HYDROGEOLOGIC ASSESSMENT AND ENHANCED MONITORING AT A LAGOON, LANDFILL AND RADIOACTIVE WASTE MANAGEMENT AREA IN S.E. MANITOBA.

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ABSTRACT

After operating Whiteshell Laboratories since the early 1960's, Atomic Energy of Canada Ltd. has now received a licence to complete a phased decommissioning of the laboratories, office complexes and other facilities. A commitment by AECL within the decommissioning licence is to develop and implement an enhanced monitoring program (EMP) for a lagoon, landfill and a radioactive waste management area (WMA). The purpose of the EMP is to: confirm our understanding of existing hydrogeologic conditions within the WMA, to ensure current environmental monitoring for the reference time of 60 years is maintained, and to monitor activities associated with decommissioning of Whiteshell Laboratories.

This paper will discuss the planning, design and implementation of the first phase of hydrogeological work for the EMP that has included constructing a database containing details for existing monitoring wells; fitness-for-service assessment for monitoring wells; groundwater monitoring and hydraulic head analyses; and selection of unserviceable wells for decommissioning. Also discussed are results of recent hydrogeological investigations, which included augering boreholes, installation of groundwater monitoring wells, soil sampling and lithology analysis, and radiological testing of soil samples.

RÉSUMÉ

Après fonctionnement des laboratoires de Whiteshell depuis le début des années soixante, l'énergie atomique du Canada Ltd a maintenant reçu un permis pour accomplir un désarmement échelonné des laboratoires, des complexes de bureaux et d'autres équipements. Un engagement par AECL dans le permis de désarmement doit développer et mettre en application un programme de contrôle augmenté (EMP) pour une lagune, le remblai et un secteur de gestion de déchets radioactifs (WMA). Le but de l'EMP est : confirmez notre compréhension des conditions hydrogéologiques existantes dans le WMA, pour maintenir le contrôle de l'environnement courant pendant la période de référence de 60 ans, et pour surveiller des activités liées au désarmement des laboratoires de Whiteshell.

Cet article discutera la planification, la conception et l'exécution de la première phase du travail hydrogéologique pour l'EMP qui a inclus construire une base de données contenant des détails pour les puits de surveillance existants ; évaluation de forme-pour-service pour surveiller des puits ; surveillance d'eaux souterraines et analyses principales hydrauliques ; et choix des puits inutiles pour le désarmement. En outre discutés sont des résultats des investigations hydrogéologiques récentes, qui ont inclus les forages de perçage, l'installation des eaux souterraines surveillant des puits, le prélèvement de sol et l'analyse de lithologie, et de l'essai radiologique des échantillons de sol.

1. INTRODUCTION

Atomic Energy of Canada completed an environmental assessment (Comprehensive Study Report) and gained Federal Government and Canadian Nuclear Safety Commission approval to proceed with the decommissioning of Whiteshell Laboratories (WL). In late 2002 AECL was granted a 6 year license by the CNSC to plan, develop and begin a phased, orderly and safe shut-down and decommissioning of the facilities at WL. Part of this decommissioning plan is the proposal to safely store low-to-medium level radioactive wastes within existing structures of the Waste Management Area (WMA) until off-site disposal becomes available. The radioactive waste is currently stored in standpipes, trenches and bunkers in a secure area referred to as the Waste Management Area (Fig. 1), located about 2 km NE of the Whiteshell main laboratory and office complex. Two other facilities, a landfill site and a lagoon, located about 1 km east and southwest of the WMA respectively, will also be used to manage and contain non-radioactive solid wastes and effluents from current laboratory operations and during the decommissioning period.

The functionality of the existing facilities for management and storage of waste is dependent on in-situ hydrogeological and hydrological conditions at the waste management area, lagoon and landfill. As part of the site license requirements for Whiteshell Laboratories, AECL's Environmental Monitoring Section has maintained a groundwater monitoring program within the waste management area which includes regular sampling and testing for radioactivity in ground and surface waters. This long-term monitoring (over 30 years) has shown that the clay-rich sediments and glacial deposits provide an effective barrier to radionuclide migration (Annual Report, 2002). The enhanced monitoring program (EMP) will be implemented to confirm the hydrogeological flow model for the WMA as described in the Comprehensive Study Report (CSR). The enhanced environmental monitoring will also assess the extent of any radionuclide migration from the WMA structures, and leachate migration from the inactive lagoon and landfill.

