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Corrective Action Decision Document/Corrective Action Plan for Corrective Action Unit 97: Yucca Flat/Climax Mine Nevada National Security Site, Nevada

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CORRECTIVE ACTION DECISION DOCUMENT/ CORRECTIVE ACTION PLAN FOR CORRECTIVE ACTION UNIT 97: YUCCA FLAT/CLIMAX MINE NEVADA NATIONAL SECURITY SITE, NEVADA

U.S. Department of Energy,
Environmental Management Nevada Program
Las Vegas, Nevada

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CORRECTIVE ACTION DECISION DOCUMENT/CORRECTIVE ACTION PLAN FOR CORRECTIVE ACTION UNIT 97: YUCCA FLAT/CLIMAX MINE NEVADA NATIONAL SECURITY SITE, NEVADA

Approved by: /s/ Robert F. Boehlecke Date: 08/09/2017

for Bill R. Wilborn
Underground Test Area Activity Lead

Approved by: /s/ Robert F. Boehlecke Date: 08/09/2017

Robert F. Boehlecke
Environmental Management Operations Manager

Table of Contents

Table of Contents *(Continued)*

List of Figures

List of Tables

List of Acronyms and Abbreviations

General Acronyms and Abbreviations

3-D	Three-dimensional
AA	Alluvial aquifer
ALARA	As low as reasonably achievable
ATCU	Argillic tuff confining unit
BLM	Bureau of Land Management
BN	Bechtel Nevada
CADD	Corrective action decision document
CAI	Corrective action investigation
CAIP	Corrective action investigation plan
CAP	Corrective action plan
CAS	Corrective action site
CAU	Corrective action unit
COC	Contaminant of concern
CR	Closure report
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DVRFS	Death Valley Regional Groundwater Flow System
EM	Environmental Management
EPA	U.S. Environmental Protection Agency
FEHM	Finite element heat-mass
FFACO	*Federal Facility Agreement and Consent Order*
FMP	Fluid Management Plan

List of Acronyms and Abbreviations *(Continued)*

ft	Foot
GIS	Geographic Information Systems
HFM	Hydrostratigraphic framework model
HST	Hydrologic source term
HSU	Hydrostratigraphic unit
IDW	Investigation-derived waste
K_d	Distribution coefficient
kg/s	Kilograms per second
km	Kilometer
km^2	Square kilometer
kt	Kiloton
LANL	Los Alamos National Laboratory
LCA	Lower carbonate aquifer
LCA3	Lower carbonate aquifer-thrust plate
LCCU	Lower clastic confining unit
LLNL	Lawrence Livermore National Laboratory
LTCU	Lower tuff confining unit
m	Meter
m^2	Square meter
MCL	Maximum contaminant level
MGCU	Mesozoic granite confining unit
mm/yr	Millimeters per year
MT	Magnetotelluric
M&O	Management and operating

List of Acronyms and Abbreviations *(Continued)*

MWAT	Multiple-well aquifer test
NAD	North American Datum
NDEP	Nevada Division of Environmental Protection
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSS	Nevada National Security Site
NSMC	Null Space Monte Carlo
NTS	Nevada Test Site
NTTR	Nevada Test and Training Range
OSBCU	Oak Spring Butte confining unit
OSHA	Occupational Safety and Health Administration
pCi/L	Picocuries per liter
PER	Preemptive review
PRT	Peer review team
QAP	Quality Assurance Plan
R_c	Cavity radius
REOP	Real Estate/Operations Permit
RN	Radionuclide
RREMP	Routine radiological environmental monitoring plan
SDWA	*Safe Drinking Water Act*
SZ	Saturated zone
TCU	Tuff confining unit
TER	Tritium exchange ratio
TM-LVTA	Timber Mountain lower vitric-tuff aquifer

List of Acronyms and Abbreviations *(Continued)*

TM-UVTA	Timber Mountain upper vitric-tuff aquifer
TM-WTA	Timber Mountain welded-tuff aquifer
TSA	Topopah Spring aquifer
UCCU	Upper clastic confining unit
UGTA	Underground Test Area
UR	Use restriction
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
UZ	Unsaturated zone
VA	Volcanic aquifer
VOIA	Value of information analysis
WDT	Well development and testing
WMP	Waste Management Plan
WW	Water Well

List of Acronyms and Abbreviations *(Continued)*

Symbols for Elements and Compounds

Am	Americium
Br	Bromine
C	Carbon
Ca	Calcium
Cl	Chlorine
Cs	Cesium
Eu	Europium
^{3}H	Tritium
I	Iodine
Ni	Nickel
Np	Neptunium
O	Oxygen
Pu	Plutonium
Sm	Samarium
Sr	Strontium
Tc	Technetium
U	Uranium

Executive Summary

This corrective action decision document (CADD)/corrective action plan (CAP) has been prepared for Corrective Action Unit (CAU) 97, Yucca Flat/Climax Mine, Nevada National Security Site (NNSS), Nevada. The Yucca Flat/Climax Mine CAU is located in the northeastern portion of the NNSS and comprises 720 corrective action sites. A total of 747 underground nuclear detonations took place within this CAU between 1957 and 1992 and resulted in the release of radionuclides (RNs) in the subsurface in the vicinity of the test cavities.

The corrective action process for the Yucca Flat/Climax Mine CAU is implemented by the U.S. Department of Energy (DOE), Office of Environmental Management Nevada Program's Underground Test Area (UGTA) Activity in accordance with the *Federal Facility Agreement and Consent Order* (FFACO). This CADD/CAP is a part of the corrective action process described in the FFACO. The CADD portion describes the Yucca Flat/Climax Mine CAU data-collection and modeling activities completed during the corrective action investigation (CAI) stage, presents the corrective action objectives, and describes the actions recommended to meet the objectives. The CAP portion describes the corrective action implementation plan. The CAP presents CAU regulatory boundary objectives and initial use-restriction boundaries identified and negotiated by DOE and the Nevada Division of Environmental Protection (NDEP). The CAP also presents the model evaluation process designed to build confidence that the groundwater flow and contaminant transport modeling results can be used for the regulatory decisions required for CAU closure.

The UGTA strategy assumes that active remediation of subsurface RN contamination is not feasible with current technology. As a result, the corrective action is based on a combination of characterization and modeling studies, monitoring, and institutional controls. The strategy is implemented through a four-stage approach that comprises the following: (1) corrective action investigation plan (CAIP), (2) CAI, (3) CADD/CAP, and (4) closure report (CR) stages.

The first two stages of the strategy have been completed for the Yucca Flat/Climax Mine CAU. A value of information analysis and a CAIP were developed during the CAIP stage. The following studies proposed in the CAIP were completed during the CAI stage (see Appendix B):

- Mineralogy study of the tuff confining unit
- Geophysical interpretation of the Paleozoic framework

- Analysis of existing seismic data
- Hydrogeologic investigation of Wells ER-6-1 and ER-6-2
- Isotope/geochemistry mass balance studies
- Analysis of existing tracer test data
- Laboratory studies of transport processes
- Rainier Mesa colloid studies
- Analysis of data for phenomenological models

Significant activities were performed to support the CAI studies including drilling 10 wells; conducting a multiple-well aquifer test (MWAT) and tracer test; compiling hydrologic and transport data; performing laboratory and field experiments to characterize RN transport properties; sampling and analyzing geochemical and isotopic data to infer groundwater flow patterns and travel times; characterizing fractures and faults, mineral composition of the rock matrix, and fracture-lining mineral isotopic compositions; constructing a hydrologic framework model and alternatives; developing hydrologic source term models, including separate analyses for unsaturated zone-hosted tests, tests emplaced in saturated alluvium and volcanic rock, and tests hosted in unsaturated carbonate rock; and developing regional groundwater models to constrain estimates of groundwater flow into and out of Yucca Flat. More than 60 reports were produced to document this work.

After completing these activities, groundwater flow and contaminant transport models were developed to forecast contaminant boundaries that enclose areas potentially exceeding the *Safe Drinking Water Act* radiological standards at any time within 1,000 years. An external peer review of the groundwater flow and contaminant transport models was completed, and the models were accepted by NDEP to allow advancement to the CADD/CAP stage.

The CADD/CAP stage focuses on model evaluation, which consists of an iterative series of five steps designed to build confidence in the site conceptual model and model forecasts. Step 1 is to identify data-collection activities to address key uncertainties in the groundwater flow and contaminant transport models; Step 2 is to document the data-collection activities in the CADD/CAP; and Step 3 is to perform the activities. In Step 4, the new data are assessed and the model is refined; the modeling results are evaluated; and a model evaluation report is prepared. The assessments are made by the modeling team and presented to the preemptive review committee. The decision is made by the modeling team with the assistance of the preemptive review committee and concurrence of DOE to continue data and model assessment/refinement, recommend additional data collection, or recommend advancing to the CR stage. A recommendation to advance to the CR stage is based on whether sufficient confidence in the model exists for designing a monitoring system and developing effective institutional controls. In Step 5, the decision to advance to the CR stage or to return to Step 1 of the process is made by NDEP.

The data-collection and evaluation activities identified for Yucca Flat/Climax Mine model evaluation are as follows:

- Sampling lower carbonate aquifer (LCA) completions for RNs
- Formalizing the ER-6-1-2 MWAT reanalysis
- Sampling near-field wells
- Performing well development and testing activities in the LCA at ER-4-1

Sampling the NASH test cavity at Satellite Well UE-2ce

- Interpreting drilling evidence from ER-2-2, ER-3-3, and ER-4-1
- Performing geochemical evaluation
- Investigating LCA surface elevations
- Reviewing historical data for detonations near or within the LCA

These activities were selected to address the following model evaluation targets:

- Basin flux through the testing area
- Exchange volume size and shape that extends into the LCA
- Extent of RN contamination in the LCA
- LCA hydraulic properties
- Strontium-90 mobility in the LCA
- Cesium-137 mobility in the LCA
- Fault transport properties
- Permeability anisotropy

The Yucca Flat/Climax Mine Base Case model and alternatives will be modified and recalibrated to incorporate the results of the model evaluation targets. Models may be eliminated from the contaminant boundary ensemble. Also, additional contaminant boundaries may be included in the ensemble as a result of the model evaluation process.

1.0 Introduction

This corrective action decision document (CADD)/corrective action plan (CAP) has been prepared for Corrective Action Unit (CAU) 97, Yucca Flat/Climax Mine, at the Nevada National Security Site (NNSS), Nevada. The CADD portion of this document describes the results of data-collection and modeling activities completed for the Yucca Flat/Climax Mine CAU, and also describes the corrective action objectives and the actions recommended to meet the objectives. The CAP portion describes the implementation plan for the corrective action. This includes presenting the CAU regulatory boundary objectives and initial use-restriction (UR) boundaries negotiated by the U.S. Department of Energy (DOE) and the Nevada Division of Environmental Protection (NDEP). The CAP portion also describes the model evaluation process to assess the reliability of model results through data collection and model refinement. The goal of this process is to build confidence that the groundwater flow and contaminant transport modeling results can be used for the regulatory decisions required for CAU closure. The corrective actions recommended in this document are in accordance with the *Federal Facility Agreement and Consent Order* (FFACO) (1996, as amended) that was agreed to by the State of Nevada; DOE, Environmental Management; U.S. Department of Defense (DoD); and DOE, Legacy Management.

1.1 Background

Yucca Flat/Climax Mine is one of five CAUs on the NNSS (formerly the Nevada Test Site [NTS]) assigned to the Office of Environmental Management (EM) Nevada Program's Underground Test Area (UGTA) Activity. The NNSS is approximately 65 miles northwest of Las Vegas, Nevada. This CAU, in the northeastern portion of the NNSS (Figure 1-1), was used for underground nuclear testing from 1957 to 1992, which resulted in the release of radionuclides (RNs) in the subsurface in the vicinity of the test cavities. Because RN contamination in the subsurface exists and this contamination could potentially migrate with groundwater, corrective action for this CAU is needed.

The Yucca Flat/Climax Mine CAU has had 747 underground nuclear detonations (744 in Yucca Flat and 3 in Climax Mine). The test cavities associated with the detonations are grouped into corrective action sites (CASs), with some sites having multiple detonations (NNSA/NFO, 2015d). Figure 1-2 shows the distribution of CASs within the Yucca Flat/Climax Mine CAU. Appendix A gives the CAS

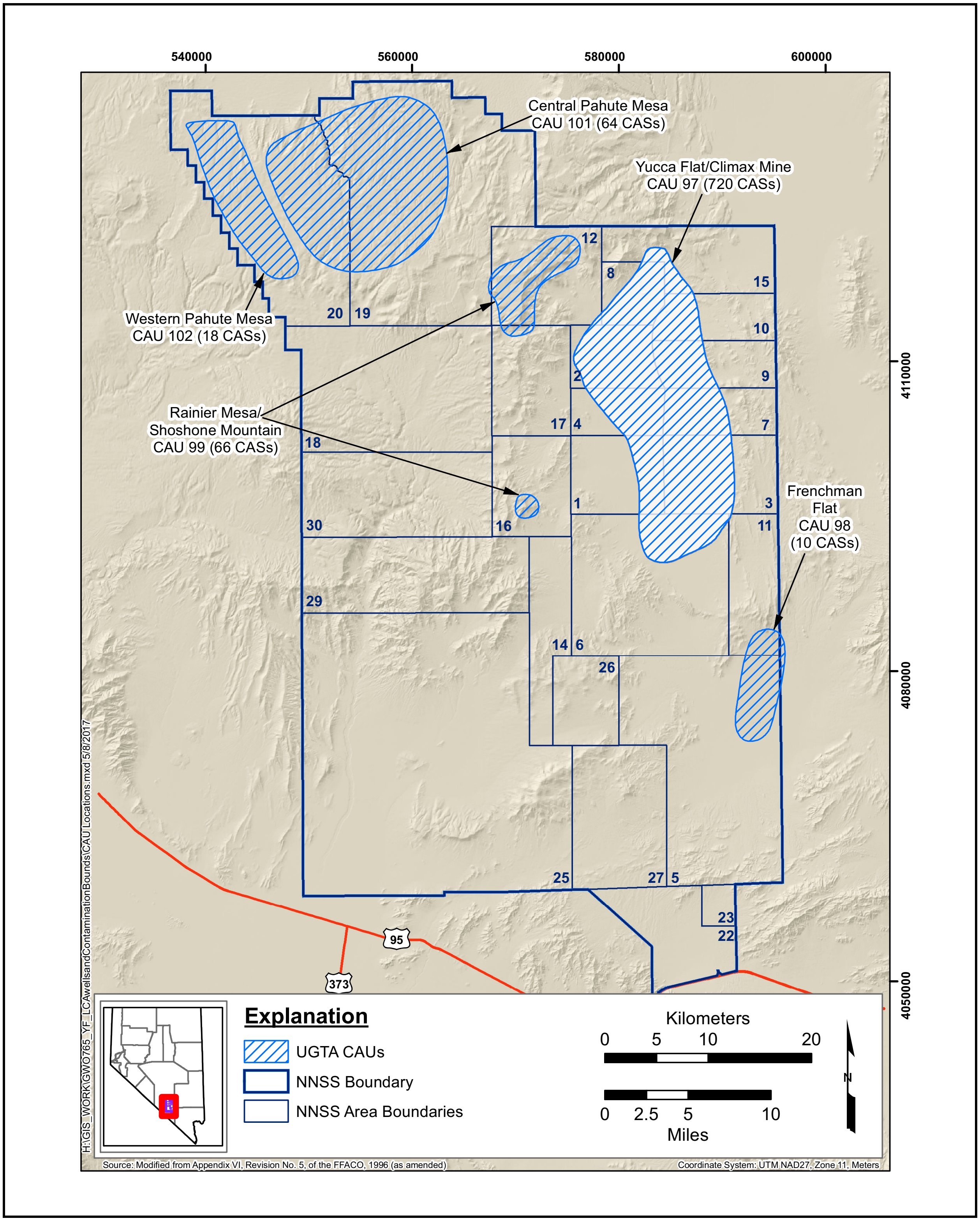

Figure 1-1
Location of the Yucca Flat/Climax Mine CAU

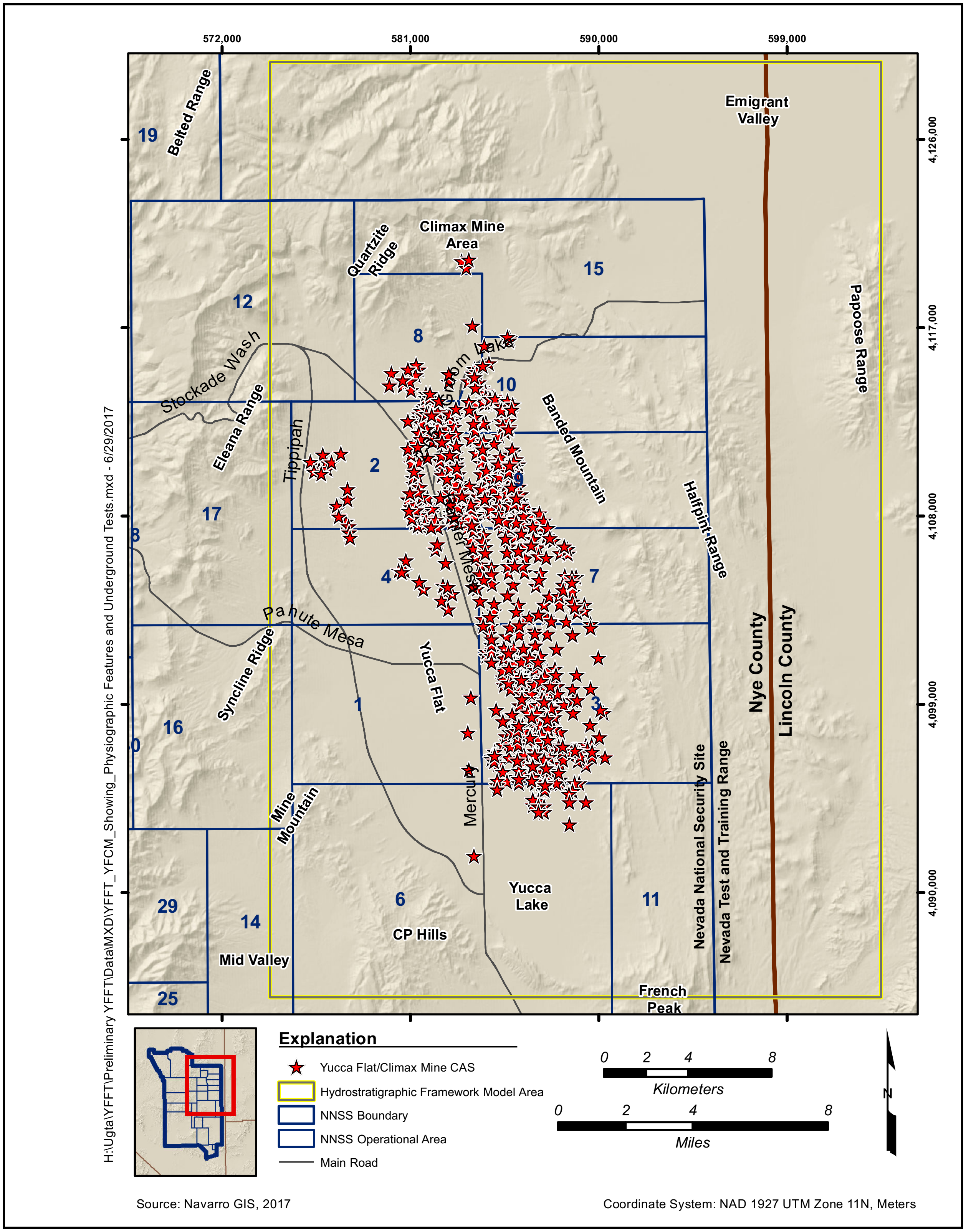

Figure 1-2
Yucca Flat/Climax Mine CAS Locations

number, location, detonation name, date expended, announced yield, working point depth, and hydrostratigraphic unit (HSU). The table also notes whether the working point is in or near the saturated zone (SZ) (see Appendix A).

