HYDROLOGIC FACTORS AND ^{90}Sr TRANSPORT AT A LOW-LEVEL WASTE DISPOSAL SITE[a,b]

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INTRODUCTION

There are several hydrologic factors that can affect contaminant migration at a waste disposal site. Many studies recognize surface water and groundwater controls as major factors. But what are the specific hydrologic processes most often associated with contaminant transport? Studies of solid waste storage areas (SWSAs) for low-level radioactive wastes at Oak Ridge National Laboratory, which is located in the humid environment of east Tennessee, have identified several mechanisms. Most of the processes are associated with groundwater movement, but in at least one case, surface runoff has played a dominant role. In all cases, consideration of localized hydrologic conditions has been the key to understanding the factors responsible for radionuclide migration.

Most hydrologic problems that lead to contaminant migration from disposal sites result from the physical changes that occur during site development and operation. For example, when a site is cleared of forest vegetation and subsequently replanted to grass, the water balance is changed.[1] In high rainfall areas,

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evapotranspiration is usually significantly reduced after this transition and the result is higher recharge to groundwater. Depending on the hydraulic properties of the underlying formation, a substantial rise in water-table elevations can result. Simulation studies for SWSAs at Oak Ridge National Laboratory indicate a rise in the range of one to two meters for average conditions. Direct observation of water levels in areas before and after clearing gave the same results. This has obvious implications for evaluations of depth to water that are based on pre-operation monitoring studies.

Another physical change in the site that can modify local hydrologic conditions is the ground surface leveling and filling often associated with operation of a SWSA. If small seeps or groundwater discharge points are buried or filled in, the resistance to discharge will be increased and the water-table elevation will rise to compensate. In addition, the infiltration capacity of the fill material may be significantly higher than that of the natural formation. If so, recharge to the groundwater reservoir will be enhanced. If there is a significant difference between permeability of the fill and original surface material, small buried swales may become preferred flow pathways for perched groundwater. Trenches that intersect such fill would be vulnerable to enhanced leaching.

The waste trenches themselves may cause modifications to hydrologic pathways. Normally, porosities and permeabilities within used trenches are significantly higher than in the surrounding formation. Thus the trench functions as a preferred pathway for groundwater migration. In some SWSAs at Oak Ridge National Laboratory, there is evidence that trenches intercept lateral migration of perched groundwater near the surface[2] and then conduct it along the trench. If sufficient water enters the trench, the lower end may fill and overflow. This is the "bathtub effect" that has been observed at many trench disposal sites in humid environments. If the materials in the trench decompose and subside, a surface depression may form and result in ponding of surface runoff. In this case, enhanced recharge to the trench can result.

Finally, if the factors just described combine to result in subsurface migration of contaminants to a point near a permanent or intermittent stream, the flushing action of storm runoff events can result in accelerated transport of materials, depending on the chemical mobility of the contaminant in question. The remainder of this paper describes a case study of a SWSA at Oak Ridge National Laboratory where many of the hydrologic factors just mentioned have played a role. The objective of the study has been to devise effective remedial actions based upon understanding of the underlying processes governing radionuclide migration.

SWSA 4 SITE HISTORY.

In 1951, SWSA 4 began receiving low-level radioactive wastes for shallow subsurface burial. Trenches and auger holes were excavated to depths of as much as 6 m, filled with wastes to within a meter of the surface, and capped with either native soil or concrete (when alpha radiation emitters were present). In 1959 when SWSA 4 was closed, the distribution and alignment of trenches was as shown in Fig. 1. Subsequently, uncontaminated fill and construction debris were added to the site, most notably on the eastern edge and northwestern end of the site. In some places, ground elevation was raised as much as 6 m. The underlying bedrock formation is the Middle Cambrian-aged Conasauga Group, which is made up of calcareous shale interlayered with limestone and siltstone.[2] Both during and following operation, there is evidence that water-table elevations were high enough to result in groundwater inundation of some trenches.[3] In 1975, a paved intercepter ditch was constructed along the northern edge of SWSA 4 paralleling Lagoon Road (Fig. 1), and asphalt diversion channels were installed to convey runoff from the three culverts under Lagoon Road to the tributary south of SWSA 4. The intent was to eliminate recharge to the site from infiltration of runoff flowing across SWSA 4.

