APPLICATION OF PROBABILISTIC PERFORMANCE ASSESSMENT MODELING FOR OPTIMIZATION OF MAINTENANCE STUDIES FOR LOW-LEVEL RADIOACTIVE WASTE DISPOSAL SITES AT THE NEVADA TEST SITE

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ABSTRACT

The U.S. Department of Energy (DOE), National Nuclear Security Administration of the Nevada Operations Office (NNSA/NV) operates and maintains two active facilities on the Nevada Test Site (NTS) that dispose defense-generated low-level radioactive waste (LLW), mixed radioactive waste, and "classified waste" in shallow trenches and pits. The operation and maintenance of the LLW disposal sites are self-regulated by the DOE under DOE Order 435.1. This Order requires formal review of a performance assessment (PA) and composite analysis (CA; assessment of all interacting radiological sources) for each LLW disposal system followed by an active maintenance program that extends through and beyond the site closure program. The Nevada disposal facilities continue to receive NTS-generated LLW and defense-generated LLW from across the DOE complex. The PA/CAs for the sites have been conditionally approved and the facilities are now under a formal maintenance program that requires testing of conceptual models, quantifying and attempting to reduce uncertainty, and implementing confirmatory and long-term background monitoring, all leading to eventual closure of the disposal sites. To streamline and reduce the cost of the maintenance program, the NNSA/NV is converting the deterministic PA/CAs to probabilistic models using GoldSim, a probabilistic simulation computer code. The output of probabilistic models will provide expanded information supporting long-term decision objectives of the NTS disposal sites.

INTRODUCTION

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Operations Office (NNSA/NV) operates and maintains two active facilities on the Nevada Test Site (NTS) that dispose defense-generated low-level radioactive waste (LLW), mixed radioactive waste, and "classified waste" (Fig. 1). The waste is buried in shallow trenches and pits, subsided surface craters created by underground testing of nuclear weapons, and large-diameter boreholes (greater confinement boreholes).

The Area 5 Radioactive Waste Management Site (RWMS) is located in north central Frenchman Flat in the southeast part of the NTS approximately 100 km northwest of Las Vegas. Frenchman Flat is a typical closed basin of the Great Basin subprovince of the basin and range physiographic province of the southwestern United States. The Area 5 facility is sited in alluvial deposits of the basin that consist mostly of unconsolidated to weakly consolidated fragmental debris of volcanic and carbonate rocks eroded from the surrounding mountain highlands flanking the basin.

The Frenchman Flat basin was one of multiple sites on the NTS used for testing nuclear weapons (1,2). Atmospheric testing was conducted in the basin playa area south of the Area 5 facility and 10 underground tests were conducted at two separate locations in the central and northern part of the basin. These tests resulted in local contamination of groundwater in the alluvial and volcanic aquifers of Frenchman Flat but monitoring wells at the Area 5 facility show that the contamination has not reached the groundwater adjacent to the facility (3).

The climate of the Area 5 facility is arid with mean annual precipitation of 12.7 cm. There are large diurnal ranges in temperature and the daily maximum air temperatures average 12 ° C in winter to 36 ° C in summer. These conditions promote high evaporation and the mean ratio between potential evapotranspiration and precipitation is 12.4. The setting is virtually ideal for shallow land disposal of LLW waste with no permanent surface water, a very thick vadose zone (approximately 235 meters thick below the Area 5 facility), and no areally distributed groundwater recharge under current climatic conditions (4). Drainage through bare-soil operational covers at inactive disposal cells is estimated to be about 1 percent of the annual rainfall (5).

The Area 5 RWMS began disposing LLW that was generated from defense activities on the NTS in 1960. In 1978, the facility operations were expanded to include disposal of containerized LLW waste shipped to the NTS by off-site generators across the DOE complex. Low-level radioactive waste has been disposed in more than 20 shallow pits and trenches with mixed LLW disposed in a single pit. Classified transuranic waste and high-specific activity waste were buried in 9 greater confinement boreholes from 1983 to 1989. These boreholes are filled with alluvial soil but not closed and this disposal configuration is no longer used. Greater than 90% of the volume of waste disposed at Area 5 is associated with actinide-bearing waste streams (4).

Fig. 1. Boundries and technical areas of the Nevada Test Site and the locations of the Area 5 and Area 3 Radioactive Waste Management Sites.