Announced yields of individual detonations within the Yucca Flat/Climax Mine CAU range from less than 1 kiloton (kt) to a maximum of 500 kt. The test with the largest announced yield within the Yucca Flat/Climax Mine CAU was STRAIT, detonated in 1976, with an announced yield range of 200 to 500 kt (NNSA/NFO, 2015d). Three tests were performed at Climax Mine in granite (HARD HAT, PILEDRIVER, and TINY TOT), and four were performed in unsaturated carbonate rock (NASH, BOURBON, HANDCAR, and KANKAKEE); the other 740 detonations had their working points in alluvium or tuff (see Table A.1-1).

1.2 Corrective Action Strategy

The UGTA strategy, defined in Appendix VI of the FFACO (1996, as amended), assumes that active remediation is not feasible with current technology. As a result, the corrective action is based on a combination of characterization and modeling studies, monitoring, and institutional controls. This approach is consistent with guidance on the use of models in environmental regulatory decision-making (NRC, 2007; EPA, 2009). The strategy is implemented through a four-stage approach that comprises the following: (1) corrective action investigation plan (CAIP), (2) corrective action investigation (CAI), (3) CADD/CAP, and (4) closure report (CR) stages (Figure 1-3).

The first two stages of the strategy have been completed for the Yucca Flat/Climax Mine CAU. A value of information analysis (VOIA) was performed and documented (IT, 1999), and a CAIP (DOE/NV, 2000a) was developed during the CAIP stage. Significant characterization (SNJV, 2006b, 2007, and 2009) and modeling (N-I, 2013) were completed during the CAI stage. The Yucca Flat/Climax Mine CAU groundwater flow and transport models (i.e., Base Case and alternative models) were developed (N-I, 2013) and reviewed by an external peer review team (PRT) (N-I, 2015; see Section 2.4). The models were accepted by NDEP to allow the CAU to advance to the CADD/CAP stage (see Section 2.5).

The CADD/CAP stage begins with DOE and NDEP identifying and negotiating initial use-restriction (UR) boundaries and CAU regulatory boundary objectives. Regulatory boundary objectives are

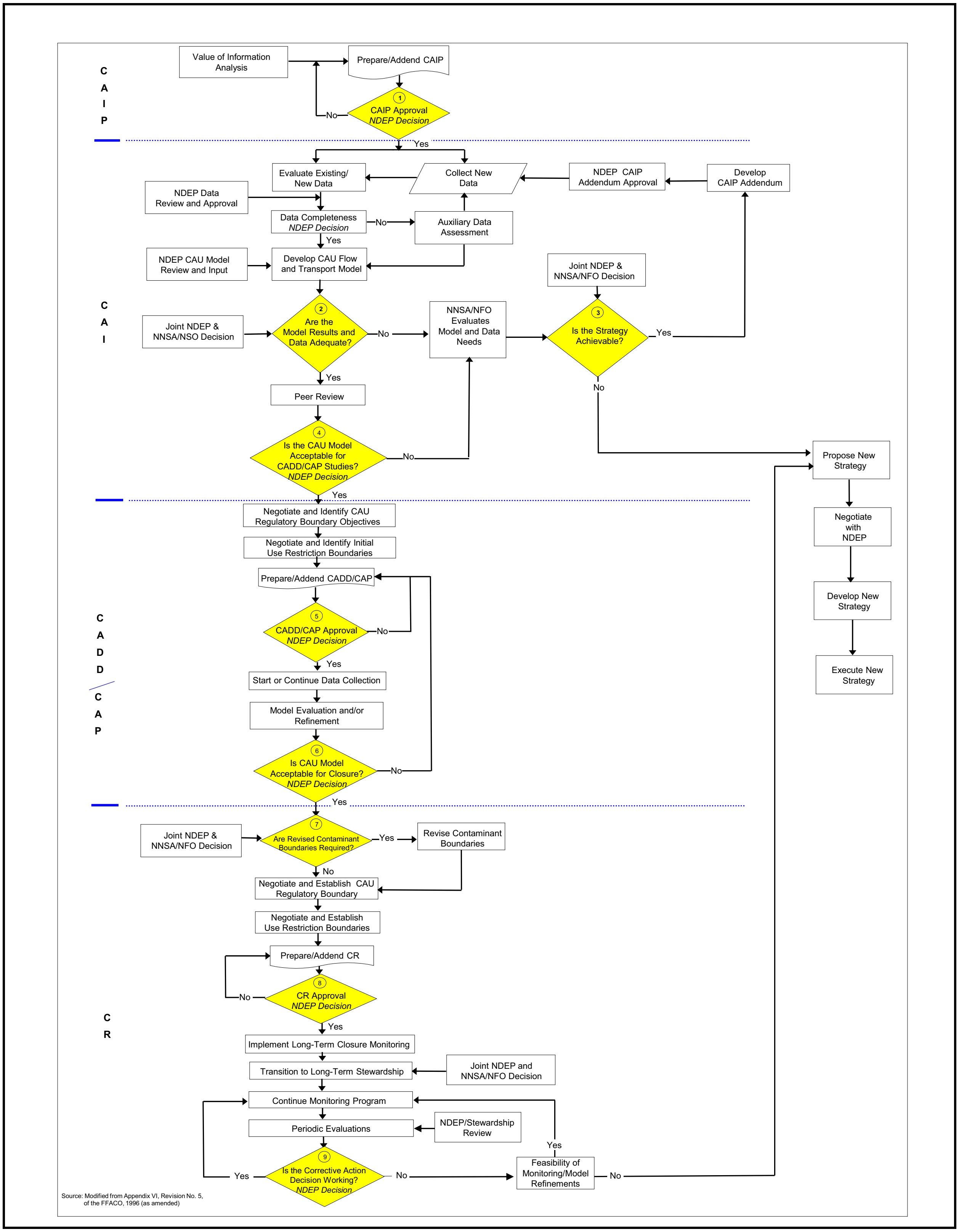

Figure 1-3
Underground Test Area Strategy Flowchart

statements of specific objectives to protect the public and environment from exposure to contaminated groundwater (FFACO, 1996, as amended). Corrective actions are described and implementation of the corrective action is planned at the beginning of the CADD/CAP stage.

As stated in the FFACO (1996, as amended), “closure in place with monitoring and institutional controls is the only likely corrective action.” The CADD/CAP stage focuses on model evaluation to ensure that existing models provide adequate guidance for the regulatory decisions regarding monitoring and institutional controls. Data-collection and analysis activities are identified and implemented to address key uncertainties in the groundwater flow and contaminant transport models. During the CR stage, final UR and regulatory boundaries are negotiated and established, a long-term closure-monitoring program is developed and implemented, and the approaches and policies for institutional controls are established and implemented.

This CADD/CAP presents a summary of the data-collection and modeling activities performed during the CAI stage (Section 2.0), the corrective action objectives and the corrective action alternative recommended to meet these objectives (Section 3.0), and the implementation plan for the recommended alternative (Section 4.0). References are provided in Section 5.0.

2.0 Corrective Action Investigation Summary

This section summarizes the activities performed during the CAIP and CAI stages of the UGTA strategy for the Yucca Flat/Climax Mine CAU. These stages, encompassing a period of 16 years, were supported by multiple organizations led by DOE. A CAIP approved in 2000 by NDEP (DOE/NV, 2000b) describes data-collection and modeling guidelines for the CAI. The CAIP was developed based on regional numerical models to look at the value of particular datasets believed to affect solute transport in NTS groundwater (DOE/NV, 1997b; IT, 1999). CAI objectives specified in the CAIP are as follows (DOE/NV, 2000b):

- Determine the characteristics of the groundwater flow system, the sources of contamination, and the transport processes to acceptable levels of uncertainty.
- Develop a credible numerical model of groundwater flow and contaminant transport for the Yucca Flat/Climax Mine CAU and downgradient areas.
- Develop stochastic predictions of the contaminant boundary at an acceptable level of uncertainty. Stochastic predictions are made using random sampling methods such as the Monte Carlo method. Numerous sets of model input parameters are sampled from estimated statistical distributions and used to predict a range of possible locations of the contaminant boundary. The range of possibilities for the location of the contaminant boundary reflects the uncertainties associated with the input parameters and defines the uncertainty associated with the location of the contaminant boundary.

To accomplish these objectives, substantial data-collection (see Section 2.1) and modeling (see Section 2.2) activities were performed that include the following:

1. Drilling 10 wells: ER-2-1 (NNSA/NSO, 2004b); ER-3-1 (DOE/NV, 1995a); ER-3-2 (DOE/NV, 1995b); ER-6-1, ER-6-1-1, and ER-6-1-2 (NNSA/NSO, 2004a); ER-6-2 (NNSA/NSO, 2008); ER-7-1 (NNSA/NSO, 2004c); ER-8-1(NNSA/NSO, 2004d); and ER-12-2 (NNSA/NSO, 2004e).
2. Conducting a multiple-well aquifer test (MWAT) and tracer test that hydraulically stressed large areas of the lower carbonate aquifer (LCA) in Yucca Flat (SNJV, 2005a and b).
3. Compiling hydrologic and transport data (SNJV, 2006b, 2007, and 2009).
4. Characterizing recharge, including developing regional infiltration models (Russell and Minor, 2002; Hevesi et al., 2003; SNJV, 2006b) and performing crater infiltration studies (Hokett et al. 2000; Pohll et al., 1996).

5. Monitoring and interpreting hydraulic heads at wells in both the LCA and the alluvium and tuffaceous rocks (including the tuff confining unit [TCU]) (Fenelon, 2005; Halford et al., 2005; Fenelon et al., 2010 and 2012).

6. Conducting laboratory (Reimus et al., 2006; Zavarin et al., 2005 and 2007) and field (SNJV, 2006c) experiments to characterize RN transport properties.

7. Sampling and analyzing geochemistry and stable isotopes to infer groundwater flow patterns and travel times (SNJV, 2006a).

8. Investigating paleo-hydrology by characterizing the isotopic composition of fracture-lining minerals (Dickerson et al., 2004).

9. Characterizing fractures (SNJV, 2005c; Prothro, 2008;) and faults (Prothro et al., 2009), and the mineral composition of the rock matrix (Prothro, 2005).

10. Constructing a hydrologic framework model (HFM) and alternatives for Yucca Flat (BN, 2006).

11. Developing hydrologic source term (HST) models (Pawloski et al., 2008; SNJV (2009), including separate analysis for unsaturated zone (UZ)-hosted tests (McNab, 2008), tests emplaced in saturated alluvium and volcanic rock (Tompson et al., 2008), and tests hosted in unsaturated carbonate rock (Carle et al., 2008).

12. Developing regional groundwater models to constrain estimates of groundwater flow into and out of Yucca Flat (Belcher et al., 2004; Pohlmann et al., 2007; Pohlmann and Ye, 2012).

13. Developing groundwater flow and transport models (N-I, 2013).

The groundwater flow and contaminant transport modeling and analysis presented in N-I (2013) indicate that the contamination is generally contained within the Yucca Flat/Climax Mine CAU. Although some numerical models indicate the potential for contamination in excess of the *Safe Drinking Water Act* (SDWA) maximum contaminant level (MCL) (CFR, 2016) to leave the southern boundary of the Yucca Flat/Climax Mine CAU, these models likely represent the more conservative end members of the range of possible alternatives. However, even for these more conservative models, it is useful to note that the MCL exceedance is dominated by short-lived RNs—notably, tritium (^{3}H), strontium-90 (^{90}Sr), and cesium-137 (^{137}Cs)—that decay to levels below regulatory concern in a few hundred years.

These CAI activities were completed in 2013, and the models were reviewed by a PRT made up of experts in hydrology, geology, and geochemistry (N-I, 2015). The PRT concluded that DOE was ready to transition to model evaluation studies in the CADD/CAP stage, subject to the requirement that the team's recommendations be considered when designing the CADD/CAP activities (see Section 2.4). Additional modeling and analysis, groundwater sampling, and well drilling were undertaken to address the PRT recommendations (Kwicklis, 2015; Navarro, 2016). NDEP formally approved the Yucca Flat/Climax Mine CAU to move to the CADD/CAP stage in 2017 (see Appendices C and D).

The CAI activities and resulting contaminant boundaries are presented in Sections 2.1 through 2.3; results and recommendations of the PRT, along with their resolutions, are presented in Section 2.4; and the conditions of model acceptance by NDEP are presented in Section 2.5.

2.1 Data-Collection Activities

The data-collection and data-analysis activities during the CAI stage were performed according to the UGTA Quality Assurance Plan (QAP) (DOE/NV, 2000b; NNSA/NSO, 2011; NNSA/NFO, 2015c). The UGTA QAP provides the overall quality assurance requirements and the general quality practices for UGTA activities. The major characterization activities to collect new data identified in DOE/NV (2000b) are listed below (see Appendix B):

- Mineralogy study of the TCU
- Geophysical interpretation of the Paleozoic framework
- Analysis of existing seismic data
- Hydrogeologic investigation of Wells ER-6-1 and ER-6-2
- Isotope/geochemistry mass balance studies
- Analysis of existing tracer test data
- Laboratory studies of transport processes
- Rainier Mesa colloid studies
- Analysis of data for phenomenological models

The scientific objectives for these activities, as described in DOE/NV (2000b), specific investigations performed to meet these objectives, and reports documenting these activities and results are presented in Table B.1-1 (see Appendix B). This work, documented in more than 60 reports, demonstrates that the data-collection and analysis activities met the CAI objectives described in the CAIP (see Appendix B). These data-collection activities and the corresponding analyses to support groundwater flow and contaminant transport model development are summarized in the following documents:

- *Phase I Hydrologic Data for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nye County, Nevada* (SNJV, 2006b)
- *Phase I Contaminant Transport Parameters for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nye County, Nevada* (SNJV, 2007)
- *Unclassified Source Term and Radionuclide Data for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nevada* (SNJV, 2009)

2.2 Modeling Activities

The groundwater flow and contaminant transport modeling activities are presented in *Phase I Flow and Transport Model Document for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada* (N-I, 2013). Modeling activities were performed according to the UGTA QAP (NNSA/NSO, 2011; NNSA/NFO, 2015c). Appendix A of N-I (2013) summarizes how the modeling and software requirements and the data management requirements were addressed. Appendix K of N-I (2013) presents the technical basis for transport model software selection and code testing.

