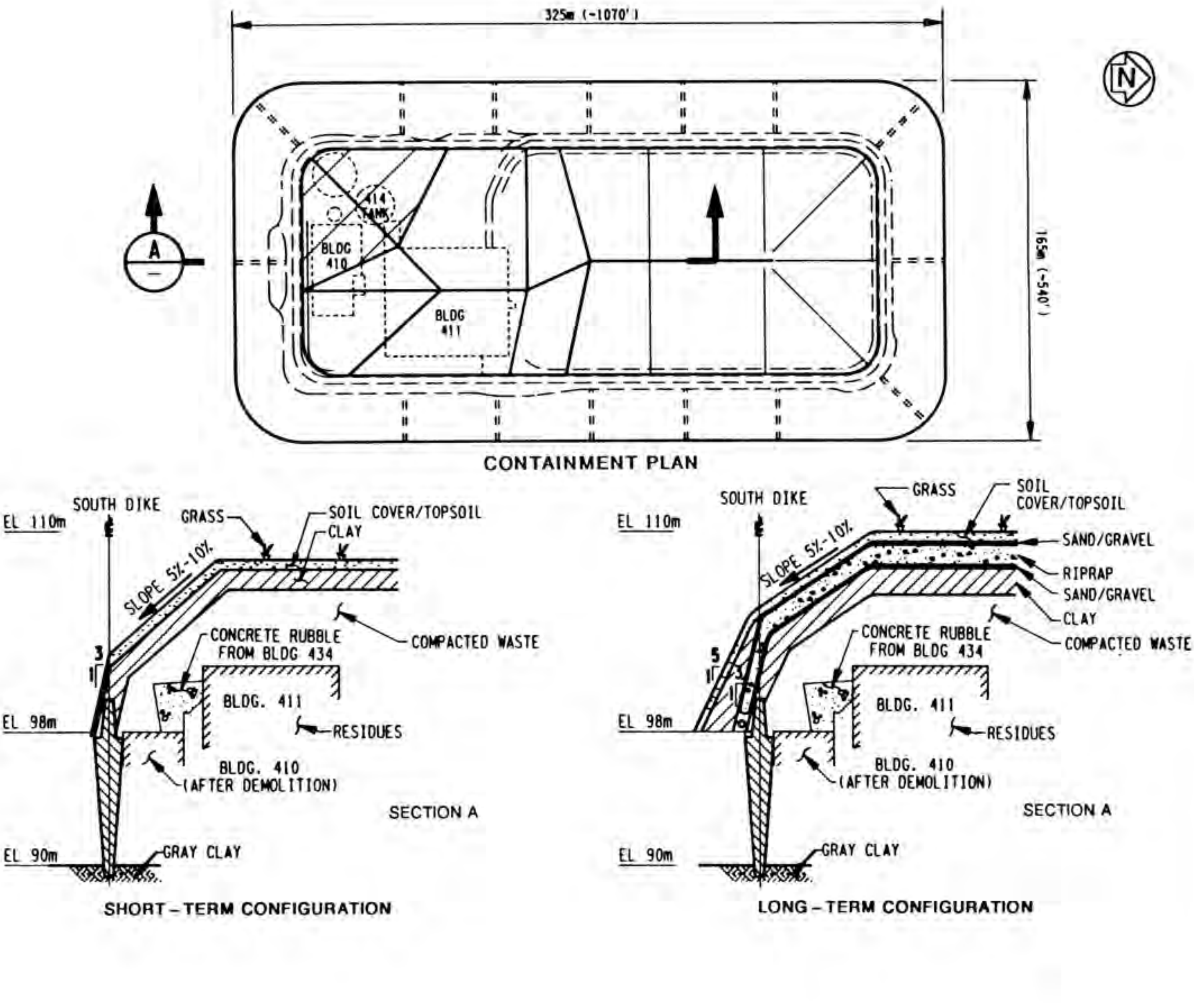


Fig. 1. Waste Containment Facility Plan and Sections.

a subsurface monitoring technique, was devised to complement the surface observations.

