An Updated Performance Assessment For A New Low-Level Radioactive Waste Disposal Facility In West Texas – 12192

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ABSTRACT

This Performance Assessment (PA) submittal is an update to the original PA that was developed to support the licensing of the Waste Control Specialists LLC Low-Level Radioactive Waste (LLRW) disposal facility. This update includes both the Compact Waste Facility (CWF) and the Federal Waste Facility (FWF), in accordance with Radioactive Material License (RML) No. R04100, License Condition (LC) 87. While many of the baseline assumptions supporting the initial license application PA were incorporated in this update, a new transport code, GoldSim, and new deterministic groundwater flow codes, including HYDRUS and MODFLOW-SURFACT™, were employed to demonstrate compliance with the performance objectives codified in the regulations and RML No. R04100, LC 87. A revised source term, provided by the Texas Commission on Environmental Quality staff, was used to match the initial 15 year license term.

This updated PA clearly confirms and demonstrates the robustness of the characteristics of the site's geology and the advanced engineering design of the disposal units. Based on the simulations from fate and transport models, the radiation doses to members of the general public and site workers predicted in the initial and updated PA were a small fraction of the criterion doses of 0.25 mSv and 50 mSv, respectively.

INTRODUCTION

On September 10, 2009, the Texas Commission on Environmental Quality (TCEQ) issued a Radioactive Material License (RML) to Waste Control Specialists LLC (WCS) authorizing, with conditions, the construction of a new facility to dispose of Class A, B and C Low-Level Radioactive Waste (LLRW) in Andrews County, Texas. The licensing, construction and opening of this facility is the first to be developed under the Low-Level Radioactive Waste Policy Act of 1980, as amended in 1985.

One of the most challenging tasks of the initial licensing of this facility was preparing a Performance Assessment (PA) that addressed the potential impacts to human health and the environment not only during operations, but for tens-of-thousands of years after the 100-year institutional control period had expired. The focus is directed towards the efforts recently undertaken to update the original PA (WCS, 2007) that was developed to support the initial licensing of the waste disposal facility to include the Compact Waste Facility (CWF) and the Federal Waste Facility (FWF).

The purpose of preparing the updated PA was not only to comply with specific license conditions, but also to incorporate new site geological and geophysical characterization data, as well as revised distribution or partitioning coefficients (K_d). Of particular interest were the leach rates from the waste and numerical K_d values established not only for soils, but also present in the waste-matrix interfaces (e.g., radiocarbon bounded with irradiated metals and effects of concrete on mobile radionuclides).

The updated PA includes future climate changes and the peak radiation doses for the period of performance (1,000 years into the future or peak dose, whichever is longer [Title 30 of the Texas Administrative Code (TAC) §336.724(1)]) as required under the regulations. While many of the baseline assumptions supporting the initial license were incorporated in the updated PA, new probabilistic fate and transport codes, such as GoldSim, and deterministic groundwater flow codes, including HYDRUS and MODFLOW-SURFACT™, were employed to demonstrate compliance with the performance objectives codified in the regulations.

MODELING PARAMETERS AND TOOLS

Partitioning Coefficients

The K_d values used in the GoldSim performance assessment serve two purposes. First, the K_d values determine the radionuclide release rates from the waste disposal unit and, second, they determine the retardation factors, which are the ratios of the pore water velocity to the radionuclide transport velocities.

Since the license application was approved by TCEQ, WCS has obtained site-specific K_d values for the mobile, long-lived radionuclides. The site-specific values were measured by the Battelle Pacific Northwest Division laboratory and are documented in Serne 2009. For most media, the report recommends K_d values of zero for C-14, Cl-36, Tc-99, and I-129. Where higher, non-zero K_d values are recommended in the waste disposal unit to account for the high pH resulting from the large quantities of concrete and grout.