The specific requirements identified in FFACO (1996, as amended) for the CAU groundwater flow and transport models and the locations where these requirements are addressed in N-I (2013) are as follows:

- Alternative hydrological framework models (Sections 4.0 and 5.0)
- Radiological and hydrological source term uncertainty (Section 2.0 and Appendix C)
- Alternative recharge models (Sections 3.0, 4.0, and 5.0)
- Alternative boundary conditions and groundwater flows (Sections 4.0 and 5.0)
- Multiple permissive sets of calibrated flow models (Sections 3.0, 4.0, and 5.0)
- Ensembles of forecasts of contaminant boundaries (Section 6.0)

- Sensitivity and uncertainty analysis of the model output (Sections 3.0, 4.0, 5.0, and 6.0)
- Probabilistic simulations of transport using plausible sets of alternative framework and recharge models, and boundary and groundwater flows from calibrated flow models (Sections 4.0 and 6.0)

2.2.1 Modeling Approach

The important components of the modeling approach included (1) a conceptual model of groundwater flow and potential contaminant transport, discussed in Section 2.2.1.1; (2) the hydrostratigraphic framework models (HFM) that incorporate understanding of the geology underlying the Yucca Flat/Climax Mine CAU, discussed in Section 2.2.1.2; (3) the HST model that represents the nature, extent and relevant composition of the potential contamination sources that result from the 747 underground detonations within the CAU, discussed in Section 2.2.1.3; and (4) groundwater flow and contaminant transport models of the unsaturated and saturated zones underlying the CAU, discussed in Section 2.2.1.4.

Uncertainty exists in the groundwater flow and contaminant transport models and in the parameters used to forecast the possible extent of contaminant migration in the next 1,000 years. Uncertainty in the flow model arises from uncertainties in the conceptual model, HFM, model inputs, model calibration targets, and in the model calibration process. The flow model requires a large number of inputs, including boundary conditions such as specified heads and/or fluxes on the lateral and bottom boundaries of the model domain, infiltration over the top of the model, material properties such as the hydraulic conductivities and the associated anisotropy and storativity. Each of these model input parameters has some level of associated uncertainty. Uncertainties in the flow model were addressed in two distinct ways:

1. Uncertainties in model parameters that were represented by continuous variables with prescribed ranges were treated as adjustable parameters using a parameter estimation code that optimized the model fit to a set of calibration targets (N-I, 2013, Section 5.5).
2. Uncertain aspects of the conceptual model, HFM, alternate parameterizations and the uncertainties arising from the calibration process (uncertainty arising from the fact that multiple sets of parameter values can achieve acceptable model calibration) were incorporated by constructing an ensemble of alternate flow models (N-I, 2013, Section 5.6; Navarro, 2016) each of which was then calibrated using the parameter estimation methodology to estimate optimum values of the material parameters for each model.

Each alternative flow model led to an alternate transport model. Alternative models to address the HST uncertainties were also developed (N-I, 2013, Section 6.4), creating an ensemble of transport models. Uncertainty exists in the transport model input parameters such as the matrix porosity, matrix diffusion coefficient, matrix sorption coefficients, fracture aperture, fracture porosity, fracture retardation, and dispersivity. For each transport model in the ensemble, the parameter uncertainty was propagated to the results using the Monte Carlo technique of conducting multiple realizations by randomly sampling each parameter distribution function and calculating the 1,000-year 95th percentile contaminant boundary forecast (N-I, 2013, Section 6.2). This led to the ensemble of contaminant boundary forecasts.

2.2.1.1 Conceptual Model

The conceptual model of groundwater flow and potential contaminant transport at the Yucca Flat/Climax Mine CAU is that groundwater in the LCA can transport contaminants downgradient from source areas for which the exchange volume intersects the saturated LCA; but contaminant transport to the LCA is negligible from the UZ and alluvial aquifer (AA)/volcanic aquifer (VA) sources that do not intersect the LCA (N-I, 2013). Several aspects of the conceptual model limit the extent of contamination from underground nuclear testing. These aspects—discussed in Winograd and Thordarson (1975), Laczniak et al. (1996), SNJV (2006a and b, and 2007), and Fenelon et al. (2012)—are as follows:

1. LCA in Yucca Flat is the only groundwater pathway for RNs to leave the Yucca Flat basin because, although the saturated portions of the AA/VA may hydraulically communicate with the LCA below them, they do not have any flow pathways directly leading outside the basin.
2. LCA in much of Yucca Flat may have limited hydraulic communication with the regional LCA upgradient to the north of the basin because of the presence of structurally high, low-permeability clastic and igneous rocks on much of the northern basin perimeter.
3. Present-day recharge may be effectively limited to the bedrock hills surrounding the basin or the slow drainage of paleo-infiltration from the alluvium and tuffaceous rocks that overlie the LCA in central Yucca Flat (Walvoord et al., 2002a and b; Kwicklis et al., 2006).
4. Drainage from tuffaceous aquifers to the LCA may be restricted to places where large-offset normal faults cut and significantly thin the intervening sparsely fractured TCUs. Additionally, 668 of the 744 detonations in Yucca Flat proper were conducted in the UZ, and more than 90 percent of the UZ detonations were emplaced above areas underlain by tuff aquifers and confining units, which provide an additional buffer against migration of RNs to the LCA.

Therefore, despite the large number of detonations in Yucca Flat, only a few emerged as potential contributors to groundwater contamination of the LCA. This conceptualization is strengthened by the modeling results presented in Section 2.2.1.4.

Groundwater velocities in Yucca Flat are small enough to keep RNs within the basin over the next 1,000 years, as demonstrated by several auxiliary studies done as part of N-I (2013) and documented in the appendices to N-I (2013). Appendix L of N-I (2013) builds on the geochemical analyses documented in SNJV (2006a) and presents evidence based on naturally occurring groundwater carbon-14 (^{14}C) and chlorine-36 (^{36}Cl) data, which serve as natural analogs to the same test-generated RNs. These conclusions are consistent with published UZ analyses (Walvoord et al., 2002a and b; Kwicklis et al., 2006), which state that significant infiltration and recharge in the center of the basin stopped shortly after the end of the last pluvial (wet) period approximately 10,000 years ago (Spaulding and Graumlich, 1986; Spaulding, 1990). Based on patterns of ^{14}C and ^{36}Cl in LCA groundwater, late pluvial-age recharge appears to be draining from the overlying AA/VA to the LCA in the vicinity of major basin-forming faults (N-I, 2013, Appendix L; Kwicklis and Farnham, 2014). Relatively low water-table temperatures in the center of the basin near major faults also indicate the drainage of cooler, shallower groundwater from the volcanic rocks and alluvium near these faults (N-I, 2013, Appendix H).

The hydraulic head data estimated for the pretesting period in Yucca Flat (Fenelon et al., 2012) indicate a head difference of 6 to 30 meters (m) between the AA/VA and the underlying LCA. The cause of this head difference has been hypothesized to be the incomplete drainage of paleorecharge to the LCA due to the presence of low-permeability TCUs separating the alluvial and tuff aquifers from the LCA (Winograd and Thordarson, 1975; Fenelon et al., 2012). Appendix F of N-I (2013) demonstrates the use of model sensitivity studies to identify combinations of model parameters consistent with that hypothesis. The sensitivity studies indicate that the paleodrainage hypothesis requires that the large-scale permeability of the TCUs be at the low end of the measurement range ($k=10^{-17}$ to 10^{-16} square meters [m^2]), despite some smaller-scale slug-test data indicating locally higher permeability values (Halford et al., 2005). The low estimated permeabilities of the TCUs are consistent with the sparse fracturing of these units as observed in rock cores (Prothro, 2008), and suggest that rapid RN transport through TCUs, if it occurs, would be restricted to faults and damage zones created by weapons testing.

2.2.1.2 Hydrostratigraphic Framework Models

HFMs were developed as the first step in the modeling process; development and evaluation of the HFMs are documented by Bechtel Nevada (BN) (2006). The HFMs were constructed using available drill-hole and geophysical data collected in the Yucca Flat/Climax Mine model area along with existing detailed surface geologic data; they represent geologic interpretations that honor the data. The Yucca Flat/Climax Mine HFM model area encompasses more than 1,250 square kilometers (km^2) in the northeastern portion of the NNSS (Figure 1-2). The model area is approximately 45 kilometers (km) in the north–south direction and approximately 29 km in the east–west direction, and includes geologic units as deep as 5.1 km below mean sea level.

Six HFMs were developed—one judged to represent the consensus on most viable integration of data (called "Base Case"), and five alternative HFMs. The HFMs consist of a thick, faulted LCA overlain by volcanic rocks that have been downfaulted during formation of an extensional structural basin and buried by alluvium; the Yucca Flat/Climax Mine basin and associated structures are represented in the HFMs by more than 178 high-angle normal faults, 2 low-angle thrust faults (the CP and Belted Range thrust faults) and 25 HSUs (14 aquifers and 11 confining units). The faults considered hydrologically significant —i.e., faults with long traces and/or offsets (>200 feet [ft] or 61 m)—and faults that were inferred to form significant structural boundaries were included in the model (BN, 2006). The Base Case and alternative HFMs represented permissible differences in the geologic conceptualization of the hydrostratigraphic framework consistent with the available data. Each model set was hypothesized to be important to groundwater flow and contaminant transport. Although they differ locally in their detailed representation of the geology, structure, and stratigraphy, the various HFMs integrated a consistent conceptual model for the origin, structure, and large-scale hydrogeologic system of the Yucca Flat/Climax Mine CAU (BN, 2006). The five alternative HFMs were as follows:

1. *CP Thrust Alternative*—addresses uncertainty in the eastern extent of the upper clastic confining unit (UCCU) in northern Yucca Flat. This alternative extends the UCCU from the Carpetbag Fault eastward to the Yucca Fault.

2. *Hydrologic Barrier in Northern Yucca Flat Alternative*—restricts inflow on the east side of Climax Stock by raising the lower clastic confining unit (LCCU) relative to the base model so that the LCA is in the UZ.

3. *Contiguous UCCU on Southwestern Yucca Flat Alternative*—reinterprets the geology in the southwestern part of the model under CP Basin as consisting of a continuous sheet of UCCU, thereby inhibiting flow in the LCA out of the southwest corner of Yucca Flat.

4. *Fault Juxtaposition Alternative*—accounts for uncertainty in local fault offsets by juxtaposing shallow volcanic aquifer HSUs against the LCA across major basin-forming faults such as the Yucca Fault.

5. *Partial Zeolitization Alternative*—accounts for uncertainty in the extent of zeolitization above the lower tuff confining unit (LTCU) and below the water table in Areas 2 and 9 and the northeast corner of Area 4.

The goal of HFM development was to incorporate the effects of structural uncertainty identified by internal review using alternative models of the hydrogeological framework of the Yucca Flat/Climax Mine CAU so that the effects of structural uncertainty of alternative arrangements of rock units on groundwater flow and transport could be investigated. The first three alternatives directly impact the hydrologic system along the lateral boundary of the Yucca Flat LCA; hence, they are outside the LCA model domain and were not directly included in the LCA groundwater flow and transport models. They were accounted for by adjusting the rates of inflow into the LCA in Yucca Flat along the boundaries. Alternative inflow conditions were considered based on the absence and presence of confining units along the model boundaries (N-I, 2013). The fault juxtaposition alternative model and the partial zeolitization alternatives were indirectly considered in the development of the saturated AA/VA flow and transport model by using high-permeability faults to connect the volcanic aquifers and the LCA, and by varying the permeability of the zones of partial zeolitization in the HFM over several orders of magnitude, respectively.

2.2.1.3 Hydrologic Source Term Models

The Yucca Flat saturated LCA flow and transport models evaluated groundwater flow and contaminant transport downgradient from detonations with estimated exchange volumes that intersect the saturated LCA. The exchange volume is the spherical volume that encompasses the immediate extent of radioactive contamination resulting from an underground nuclear detonation and is conceptualized as having its center at the detonation working point. Contaminant migration from detonations with working points in the overlying UZ and saturated AA/VA system to the saturated LCA was also evaluated.

RNs listed in the unclassified RN inventory for Yucca Flat (Finnegan et al., 2016) are screened to identify only those potentially relevant to the contaminant boundary calculations. Initial RN concentrations distributed around each detonation point in the exchange volume were calculated considering uncertainties in the RN inventory, melt-glass partitioning factors, exchange volume size, glass dissolution amounts, and matrix sorption (N-I, 2013, Appendix C). If the initial concentration of an RN had a 5 percent or greater probability of exceeding one-tenth of its SDWA MCL as listed in the CFR (2016), the RN became a candidate for inclusion in the HST. Further screening resulted in the exclusion of calcium-41 (^{41}Ca); nickel-63 (^{63}Ni); ^{90}Sr; ^{135}Cs and ^{137}Cs; and plutonium-238, -239, and -240 (^{238}Pu, ^{239}Pu, and ^{240}Pu) from UZ and saturated AA/VA HSTs as a result of their high matrix sorption coefficients and limited mobility in volcanic rock and alluvium. The LCA HST is similar to the UZ and saturated AA/VA HSTs except ^{63}Ni, ^{90}Sr, and ^{137}Cs are included because of their potentially lower sorption coefficients in carbonate rock. Colloid-facilitated transport of ^{238}Pu, ^{239}Pu, and ^{240}Pu in the LCA was investigated with a one-dimensional model in N-I (2013, Appendix M). These RNs are shown to be far less important than other nonsorbing or slightly sorbing RNs in defining the contaminant boundary in the LCA, so they were not considered in the three-dimensional (3-D) transport models of the LCA. Table 2-1 presents the RNs included in the UZ, AA/VA, and LCA models.

Table 2-1
Radionuclides Included in the Hydrologic Source Term

Transport Model	Radionuclide
UZ and SZ AA/VA	Tritium (^{3}H) Carbon-14 (^{14}C) Chlorine-36 (^{36}Cl) Technetium-99 (^{99}Tc) Iodine-129 (^{129}I) Uranium-235 and -238 (^{235}U and ^{238}U) Neptunium-237 (^{237}Np)
LCA	Above RNs plus: Nickel-63 (^{63}Ni) Strontium-90 (^{90}Sr) Cesium-137 (^{137}Cs)

2.2.1.4 Groundwater Flow and Transport Models

The CAU groundwater flow and transport models were built using the Los Alamos National Laboratory (LANL) Finite Element Heat and Mass Transfer (FEHM) code (Zyvoloski et al., 1997b) as specified in the CAIP (DOE/NV, 2000b). The grid flexibility allowed by the FEHM finite-element meshing approach is desirable for representing the complex hydrogeologic setting in Yucca Flat and near-field features associated with underground nuclear detonations. In addition, the common computational platform provided by FEHM facilitates the transfer of results from one model to another, which takes place primarily through the exchange of outputs and inputs along the common model boundaries. The FEHM code has been tested extensively as part of the Yucca Mountain Project; code verification is documented in Zyvoloski et al. (1997a and b), Dash et al. (1996), and Reeves et al. (1994). Transport simulations for steady-state groundwater flow were performed using the PLUMECALC code (Robinson et al., 2011).

The Yucca Flat/Climax Mine CAU groundwater flow and transport model development consisted of the following three models (Figure 2-1):

- Yucca Flat UZ flow and transport model
- Yucca Flat saturated AA/VA system flow and transport model
- Yucca Flat saturated LCA flow and transport model

These models addressed the most significant hydrogeological features\ and flow and transport processes at spatial and temporal scales relevant to the analyses as presented within this section for each model.

The contaminant flux from Climax Stock to the saturated LCA was insignificant in comparison to the inventory initially present in the LCA or forecasted to be transported to the LCA from the overlying UZ and saturated AA/VA rock units (Pohlmann et al., 2007). Therefore, because of their relatively small RN inventory and the northern location, the Climax Mine detonations were not explicitly included in the final flow transport models.

Because the 744 underground nuclear detonations in Yucca Flat were conducted either above the water table (668 detonations) or in the local saturated AA/VA system (76 detonations), a major role of the UZ and SZ AA/VA system models was calculating RN fluxes from the detonation locations

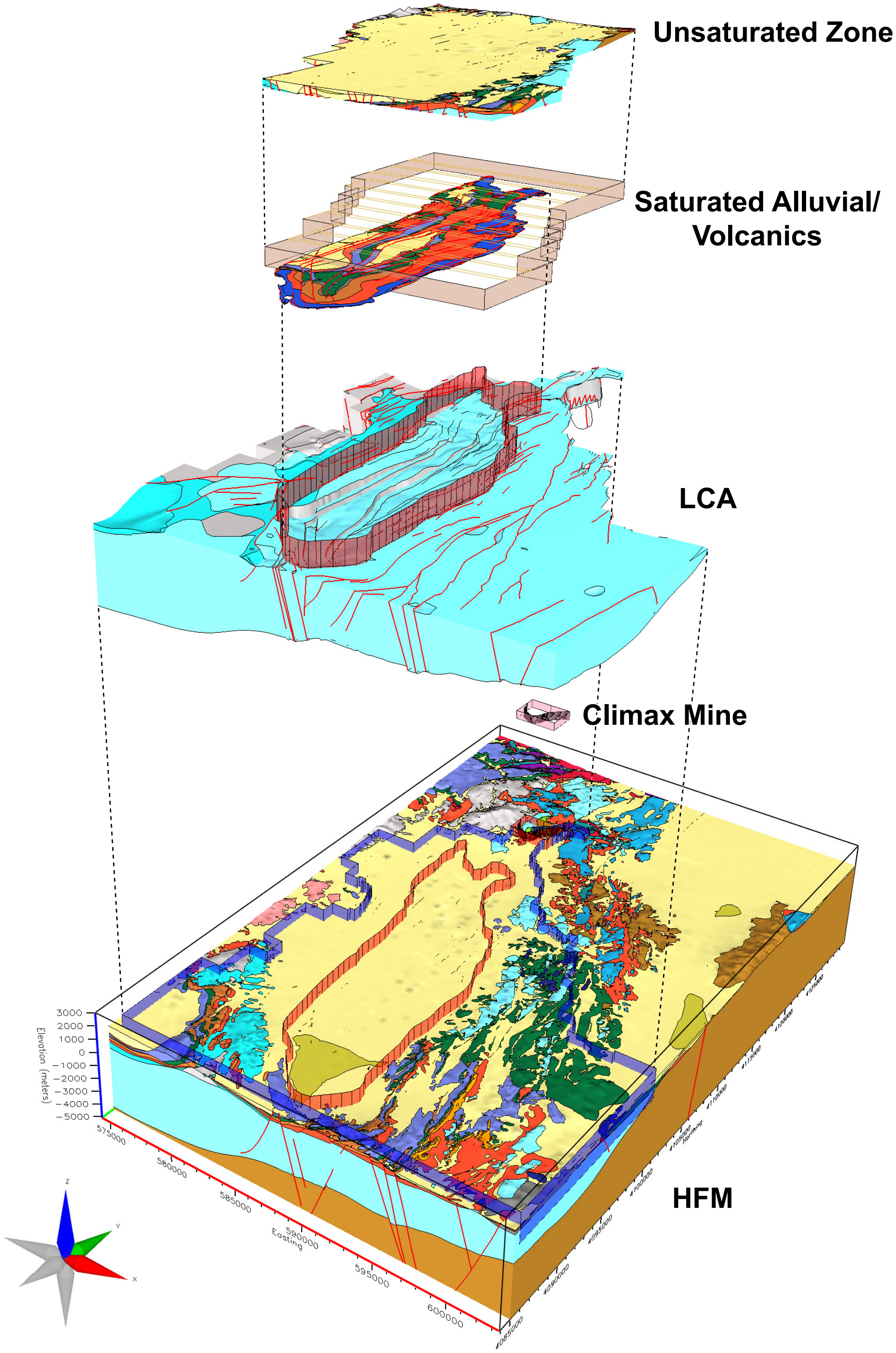

Figure 2-1
3-D Perspective of Yucca Flat/Climax Mine CAU Flow and Transport Model Domains

(working points) in the UZ and the saturated AA/VA system to the regionally connected LCA. The Yucca Flat UZ flow and transport model evaluated the effects of enhanced crater recharge, background net infiltration, and other factors in the Yucca Flat basin on contaminant transport to both the saturated AA/VA system and LCA. The Yucca Flat saturated AA/VA system flow and transport model evaluated the effects of transient, test-induced overpressurization on contaminant transport to the saturated LCA. The Yucca Flat saturated LCA flow and transport model evaluated groundwater flow and transport of contaminants entering the LCA from shallower models as well as the contaminants from detonations with exchange volumes that intersect the saturated LCA.