In 1979, an evaluation of the effectiveness of the runoff diversion channels for reducing ^{90}Sr transport showed that no significant decrease had occurred.[4] Further work[5] indicated that SWSA 4 was the most important non-point ^{90}Sr source in the White Oak Creek drainage.

RADIONUCLIDE TRANSPORT STUDIES

There were two general approaches used to gain understanding of processes governing ^{90}Sr transport at SWSA 4. The first involved examination of historical records of ^{90}Sr contamination in observation wells and the second employed a direct field study of hydrologic transport. Unfortunately, few early data are available to examine trends at groundwater observation wells.

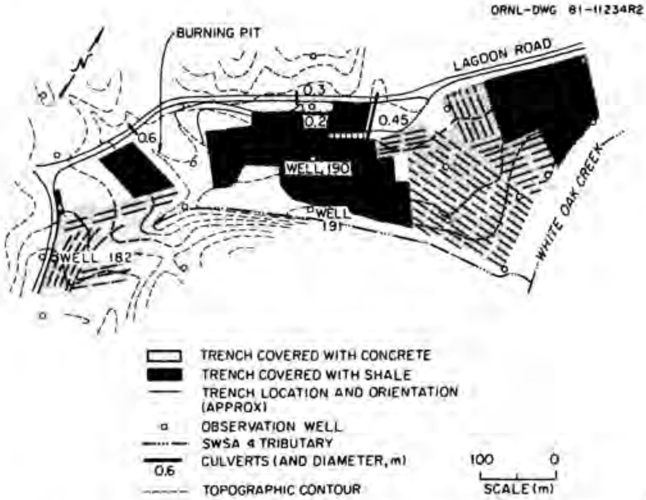

Fig. 1. Trench alignment and type of cover at SWSA 4.[7]

Figure 2 shows a plot of ^{90}Sr concentration observations at wells 182, 190 and 191, which were selected because a few early observations were available and because they represent up-slope (182), mid-slope (190) and down-slope (191) locations. Although these data are limited, they do suggest migration away from up-slope wells and toward the down-slope well. This is fully consistent with observed groundwater elevation contours, which are a subdued replica of the topographic contours.

Field studies employed a surface water monitoring system that allowed measurement of flow and ^{90}Sr concentration at several locations along the SWSA 4 tributary. This study is described in detail elsewhere,[6] so only the results are summarized here. It was found that ^{90}Sr transport is closely associated with storm events and that the increase in flux with a storm event does not appear to exhibit any significant lag, as might be expected if groundwater flow was the primary transport mechanism during the storm. It was also observed that there was virtually no change in ^{90}Sr concentration in surface runoff

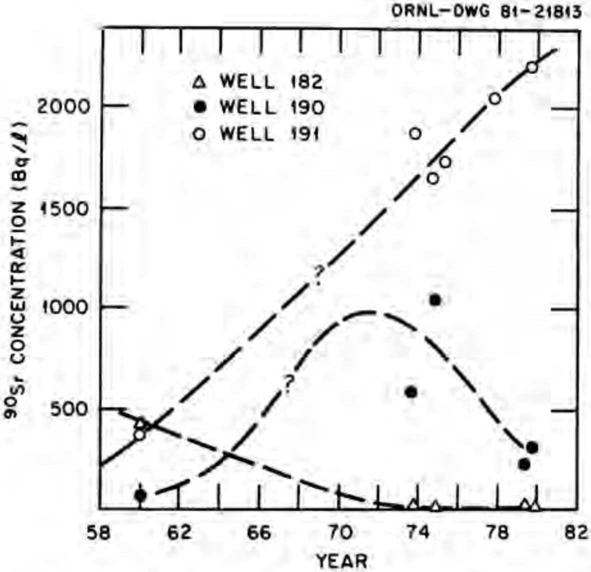

Fig. 2. ^{90}Sr concentrations in groundwater samples from SWSA 4 wells.

along the lower 40% of the SWSA 4 tributary. Detailed sampling yielded sufficient data to construct Fig. 3, which shows the distribution of ^{90}Sr concentration in surface water and groundwater within SWSA 4.