The K_d values are collected from several sources. First, the Texas regulations contain K_d values to use for certain radionuclides. The preferred K_d values are contained in 30 TAC 350.73(e). To the extent possible, these K_d values are used to represent the leaching characteristics of the waste. Since the waste canisters and the disposal units will be backfilled with grout, a high pH (alkaline) environment will be created in the disposal units. Whenever pH-dependent K_d values were available, the values for high pH were used. For K_d values that were not provided in 350.73(e), values were taken from the RESRAD input guide (Yu 2001), which contains a compendium of K_d information from a variety of sources. This K_d information was used in the Waste Control Specialists LLC (WCS) *Application for License to Authorize Near-Surface Land Disposal of Low-Level Radioactive Waste* (LA), Rev. 12c. K_d values for clay were used for the red bed material and K_d values for sand were used to represent the water-bearing sandstone formations. The RESRAD database contains soil-dependent K_d values for almost all of the radionuclides in the inventory. For the remaining radionuclides that have no soil dependent K_d values available, the RESRAD default values are used.

Pathways

The transport pathways consider the routes by which radionuclides may migrate from the disposal units to the accessible environment. Transport pathways generally include air, surface water, groundwater, soil and biotic pathways. The transport pathways are combined into exposure scenarios, which represent potential activities or conditions through which humans may become exposed to radionuclides. For example, an onsite resident scenario after facility closure may include exposures from inhalation of airborne radionuclides, use of groundwater, and external radiation from contamination exhumed from the disposal units by the individual.

The scenarios are selected to demonstrate compliance with the facility performance objectives, which include protection of members of the general public, protection of workers at the facility, and protection of inadvertent intruders who occupy the site after the period of institutional controls have ended. The scenarios cover the operational period, the institutional control period, and the post-institutional control period, as required by Texas regulations.

To assist with the pathway analysis conducted in the updated PA, new probabilistic fate and transport codes, such as GoldSim, HHYDRUS, and MODFLOW-SURFACT™ were employed to demonstrate compliance with the performance objectives.

GoldSim

GoldSim is used as the PA code for dose calculations. The exposure to a receptor such as a future onsite resident farmer is calculated by GoldSim as the sum of the exposures received from various interrelated exposure pathways. For instance, the exposure pathway and receptor dose resulting from drinking contaminated groundwater and eating garden vegetables watered with the same contaminated water is related to the exposure received from eating domestic animals, who have in turn been exposed by drinking contaminated groundwater. The interconnections among the exposure pathways are explicitly defined in GoldSim. GoldSim is also capable of conducting multiple runs using input variables for which multiple potential values and distributions are available, resulting in a cumulative probability distribution for the potential dose to a receptor.

GoldSim is also used to calculate transport through the geologic system from the waste cell through the landfill liner to the underlying 68.6-m (225-foot) zone in the Dockum Group hydrogeologic system, and each radionuclide is assigned a specific K_d value. The GoldSim calculations of transport through the Dockum hydrogeologic system have been compared to both analytical and numerical solutions for flow and transport, with excellent results.

In the LA, an onsite resident obtained a small portion of a domestic water supply from a well located at the edge of the landfill. As calculated by RESRAD, the water obtained from the well was diluted by a factor of about 400, relative to the concentrations present in undiluted leachate derived from flow through the landfill. The GoldSim analysis does not assume any dilution of the leachate that enters the 68.6-m (225-foot) zone. However, additional water to meet the domestic water demand is assumed to be supplied from an uncontaminated source that is mixed with the well water after it is withdrawn from the 68.6-m (225-foot) zone.

The water demand and well withdrawal rate in the GoldSim model serve a similar purpose, which is to calculate the mixing factor of leachate in water used for the dose calculations. Pumping rate calculations in GoldSim show the maximum sustained withdrawal rate from a well in the68.6-m (225-foot) zone is about 0.4 L/day. The total water demand for the intruder is set at 466 m^3/yr; this demand can't be supplied solely by the well. The radionuclide concentrations for dose calculations are obtained by combining the well pumping rate (0.4 L/day of leachate) with enough additional clean water to equal the water demand. With this simple mixing model, the radionuclide concentrations for the dose calculations depend on both the well pumping rate, which specifies how much leachate is withdrawn, and the water demand, which determines how much additional clean water is required.