The groundwater flow regime in the Yucca Flat/Climax Mine CAU is influenced by local recharge, and in the LCA, also by limited underflow from areas to the north, east, and west of Yucca Flat. Current understanding is that infiltration rates through the alluvium in the center of the basin are small (less than 0.1 millimeter per year [mm/yr]) and that recharge may be primarily from the continued drainage of paleo-infiltration from the UZ (Walvoord et al., 2002b; Kwicklis et al., 2006). In contrast, present-day infiltration and recharge rates in the bedrock hills bordering the basin may be several millimeters per year (SNJV, 2006b). UZ model results indicate that percolation through the UZ is generally downward with some lateral flow along the dipping lower-permeability TCUs toward faults. Groundwater flow in the AA/VA system is confined to Yucca Flat because the aquifers and aquitards in this system thin or become unsaturated along the margins of the basin. The groundwater in the AA/VA system drains into the underlying, regionally extensive LCA by either diffuse leakage through the low-permeability TCUs or focused flow along the numerous north–south trending normal faults that cut the confining units in the center of the Yucca Flat basin. The contours of hydraulic heads presented in Fenelon et al. (2012) and model results presented in N-I (2013) indicate that flow in the LCA is inward from the margins of the basin and generally southward. The absence of significant declines in hydraulic heads in the LCA across the accommodation zone that separates Yucca Flat and Frenchman Flat (Fenelon et al., 2010 and 2012) indicates that the LCA is hydraulically well-connected between these basins, despite their different structural styles and the termination of major basin-forming Yucca Flat faults in this area.

UZ Flow and Transport Model

The Yucca Flat UZ flow and transport model (N-I, 2013; Section 3.0) was developed to calculate the migration of contaminants from the 668 detonations expended above the regional water table to the SZ. Mesh refinement near the detonation points allowed the water-accessible RNs (i.e., the HST) to be placed directly into the flow and transport model so that absolute consistency between the source release and transient flow rate can be maintained through time.

The percolation flux in this model includes both background, steady-state net infiltration, and the transient effects of enhanced recharge associated with the subsidence craters that formed above 459 of the 744 detonations in Yucca Flat (Grasso, 2000 and 2001). The enhanced recharge associated with the subsidence craters results from overland flow in the watersheds that feed individual craters following significant precipitation events (Pohll et al., 1996; Wilson et al., 2000; Hokett et al., 2000). The background net infiltration outside the craters is assumed to range from less than 0.1 mm/yr (based on regional infiltration maps) to 1, 5, and 10 mm/yr (based on alternative cases) to bound the possible effects of pluvial drainage (N-I, 2013).

RN releases to the SZ from detonations above the water table were significantly affected by the assumed steady-state percolation flux, which controls RN movement before the enhanced crater infiltration arrives at the detonation's RN exchange volume. Because of the slow transport through the UZ, contaminants from the UZ sources remained in the UZ except in the vicinity of detonations that underlie craters with significant crater recharge or detonations that have exchange volumes near the water table. UZ detonations with working points and exchange volumes near the water table were the only detonations that resulted in discharge concentrations to the SZ exceeding an MCL because of the low percolation fluxes and advective transport velocities in the UZ. The calculated contaminant flux from the UZ sources to the water table was a small fraction of the mass initially in place in the UZ. Most (about 98 percent for the 5-mm/yr infiltration rate case) of the RN mass that arrived at the water table did so in the portion of the model domain underlain by the saturated AA/VA system, which provided an additional barrier to the migration of RNs to the LCA.

Saturated AA/VA System Flow and Transport Model

The Yucca Flat saturated AA/VA system flow and transport model was developed to calculate the migration of contaminants from the 76 detonations expended below the water table, as well as detonations expended above the water table with exchange volumes that extend below the water table. Like the UZ model, this model used a sophisticated gridding process that allowed the volume centered around each detonation point to be locally refined, thereby enabling the RN mass to be placed directly into the model. With this approach, complex near-field transient flow processes associated with the nuclear detonations were simulated and their influence on RN transport explicitly calculated. The model used transient pressure responses measured at a number of wells in the tuff aquifers and confining units (Fenelon, 2005), as well as measured ground subsidence data, to calibrate some HSU and fault permeabilities, and some parameters related to conceptual models for different test effects. The model demonstrated that aquifer compaction caused by the shock waves from underground nuclear detonations resulted in elevated pore pressures that, over the decades of active testing and for decades thereafter, caused drainage rates from the saturated tuffs to the LCA to be many times the long-term infiltration rates. Both the rock properties and ambient flow conditions in the saturated AA/VA system are thus conceptualized as being significantly changed as a result of nuclear testing. Different conceptual models of permeability and pore-pressure changes in the damage zones adjacent to detonations, and initial RN distributions in the exchange volume were investigated with detailed submodels (N-I, 2013, Appendix G) and the 3-D saturated AA/VA system model.

In most of the saturated AA/VA system model runs, the contaminant pathways from the saturated AA/VA rock units to the LCA were conceptualized as being restricted to the major faults in the central portion of Yucca Flat. This conceptualization is a result of the assumption that fracture networks are discontinuous in the thick TCUs between the working points and the LCA or are sealed by clays and paleosols at the top of the LCA, thereby preventing contaminants from migrating directly downward from the exchange volumes to the LCA. However, alternative saturated AA/VA system model runs were made to allow for the possibility that test-induced fracturing creates permeable pathways through which RNs can migrate vertically downward from the detonation locations to the LCA. Results showed that some of the largest masses of RN transport to the LCA are produced by these alternative model runs. However, these models calibrated poorly compared to other models (Navarro, 2016; Appendix A, Figure A-1c), and were shown to be unlikely because contamination in the LCA has not been observed near large-yield, deeply buried tests located either close to the LCA or near faults (U-3cn-5, UE-7nS, ER-2-2, ER-3-3, ER-4-1, and ER-7-1) (see Appendix C, Table ES-1, Section 2.3.2).

RN contaminants that are initially emplaced within the saturated AA/VA system model or that enter the model by downward percolation from the overlying UZ sources generally remain within the saturated AA/VA system. As in the case of contaminant flux from the UZ sources, the contaminant flux from the saturated AA/VA system sources to the LCA is most significant in the first few decades after the detonations and decreases with time to insignificant levels as a result of radioactive decay. The contaminant flux to the LCA is controlled by releases from a small subset of the 76 detonations conducted in the saturated AA/VA system, the exchange volumes of which directly intersect the fault damage zones. This is because contaminants from those detonations can be transported directly down the fault to the LCA. For those detonations with exchange volumes that do not directly intersect faults, the contaminants can migrate laterally in the aquifer until the travel path intersects the nearest fault, at which point the transport occurs downward through the transmissive fault to the LCA; however, release rates from those detonations are small because of the low advective velocities in the AA/VA system.

Saturated LCA Flow and Transport Models

The Yucca Flat saturated LCA flow and transport models evaluated groundwater flow and contaminant transport downgradient from detonations with exchange volumes that intersect the saturated LCA. The Yucca Flat saturated LCA flow models included all major faults in the basin with offsets greater than 60 m. In total, 106 faults or fault segments are incorporated into the model grid of the LCA where they are discretized in a way that allows the low-permeability fault cores and high-permeability damage zones to be explicitly represented in the models. Calibration of the LCA flow model was accomplished using long-term steady-state hydraulic head data and drawdown data associated with an 87-day multiple-well aquifer test (MWAT) in ER-6-1-2 (SNJV, 2005a). The use of the MWAT data in model calibration provided important constraints on uncertain parameters, most importantly, groundwater inflow from the north, which strongly impacted RN transport rates and transport distances.

A calibration-constrained Monte Carlo approach known as Null Space Monte Carlo (NSMC) was used to determine which model parameters can be changed and by how much, while still keeping the model in calibration. From this analysis, posterior distributions of inflow rates from north of Yucca Flat were generated to be used as boundary conditions to the RN transport models for the LCA. The inflows from the north were estimated from the NSMC analysis at a rate of 130 kilograms per second (kg/s), with a range of 60 to 400 kg/s. These values are far smaller than the value of 1,300 kg/s estimated by Pohlmann et al. (2007) for Climax Mine models, but still larger than the value of 55 kg/s estimated with the most recent U.S. Geological Survey (USGS) Death Valley Regional Flow System (DVRFS) Model (Faunt et al., 2012) or the value of approximately 1 kg/s advocated by other USGS researchers (Winograd and Thordarson, 1975; Halford, 2012). An alternative numerical flow and transport model for the LCA was developed that investigated a conceptual model of limited hydraulic continuity of the LCA across northern Yucca Flat and a reduced inflow rate of 1 kg/s. This alternative model was calibrated to the observed steady-state and transient MWAT datasets (N-I, 2013) and resulted in less RN contaminant transport than the conservative Base-Case flow model. The LCA portion of the RN source term was assumed to be immediately available for transport within the saturated LCA, whereas RN inputs from the overlying UZ and saturated AA/VA system were assumed to arrive significantly later, after much of the inventory of short-lived RNs such as ^{3}H had decayed.

The ability of the LCA models to consider RN inputs from the UZ, the saturated AA/VA system, and the saturated LCA separately allowed the relative importance of these inputs to the overall LCA source term to be evaluated. The metrics used to evaluate the importance of these individual contributions to the overall LCA source term were the exceedance volume and the maximum southern extent of contamination. The exceedance volume is the volume of the saturated LCA where the probability of exceeding the MCL of a single RN is 5 percent or greater. The maximum southern extent of contamination was selected because of the tendency of RNs to migrate along the thin damage zones of major faults, represented as high-permeability zones in the LCA models.

The direct contributions to the LCA source term from the UZ arrived predominantly along the basin margins in the northern part of Yucca Flat where the water table is in the LCA. The exceedance volume and maximum southern extent for the RN inputs from the UZ were not significant relative to these metrics for the source-term contributions from the saturated AA/VA system or from the sources initially in the LCA.

The sources originating from the saturated AA/VA system are more important than the UZ sources but less important than the RN sources initially in the LCA. The contaminant boundary associated with the saturated AA/VA system sources is controlled by the more mobile species such as short-lived ^{3}H and long-lived ^{129}I, ^{99}Tc, and ^{36}Cl. The saturated AA/VA system model contributions to the LCA are nearly the same with or without the UZ contributions, demonstrating the effectiveness of the saturated tuffs as a barrier to RN migration from the UZ to the LCA.

The RN mass assumed to be initially in place in the LCA dominates the calculated exceedance volume and maximum southern extent of contamination in the LCA models. For assumed exchange volumes of 1, 2, and 3 cavity radii (R_c), estimated using the maximum announced yield (NNSA/NFO, 2015d), there are 4, 12, and 39 detonations whose exchange volumes extend into the top of the saturated LCA. The contaminant boundary associated with these sources is controlled by the initial mass assumed to be emplaced in the saturated portion of the LCA and by the mobility of ^{3}H, ^{90}Sr, and ^{137}Cs. Using ^{3}H as an indicator of potential significance of the initial RN mass in the saturated LCA to the determination of the contaminant boundary, approximately 7 moles of ^{3}H were initially assumed to be in the saturated LCA. In the LCA models, the mobility of ^{3}H, ^{90}Sr, and ^{137}Cs was determined by groundwater flow rates through the basin, transport model parameters such as fracture porosity and spacing, matrix diffusion, and sorption coefficients for ^{90}Sr and ^{137}Cs.

2.3 Contaminant Boundaries

A contaminant boundary is formally defined as a probabilistic model-forecast perimeter and a lower HSU boundary that delineates the extent of RN-contaminated groundwater from underground testing over 1,000 years (FFACO, 1996, as amended). The contaminant boundary is defined by a fifth percentile likelihood of exceeding the SDWA regulatory standards over 1,000 years (FFACO, 1996, as amended). That is, the area outside the contaminant boundary has a 5 percent or less chance of exceeding the radiological standards of the SDWA during the next 1,000 years.

To compute these probabilities, Monte Carlo simulation was used to compute exceedances of the SDWA regulatory standards. The concentrations of the alpha-, beta- and photon-emitting RNs and uranium were converted to units of picocuries per liter, millirem per year, and micrograms per liter, respectively. For each simulation time, model element, and regulatory group, the values were summed and compared to the SDWA MCLs (Table 2-2). If the relative number of exceedances (i.e., relative to the total number of realizations and time increments) was 0.05 or higher, the element was included within the contaminant boundary.

Table 2-2
Radionuclide Regulatory Groups

Regulatory Group	HST Radionuclide	Maximum Contaminant Level
Beta/Photon Emitter	^{3}H, ^{14}C, ^{36}Cl, ^{63}Ni, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs	4 millirem per year
Alpha Particles	^{237}Np	15 picocuries per liter
U	All Isotopes	30 micrograms per liter

Source: EPA, 2002

The time-cumulative 1,000-year 95th percentile contaminant boundary ensemble for groundwater in the LCA is presented in Figure 2-2. The distinguishing attributes of each model within the ensemble are described in Table 2-3. Although only eight cases were shown in the original contaminant boundary ensemble, all 11 cases were presented in N-I (2013) and reviewed by the PRT. The ensemble presented in Figure 2-2 represents the time-cumulative maximum extent of the SDWA MCL exceedance within the 1,000-year simulation period for each model. The royal blue layer (Base Case [3 R_c]) is the most extensive; each successive layer has a lesser extent, ending with the least extensive in yellow (Figure 2-2).

Figure 2-3 illustrates the temporal evolution of the 95th percentile of RN concentrations exceeding the SDWA MCLs at 100, 300, and 1,000 years. Note that the results shown in Figure 2-2 differ from those in Figure 2-3 because the latter figure is a snapshot in time, not time-cumulative. The significant decrease in the 95th percentile contaminant extent with time indicates that the time-cumulative contaminant boundary is controlled by the short-lived RNs such as ^{3}H, ^{90}Sr, and ^{137}Cs, which decay to levels below regulatory concern in a few hundred years.