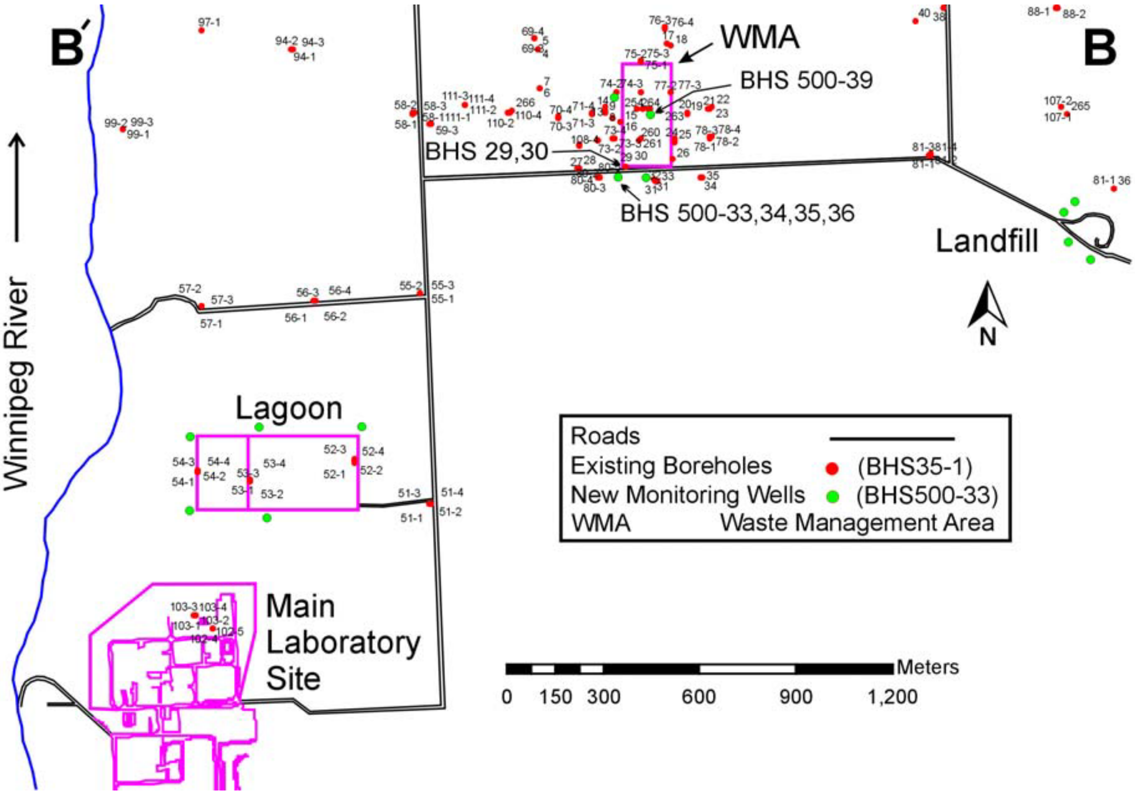

Figure 1. Whiteshell Laboratories, Waste Management Facilities and Boreholes

2. PREVIOUS WORK

Initial geotechnical and hydrogeological investigations were carried out at Whiteshell Laboratories in 1959 as part of foundation engineering work for the reactor building and laboratories and office complexes (Shawinigan, 1960). An extensive borehole test drilling and groundwater monitoring well installation program was undertaken at and adjacent to the WMA in the late 1960's and early 1970's, mainly by researchers from the University of Waterloo (Cherry et al. 1973, Clister 1973, Grisak and Cherry, 1975). This work included stratigraphy mapping, aquifer pump tests, single well response testing and computer model simulation. Many of the groundwater monitoring wells installed as part of this characterization work have been maintained and used for long-term environmental monitoring as part of the site licence requirements. Other detailed groundwater investigations, including large-scale tracer injection–withdrawal tests, were completed in the bedrock. These investigations were carried out immediately northeast of the WMA as part of the Canadian Nuclear Fuel Waste Management Program (Frost et al, 1995). More recent work has included sampling of the soil trench covers of the WMA and laboratory gamma spectroscopy analyses of the recovered soil samples as part of environmental assessment work for the CSR (Ridgway et. al. 2003).