INTERNAL MONITORING SYSTEM

The monitoring system was installed in the fall of 1986 and consists of off-the-shelf instruments that have been used in geotechnical applications in dam and tunnel construction. The instrumentation includes 13 vibrating wire pressure transducers (VWPTs) to detect a rise in the potentiometric surface, with a secondary system of three pneumatic pressure transducers (PPTs) to verify the VWPT results.

The internal monitoring system uses a type of equipment developed more than 30 years ago to measure the accumulation of water inside earthfill and rockfill dams during reservoir filling. The users of this type equipment soon realized that it also had the ability to measure the increase and decrease of pore-water pressure in and under dam and other embankments as the height of fill is increased during construction. The equipment is often employed behind tunnel liners to measure the re-establishment of hydrostatic head after the liner is installed. This type of information becomes especially important for the rock or soil mass surrounding a pressure penstock to detect leakage from the penstock before a catastrophic failure might occur. The development and refinement of the equipment was rapid once the concept was demonstrated, and high quality equipment is readily available.

THE VWPTs and PPTs installed in the NFSS containment structure are not unique. They are customized for this application only by attachment, by the supplier, of a special cut-to-length readout cable for each instrument. Use of a continuous cable (no connections or splices) from the instrument to the readout box precludes opportunity for entry of water into the cable and resulting loss or degradation of signal.

The main instruments at the site are VWPTs. The VWPT is a reliable and accurate device for measuring liquid pressures within the ground. The transducer converts fluid pressure to an electrical signal that is transmitted to a remote reading station by cables. The instrument is designed for burial in soil and is corrosion-resistant and water-proof. The sensing element is a small diameter steel wire, restrained at both ends, which vibrates at a natural frequency determined by the tension in the wire. One end of the wire is fixed to the transducer body. The other end is fastened to a thin flexible-steel diaphragm in contact with the fluid media. Flexure of the diaphragm due to changes in fluid pressure changes the tension in the wire, which causes a change in the natural frequency. An integral electrical circuit drives the wire in constant oscillation at its natural frequency. A pickup sensor and data acquisition system measure the frequency and display the readings of the transducer.

Each instrument is calibrated before installation using known pressures. Resolution of the instruments is a function of the maximum pressure for which the instrument is designed and of the duration of each reading. The instruments installed at the NFSS have a pressure range of 6 bar (88 psi) and resolution of 0.1 percent of full reading. This is approximately equal to a change of 5 cm in water level.

The other type of instrument in use at the NFSS is the PPT. PPTs are paired with VWPTs at three locations, and used to verify the operation of the VWPTs. The PPT is a device that converts fluid pressure into pneumatic pressure, which can be measured at a remote reading station. The pore-water pressure acts on a flexible diaphragm having a negligible spring force. The force on the diaphragm due to the water pressure causes a valve to close. A reading is made by applying gas pressure in a chamber in the instrument until it balances the pore-water pressure. Thus, the PPTs use a manual, balanced-gas pressure system to measure the hydrostatic pressure at the instrument.

Both types of instruments will react to the entry of water as soon as the saturation elevation begins to rise at the floor of the containment. This condition will become evident before a head can develop to create a gradient and potential for discharge of water from the containment structure.

The instrument layout selected for and implemented at the NFSS takes into account: the design size of the containment structure, the time that would elapse after entry of water into the cell before it could be detected, and the accuracy desired in locating the water entry point. Using these criteria, nine instruments are installed in the north portion where only soil-like wastes are stored. The instrument layout is shown in Fig. 2. Four instruments are installed in the southern portion where a concrete, reservoir-like, foundation structure was used to retain certain wastes. Slush-grouted, concrete rubble, flattened pipes, and other inorganic structural materials, along with soil, are also buried in the southern portion and complicate the flow pattern there.