The model results indicated that contaminants entering the LCA from detonations with exchange volumes that are near or straddle the saturated LCA, or detonations in the AA/VA system model that are near faults with assumed hydraulic connection to the LCA (Figure 2-2) generally move southward

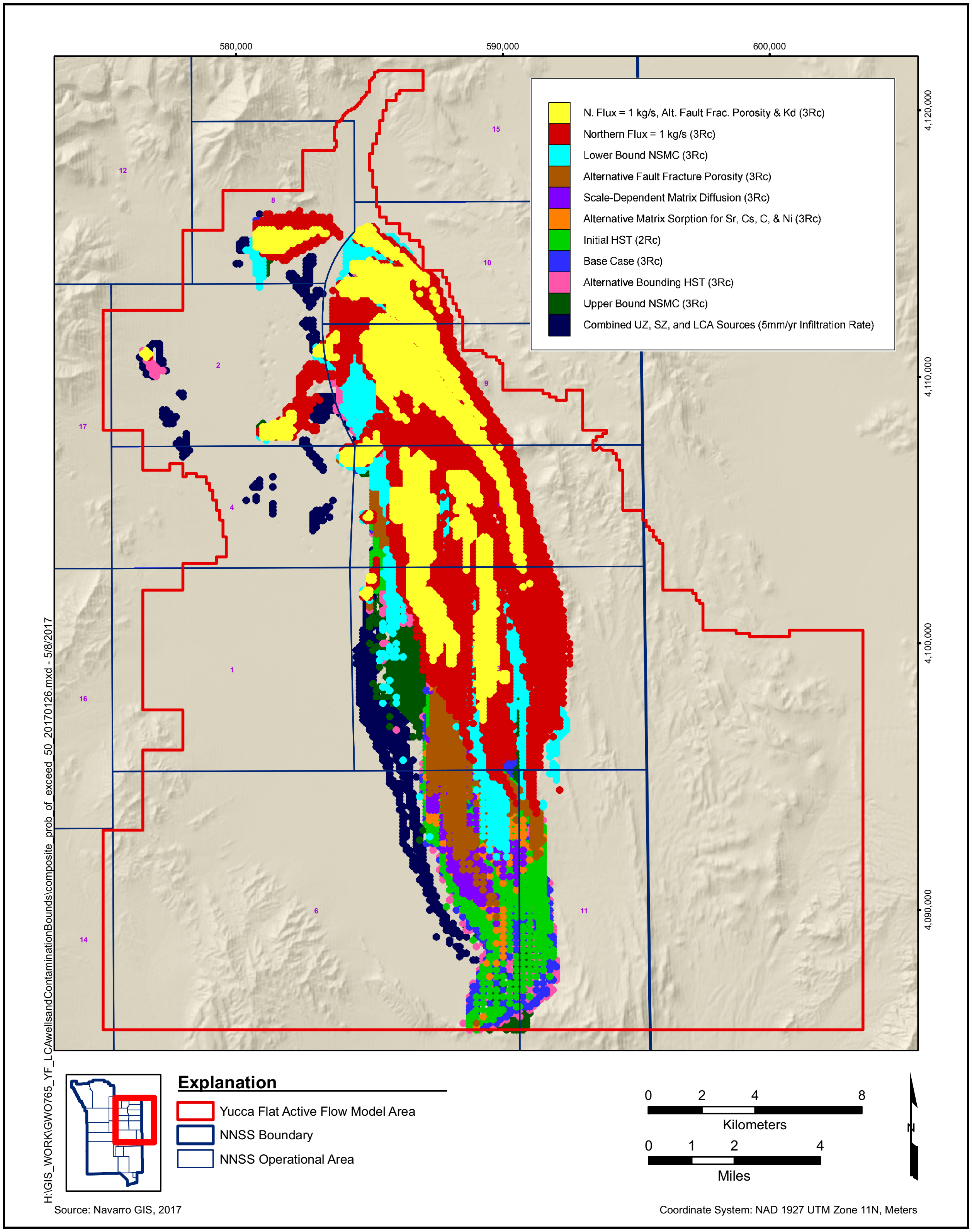

Figure 2-2
Yucca Flat/Climax Mine Contaminant Boundary Ensemble

Table 2-3
Contaminant Boundary Ensemble Description

No.	Case Name	Description/Salient Features	Important Parameters
1	Base Case (3 R_c)	• Nominal case for assessing alternative flow and transport parameterizations (N-I, 2013, Section 6.5.2), Basin Flux = 268.3 kg/s.	
2	N. Flux = 1 kg/s, Alt. Fault frac. Porosity & K_d (3 R_c)	• Limited influx of groundwater to the LCA in northern Yucca Flat fixed at 1.0 kg/s analysis (N-I, 2013, Section 5.6.3), Basin Flux = 139.3 kg/s. • Fault zones are more highly fractured with a higher fracture porosity. The upper one-third of the fracture porosity distribution (from 4.3E-03 to 2E-02) was selected for sampling (N-I, 2013, Section 6.3.6.1). • Matrix distribution coefficient (K_d) distributions that are non-zero for Ni, Cs, C, and Sr in carbonate rock (N-I, 2013, Section 6.5.7).	Northern influx boundary, Fault fracture porosity, and matrix K_d
3	Northern Flux = 1 kg/s (3 R_c)	• Limited influx of groundwater to the LCA in northern Yucca Flat fixed at 1.0 kg/s analysis (N-I, 2013, Section 5.6.3), Basin Flux = 139.3 kg/s.	Northern influx boundary
4	Lower Bound NSMC (3 R_c)	• "Slow" alternative flow field identified in the NSMC analysis (N-I, 2013, Section 5.6.2).	Fault and country rock hydraulic conductivity
5	Alternate Fault Fracture Porosity (3 R_c)	• Fault zones are more highly fractured with a higher fracture porosity. The upper one-third of the fracture porosity distribution (from 4.3E-03 to 2E-02) was selected for sampling (N-I, 2013, Section 6.3.6.1).	Fault fracture porosity
6	Scale-dependent Matrix Diffusion (3 R_c)	• Using an alternative distribution of matrix diffusion coefficient that considers an increase in matrix diffusion with an increase in scale (N-I, 2013, Section 6.5.7).	Matrix diffusion coefficient
7	Alternate Matrix Sorption of Sr, Cs, C, & Ni (3 R_c)	• Less conservative matrix K_d distributions that are nonzero for Ni, Cs, C, and Sr in carbonate rock (N-I, 2013, Section 6.5.7).	Matrix K_d
8	Initial HST (2 R_c)	• Fixed 2 R_c exchange volume with uniform mass distribution used for all RNs (N-I, 2013, Section 6.5.3).	Initial source volume radius
9	Alternative Bounding HST (3 R_c)	• Entire initial inventory was placed in the saturated LCA for eight selected sources (N-I, 2013, Section 6.5.3)	HST
10	Upper Bound NSMC (3 R_c)	• "Fast" alternative flow field identified in the NSMC analysis (N-I, 2013, Section 5.6.2).	Fault and country rock hydraulic conductivity
11	Combined UZ, SZ and LCA Sources (5-mm/yr Infiltration Rate)	• Averaged net infiltration rates increased from 0.1 to 5 mm/yr to capture the upper bounds of possible infiltration rates in the center of the Yucca Flat basin (N-I, 2013, Sections 6.5.2 and 6.5.4).	Net infiltration rate

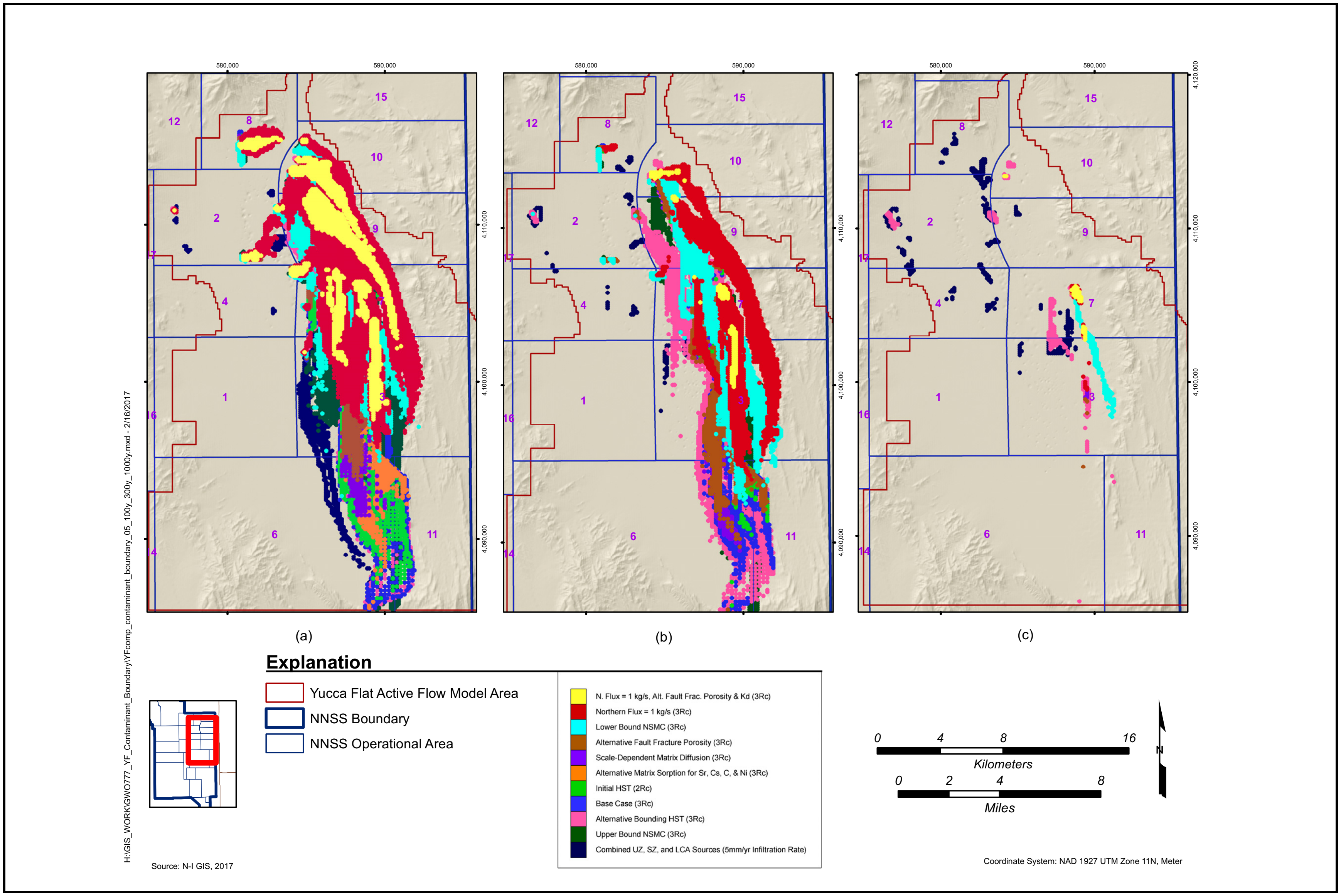

Figure 2-3
Composite Contaminant Boundary at (a) 100 Years, (b) 300 Years, and (c) 1,000 Years

in the eastern half of Yucca Flat. Contaminant migration is generally aligned with and centered about major faults, which are assumed to have damage zones with higher permeability than the unfaulted country rock.

The varying contaminant boundary extent shown in Figure 2-2 results from uncertainties and different assumptions in the underlying models (Table 2-3). By comparing the extent of the individual contaminant boundaries shown in Figure 2-3 with the individual model attributes listed in Table 2-3, it is possible to identify the relative impact that different model uncertainties had on the extent of the calculated contaminant boundaries. The model uncertainties that had the largest impact on the extent of the contaminant boundary, as evidenced in Figure 2-3, became logical targets for uncertainty reduction through additional data collection and analysis during the CADD/CAP stage. Conversely, uncertainties with relatively small impact on the contaminant boundary were assigned lower priority. For instance, relative to the Base Case (3 R_c) contaminant boundary (Case 1 in Table 2-3), the southern extent of the contaminant boundary for the Northern Flux alternative (Case 3 in Table 2-3) was considerably smaller, as shown by difference in the extent of the royal blue and red contaminant boundaries in Figure 2-2. This difference highlights the potentially large benefits of better constraining the northern inflow through additional data collection and analysis. The difference between the Base Case (3 R_c) (royal blue) and the Initial HST (2 R_c) (green) contaminant boundaries in Figure 2-3 demonstrated the relatively small benefits that can be expected to be gained by reducing uncertainty in the size of the exchange volume over the range of 3 R_c to 2 R_c. The Alternative Matrix Sorption for Sr, Cs, C, and Ni (3 R_c) Case (Case 7 in Table 2-3)—which has non-zero sorption for Sr, Cs, C and Ni—was only somewhat smaller than the Base Case (3 R_c) (Case 1 in Table 2-3) because longer-lived ^{90}Sr migrated only marginally farther than ^{3}H at concentrations above regulatory limits when it was treated as nonsorbing (compare the orange and blue contaminant boundaries in Figure 2-2). Including the UZ and SZ AA/VA model contributions for the 5-mm/yr case (Case 11), combined UZ, SZ and LCA sources (5-mm/yr infiltration rate) only marginally increases the extent of the contaminant boundary relative to the Base Case (3 R_c) (Figure 2-2), indicating that resolving uncertainties in the UZ and SZ AA/VA models through additional data collection would have only secondary effects on the calculated extent of the contaminant boundaries unless more dominant uncertainties driving the extent of the contaminant boundary were resolved first.

Based on the models and analyses of groundwater flow and contaminant transport presented in N-I (2013), it is likely that most contaminants originating from underground nuclear testing in the Yucca Flat/Climax Mine CAU will be confined to the Yucca Flat model domain over the next 1,000 years. This is especially true for more than 99 percent of the RN inventory that is initially in the UZ and the saturated AA/VA system, where releases to the LCA are delayed and peak concentrations decrease because of natural attenuation associated with decay, diffusion, dilution, and sorption. This delay was especially important for short-lived RNs such as ^{3}H, ^{90}Sr, and ^{137}Cs, which are considered mobile in the LCA. Observations of RN concentrations at wells adjacent to underground nuclear detonations of potential importance for RN migration in the LCA indicate that site conditions are conservatively represented by the conceptual and numerical flow and transport models presented in N-I (2013). A number of models included in the ensemble indicate the potential for contamination in excess of the SDWA MCL to leave the southern boundary of the Yucca Flat/Climax Mine CAU; however, these models likely represent the more conservative end members of the range of possible alternatives. Some of the conservative assumptions in the flow and transport model include high values of flux through the Yucca Flat basin, lack of sorption for ^{90}Sr and ^{137}Cs in the LCA, and large exchange volumes intersecting the saturated LCA. When these conservative assumptions are relaxed, contaminant boundaries will likely indicate substantially less extensive contaminant transport. Most of the RNs that either reach or are initially in the LCA are likely to remain within the Yucca Flat basin or be removed by radioactive decay over the next several hundred years.

2.4 Peer Review

As required by the UGTA Strategy (Figure 1-3), an external peer review was performed and documented in *External Peer Review Team Report for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada*, Rev. 1 (N-I, 2015). The PRT was tasked with addressing the following questions:

1. Are the approaches, assumptions, and results consistent with the use of the models as decision tools for meeting *Federal Facility Agreement and Consent Order* regulatory requirements?

    a. Are the models of sufficient scale/resolution to adequately forecast contaminant transport in the Yucca Flat/Climax Mine setting?

    b. Have the key processes been included in the models?

c. Are the flow and transport modeling results and uncertainties technically sound and defensible?

d. Are the conceptual models used in the different flow and transport models sufficiently consistent to provide representative integrated model results?

2. Are the datasets and modeling results adequate for a transition to model evaluation studies in the CADD/CAP stage—the next stage in the UGTA strategy for the Yucca Flat/Climax Mine corrective action unit?

To assist the PRT in answering these questions, Wilborn (2014) provided clarification regarding the regulatory requirements that the modeling approaches, assumptions, and results are meant to support (Question 1) and what constitutes dataset and modeling result adequacy to advance from the CAI to CADD/CAP stage (Question 2). The clarification was summarized this way:

> "The model and supporting information should be sufficiently complete that the key uncertainties can be adequately identified such that they can be addressed by appropriate model evaluation studies. The model evaluation studies may include data collection and model refinements conducted during the CADD/CAP stage. One major input to identifying 'key uncertainties' is the detailed peer review provided by independent qualified peers."

The PRT answered "yes" to both questions with the caveat that the uncertainties and associated recommendations identified in their report (N-I, 2015) be carefully addressed during the CADD/CAP stage. The uncertainties identified by the PRT were grouped into nine main categories: (1) model domain/boundary conditions, (2) model calibration, (3) hydraulic properties and pathways, (4) source term and mass flux, (5) transport, (6) simulating critical observations, (7) uncertainty assessment, (8) unforeseen uncertainties, and (9) location of RN plumes. These uncertainties are summarized in Boehlecke (2016), which is presented in Appendix C.

At the request of NDEP, these uncertainties were addressed before advancing to the CADD/CAP stage. Additional modeling and analysis, groundwater sampling, and well drilling performed to address the concerns are documented in *Response to External Peer Review Team Report for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada,* Rev. 1 (Navarro, 2016). These responses are also summarized in Boehlecke (2016) (see Appendix C).

In some cases the uncertainties identified by the PRT were addressed by calibrating flow models to explore alternate conceptual models and bounding scenarios. Particle tracking calculations were also performed, and transport modeling was done on a subset of cases to assess the 95th percentile contaminant boundary. Navarro (2016) noted that most alternative models that produced acceptable calibrations to the data did not produce contaminant transport more extensive than the Base Case, demonstrating that the models and parameter ranges considered in N-I (2013) adequately bound the range of uncertainty. Hence, it was concluded that it was not necessary to further address these recommendations.

It was noted that a small fraction of realizations (less than 10 percent) led to the 95th percentile contaminant boundary crossing the southern extent of the model domain for the existing Base Case model. However, flux estimates resulting from the reanalysis of the data from the ER-6-1-2 MWAT led to boundary flux values (19 kg/s) that were nearly an order of magnitude smaller than those from the Base Case (189.6 kg/s). Preliminary simulations using these lower flux values have led to 95th percentile contaminant boundary forecasts that were well north of the southern boundary of the model, indicating that the contaminant boundaries associated with the Base Case model are quite conservative. Navarro (2016) stated that these models will be explored more fully during the model evaluation phase of the CADD/CAP stage.

While exploring uncertainties in hydraulic properties and pathways, three models with alternative fault conceptualizations led to percent particle breakthrough at 1,000 years greater than that for the Base Case: (1) faults without low permeability cores, (2) no faults with traces < 3 km, and (3) only large basin-forming faults. The commitment to explore these alternate models using more realistic flux constraints during the CADD/CAP stage was made in Navarro (2016).