The sensitivity cases alter the mixing assumptions by changing the water demand from the baseline value of 466 m^3/yr to a much lower value of 41 m^3/yr, leading to higher concentrations in the water. The GoldSim model was built with a RESRAD switch option that looks at an intermediate water demand value of 250 m^3/yr, the same value used in the LA. The basis for the 250 m^3/yr value is not explained in the RESRAD manual. Conceptually, a decrease in the water demand produces the same effect as an increase in the well pumping rate, as they both affect the concentration.

The GoldSim model can be compared to the original RESRAD analysis by activating a RESRAD switch, which turns on some of the RESRAD parameters used in the LA. The RESRAD parameters implemented in GoldSim include the K_d's used in the LA, a domestic well capacity of 1.7 L/d (the RESRAD default value) and an infiltration rate of 1 mm/yr. GoldSim conducts the pathway analysis with the RESRAD switch on in a considerably more realistic manner than RESRAD is capable. In GoldSim, contaminated water enters the 68.6-m (225-foot) zone at a rate of 1 mm/yr after traveling downward through the Dockum. GoldSim preserves mass by displacing the existing water in the 68.6-m (225-foot) zone at the rate of 1 mm/yr. Additionally, in GoldSim the domestic well is located at the edge of the waste cell (which accounts for the sloping sides), providing approximately 20 m of horizontal travel in the 68.6-m (225-foot) zone, with some minor dispersion.

The addition of realistic constraints and assumptions in the GoldSim analysis results in a maximum CWF dose approximately one order of magnitude lower than the analysis in the LA using the RESRAD switch. The CWF peak dose is 0.61 µSv/yr (6.1E-02 mrem/yr) from Cl-36 at about 21,000 years rather than 15,600 years as documented in the LA.

For the FWF, the peak dose is more than two orders of magnitude lower. The FWF peak dose with the RESRAD switch applied is 0.069 µSv/yr (6.9E-03 mrem/yr) from Tc-99 at 60,000 years, rather than 36,000 years in the LA. The reduction in dose is attributable to the Tc-99 inventory limit imposed by TCEQ, as well as the more realistic modeling with GoldSim.

The results of the GoldSim calculations show compliance with the 0.25 mSv/yr (25 mrem/yr) performance objective for members of the general public. The results also show doses to the onsite individuals that are below the limits imposed by the performance objectives. Results for the GoldSim model without the RESRAD switch applied can be seen in the RESULTS section.

HYDRUS

HYDRUS, a software package for simulating flow and transport in two- and three-dimensional variably saturated media, is used to model the infiltration of precipitation through the cover system and into the waste cells under current and future climatic conditions. The cover system for both the FWF and the CWF are almost identical. Hence the same infiltration model is used to estimate infiltration through the cover for both facilities. In no instance is there saturation developed in the drainage layer, therefore the difference between the slopes of 3 and 4% of the drainage layer are irrelevant.

The HYDRUS model uses daily climatic precipitation and evapotranspiration forcings based on 57 years of climatic information from the Hobbs', New Mexico weather station for the current climatic conditions, and the Wichita, Kansas weather station for hypothetical future wetter conditions. Wichita is the surrogate location for the future hypothetical climate determined in a future climate study presented in the LA. Parameters for the various subsurface layers modeled with HYDRUS are based on recent laboratory analyses of samples obtained during excavation of the CWF and FWF, as well as analyses reported in the LA.