The instruments are placed at the base of the wastes and at the top of original ground at all locations. The instruments were installed in boreholes drilled to the base of the wastes. Each instrument was installed 15 cm above the bottom of the borehole, then embedded in approximately 90 cm of sand. A 30-cm thick bentonite seal was placed above the sand and the remaining portion of the borehole was filled with bentonite grout. The bentonite extends into the base of the clay cap (Fig. 3). All readout cables are placed within the clay cover of the cap and are approximately 30 cm above the waste. The cables were placed using a zig-zag pattern within trenches so that cable tension would not

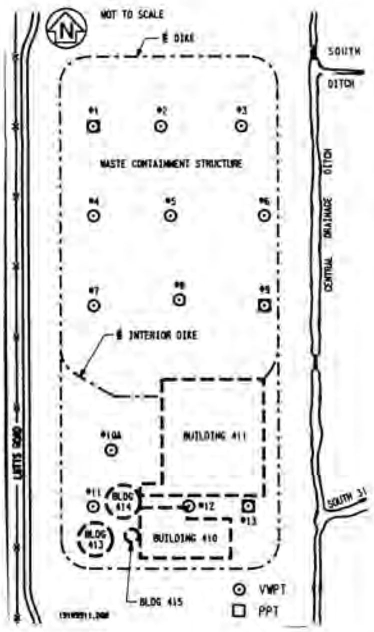


Fig. 2. Locations of VWPT's and PPT's on WCS.

result if settlement or other cap movement occurred. The cables run laterally across and off the sides of the cells so that no vertical penetrations through the top of the cap are made. The cables terminate at a small building where the readout equipment is located.