ANALYSIS OF FIELD RESULTS

The distribution of ^{90}Sr contamination shown in Fig. 3, together with earlier data from well water analyses, strongly suggest a general pattern for ^{90}Sr migration from SWSA 4. In the early years, groundwater transport was the dominant migration factor. The combination of vegetation changes, filling and leveling and the hydraulic properties of the native soils resulted in increased water-table elevations. These in turn allowed groundwater to enter trenches and mobilize some of the

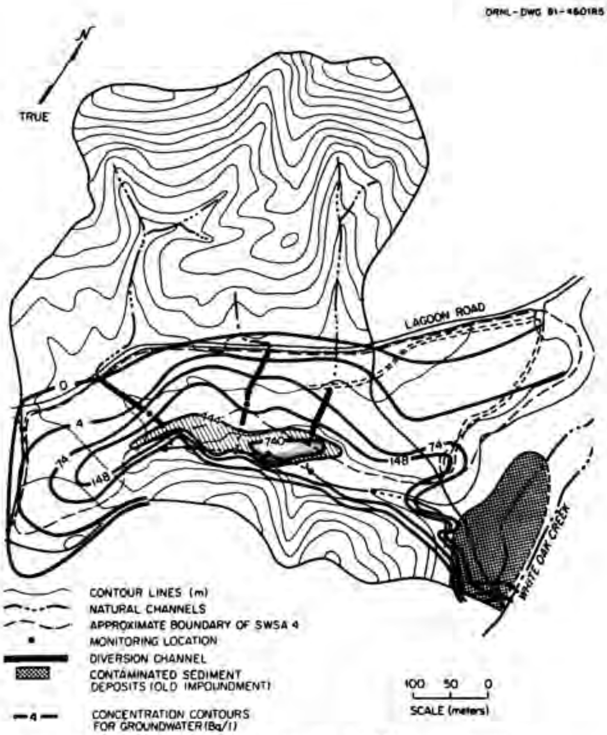

Fig. 3. Spatial distribution of ^{90}Sr content in groundwater and surface water in SWSA 4.

radionuclides. In at least one case, a bathtub effect was observed.[7] After several years, this groundwater migration resulted in increased concentrations at the down-gradient discharge point that is marked with the highest ^{90}Sr contours in Fig. 3. This area contains well 191, which was discussed earlier (see Fig. 2). Once the contamination had migrated into the area where the diversion channels discharge the runoff from the area north of SWSA 4, it became susceptible to flushing by rainy season runoff. This includes not only storm flows, but also the dry weather flows that recharge the contaminated area and keep it primed for quick response during storms.

RECOMMENDED REMEDIAL ACTION

From the foregoing discussion, it is apparent that an improved diversion of surface runoff is needed at SWSA 4. All surface runoff from the portion of the basin to the north of SWSA 4 should be intercepted and diverted around the area. This will eliminate most of the export of ^{90}Sr during storms as well as reducing recharge of the contaminated zone during the wet season. Estimates based on contributing areas for both surface and groundwater flows indicate that up to an 80% reduction in transport in an average year could be achieved.[6] However, it should also be noted that continued groundwater transport within SWSA 4 is likely. Data recently published by the U.S. Geological Survey[8] show that at present the depth to the water table during winter conditions is less than 2 m in nearly all wells in the area containing trenches. Thus the groundwater component of transport will require additional study, even after remedial action to divert surface runoff, to insure that radionuclide export from SWSA 4 falls within acceptable limits.

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