The Area 3 RWMS is located in southern Yucca Flat, another closed basin of the NTS located directly north of but geographically separate from the Frenchman Flat basin. This facility is also sited in basin-fill alluvial deposits but waste is disposed in surface subsidence craters formed from underground testing of nuclear weapons. To date, two pairs of craters have been enlarged and combined to form two individual waste cells; one crater is used as a single disposal cell, and two craters are available for future disposal activities.

Like Frenchman Flat, Yucca Flat was utilized as an area for atmospheric and underground testing of nuclear weapons but more than 700 tests were conducted in the Yucca Flat basin. Underground testing has contaminated groundwater directly beneath Area 3 (2).

The elevation of Yucca Flat at the Area 3 facility is approximately 300 meters higher than the Area 5 RWMS. Consequently, average annual precipitation in Yucca Flat is about 16.3 cm and daily average temperatures range from 0 ° C in winter to 40 ° C in summer. The average ratio between potential evapotranspiration and precipitation at the Area 3 RWMS is 9.3. The approximate depth to groundwater beneath the Area 3 facility is 490 meters. Drainage through bare-soil operational covers at the Area 3 facility is estimated to be about 10 percent of the annual rainfall (5).

Both containerized and bulk wastes have been disposed at Area 3 since 1968 (6). One disposal unit at Area 3 is now closed (U-3ax/bl) and covered with a vegetated monolayer closure cap consisting of alluvial soils. Major disposed radionuclides in this cell on an activity basis are ^{3}H, ^{90}Sr, and ^{137}Cs. The cell contains < 7000 Ci of long-lived activity (6). The U-3ah/at disposal cell was opened for disposal in 1988 and remains active. Approximately 20% of the disposal volume is bulk soil and debris from the cleanup of atmospheric testing of nuclear weapons. The remaining inventory is containerized waste from off-site generators. Projected activity (decay corrected) of disposed inventory to an expected closure date of 2013 is only about 240 Ci of mostly ^{3}H, ^{241}Pu, ^{239}Pu and ^{240}Pu (6). Disposal activities at the remaining cell, U-3bh began in mid-1997 and the cell contains only bulk soils from cleanup of plutonium-contaminated soils.

PERFORMANCE ASSESSMENT AND COMPOSITE ANALYSIS PROCESS

The DOE requires the completion of performance assessments and composite analyses for their LLW disposal facilities. The PAs provide the basis for establishing with reasonable expectation that disposal sites meet the radiological performance objectives established in DOE M 435.1 (7,8). The CAs provide planning documents to assess the effects of all interacting sources of radioactive materials at DOE sites and ensure doses are consistent with long-term protection of the public. Compliance with these requirements is achieved through completion and acceptance of deterministic PA/CAs that are reviewed by the Low-Level Waste Federal Review Group (LFRG).

The Area 5 PA was conditionally accepted by the LFRG in 1996. A comparison of conservative deterministic estimations of radiological releases from the facility with the performance objectives of DOE O 435.1 is presented in Table 1. The facility readily meets performance objectives with two exceptions. These are the dose estimations associated with two scenarios for the inadvertent human intruder (IHI), both of which exceed the performance objectives. The first is the chronic dose for the post-drilling intruder scenarios for Pit 6, a disposal cell containing a high-Th content waste stream, and the second is the chronic dose for the agricultural scenario where a resident intruder excavates a basement that extends into the buried waste inventory (see Table 1). The Area 5 facility is under active institutional control both currently and for the indeterminate future (9) and IHI is not now possible.

NNSA/NV has multiple options for meeting the intruder doses that exceed the performance objectives. Selection of a specific option or options will be established through closure activities planned over the next decade (10) and will depend partly on programmatic analysis of the alternative decision objectives. The most direct option is to keep the facility under continuing active institutional control established through the NNSA control of the NTS. Alternatively, the revised PA calculations show that the Pit 6 performance objective can also be met through establishing inventory limits on disposal of high-Th content waste in Pit 6. The Pit 6 inventory current to calendar year 2000 is 66

Table I Performance objectives and results of the Area 3 and Area 5 RWMS Performance Assessments