The VWPTs are read using a multichannel data acquisition system that automatically records data. The vibrating wire scanner/recorder has a built-in electrosensitive printer that is used to print the readings. The PPTs are read using a portable pneumatic indicator, and the readings are manually recorded on data sheets.

The installed instruments are performing as expected. The readings show a progression toward equilibrium of the water that had entered the containment structure during construction and while the wastes were being placed.

INTERPRETATION OF RESULTS

Presently, the data collected from the instruments show that equilibration of water levels within the cell is continuing at a decreasing rate. No indication of cap or cell distress

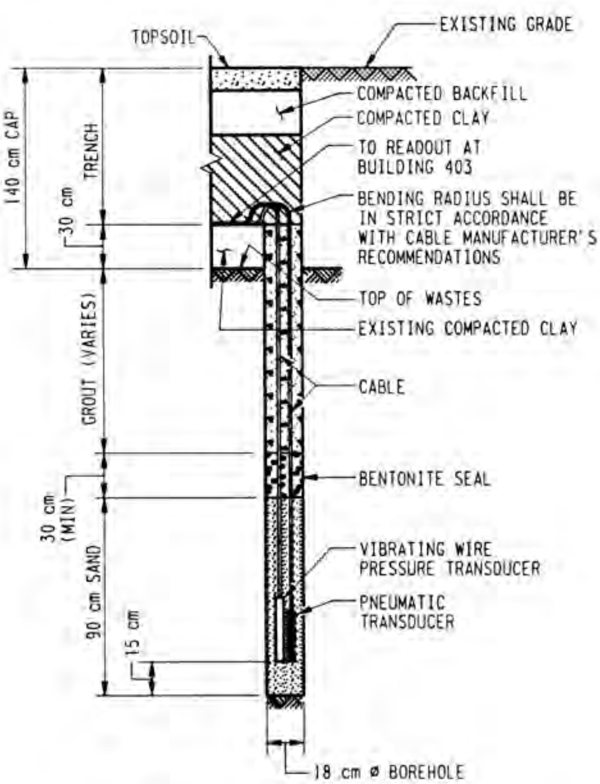
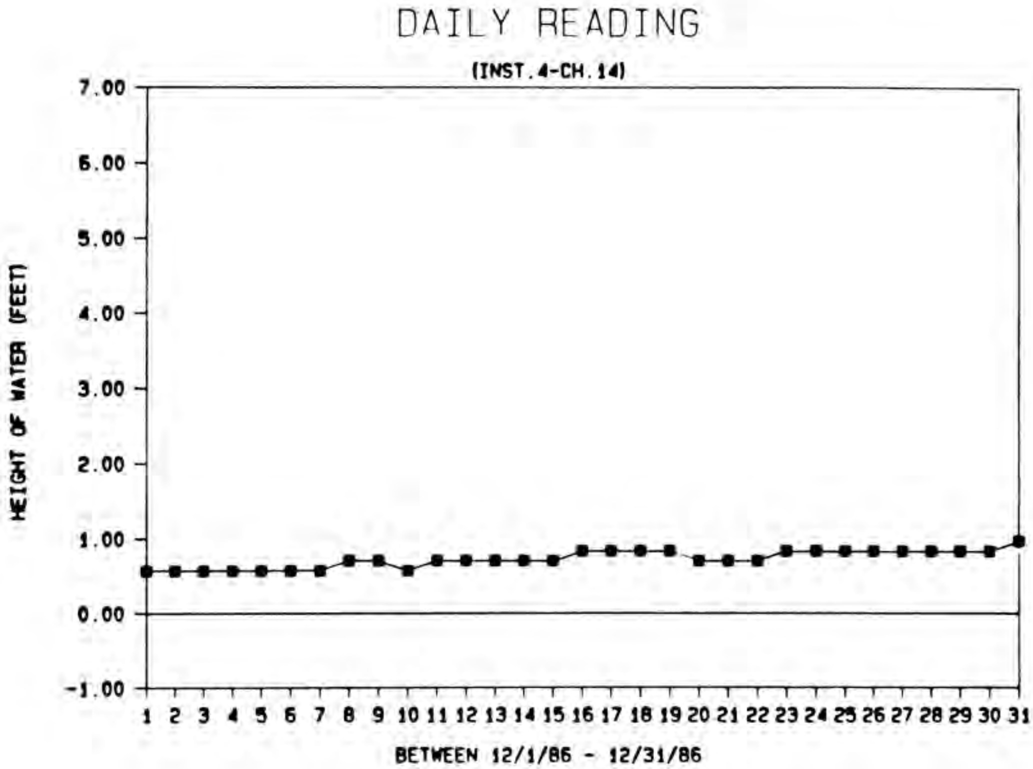