Thirteen (13) scenarios were run with the HYDRUS model, simulating various boundary conditions, atmospheric forcings, and conditions of cover naturalization, degradation, and erosion. Additional sensitivity analyses were conducted to assess the impact of extending the model further downward and including the 68.6-m (225-foot) zone. For each scenario, the 57-year history of climatic forcings was repeated 100 times, for a total simulation time of 5,700 years, to limit the influence of boundary and initial conditions. The moisture fluxes through the waste were significantly less than the fluxes presented in the LA, due to the more detailed moisture balances and infiltration/evapotranspiration capabilities of the HYDRUS code compared to the RESRAD code. Results indicate that the average downward flux for current climate conditions (Hobbs climate and ET forcings) range from approximately 0 to 0.02 mm/yr. Average downward flux for future-climate conditions range from less than 0.01 mm/yr (for the eroded model) to approximately 0.3 mm/yr. Additional sensitivity analysis showed that the model is relatively insensitive to the location of and prescribed pressure head at the bottom boundary as well as the inclusion of the 68.6-m (225-foot) zone.

Both the current- and future-climate conditions fluxes are much less than the 1 mm/yr flux used in the original license application. This indicates that this more realistic 2-D heterogeneous infiltration model, which directly interacts with atmospheric forcings, leads to lower flux compared to the more conservative HELP/VS2DI models used in the LA.

The moisture fluxes as well as saturation profiles through the landfill cover system are input to GoldSim as part of the array of calculated infiltration rates from the landfill into the Dockum. The range of potential fluxes to the Dockum from the landfill is used by GoldSim to calculate radionuclide concentrations entering the groundwater in the 68.6-m (225-foot) zone.

MODFLOW-SURFACT™

MODFLOW-SURFACT™ is used to model the Ogallala-Antlers-Gatuña (OAG) groundwater system. The updated model is significantly larger than the OAG model presented in the LA. The OAG model is approximately 8.5 by 10 miles, extending into Gaines County to the north, Lea County to the west, the southern boundary of the Flying W ranch to the south and about 4 miles east of the ranch boundary to the east. The primary objective of the OAG model is to evaluate whether water from the OAG could intrude on the CWF and FWF facilities and saturate all or part of the granular drainage layer above the compacted clay performance cover, thereby potentially increasing the downward flux of water through the waste. The model was designed to include the relatively large surface depression about 1.61 km (1 mi) east of the eastern ranch boundary which occasionally has water in it, though currently the depression is dry. Also included in the model are small playas and other low areas that are the locations of intermittent recharge to the OAG. Studies of chloride profiles in soils on the facility indicate that there is no recharge to the subsurface in interplaya areas, consistent with the literature on recharge in arid and semi arid areas.

The hydraulic conductivity distribution in the OAG was assigned based on 1) the observed texture in drill cuttings, 2) the geologic interpretation that sediments in the buried channels on the top of the Dockum will likely have higher hydraulic conductivities than elsewhere, and 3) the observations that OAG sediments in the vicinity of the top of the red bed ridge will likely have lower hydraulic conductivities because development of the caprock and younger caliches has penetrated further into the OAG sediments, occluding pore space and reducing the hydraulic conductivity. The steady state OAG model was calibrated to observations of wet and dry conditions as determined from 231 wet and dry wells on the WCS site and vicinity. Virtually all of the wells with water were used as calibration targets, eliminating only those that were clearly affected by anthropogenic activities such as infiltration from drainage ditches. Hydraulic head residuals were less than +/-0.06 m (+/-0.2 ft) in the facilities area where the most head measurements were available. The normalized root mean square error was 6 percent, indicating that the target head errors constitute a small fraction of the steady-state model's range of heads, corroborating the good quality of the calibration (Anderson and Woessner, 1992).

The calibrated flow model was used to evaluate groundwater flow in the OAG under current and future climatic conditions. Under current climatic conditions the model shows, in the facilities area, wet and dry conditions similar to those observed in the field and a flow pattern consistent with observations reported in the monthly OAG groundwater reports (Grisak and Baker, 2009, 2010, 2011).