<table>
<tr><th colspan="4">MEMBER OF PUBLIC</th></tr>
<tr><th>Performance Objective</th><th>Area 3 RWMS (Base Case) 1,000-year (yr) analysis; maximum values unless specified otherwise</th><th>Area 5 RWMS (Base Case); 10,000-yr analysis; maximum values unless specified otherwise</th><th>Area 5 RWMS (Subsided Case); 10,000-yr analysis; maximum values unless specified otherwise</th></tr>
<tr><td>25 mrem/yr, all paths</td><td>0.0009 mrem/yr;
0.00004 mrem/yr (mean)</td><td>0.6 mrem/yr</td><td>0.8 mrem/yr</td></tr>
<tr><td>10 mrem/yr, airborne emissions excluding radon</td><td>0.0004 mrem/yr;
0.00003 mrem/yr (mean)</td><td>0.2 mrem/yr</td><td>0.2 mrem/yr</td></tr>
<tr><td>Average annual ^{222}Ra flux < 20 pCi/m^2/s</td><td>0.1 pCi/m^2/s;
0.02 pCi/m^2/s (mean)</td><td>6 pCi/m^2/s</td><td>10 pCi/m^2/s</td></tr>
<tr><td>Protect Groundwater Resources</td><td>No Release (mean)</td><td>No Release</td><td>See Below</td></tr>
<tr><td>• ^{226}Ra + ^{228}Ra < 5 pCi/L</td><td>Not Applicable[1]</td><td>Not Applicable[1]</td><td>0.3 pCi/L</td></tr>
<tr><td>• Gross alpha < 15 pCi/L</td><td>Not Applicable[1]</td><td>Not Applicable[1]</td><td>9 pCi/L</td></tr>
<tr><td>• Man-made beta-gamma emitters < 4 mrem/yr</td><td>Not Applicable[1]</td><td>Not Applicable[1]</td><td>1 mrem/yr</td></tr>
<tr><th colspan="4">INADVERTENT HUMAN INTRUDER</th></tr>
<tr><td>500 mrem Acute</td><td>< 0.04 mrem (mean)</td><td>0.2 mrem drilling, shallow land burial;
22 mrem drilling, Pit P06C</td><td>Not Assessed[2]</td></tr>
<tr><td>100 mrem/yr Chronic</td><td>0.04 mrem/yr (mean)</td><td>157 mrem/yr agricultural, shallow land burial[3];
Not applicable (too deep), agricultural, Pit P06C;
0.7 mrem/yr postdrilling, shallow land burial;
177 mrem/yr postdrilling, Pit P06C[4]</td><td>Not Assessed[2]</td></tr>
</table>

[1] Under the Base Case, there is not a groundwater pathway.

[2] Results would be the same as the Base Case.

[3] Assumes monolayer-ET closure cover to be a minimum of 4 meters (m) (13 feet [ft]) thick to comply.

[4] Assumes an inventory limit of 163 Ci in Pit P06C to comply

curies, well below a calculated inventory limit of 163 Curies necessary to meet the intruder performance objective. An additional option is to weight the intruder dose by the probability of IHI scenarios (likelihood that the scenario will occur). Traditionally, PAs assume that IHI will occur. However, the NTS is located in a remote area of Nevada, well removed from population centers where the likelihood of human intrusion should be significantly less than 1 (probability of 1 = intrusion will occur). An expert judgment elicitation using a panel of subject matter experts was convened to provide inputs to establish probability distributions for the factors included in models of inadvertent human intrusion (10). The expected probability of drilling intrusion into Pit 6 is 0.009 over 1,000 years and the probability weighted maximum yearly dose for an intruder is 1.5 mrem yr^{-1}, well below the performance objective.

Similarly, there are two options for meeting the performance objective of the agricultural scenario. The first option is to increase the thickness of the closure cap to prevent excavation intrusion into the waste. Most construction excavations are 2 to 3 m thick in southern Nevada. Construction of a 4-m thick closure cap on LLW cells in the Area 5 facility yields an estimated scenario dose of 0.004 mrem yr^{-1} at 1,000 years after closure. A second option is to weight the intruder doses by the occurrence probability of the agricultural scenario for the Area 5 facility. The probability of the agricultural scenario at the disposal facility is 0.06 for the 1,000-year compliance interval; the probability weighted maximum dose for this interval is 4.6 mrem yr^{-1}.