Fig. 3. Internal Instrumentation Installation.



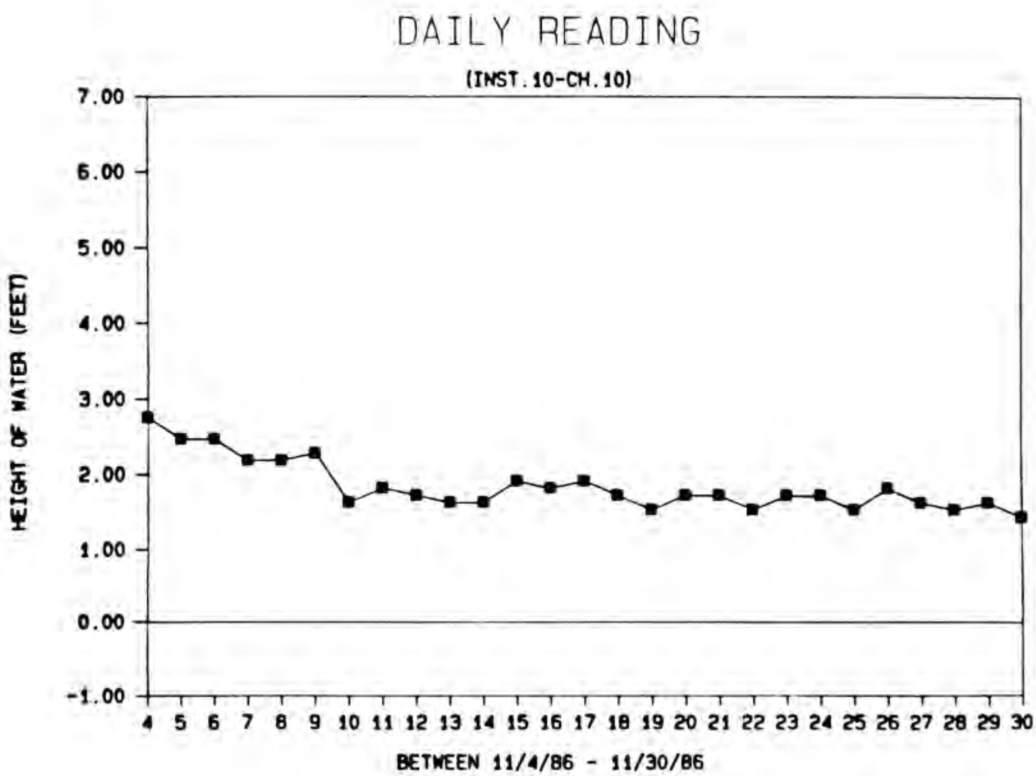


Fig. 4. Examples of Readout Data.

or failure is evident from the instrument data. An example of the read out data is shown in Fig. 4.

The water level variations are expected to become almost imperceptible if containment structure integrity continues.

Lessons Learned

Take care during installation; most lessons learned during selection, installation, and operation of the transducer equipment are related to instrumental installation. The most difficult aspect of installation is to ensure that the readout cable is installed in a fashion that will not result in stretching, severe bending, or shear loading at the transition from the cell to the surrounding formation or introduce moisture into the transducer or the outer cable sheath. Careful planning and inspection during installation were performed to prevent these problems.

Maintain manual readout capability; operation of the equipment at NFSS is automatic. A readout instrument automatically reads each instrument daily and records the data. The information is then available for reduction. However, at NFSS a lightning-induced power surge damaged the readout instrument making manual measurements necessary to maintain the desired frequency of readings. This problem might have been prevented by incorporating a voltage surge protection device in the power supply line.

CONCLUSIONS

The use of internal monitoring devices to detect accumulation of water within a waste storage cell provides an opportunity to respond to indications of cell structural distress before the cell has begun to discharge water contaminated by the wastes. A delay after containment structure failure always occurs before discharged water is identified by the environmental monitoring program. The internal monitoring system provides continuous data about local and general internal conditions. The instrumentation can identify local elements of the containment that need more intensive inspection. The instrumentation offers the ability to identify areas within the containment where liquid extraction or cap repair may be desirable. The internal monitoring system can be replaced at the end of its design life, which provides the flexibility to indefinitely extend the intensive monitoring period of a facility. Since the need to extend the monitoring depends on the individual facility's behavior, the flexibility to extend the system life is an important capability.

Therefore, the internal monitoring system provides timely, accurate, and reliable information for planning and evaluating the behavior of the containment structure. This system of internal monitors is especially relevant to storing waste that will not generate large quantities of leachate during decomposition of organics and may be applicable to an even larger range of waste types.

REFERENCES

1. G.D. Coxon, J.F. Nemec, and J.M. Hoffman "The Niagara Falls Storage Site and Its Relevance to Remedial Action at the Oak Ridge Reservation Presented at the "Oak Ridge Model" Conference, February 3-5, 1987, Oak Ridge, Tennessee (1987).

2. M.G. Jones and J.A. Blanke, "Waste Containment and Monitoring System for the Niagara Falls Storage Site," Proc, Eight Annual Symposium on Geotechnical and Geohydrological Aspects of Waste Management Geotechnical Engineering Program, Colorado State University, Fort Collins, Colorado, pp 537-545 (1986).

3. M.G. Jones and R.B. Barber, "Development of a Waste Containment Structure for the Niagara Falls Storage Site," Proc, Second International Conference on Radioactive Waste Management, Canadian Nuclear Society, Winnipeg, Manitoba, Canada, September 7-11, 1986, pp 93-96 (1986).

4. L.F. Campbell and G.D. Coxon, "The Niagara Falls Storage Site Remedial Action Project" Presented to the American Nuclear Society 1985 Annual Meeting, June 11, 1985, Boston, Massachusetts (1985).

5. J.A. Blanke, C.A. Knoke, and B.C. McConnel, "Status of the Design and Construction of the Niagara Falls Storage Site." Proc, Waste Technology, 88 Tucson, Arizona, March 1988.