In the process of responding to the PRT, three new wells (Figure 2-4) were drilled near deeply buried large-yield detonations (ER-2-2 and ER-4-1) or near faults (ER-2-2 and ER-3-3) to investigate the extent of contamination associated with tests near the LCA or near faults (Kwicklis, 2015). No ^{3}H was detected above the field screening level of about 1,500 picocuries per liter (pCi/L) in the LCA. In addition, three wells completed in the LCA (ER-7-1, UE-7nS, and WW-2) were sampled, and no new detections of elevated ^{3}H concentrations in the LCA were observed (Figure 2-4). These results support the observation that ^{3}H contamination of the LCA is of limited areal extent and that

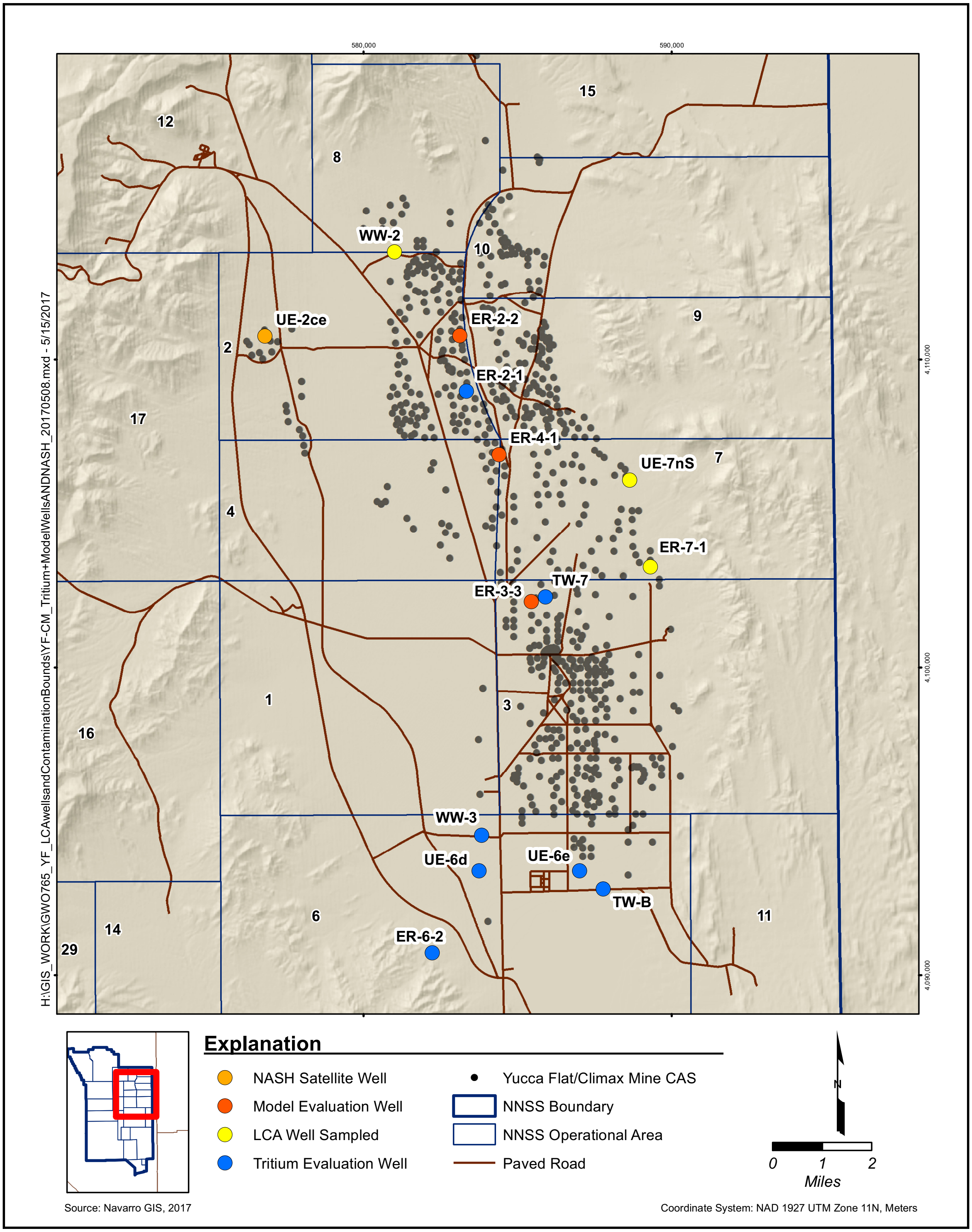

Figure 2-4
Data-Collection Locations for Response to PRT Recommendations

simulations documented in the flow and transport model document (N-I, 2013) adequately bound RN transport.

Some wells with a history of sporadic low-level ^{3}H detections (Figure 2-4) were resampled and the samples were found to be ^{3}H-free, indicating that many earlier, low-level ^{3}H detections were probably sampling artifacts (ER-6-2) or cross-contamination transferred between wells by sampling equipment (UE-6e, UE-6d), and not the leading edge of an unanticipated contaminant plume. In other instances where low-level ^{3}H detections were repeated over several years or decades (TW-B) or were confirmed by recent low-level ^{3}H measurements (WW-3), explanations unrelated to RN transport from nuclear tests were provided. In one instance, new models demonstrated that ^{3}H transport from the HAYMAKER detonation to a water-supply well (WW-A) resulted from pumping over a long period of time combined with hydrodynamic dispersion.

Another set of observations evaluated included the near-field measurements of ^{3}H, ^{90}Sr, and ^{137}Cs measured in groundwater at the NASH Satellite Well UE-2ce over several decades (Figure 2-4). NASH was a 39-kiloton-yield test detonated January 19, 1967, in the unsaturated lower carbonate aquifer-thrust plate (LCA3) about 2.6 R_c above the water table (N-I, 2013, Table B-1; NNSA/NFO, 2015). The UE-2ce well is 183 m south of the NASH working point. The well was intermittently pumped between 1977 and 1984, and again in 2008; and was bailed at other times. The RN recovery data from Well UE-2ce show that although ^{3}H exceeded 1,000 times its MCL during pumping, ^{90}Sr and ^{137}Cs never exceeded their MCLs, despite being estimated to be more than 10^{+05} times their MCLs in the carbonate source term (N-I, 2013, Figure 2-6). This suggests that ^{90}Sr and ^{137}Cs are attenuated by sorption in the field, which significantly slows their migration relative to ^{3}H.

While Navarro (2016) concluded that it was not necessary to further address many of the PRT recommendations, some uncertainties identified by the PRT were shown to potentially impact the contaminant boundary ensemble presented in N-I (2013). These uncertainties will be further explored in the CADD/CAP stage. The overall conclusion from this effort is that the original Yucca Flat/Climax Mine flow and transport models documented in the flow and transport model document conservatively bounded the contaminant migration in Yucca Flat/Climax Mine and that the new models recommended by the PRT did not lead to the development of credible transport scenarios with different transport pathways or contamination over a larger spatial extent.

During the review of Navarro (2016), the Yucca Flat/Climax Mine preemptive review (PER) committee requested that specific criteria be developed to distinguish between plausible and implausible models and that a more realistic model than the present Base Case model be developed. The committee stated that as a result of responding to the PRT comments, new data had been collected and older datasets reanalyzed, so that the modeling team could evaluate model plausibility and further test only models that agree with important existing data and observations. The committee also stated that evaluations performed as a result of PRT comments allowed the Yucca Flat/Climax Mine modeling team to focus on remaining key uncertainties to be addressed during model evaluation as described in the Wilborn (2014) clarification. The PER committee recommended that the Yucca Flat/Climax Mine CAU advance to the next stage of the FFACO strategy, Decision 4, because the PRT process met its objective (see Appendix C).

On December 15, 2016, NNSA/NFO requested approval by NDEP to advance to Decision 4 of the UGTA strategy, thus completing the peer review process. This request included three attachments (see Appendix C):

- Executive summary from Navarro (2016) summarizing the peer reviewers' recommendations and NNSA/NFO responses.
- Yucca Flat/Climax Mine PER committee memorandum closing out the review process for Navarro (2016). The memorandum stated that all comments were adequately addressed.
- Justification for proceeding to Decision 4 of the UGTA strategy for the Yucca Flat/Climax Mine CAU.

On December 20, 2016, NDEP concurred that the peer review requirement of the FFACO UGTA strategy had been adequately addressed and approved NNSA/NFO's request to proceed to Decision 4 of the FFACO UGTA strategy for CAU 97: Yucca Flat/Climax Mine (see Appendix C).

2.5 Model Acceptance

On January 18, 2017, NNSA/NFO requested NDEP's acceptance of the Yucca Flat/Climax Mine flow and contaminant transport models (see Appendix D). The justification for recommending NDEP acceptance of the Yucca Flat/Climax Mine flow and transport models for CADD/CAP studies included the following:

1. The flow and transport document (N-I, 2013) addressed the FFACO requirements, including development of ensembles of contaminant boundary forecasts that incorporated multiple alternative models of boundary conditions, recharge, HFMs, alternative sets of calibrated flow models, and Monte Carlo simulations of RN transport.

2. NDEP identified no deficiencies in the data or model results and agreed to proceed to external peer review (Murphy, 2014).

3. The PRT (N-I, 2015) recommended that the Yucca Flat/Climax Mine CAU was ready to transition to model evaluation studies in the CADD/CAP stage.

4. Supplemental analyses (Navarro, 2016) addressed the uncertainties noted by the PRT and demonstrated that the Yucca Flat/Climax Mine flow and transport models documented in N-I (2013) are suitable representations of flow and transport behavior and appropriately bound the uncertainties in the contaminant boundary ensemble forecasts.

5. PRT recommendations regarding parameter adjustments and conceptual models did not result in the development of credible models that produced significantly different transport pathways or contamination extents.

6. Long-standing conceptual models of the general hydrogeology of Yucca Flat were upheld by UGTA work:

    - Limited inflow into Yucca Flat due to low-permeability rock northwest, north and northeast of the basin

    - Low or zero long-term net infiltration through alluvium, and small recharge in surrounding hills

    - Groundwater ^{14}C ages and $^{36}Cl/Cl$ ratios indicating late ice-age recharge in both the shallow AA/VA and in the LCA (supports near-absence of modern recharge)

    - Hydraulic head differences of 6 m to 20 m between shallow AA/VA flow system and LCA due to slow drainage of paleorecharge across the relatively impermeable TCU

7. The evaluations described in Navarro (2016), which were performed as a result of PRT comments, allow the Yucca Flat/Climax Mine Modeling Team to focus on remaining key uncertainties to be addressed during model evaluation. CADD/CAP activities identified during peer review include ER-6-1-2 MWAT reanalysis and alternative fault conceptualization evaluations. As recommended by the PER committee, a more realistic model than the present Base Case model will also be developed during the CADD/CAP stage.

8. NDEP agreed that the peer review process has been completed and that the Yucca Flat/Climax Mine CAU can advance to Decision 4 of the FFACO strategy (see Appendix C).

On January 23, 2017, NDEP accepted the Yucca Flat/Climax Mine flow and transport models for CADD/CAP studies and approved proceeding to the CADD/CAP stage for Yucca Flat/Climax Mine CAU 97. Approval was given with the conditions that all planned actions in Justification No. 7 above be identified in the CADD/CAP. In addition, the results of all these actions must be documented and presented to the NDEP via interim documents, letters, or presentations during the CADD/CAP stage (see Appendix D).

3.0 Corrective Action Alternative

This section presents the corrective action objectives for the Yucca Flat/Climax Mine CAU and describes the corrective action alternative recommended to meet these objectives.

3.1 Corrective Action Objectives

The objective of the corrective actions for the Yucca Flat/Climax Mine CAU is to identify the nature and extent of the contamination to ensure the public and the environment are protected from exposure to the contamination.

3.2 Recommended Alternative

The recommended corrective action alternative for the Yucca Flat/Climax Mine CAU involves a balance of modeling, monitoring, and institutional controls (FFACO, 1996, as amended). Three assumptions for this alternative are described in *Nevada Test Site Environmental Management End State Vision* (DOE, 2006). First, cost-effective groundwater technologies to remove or stabilize subsurface radiological contamination have not been developed. Second, because of the high remediation costs, closure in place with monitoring and institutional controls is the only feasible corrective action. Third, exposure to potential risks from radiological contamination of groundwater requires access to groundwater, which can be restricted using institutional controls.

The long-term end-state vision for the NNSS is to restore the environment to an extent that will allow the maximum continuation of the national security mission conducted by NNSA/NFO, the national laboratories, and contractors. The end-state vision includes cleanup goals that are protective under the planned future uses of the NNSS described in *Final Site-Wide Environmental Impact Statement for the Continued Operation of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada* (NNSA/NSO, 2013).

The end state for the deep underground radioactive contamination addressed by the UGTA Activity includes developing contaminant boundaries based on the results of the groundwater flow and contaminant transport modeling to define areas containing water that may be unsafe for use. A monitoring plan will be developed to ensure future protection of the public and the environment.

Institutional controls will be continued or enhanced to restrict access to contaminated groundwater; and wells will be monitored, sampled, and refurbished or replaced, as applicable (DOE, 2006). The current assumption, as stated in the *Nevada Test Site Environmental Management End State Vision* (DOE, 2006), is that once the UGTA Activity CAUs are ready for closure (currently planned for fiscal year 2030), responsibilities for long-term stewardship (long-term monitoring and management activities) will be turned over to the landlords, currently NNSA/NFO. Although the responsible organization may be reassigned by 2030, planning and mitigation strategies are in process and will continue to be implemented to ensure proper stewardship of the contaminated sites to protect workers, the public, and the environment, now and for future generations.

Few options are available for remediating groundwater contaminated with RNs (Van Deuren et al., 2002). Because RNs cannot be destroyed or degraded, applicable remedial approaches are limited to separation, concentration/volume reduction, or immobilization. These approaches require that the resulting wastes be contained and isolated for long periods of time, which increases the risk of exposure. Potential remediation alternatives were previously evaluated by the UGTA Activity (DOE/NV, 1997a). The alternatives evaluated by DOE/NV (1997a) represented presumptive remedies outlined by U.S. Environmental Protection Agency (EPA, 1994), including the following:

- No action
- Intrinsic remediation alternative: natural attenuation
- Institutional controls
- Pump and in situ treatment
- Excavation, physical separation/chemical extraction, and onsite disposal

The American Society of Mechanical Engineers and the Institute for Regulatory Science, with the participation of stakeholders, performed a peer review of the UGTA corrective action strategy (ASME/RSI, 2001). With respect to the evaluation of potential remediation alternatives, the peer review determined the following:

1. The evaluation of potential alternatives that address the remediation of groundwater contamination was appropriate, given the constraints of the technology and the unique characteristics of the groundwater contamination addressed by the UGTA Activity.

2. Based on cost and maintaining radiological exposures as low as reasonably achievable (ALARA), the focused evaluation supported the more passive technologies of intrinsic remediation and institutional controls (i.e., UGTA corrective action strategy).

3. Although no known "breakthrough" technology has been reported in the area of remediation of RN-contaminated groundwater since the evaluation performed by the DOE, Nevada Operations Office (DOE/NV) (1997a), there is a recurrent need for further evaluation of remedial alternatives as new methods are discovered and/or demonstrated to be effective.

As described in FFACO (1996, as amended), DOE and NDEP will evaluate technological advances in groundwater remediation during the life cycle of the UGTA Activity, and significant changes in technology and/or the cost of remediation alternatives could lead to a reevaluation of alternatives to the UGTA strategy. At this time, there are no new technologies that warrant such an evaluation. Therefore, the alternative recommended to meet the corrective action objectives identified in Section 3.1 continues to be closure in place with modeling, monitoring, and institutional controls. The three components (modeling, monitoring, and institutional controls) planned for the CADD/CAP and CR stages are presented below.

Modeling

Groundwater flow and contaminant transport model evaluations and possible refinements continue through all stages of the UGTA strategy. During the CADD/CAP stage, contaminant boundary forecasts and model uncertainties, initially developed during the CAI stage, are tested through further data-collection, data-evaluation, and modeling activities. The goal of modeling during the CADD/CAP stage is to build confidence that flow and contaminant transport modeling results can be used for the regulatory decisions required for CAU closure. This process is described in Section 4.4. The regulatory decisions include identifying and establishing CAU regulatory boundary objectives and boundaries; identifying institutional controls, including UR boundaries; and developing a long-term closure-monitoring program. These decisions are made during the CADD/CAP and CR stages. During the CR stage, model evaluation includes evaluating the monitoring results for consistency with the forecasts of contaminant boundaries, and adhering to the UR and regulatory boundaries.

Monitoring

A long-term closure-monitoring program is planned and implemented during the CR stage. The monitoring plan consists of a groundwater monitoring strategy and describes the implementation of this strategy to ensure compliance with the necessary requirements. This strategy essentially verifies through appropriate monitoring activities that contaminants of concern (COCs) have not exceeded the SDWA standards (CFR, 2016) at the regulatory boundary and that adequate institutional controls are established and administered. Monitoring for changed conditions (e.g., seismicity and water development) will also be included. The long-term closure-monitoring program will include activities such as performing periodic analysis of monitoring results, determining optimum performance indicators, evaluating performance criteria, locating new monitoring wells, and replacing monitoring wells as needed. The monitoring network design includes the technical requirements and physical layout of the well system. The distance between the monitoring well(s) and the UR and regulatory boundaries is predicated on the need to provide adequate early warning. Periodic water sampling of the monitoring well(s) will confirm that UR and regulatory boundaries are sufficient.