The Area 5 CA was completed and conditionally accepted by the LFRG in 2000. The primary concern with the composite analysis was incomplete information with respect to the nature and future extent of groundwater contamination in Frenchman Flat from underground testing of nuclear weapons. This concern can be resolved by maintaining the ongoing institutional control of the NTS that prohibits all public access to groundwater on the site.

The combined Area 3 PA and CA were conditionally accepted by the LFRG in 1999. A comparison of the estimated radiological doses from the facility with the performance objectives of DOE O 435.1 is listed in Table 1. Note that the estimated releases from the Area 3 facility are considerably less than the estimated releases from the Area 5 facility due largely to the much lower curie content of disposed waste at Area 3. A significant review issue for the Area 3 CA is a requirement for conducting a comprehensive options analysis of the effects of cumulative releases from the facility combined with doses to the member of public from groundwater contamination below the Area 3 facility from underground nuclear testing. Three options were considered for an options analysis including characterization of the hydrological source term from underground testing, remediation of the underground contamination, and identification of the contaminant boundary where the boundary definition is based on the requirements of the Safe Drinking Water Act. The extreme cost of detailed characterization studies and/or cleanup/mitigation makes the third option the only viable approach to assessing the UGTA contamination for the CA.

The accepted PA/CAs for the NTS radioactive waste management sites are based on highly conservative and deterministic performance assessment models. The differences between deterministic and probabilistic PAs and the impact of conservatism on long-term management of a low-level waste disposal facility are examined in the next section.

DETERMINISTIC AND PROBABILISTIC PERFORMANCE ASSESSMENTS

Deterministic PAs have proven useful across the DOE complex and multiple sites have completed and received approval of their PA/CAs. Following review and approval, DOE disposal sites transition to a PA maintenance program. A key conceptual outgrowth of the PA knowledge gained across the DOE complex is the importance of uncertainty in evaluating the results of PAs. Nearly all performance assessments are highly uncertain by virtue of a combination of source inventory uncertainty, the complexity of the processes of fate and transport that affect disposed waste, and the complexity of receptor exposure models. The requirement of predicting contaminant releases over a 1,000-year compliance interval provides yet another component of uncertainty. PA results tend to be model dependent, data deficient and uncertain.

The regulatory requirements of DOE Order 435.1 are deterministic and are based on fixed-point dose limits for multiple pathways leading to radiological exposures for the Member of Public (MOP; see Table 1). The model outputs for the Area 5 and Area 3 PA/CAs are deterministic consistent with the regulatory standards. The intent of a deterministic PA is to bound uncertainty through the use of conservative assumptions and parameter values where the basis for conservatism in the models is underestimation of the true performance of a waste disposal facility. However, uncertainty is not defined quantitatively. Quantification and assessment of the potential for uncertainty reduction are important goals of a PA maintenance program

The Area 5 and Area 3 RWMSs continue to receive and dispose LLW from cleanup activities on the NTS and from off-site generators across the DOE complex. The NTS LLW disposal sites were recently designated by DOE Headquarters as a regional disposal center along with the Hanford site in Washington State (*Federal Register,* February 25, 2000). The impact of uncertainty on the conclusions of PA/CAs for the NTS facilities must be evaluated systematically during the post-compliance PA maintenance period to aid the NNSA/NV in the efficient management of their continuing disposal operations. Additionally, quantification of uncertainty provides information that can be used for more effective management of monitoring and closure programs. Verification of the long-term safety of the Nevada LLW disposal sites is a two-step process. The first step is demonstration of compliance, with reasonable expectation, of meeting the performance objectives of DOE Order 435.1. This has been accomplished through preparation and review of deterministic PA/CAs. The second step is to develop increased confidence that the PA/CA conclusions are reasonable, are well supported and will remain valid for the required 1,000-year compliance interval. The NNSA/NV program is now initiating programmatic activities that focus on the second step of the process. The approved PA/CAs for the Area 5 and Area 3 RWMSs are being converted into probabilistic performance assessment models to increase programmatic efficiency, to more fully assess uncertainty of the disposal systems, and to facilitate decisions concerned with the long-term operation and closure of the disposal sites.