3. SETTING AND HYDROLOGY

Whiteshell Laboratories is located about 100 km northeast of Winnipeg and about 10 km northwest of the town of Pinawa. The site, owned by Atomic Energy of Canada encompasses an area of about 4500 ha. The laboratory and office complex consists of ten major buildings and several other support facilities. The site is located adjacent to the Winnipeg River and lies on the transition zone from Canadian Shield terrain to mixed prairie farmland.

Drilling completed at the 3 facilities (WMA, lagoon and Landfill) as part of the EMP showed that the Pleistocene deposits ranged from 15 to 22 m in thickness (Fig. 2). The stratigraphy within the study area has been delineated into six hydrostratigraphic units (Robertson and Cherry, 1975). A surficial unit is wide spread within the study area and consists of inter-bedded silts and clays and is referred to as the lacustrine silt unit. This unit is underlain by a silty clay that is referred to as the lacustrine clay unit. A clay loam or clay till unit is also common within the study area and was intersected in boreholes at all 3 facilities as part of the recent drilling investigations. This unit is referred to as simply, clay till. Underlying the clay till is a basal sand that grades into gravel and lacustrine sand units. The basal sand unit grades eastward into a fine-to-medium lacustrine sand and is referred to as the lacustrine sand unit. The basal sand and associated sand units are referred to as the aquifer. A surficial sand, and sand-gravel unit that consists of aeolian sand and less sorted sand and gravel is located in the upland recharge and landfill area.

Groundwater flow patterns for the study area are shown in Fig. 2. Precipitation waters infiltrate the sand and gravel units of the upland recharge area and generally flow in a east-to-west direction (B-B'). Along the flow path a central groundwater discharge area is located within the WMA.

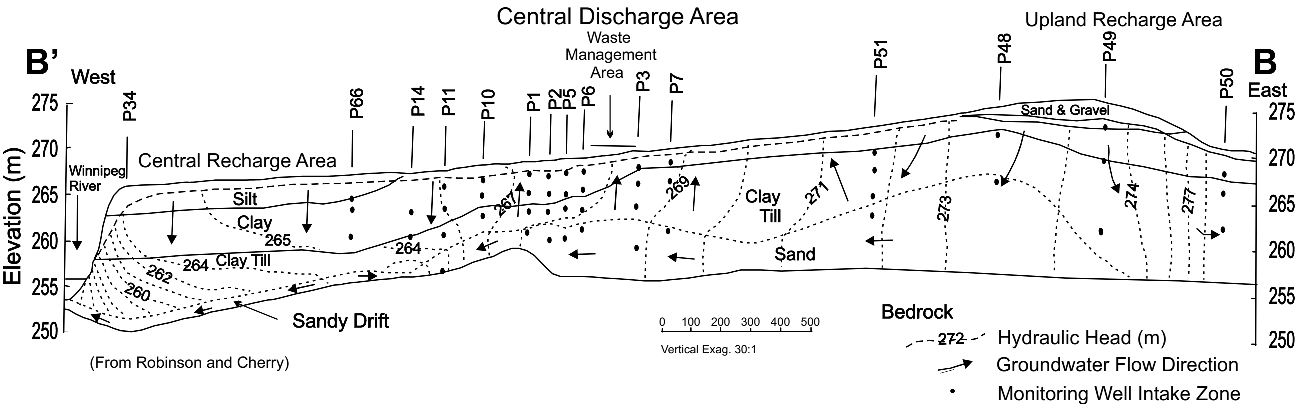

Figure 2. Stratigraphy and groundwater flow patterns

Here, groundwater moves upward from the basal sand unit into the overlying clays and silts. West of the discharge area is a central recharge area where groundwater moves downward through the clays and silts into the basal sand unit. Groundwaters from the basal sand and sandy drift unit discharge to the Winnipeg River.