Institutional Controls

Institutional controls limit access to activities in areas of potentially contaminated groundwater by establishing active and/or passive controls. Active institutional controls include controlling site access, performing maintenance or remedial actions, controlling or remediating releases, and monitoring disposal systems. Passive institutional controls include land ownership, buffer zones, land use requirements, markers, public records, archives, and other methods of preserving knowledge of a site and its hazards.

The NNSS encompasses approximately 1,360 square miles of land and is surrounded by the DoD Nevada Test and Training Range (NTTR) and unpopulated land controlled by the Bureau of Land Management (BLM). Active and passive institutional controls have been in place at the NNSS and at NTTR for more than 50 years. Some parts of the perimeter are not fenced, but the NNSS is posted as a restricted area and is actively patrolled; access is prohibited except at designated entrances. Beyond the perimeter, the BLM land and NTTR provide buffer zones of limited access. Barricades and security stations control the few roads that access NNSS boundaries. Inactive facilities and areas known to be contaminated are fenced and posted with warning signs in accordance with the Occupational Radiation Protection standards (CFR, 2017).

Two DOE policies are established to describe institutional controls:

- DOE P 454.1, *Use of Institutional Controls*, guides decisions on DOE's planning, maintenance and implementation of institutional controls (DOE, 2003).
- NFO P 454.X, *Institutional Control of the Nevada National Security Site,* provides NNSA/NFO policy for the continuity of institutional control of the NNSS and the management of URs resulting from such controls (NNSA/NFO, 2015a).

UR boundaries are identified in this CADD/CAP document (see Section 4.1) and established in the CR. Possible institutional controls associated with UR boundaries are introduced in Section 4.1.

4.0 Implementation of the Corrective Action Plan

The corrective action alternative will be carried out in two stages (i.e., CADD/CAP and CR) within the UGTA strategy (Figure 1-3). This section provides the plan for implementing the corrective actions associated with the CADD/CAP stage and includes the model evaluation process for this stage. During this stage, data-collection and analysis activities are identified and implemented to address key uncertainties in the flow and contaminant transport models. In addition, the initial UR boundaries and the CAU regulatory boundary objectives were identified and negotiated between NDEP and DOE. The final UR boundaries and the CAU regulatory boundaries are established and negotiated at the beginning of the CR stage; the CR will document these boundaries. The CR will also describe the long-term closure-monitoring program, the approaches and policies for institutional controls, and the transition of the UGTA Activity to long-term stewardship.

4.1 UR Boundaries

The initial UR boundary for the Yucca Flat/Climax Mine CAU is presented in Figure 4-1. This boundary surrounds the 50-year 95th percentile contaminant boundary and all UGTA CASs within the Yucca Flat/Climax Mine CAU. The 50-year contaminant boundary was selected as the basis for establishing the initial UR boundary because it approximately represents the current time period. As discussed in the responses to the PRT (Navarro, 2016), the contaminant boundary ensemble is considered conservative and using the 1,000-year contaminant boundary would result in a UR area that is larger than necessary. The final UR boundaries, defined and implemented during the CR stage, will be based on the contaminant boundary refinements planned during the model evaluation process (see Section 4.5.3).

Institutional controls within the UR boundaries are required to prevent the use of and exposure to potentially contaminated groundwater for purposes other than environmental investigations or other activities that support the NNSS mission. Restrictions are established to protect the public, workers, and environment and to protect the environmental investigations performed by UGTA to evaluate the conceptual and numerical models of flow and transport. The considerable depth to groundwater within the Yucca Flat/Climax Mine CAU effectively restricts surface exposure to contaminated

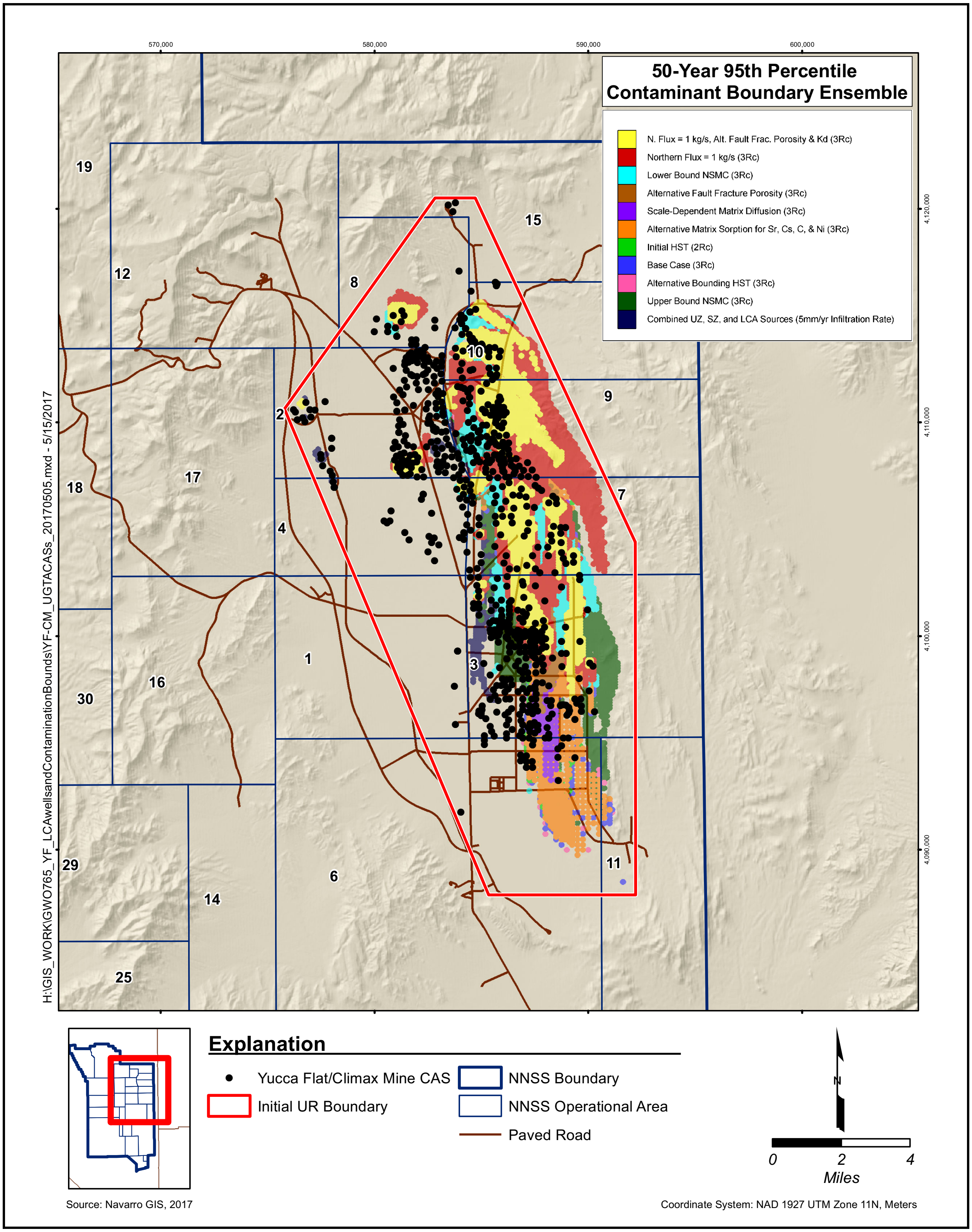

Figure 4-1
Initial UR Boundaries

groundwater to onsite environmental workers via deep drill holes and water wells. These URs will not require onsite postings or physical barriers other than those already in place for the NNSS.

Institutional controls are administered through NFO orders establishing requirements for use of and operations on the NNSS. The current order, NFO Order 410.X1, describes the screening and siting process (NNSA/NFO, 2013), and NFO Order 412.X1 describes the Real Estate/Operations Permit (REOP) process established to ensure work is coordinated among the multiple agencies (NNSA/NFO, 2016). If the potential for impacting forecasted contaminant migration exists, NDEP will be notified, and a path forward will be determined by the EM Nevada Program and NNSA/NFO.

The EM Nevada Program maintains UR records for as long as the land is under its jurisdiction. These URs are documented on a UR form and map and filed in the management and operating (M&O) contractor's Geographic Information Systems (GIS), the FFACO database, and EM Nevada Program CAU/CAS files.

4.2 CAU Regulatory Objectives

Regulatory boundary objectives are statements of specific objectives for each CAU to protect the public and environment from exposure to groundwater contaminated by underground testing of nuclear weapons on the NNSS. The objectives may be revised during the CADD/CAP and CR stages. Regulatory boundaries are established during the CR stage. If RNs (above the levels agreed upon in the CR stage) reach the regulatory boundaries, DOE will be required to get NDEP approval for a plan to meet the specific CAU regulatory boundary objectives. The regulatory boundary objective for the Yucca Flat/Climax Mine CAU is to verify that RN contamination from the Yucca Flat/Climax Mine CAU is contained within the Yucca Flat basin, thus not impacting the Frenchman Flat LCA or downgradient receptors.

The Yucca Flat hydrographic area is shown in Figure 4-2. The hydrographic area will represent the Yucca Flat basin, with respect to the regulatory boundary objective. Within the Yucca Flat/Climax Mine CAU to the north, east and west, flow in the LCA is inward from the margins of the basin and generally southward. The absence of significant declines in hydraulic heads in the LCA across the accommodation zone that separates Yucca Flat and Frenchman Flat indicates that the LCA is hydraulically well-connected between these basins (Fenelon et al., 2010 and 2012). The Yucca

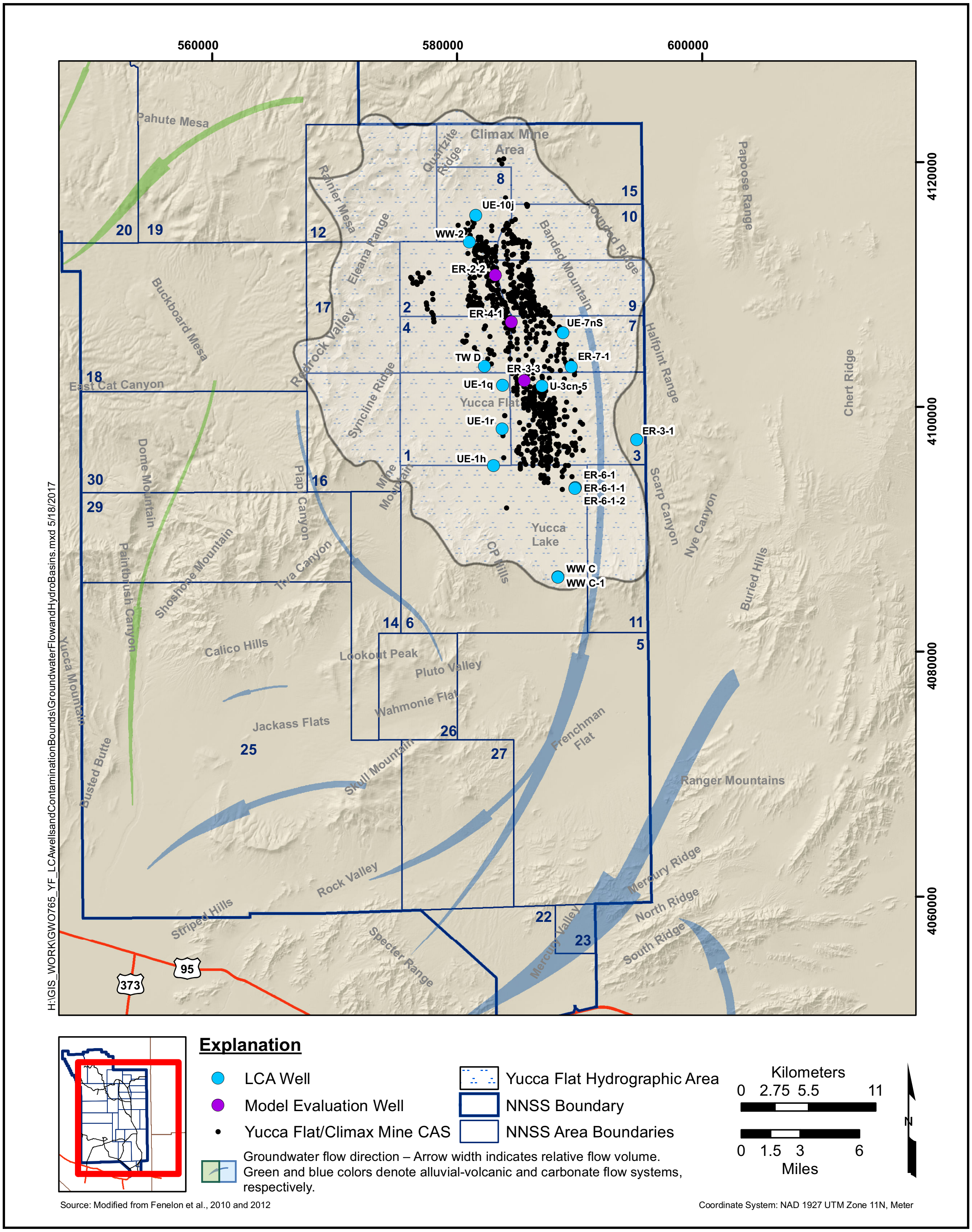

Figure 4-2
Yucca Flat Hydrographic Area

Flat/Climax Mine regulatory boundary objective verifies that contamination does not migrate into Frenchman Flat CAU 98 or receptors further downgradient.

4.3 Model Evaluation Purposes

The Yucca Flat/Climax Mine groundwater flow and transport models are designed to inform regulatory decisions. Although these decisions are not based solely on one particular model, it is desirable that the models provide a reasonably accurate representation of the likely extent of contamination and its uncertainty. The model evaluation process, inherent throughout different stages of the UGTA strategy, continues during the CADD/CAP stage with an increased focus on assessing the reliability of model results and testing contaminant boundary forecasts through data collection and analyses, and model refinements. Model evaluation will continue at existing and/or new wells with the purpose of gathering data to increase confidence in the reliability of model results. This iterative process of model evaluations and refinements will continue until model acceptance by NDEP at the end of the CADD/CAP stage (FFACO, 1996 as amended). The model evaluation process during the CADD/CAP stage is used to establish sufficient confidence in the models to guide development of the long-term monitoring network and institutional controls that meet the objectives of site closure. Models that are demonstrated through additional data collection and analysis to be poor representations of the groundwater flow and transport regime can be eliminated as a basis for informing regulatory decisions. Conversely, models that are consistent with field and laboratory data can be relied on more heavily. This is consistent with the philosophy of using models to inform, but not dictate, regulatory decisions.

4.4 Model Evaluation Approach

As stated in FFACO (1996 as amended), the model evaluation process of the CADD/CAP is a confidence-building iterative loop consisting of locating and developing model-evaluation wells; collecting and evaluating new data; evaluating the impact of new data on model forecasts; and assessing the acceptability of the model forecasts and model results for progression to CAU closure. This iterative process of model evaluations and refinements will continue until model acceptance by NDEP at the end of the CADD/CAP stage (FFACO, 1996 as amended).

The Yucca Flat / Climax Mine model evaluation approach includes ensuring that the models in the final ensemble are based on input data that fall within the range of plausible values based on field data; ensuring that model results are consistent with field observations of contaminated groundwater; and reducing uncertainty in input parameters that were shown through sensitivity analysis in N-I (2013) to have a large impact on the southern extent and overall volume of contaminated groundwater. It is expected that, as a result of these activities, models in the current contaminant boundary ensemble (N-I, 2013) that are inconsistent with existing or new data will be eliminated, and that new models that are consistent with data observations will be created, so that the final ensemble of contaminant boundaries will have greater reliability than contaminant boundaries in the current ensemble. If a data-collection activity is deemed inconclusive, the affected target may be included as an alternative model in the ensemble. The plan described in this document therefore allows for model acceptability to be achieved, even if some of the individual model evaluation targets (see Table 4-1) are not met.

The general approach to building confidence in the model is fourfold:

- Collect new data to address key uncertainties
- Evaluate new data to determine whether they are consistent with the model forecasts
- Review results by independent scientific experts (i.e., PER committee)
- Refine the model, if necessary

The word “data,” in this case, also refers to new interpretations of historical data or new interpretations of data collected during the CAI stage. This general approach allows evaluation of models from multiple perspectives and will be used collectively to build the required confidence in model results to move to the CR stage. Although it is not possible to prove that a model is correct, it is possible to prove that it is not correct through new data collection and analysis. This approach is referred to in the second item above, where consistency of the new data with the model builds confidence in the forecasts. Metrics such as the value of the parameter estimation objective function or the relative extent of the 95th percentile contaminant transport boundary, where applicable, may be used to determine the impact of the new data on the model forecasts.

Confidence in the model is also built through independent review of data-collection and modeling results by a PER committee composed of UGTA participants knowledgeable in the hydrogeology, geology, testing history, and radiochemistry of the Yucca Flat/Climax Mine CAU. The PER committee performs technical reviews to assure that work is comprehensive, accurate, and technically sound (NNSA/NFO, 2015c). Existing representations of the contaminant boundary could be removed and new model representations added to the final contaminant boundary ensemble (see Section 4.5.3).

The approach to CADD/CAP model evaluation is implemented through an iterative series of five steps designed to build confidence in the site conceptual model and contaminant boundary forecasts (Figure 4-3) as follows:

- Step 1: Identify model evaluation targets and data-collection activities.
- Step 2: NDEP reviews CADD/CAP or CADD/CAP addendum.
- Step 3: Collect model evaluation data.
- Step 4: Assess impact of new data and refine models as necessary.
- Step 5: NDEP decides to move the CAU to the CR stage or return to Step 1.