Outside the facilities area, the calibrated flow system is consistent with the regional flow regime in the High Plains/Ogallala aquifer reported in the literature and modeled in the Texas Water Development Board (TWDB) Groundwater Availability Model (GAM) reports. Under future climatic conditions, similar to those at Wichita, Kansas, the extent of the saturation in the OAG expands slightly; however, saturation in the OAG does not extend to the buffer zones of the landfills because of their location on the topographically high axis of the buried red ridge. This is consistent with current observations in OAG wells. Under future climate conditions, the modeled elevation of the surface of the OAG water is about nine feet below the lowest elevation of the top of the red bed at the northern edge of the buffer zones. Water from the OAG cannot intrude on the facilities and saturate all or part of the granular drainage layer above the compacted clay performance cover; therefore, OAG saturation that could potentially increase the downward flux of water through the waste will not occur.

RESULTS AND DISCUSSION

The most important pathway to analyze with the GoldSim model is the intruder resident where the highest post institutional control receptor dose results from drinking contaminated groundwater, eating garden vegetables watered with the same contaminated water, and eating domestic animals that have in turn been exposed by drinking contaminated groundwater.

For the CWF, the GoldSim model was run for a period of 100,000 years. The doses are shown in Table I. The highest peak dose is 0.023 μSv/yr (2.3E-03 mrem/yr) from Cl-36 at year 100,000. This dose includes the drinking water, milk, meat, and produce pathways. The maximum combined dose from Cl-36 and Tc-99 is 0.037 μSv/yr (3.7E-03 mrem/yr). Doses from C-14 and I-129 are two to four orders of magnitude smaller and have no impact on the final dose rate.

Table 1. Peak Dose per Radionuclides

Facility	Radionuclide	Peak Dose	Time Period

		(μSv/yr)	(yr)
CWF	C-14	0.029	30,000
	Cl-36	0.023	100,000
	Tc-99	0.014	100,000
	I-129	6.5E-06	100,000
FWF	C-14	7.4E-06	29,000
	Cl-36	7.7E-05	100,000
	Tc-99	0.015	100,000
	I-129	6.9E-04	100,000

For the FWF, the GoldSim model was run for the same period. The doses are shown in Table I. The highest peak dose is 0.015 μSv/yr (1.5E-03 mrem/yr) from Tc-99 at year 100,000. The dose includes drinking water, milk, meat, and produce pathways. The maximum combined dose from Cl-36, Tc-99 and I-129 is 0.016 μSv/yr (1.6E-03 mrem/yr).

Doses were not calculated beyond 100,000 years because of the great uncertainties involved in such long time frames. The 100,000-year simulation was sufficient for the more mobile radionuclides to arrive at the well. The analyses demonstrated compliance with the 0.25 mSv/yr (25-mrem/yr) performance objective in 30 TAC 336.724 for a time period far beyond the 1,000-year period referred to in the TCEQ guidance document.

CONCLUSIONS

In a comparison between the results of the updated PA against the one developed in support of the initial license, both clearly demonstrated the robustness of the characteristics of the site's geology and engineering design of the disposal units. Based on the simulations from fate and transport models, the radiation doses to members of the general public predicted in the initial and updated PA were a fraction of the allowable 25 mrem/yr (0.25 msievert/yr) dose standard for tens-of-thousands of years into the future. Draft Texas guidance on performance assessment (TCEQ, 2004) recommends a period of analysis equal to 1,000 years or until peak doses from the more mobile radionuclides occur.

The EPA National Emissions Standards for Hazardous Air Pollutants limits radionuclide doses through the air pathway to 10 mrem/yr. Gaseous radionuclide doses from the CWF and the FWF, due to decomposition gases, are a small fraction of the dose limit.

The radon flux from the CWF and FWF were compared to the flux limit of 20 pCi/m^2-s from 40 CFR 192. Because of the thick cover system, the calculated radon flux was a very small fraction of the limit.

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