4. HYDROLOGY DATA AND FITNESS-FOR-SERVICE

Hydrogeological data, including existing information on groundwater monitoring wells, monitoring well construction, water level records and datums are being compiled and stored in a database that will incorporate existing and new monitoring well data. This has included examination and analyses of manual groundwater level recordings and strip chart records that had been previously collected but not compiled and entered into a database. In addition, field checks have been made to all monitoring wells and data collected to verify location, depth, tag number and condition of the monitoring wells. Based on this information, the serviceability- Fitness-For–Service determination of the groundwater monitoring wells is being made with regard to future environmental monitoring requirements. Wells that are unserviceable because of unsuitable location, casing/standpipe deterioration, blockage or hydraulic seal failure will be decommissioned. Over one hundred wells, most located in the WMA and Lagoon area were determined to be serviceable and are now form part of the current groundwater monitoring network. Groundwater monitoring includes routine collection of water level data, construction of hydrographs and archiving of data. Some of the water level data will be used to confirm the understanding of groundwater flow within the WMA. Hydraulic testing will be completed on some of the existing and newly installed groundwater monitoring wells to ensure functionality and provide an estimate of hydraulic conductivity. Groundwater samples will be collected and analyzed for major ions, pH and conductivity as part of hydrochemical characterization.

5. HYDROGEOLOGIC INVESTIGATIONS AND INSTRUMENTATION

During the first phase of the EMP implementation, forty-two groundwater monitoring wells were installed at 13 piezometer nest sites at the WMA, Lagoon and Landfill (Fig. 1). One continuously sampled (in advance) borehole was augered to refusal at each of the 3 facilities. This was achieved using a 5.5 cm outside diameter (o.d.) split-spoon sampler and 22 cm o.d. and 12 cm i.d (inside diameter) hollow-stem augers. At most locations, the split spoon was driven into the sediments using a drill assist pulley-drive hammer system.

At piezometer nest locations, where the soils were firm, 12.5 cm solid stem augers were used to auger to targeted depths. Recovered soil samples were "quick logged" in the field, bagged, and tagged so that more detailed soil logging could be completed in the laboratory. As a precaution, soil samples collected from boreholes augered near the trenches in the WMA were surveyed to identify significant levels of radioactive contamination prior to packaging for transport to the laboratory for analysis.

A priority for groundwater monitoring well installations is to ensure the casing, well screens and backfilling materials used are of good quality, and will remain serviceable for the 60-year reference decommissioning period (Comprehensive Study Report, 2001). To achieve this, stainless steel (# 316), flush joint, ASTM thread casing and Johnson stainless steel well screens are being used to construct the groundwater monitoring wells. A sand pack of # 65 Unimin silica sand was placed around each monitoring interval and a continuous hydraulic seal of about 0.3m length of bentonite pellets, followed by placement of continuous hydraulic bentonite seal from above the monitoring interval to ground surface (Fig. 3a).

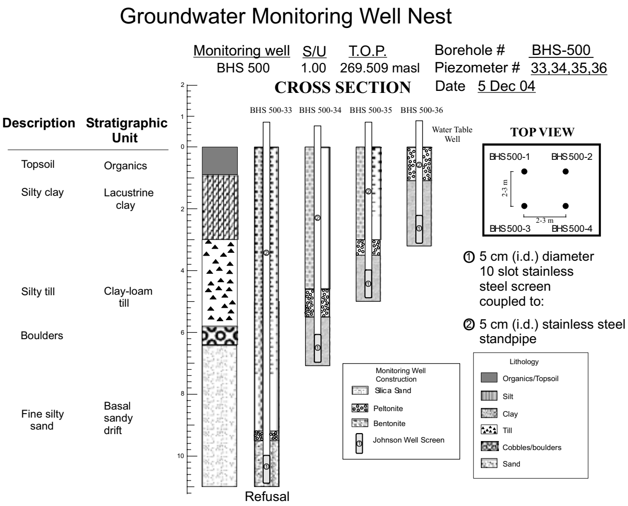

Figure 3a. Groundwater Monitoring Well Nest BHS-500-33-34-35-36

6. LABORATORY WORK

Current laboratory work includes completing descriptive lithology and stratigraphy logs for the split-spoon and grab auger samples. Dispersion tests have been completed on some of the soil samples and selected samples will be mechanically sieved to determine soil particle size. Laboratory testing for gamma radioactivity has been completed for some of the soil samples.