A probabilistic PA model uses probability distributions to represent significant input parameters and propagates these distributions through numerical models using Monte Carlo simulation (12,13,14). Probabilistic models encompass uncertainty in the inventory, in fate and transport processes and in exposure pathways to potential receptors. Probabilistic PA models attempt to represent and evaluate the multiple components of uncertainty including natural variability, parameter uncertainty, model uncertainty and scenario uncertainty. The outputs of these models are also probability distributions that, if correctly constructed, represent an expected or "best-estimate" of the performance of a disposal site and the uncertainty associated with that estimate, conditioned on the model assumptions. Probabilistic PA models generally include probabilistically based sensitivity and uncertainty analyses and may include formal methods of uncertainty reduction and measurement of the value of uncertainty reduction. This suite of approaches and methodology is described by many names including probabilistic risk assessment, quantitative risk assessment, quantitative uncertainty analysis, uncertainty analysis, risk modeling and/or more simply, probabilistic modeling. There is no clearly agreed upon definition of probabilistic modeling but three components are nearly always at the heart of all probabilistic models: 1) use of probability distributions to describe and represent uncertainty; 2) propagation of uncertainty through Monte Carlo simulation; and 3) calculation of model outputs as probability distributions.

The PA Maintenance Program

The primary goal of the Nevada PA maintenance program is to ensure that the conclusions of the performance assessment and composite analysis remain valid over the operational life of the LLW disposal facility as well as the post-closure period (15). Figure 2 is a schematic illustration of the major components of a LLW disposal system. Successful isolation of LLW through shallow trench burial requires a series of operational and assessment steps that are evaluated through the performance assessment process:

1. Safe operational disposal and tracking of radionuclide inventories of LLW;
2. Projection of future disposal inventories through the facility operational lifespan;
3. Assessment and projection of the fate and transport of waste radionuclides along multiple release pathways, including changes in these processes through the 1,000-year compliance interval;
4. Conversion of estimated releases of radionuclide concentrations along transport pathways into doses to the MOP where the location and exposure scenarios are dependent on the local setting, on institutional control policies, and other interacting sources of radiological contamination; and
5. Comparing the resulting dose calculations to the multiple performance objectives of DOE Order 435.1