7. HYDROGEOLOGY

Additional monitoring wells are being installed in the WMA to compliment the existing groundwater monitoring network. These wells will provide an enhanced monitoring network to ensure the wastes within the trenches and borders of the WMA are not migrating into groundwaters. Another purpose of the new wells is to confirm our understanding of groundwater flow patterns and groundwater flow rates for the WMA and adjacent areas. Previous work has shown that the WMA is located in a groundwater discharge area. Groundwater data analyses shows that for most of the time, groundwater moves upward from a basal sand unit into the overlying silts and clays. The groundwater flow directions are important as the clays and silts have lower hydraulic conductivities (10^{-9} m/s) than the basal sand unit (7×10^{-6} m/s). Therefore, the clay-rich sediments offer lower conductivities and presumably better containment capability than the basal sand unit. Laboratory studies on soils from the WMA also show that the clays have a high nuclide retention (Kd) factor (Robertson and Cherry, 1985).

The hydrograph of groundwater levels for a recently installed piezometer nest (BHS-500-33,34,35,36) with four monitoring intervals is shown in Fig.3b. The new monitoring wells were installed about 30 meters south of existing monitoring wells BHS 29 and BHS 30 (Fig. 1). The BHS 29 and 30 wells at this location are constructed of steel casing and previous investigations and hydraulic head analyses showed that the carbon steel wells, with time, may be subject to well failure and as a result, loss of monitoring well integrity (Ridgway et al, 2003). To ensure long-term groundwater monitoring capability at this location, the piezometer nest (BHS-500 33 to 36) was installed. The casings and well screens of this installation, and all new wells consist of stainless steel casing and well screens. The stainless steel construction should minimize oxidation and remain serviceable for longer periods than steel casing. In addition, the newly installed piezometer nest at this location has 4 monitoring intervals, compared to 2 monitoring intervals for the existing BHS29 and 30 wells. The additional monitoring intervals allows for more detailed monitoring of the vertical distribution of hydraulic head and provides additional groundwater sampling points.

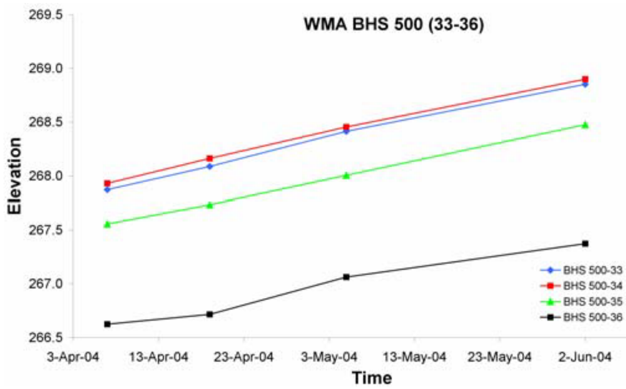

Figure 3b. Hydrograph for borehole BHS-500-33-36

The water levels in this piezometer nest (BHS-500-33-36) were allowed to reach static levels during the winter period of 2004. Water level monitoring in this (and other newly installed wells) commenced in 2004 April. These measurements show (Fig. 3b) that the vertical head distribution is such that hydraulic heads, at depth, are greater than the water table and near surface monitoring intervals. This provides additional field evidence that groundwater is moving upward from the basal sand unit into the overlying silts and clays at this location.

In addition to recent water level monitoring and analyses, historical groundwater monitoring well data is being compiled to assist in confirming our understanding of groundwater flow within the WMA. An example of this is the water level data for groundwater monitoring well BHS 29 and 30 monitoring wells (Fig. 4). The historical data for this pair of wells was compiled and hydrographs constructed as part of the current data review. These analyses show that the hydraulic heads at depth (monitoring interval 6-9 m) for well BHS30 are consistently greater than the water table well, BHS29. This indicates that groundwater flow paths and discharge areas within the WMA appear to be stable and groundwater is consistently moving upward from the basal sand "aquifer" unit. The continuous groundwater discharge conditions within the WMA are important for waste management and containment. The groundwater flow is directed upward into the low permeability clays and away from the underlying more permeable basal sand unit

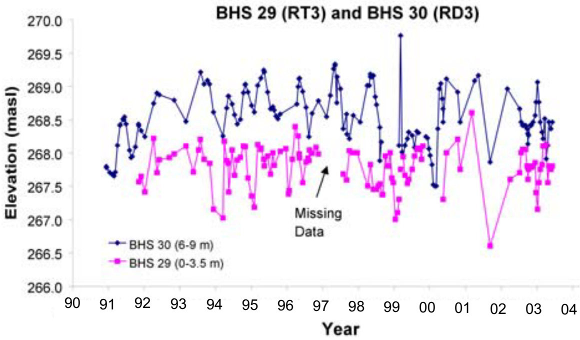

Figure 4. Hydrograph for groundwater monitoring wells BHS-29 and BHS-30

8. GAMMA SPECTROGRAPHIC ANALYSES OF SOIL SAMPLES

On-site field radioactivity testing was conducted using standard detection monitors (Ludlum Model 12 Ratemeters) during the drilling and soil core sampling procedures for boreholes drilled in the WMA. The field-testing did not detect any radioactive contamination. As a follow up, and to verify that soil and groundwaters from the recently drilled WMA boreholes are free of detectable radioactive materials, laboratory spectrography gamma assaying of 21 core (split spoon) soil samples from boreholes BHS-500-39 were conducted. Gamma spectrography counting was completed using a Canberra In-Situ Object Counting System (ISOCS) with each soil sample analyzed (counted) for 1 hour. The spectrographic analyses included assessment for major nuclides such as Co-60, Cs-134, Cs-137, and Am-241, that are typical of the trench radioactive wastes in the WMA. Gamma spectrography assessment (data for 5 of the 23 soil samples analyzed are provided in Table 1) shows that nuclide activity is below the detectable limits of the ISOCS counting system. This provides evidence that there is no significant release of radionuclides from the trenches into the soil and groundwater at this monitoring location. The piezometer nest and recovered soil samples are located within the groundwater flowpath and any radioactivity migrating from the trenches would likely be detectable.

Table 1. Gamma spectrographic analyses for soil samples recovered from borehole BHS-500-39 of WMA

Sample ID:	SS# 1		SS# 5		SS# 9		SS# 17		SS# 21	
Gamma cps/sample (40 - 2048 keV) :	0.37		0.94		<0.55		0.32		<0.55	
Nuclide	Bq/gram	Err 2s%	Bq/gram	Err 2s%	Bq/gram	Err 2s%	Bq/gram	Err 2s%	Bq/gram	Err 2s%
Na-22	< 3.75E-01	----	< 1.07E-01	----	< 1.02E-01	----	< 1.92E-01	----	< 9.54E-02	----
K-40	< 1.03E+01	----	< 3.00E+00	----	< 2.73E+00	----	< 5.25E+00	----	< 2.66E+00	----
Mn-54	< 3.26E-01	----	< 9.25E-02	----	< 8.36E-02	----	< 1.65E-01	----	< 8.59E-02	----
Co-57	< 1.46E+00	----	< 4.71E-01	----	< 4.22E-01	----	< 8.48E-01	----	< 4.25E-01	----
Co-58	< 2.91E-01	----	< 9.31E-02	----	< 7.98E-02	----	< 1.55E-01	----	< 8.67E-02	----
Co-60	< 3.23E-01	----	< 8.76E-02	----	< 8.66E-02	----	< 1.69E-01	----	< 7.61E-02	----
Zn-65	< 8.65E-01	----	< 2.47E-01	----	< 2.33E-01	----	< 4.74E-01	----	< 2.26E-01	----
Nb-94	< 2.96E-01	----	< 8.97E-02	----	< 7.71E-02	----	< 1.58E-01	----	< 8.09E-02	----
Ag-110m	< 4.19E-01	----	< 1.28E-01	----	< 1.16E-01	----	< 2.27E-01	----	< 1.16E-01	----
I-131	< 2.50E-01	----	< 7.42E-02	----	< 6.80E-02	----	< 1.30E-01	----	< 6.82E-02	----
Cs-134	< 3.44E-01	----	< 9.67E-02	----	< 9.29E-02	----	< 1.84E-01	----	< 9.25E-02	----
Cs-137	< 3.36E-01	----	< 9.86E-02	----	< 9.01E-02	----	< 1.75E-01	----	< 8.87E-02	----
Ce-144	< 1.43E+00	----	< 4.67E-01	----	< 4.17E-01	----	< 8.38E-01	----	< 4.18E-01	----
Eu-152	< 1.50E+00	----	< 3.87E-01	----	< 3.96E-01	----	< 7.66E-01	----	< 3.60E-01	----
Eu-154	< 1.06E+00	----	< 3.01E-01	----	< 2.86E-01	----	< 5.40E-01	----	< 2.69E-01	----
Ra-226	< 5.10E+00	----	< 1.60E+00	----	< 1.46E+00	----	< 2.89E+00	----	< 1.47E+00	----
Th-232	< 1.54E+00	----	< 4.54E-01	----	< 4.25E-01	----	< 7.76E-01	----	< 4.13E-01	----
U-235	< 1.48E+00	----	< 4.82E-01	----	< 4.40E-01	----	< 8.67E-01	----	< 4.39E-01	----
Np-237	< 1.25E+00	----	< 4.21E-01	----	< 3.80E-01	----	< 7.61E-01	----	< 3.85E-01	----
Am-241	< 3.72E-01	----	< 1.29E-01	----	< 1.19E-01	----	< 2.38E-01	----	< 1.19E-01	----