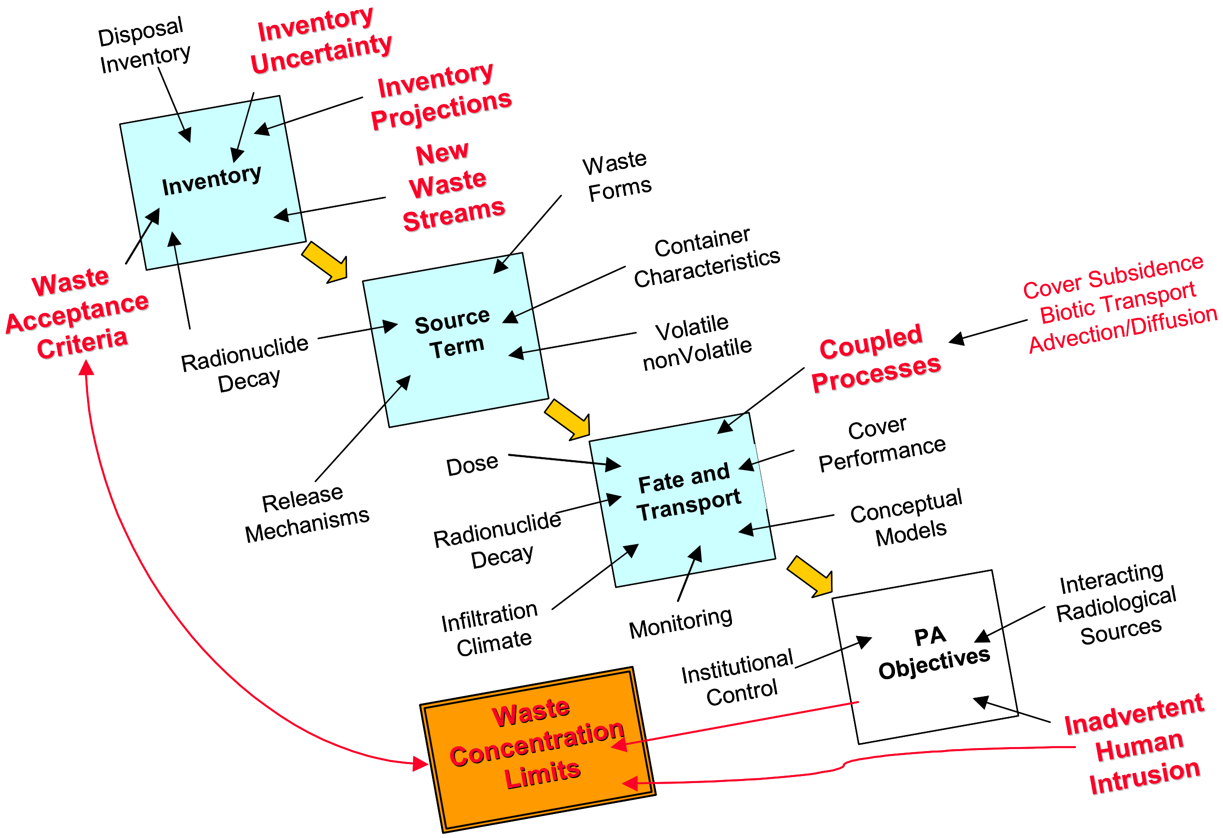

Fig. 2: Diagram of the major components of a performance assessment model. The arrow-labeled items are uncertain components and processes of the model and the bolded items are the major components of the total system uncertainty.

6. Assessment of geochemical release processes for the local disposal setting, the range of waste forms, and the container characteristics for both volatile and non-volatile radionuclides;

An active waste disposal system represents a dynamic system where an uncertain inventory (radionuclide concentrations, volume) representing multiple waste streams is disposed through the facility lifetime and/or up to the disposal capacity of the site. At closure, the waste inventory becomes fixed (but still uncertain) and remains isolated in shallow trenches with a minor component released largely through uncertain processes of moisture infiltration, source term release and fate and transport. For the Nevada disposal sites, these uncertain processes are episodic rainfall that may or may not lead to transient infiltration events into the waste, leaching of radionuclides from highly variable waste forms, upward transport through coupled advection, diffusion, and biotic transport, and atmospheric releases to receptors (members of the public). There is uncertainty in both the current day effects of these interrelated processes as well as the future state of the system. A deterministic performance assessment model presents a single result of calculations of the behavior of a LLW disposal system model where the expected system behavior is *bounded* through the application of conservative assumptions and model calculations. An enhanced understanding of the disposal system interactions can be obtained through a probabilistic examination of the system dynamics and the effects of uncertainty on the system behavior. Where required, this understanding should be translated into operational, and management constraints on active waste disposal sites.

MAINTENANCE STRATEGY FOR THE AREA 5 AND AREA 3 FACILITIES

As noted above, the primary goal of the maintenance program is to ensure the disposal sites remain consistent with the performance objectives assessed through the PA and CA. Using probabilistic modeling, the following additional goals are being evaluated as a part of maintenance activities for the Area 5 and Area 3 RWMSs:

1. Evaluating the uncertainty in the estimated performance of the disposal sites for the multiple performance objectives of DOE Order 435.1;
2. Assessing reduction in model conservatism and the resulting reduction in uncertainty in the PA/CAs;
3. The programmatic benefits of uncertainty reduction for the decision objectives of the disposal sites;
4. Testing and verifying the conceptual models of the geohydrological setting of the disposal systems including testing of alternative conceptual models with site characterization data;
5. Iteratively assessing the impacts of data gathered from site monitoring and additional site characterization studies on the PA/CA results;
6. Streamlining the monitoring program based on the results of sensitivity and uncertainty analysis of the results of probabilistic modeling of system performance;
7. Iteratively evaluating and refining waste concentration limits for the disposal sites;
8. Continuing evaluations on a case-by-case basis of the acceptability of new waste streams for disposal at the NTS facilities;
9. Applying the results of probabilistic modeling for refining and reducing the cost of strategies used for the monitoring program and to close disposal cells; and
10. Using the results of iterative probabilistic modeling to establish decision objectives for transitioning the disposal sites to long-term stewardship.