9. SUMMARY

An enhanced monitoring program (EMP) is being implemented at Whiteshell Laboratories to ensure the existing lagoon, landfill and radioactive waste management area facilities are providing adequate waste containment. During the first phase of this work, progress has been made on constructing a database on existing groundwater monitoring wells, compiling and analyzing historical groundwater level data, installing additional groundwater monitoring wells and analyses of newly acquired data.

These analyses are assisting in confirming our understanding of groundwater flow conditions within the WMA. The WMA is located in a groundwater discharge area and hydraulic head analyses show groundwaters move upward from the more permeable sand aquifer into the overlying lower permeability silts and clays. In addition to lower permeability, the silts and clays have a significant retardation factor, and this is important for longer-term waste containment in the trenches of the waste management area.

Gamma spectrography analyses has been completed on some of the soils samples recovered from boreholes augered adjacent to trenches storing radioactive waste in the WMA. No detectable (above background) radioactivity has been recorded for any of the samples analyzed to-date. These data support the results of previous WMA soil sampling and testing, which also showed the soils to be free of radionuclides.

During the next phase of implementing the EMP plan, additional groundwater monitoring wells will be installed and soil samples will be collected from the boreholes. Radiological analyses, hydrochemical sampling, and groundwater level monitoring will be completed and all data entered into a database for archiving and future reference.

10. REFERENCES

Atomic Energy of Canada Limited 2001. Whiteshell Laboratories Decommissioning Project Comprehensive Study Report, Volumes 1, 2, and 3 (Addendum). Whiteshell Laboratories, Pinawa, Manitoba.

Annual Program Report, 2002. Annual Report of Radiological Monitoring Results of the Chalk River and Whiteshell Laboratory Sites Volume 2-Environmental monitoring-Whiteshell, Rev. 0, AECL, March 2003.

Cherry, J.A., G.E. Grisak and W.E.Clister. 1973. Hydrogeological studies at a subsurface radioactive waste management site in west-central Canada. International Symposium on Underground Waste Management and Artificial Recharge, AAPG-USGS (1), 436-467.

Clister, W.E., 1973. Hydrogeology of a subsurface radioactive waste management area site in a shallow groundwater flow system. M. Sc. Thesis. Department of Earth Sciences, University of Manitoba, 138p.

Frost, L.H., N.W. Scheier, and C.C. Davison. 1995. Two-well radioactive tracer experiment in a major fracture zone in granite. Atomic Energy of Canada Limited Technical Record, TR-671.

Grisak, G.E. and J.A. Cherry, 1975. Hydrologic Characteristics and response of fractured till and clayconfining a shallow aquifer. Canadian Geotechnical Journal, 12(1). National Research Council of Canada.

Ridgway, W.R., E. Wolowich, G.A. Thorne, B. Horning, J. Bell, J. Racicot and K. Ross. 2003. Hydrogeological Assessment of Atomic Energy of Canada's Low Level Radioactive Waste Management Trenches at Whiteshell Laboratories. Proceedings of 56th Canadian Geotechnical Conference, 4th Joint IAH-CNC/CGS Conference, Winnipeg Canada, Sept. 30-Oct 1, 2003.

Robertson, W.D. and J.A. Cherry, 1985. Review of Hydrogeology of the Radioactive Waste Management Site. Final Report. Prepared for: Atomic Energy of Canada Limited.

Shawinigan Engineering Co. Ltd. 1960. Report on the proposed Whiteshell Nuclear Research Establishment. Unpublished Report 2410

Wardrop Engineering Inc. 2001. Hydrograph Record Review-Well Nest Numbers 1 and 5, AECL Whiteshell Laboratories. Waste Management Area. File 000025-02-00