One of the major barriers to successful application of probabilistic models to PA problems, both in terms of cost and application difficulty, has been implementation of probabilistic models utilizing stochastic simulation routines. Prior to the about the last decade, application of probabilistic modeling required custom programming (16). Dynamic simulations were generally programmed in FORTRAN or in simulation languages. Specialized computer codes were usually developed for both input and output of data and model results. Today there are many commercially available computer software codes built around highly versatile simulation routines that have completely removed the cost and drudgery of probabilistic modeling. The software codes are relatively easy to use, and many contain timesaving routines for input of data as probability distributions, for running simulations with multiple sampling options, and for displaying simulation results. Additionally, while these software codes have become increasingly easy to use and apply to environmental problems, the processing power of conventional desktop computers has escalated dramatically. Monte Carlo simulations that once required hours to days to run can now be completed in minutes or hours on most modern desktop computers. The capability of designing and running complex simulations of waste disposal systems is unprecedented and all but the largest probabilistic modeling problems can be run routinely with relatively modest computer resources.

A range of well-documented commercial computer codes was examined for application to probabilistic PA modeling. Based on this examination, the GoldSim probabilistic simulation software (17) has been selected for use in the PA maintenance program. GoldSim is a graphical, object-oriented computer program designed to facilitate dynamic, probabilistic simulations for a wide variety of technical problems including a built-in flow and transport module that is well suited to PA studies. The primary strengths of GoldSim include: 1) it was designed from inception as a fully probabilistic computer code; 2) it is highly versatile for PA applications; and 3) the program contains modules designed for probabilistic modeling of the multiple components of a waste disposal system; 4) the GoldSim computer code has been used for multiple national and international performance assessment studies; it is used for the total system performance assessment studies of underground disposal of high-level radioactive waste by the Yucca Mountain Project (18); 5) the computer code has been verified and documented (19).

TRANSITIONING FROM DETERMINISTIC PA MODELS

The major steps for developing a PA model include:

1. Define Performance and Decision Objectives
2. Develop Conceptual Model(s)
3. Develop the Mathematical Models Needed for the Conceptual Model(s)
4. Quantify the Input Parameters
5. Implement and Solve the Mathematical Models using Computational Tools (generally numerical computer models)
6. Perform Sensitivity and Uncertainty Analysis
7. Evaluate and Document the Modeling Results

These fundamental steps are the same for either a deterministic or probabilistic PA; they differ only in the details of implementation of steps 3 through 6 and in presentation of results in step 7. Fundamentally, most of the work needed for the development of probabilistic PA models has already been completed in the deterministic PAs. The conceptual model(s), the model framework and the numeric structure of model components are implemented already in deterministic PA models. These deterministic models have been reviewed, validated and accepted by the LFRG. To retain that acceptance level, the probabilistic PA model must be carefully tied to and provide comparable results with the deterministic models.

The NNSA/NV program is in the process of converting the deterministic PA/CAs for the Area 5 and Area 3 RWMSs into integrated probabilistic models. The following steps are being followed for this process and current studies are focused on benchmark comparison of the results of the approved deterministic and newly developed probabilistic models:

1. Incorporate the existing PA structure in the probabilistic model and input fixed-point (deterministic) parameters into the GoldSim probabilistic computer program.
2. Benchmark the GoldSim model results against the results of the approved PAs using the PA performance objectives as the main basis for comparison. Document and compare model outputs at a sufficient level of detail to allow a reviewer to readily compare the model results and assess model equivalency.
3. Retain the model framework and systematically convert deterministic parameter inputs for the PA model into probability distributions.
4. Re-run the GoldSim model with probability distributions for input parameters. Compare the revised results with the deterministic data runs to calibrate differences in output between the probabilistic versus deterministic data sets.
5. Conduct sensitivity analysis of the model output from the revised probabilistic computer output to identify the input parameters that most significantly impact the output results.
6. Use the results of sensitivity analysis to assess the value of revising the model structure, gathering additional information and/or refining parameter distributions. Uncertainty and sensitivity analyses should be performed in tandem to assess uncertainty components that can be attributed to input parameters and to target future data collection on the most sensitive parameters.
7. Use monitoring and/or characterization data to revise the input probability distributions in the GoldSim model using the new information. Continue iterative cycles of data assessment, model revision and model runs to attempt to reduce uncertainty. The iterative cycles should not be open-ended. Completion of modeling efforts should be guided by value of information studies using programmatic decision objectives established for the Nevada disposal sites.

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