These steps are described in the following sections.

4.4.1 Identify Model Evaluation Targets and Data-Collection Activities (Step 1)

This step begins with identifying and prioritizing key model uncertainties to address as part of model evaluation. A list of model evaluation targets is then developed for the key uncertainties thought to have a significant impact on contaminant boundaries. Data-collection activities are then identified to address those targets. Data, in this case, also refers to new interpretations of historical data or new interpretations of data collected during the CAI stage.

Once data-collection and analysis activities are identified, the CADD/CAP (or addendum) is prepared to describe the data-collection activities, the uncertainties addressed, and the approach used for selection. A CADD/CAP addendum is prepared with each subsequent iteration of the model evaluation process. The CADD/CAP or addendum is reviewed by the PER committee and approved by DOE before it is finalized.

An expert elicitation panel was convened to support this step of the model evaluation process (Kwicklis, 2016). The panel consisted of 14 subject matter experts in geology, hydrogeology, numerical modeling, hydraulic analysis, geochemistry, and the UGTA Activity regulatory framework. The elicitation was performed to determine key uncertainties associated with the Yucca Flat

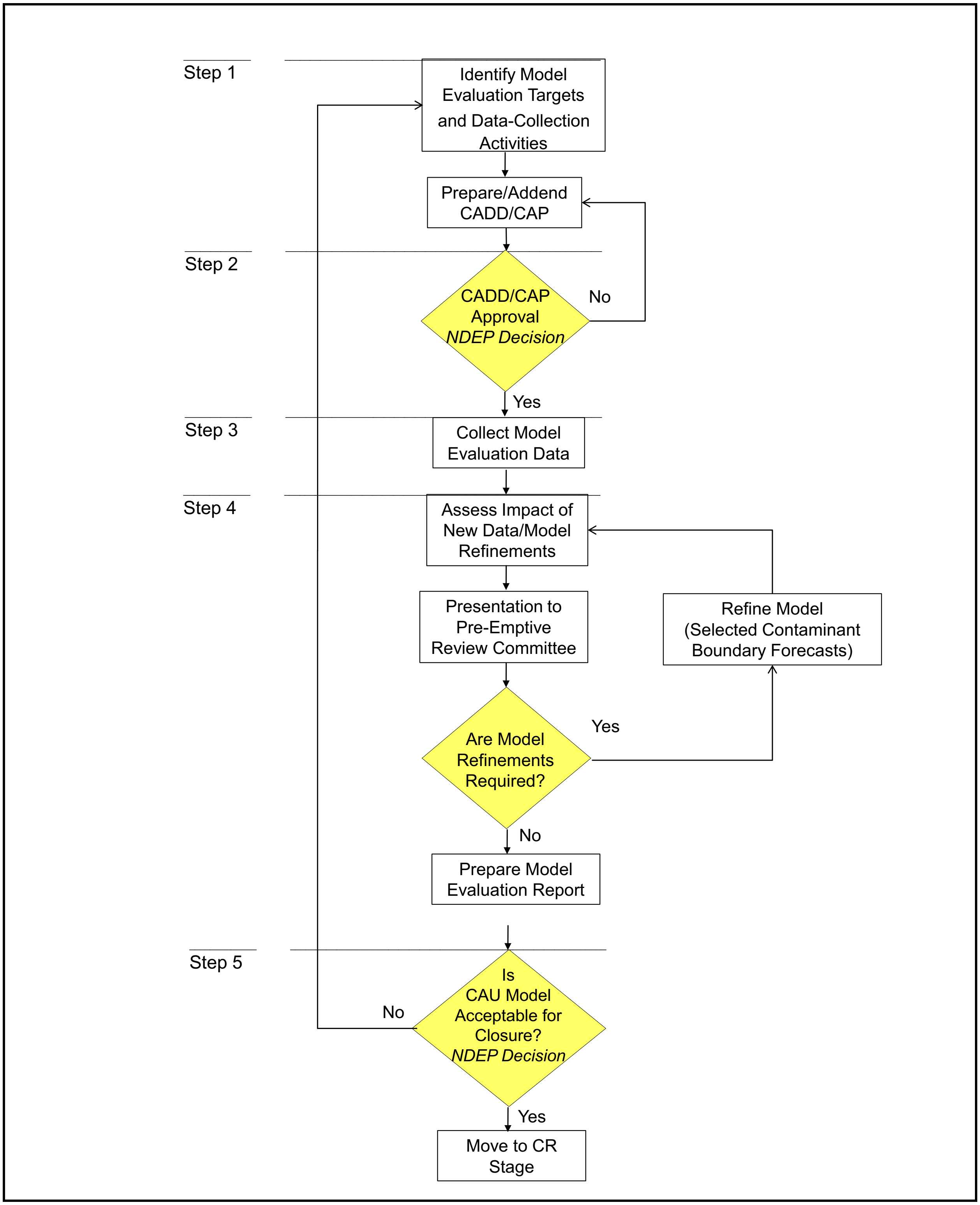

Figure 4-3
Process Flow Diagram for CADD/CAP Model Evaluation Process

contaminant transport model and to identify data-collection activities to address these uncertainties during the CADD/CAP stage.

4.4.2 NDEP Review of CADD/CAP or CADD/CAP Addendum (Step 2)

NDEP reviews the CADD/CAP or addendum in Step 2. If approved, the process will move to Step 3. If the CADD/CAP is not approved, it will be revised and resubmitted to NDEP.

4.4.3 Collect Model Evaluation Data (Step 3)

Data-collection activities are completed in Step 3. Model evaluation data, in this case, also refers to new interpretations of historical data or new interpretations of data collected during the CAI stage. The activities are performed in compliance with the UGTA QAP (NNSA/NFO, 2015c) and within the controls established by REOPs, field activity work packages, and/or standard operating procedures.

4.4.4 Assess Impact of New Data and Refine Model as Necessary (Step 4)

Step 4 involves the following activities:

- Assess the impact that the new data have on the models.
- Present results to PER committee.
- Determine whether further model refinements are necessary.
- Refine model if necessary.
- Prepare the model evaluation report.

This step begins with an assessment of the impact that new data have on the model (conceptual and/or numerical model) results. Models are refined if the newly collected data are inconsistent with the current model forecasts or if addition of the new data may improve the quality of the model results with respect to their use for regulatory decisions. The decision for model refinements has already been made by the PER and Modeling Team (Section 2.4) and promised to NDEP (Section 2.5). Criteria based on the model-evaluation targets will be applied to produce more realistic Base Case and alternative models (i.e., models that are consistent with the new data and established criteria) (see Section 4.5.3). The modeling team will also determine whether the new data indicate that some of the alternative forecasts can be eliminated or given more credence. The data-collection results for each target will result in either revision to individual models or the elimination of a model from the contaminant boundary ensemble.

The modeling team will present the data-collection results, established criteria, and model refinement results to the PER committee. The PER committee will be asked to recommend whether additional model refinements are necessary. If additional model refinements are required, they will be performed and the process will return to the beginning of Step 4, assessing the impact of model refinement (Figure 4-3). Once it has been determined that model refinements are not necessary, the modeling team will recommend advancement to the CR stage or additional data collection. A recommendation to proceed to the CR stage will focus on the adequacy of the model for regulatory decisions, including identifying and establishing CAU regulatory boundary objectives and boundaries; identifying institutional controls, including UR boundaries; and developing a long-term closure-monitoring program. The recommendations made by the modeling team may be based on scientific judgment in addition to quantitative measures. The PER committee will provide recommendations for the path forward. Once the modeling team and the PER committee determine that further model refinements are not required, the modeling team will prepare a model evaluation report.

The model evaluation report will present the following:

- Data-collection and analysis description, and results with respect to model evaluation targets
- Data impact assessment and model refinements (i.e., contaminant boundary forecasts)
- PER committee recommendations to modeling team (from presentations)
- Modeling team recommendations to either collect additional data or proceed to the CR stage

4.4.5 Decision To Move to CR or Return to Step 1 (Step 5)

If DOE concurs with a recommendation to proceed to the CR stage, the final decision will be made by NDEP. The process will return to Step 1 if model forecasts are not considered to be sufficiently reliable for designing a monitoring system, developing effective institutional controls, or supporting the regulatory boundary objective; otherwise, the CAU will proceed to the CR stage. If the decision is to not move to the CR stage, model uncertainties identified in the model evaluation report will be used to select model evaluation targets and data-collection activities to address them (Step 1).

4.5 Data-Collection Activities

Extensive data collection and alternative model testing were performed in response to the Yucca Flat/Climax Mine PRT recommendations (Section 2.4). Three new wells (Figure 4-4) were drilled; several wells were sampled (Figure 4-4); and significant modeling activities were performed to

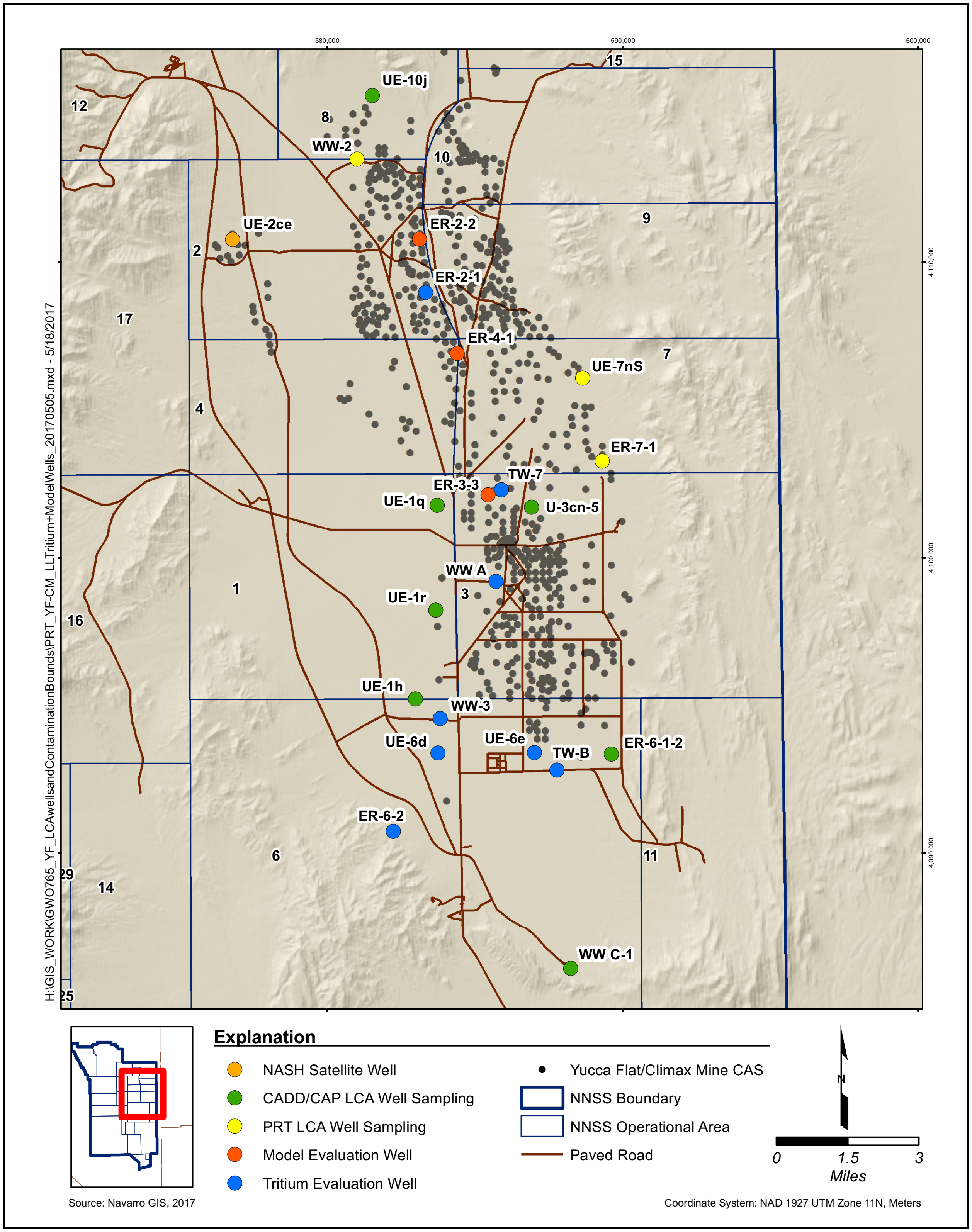

Figure 4-4
Yucca Flat/Climax Mine Data-Collection Locations

demonstrate that the PRT's perceived uncertainties are already sufficiently bounded by the contaminant boundary ensemble presented in N-I (2013). While it was concluded that further addressing many of the PRT's recommendations was unnecessary, some uncertainties that impact the contaminant boundary were identified as a part of the PRT response process (Section 2.4).

The expert elicitation panel identified and ranked a set of uncertainties in order of importance based on their potential impact on the contaminant boundary (Kwicklis, 2016). Uncertainty selection was based on the results of the PRT response process (Navarro, 2016) as well as the results described in N-I (2013). Model evaluation targets were then identified (see Section 4.5.1) and data-collection activities to address these targets were selected (see Section 4.5.2). Data-collection activities included analysis of historical data and analysis of data collected during the CAI stage. The model evaluation targets and data-collection activities planned to address them are presented in Table 4-1.

During the PRT response process, the PER committee requested that model refinements be performed to develop less conservative contaminant boundaries (Figure 2-3). NDEP also agreed to these refinements (Section 2.5). The Yucca Flat/Climax Mine Base Case model will be modified and recalibrated to incorporate the results of the model evaluation targets (Table 4-1). Criteria based on the model-evaluation targets will be applied to produce more realistic Base Case and alternative models (i.e., models that are consistent with the new data and established criteria). These criteria and the approach to refine the model are presented in Section 4.5.3.

4.5.1 Model Evaluation Targets

The expert elicitation panel identified and ranked a set of uncertainties in order of their potential impact on the contaminant boundary (Kwicklis, 2016). This selection was based on uncertainties identified in N-I (2013) and Navarro (2016). The potential impact of the uncertainty on the contaminant boundary was estimated based on the outcome of analyses during the PRT response period as described in Navarro (2016), sensitivity and uncertainty analysis presented in N-I (2013, Section 6), and expert judgment. The targets were then categorized as having high, medium, or low priority. The high-priority targets in order of decreasing priority include the following:

- Basin flux through the testing area
- Exchange volume size and shape
- Extent of RN contamination in the LCA

Table 4-1
Model Evaluation Targets and Associated Data-Collection/Data-Analysis Activities
(Page 1 of 2)

Model Evaluation Target	Discussion	Data-Collection/Data-Analysis Activities
Basin flux through testing area	Overall volumetric flow rates through the testing area were shown in Navarro (2016) to have a dominant effect on the southern extent of the contaminant boundary.	• Formalizing ER-6-1-2 MWAT reanalysis (Section 4.5.2.2) • Well development and testing (WDT) in ER-4-1 LCA (Section 4.5.2.4)
Exchange volume size/shape that extends into the LCA	The contaminant boundary in the LCA is dominated by deeply buried detonations in the northern half of the basin with exchange volumes that are assumed to intersect the saturated LCA at 2 R_c (12 detonations) or 3 R_c (39 detonations) (N-I, 2013). The uncertainty in number and location of tests where the exchange volume intersects the saturated LCA depends both on the size of the exchange volume and the modeled surface elevation of the LCA.	• Sampling LCA completions for RNs (Section 4.5.2.1) • Sampling near-field wells (Section 4.5.2.3) • Drilling evidence from ER-2-2, ER-3-3, and ER-4-1 (Section 4.5.2.6) • Investigation of LCA surface elevations (Section 4.5.2.8) • Review of historical data for detonations near or within the LCA (Section 4.5.2.9)
Extent of RN contamination in LCA	Evaluation of the present extent of RN contamination in the saturated LCA can be used to bound the present-day contaminant boundaries.	• Sampling LCA completions for RNs (Section 4.5.2.1) • Sampling NASH test cavity at Satellite Well UE-2ce (Section 4.5.2.5) • Drilling evidence from ER-2-2, ER-3-3, and ER-4-1 (Section 4.5.2.6)
LCA hydraulic properties	The flow system, and hence the contaminant boundary uncertainty, is strongly influenced by groundwater flow and transport properties of fault zones and the country rock.	• Formalizing ER-6-1-2 MWAT reanalysis (Section 4.5.2.2) • WDT in ER-4-1 LCA (Section 4.5.2.4) • Drilling evidence from ER-2-2, ER-3-3, and ER-4-1 (Section 4.5.2.6)
^{90}Sr mobility in the LCA	^{90}Sr was shown to be a significant contributor to the modeled extent of contamination in the LCA, and including matrix sorption in the model for ^{90}Sr significantly reduced this extent (N-I, 2013, Section 6.0 and Figure 6-84).	• Sampling LCA completions for RNs (Section 4.5.2.1) • Sampling NASH test cavity at Satellite Well UE-2ce (Section 4.5.2.5) • Review of historical data for detonations near or within the LCA (Section 4.5.2.9)
^{137}Cs mobility in the LCA	^{137}Cs was shown to be a significant contributor to the modeled extent of contamination in the LCA, and including matrix sorption in the model for ^{137}Cs significantly reduced this extent (N-I, 2013, Section 6.0 and Figure 6-84).	• Sampling LCA completions for RNs (Section 4.5.2.1) • Sampling NASH test cavity at Satellite Well UE-2ce (Section 4.5.2.5) • Review of historical data for detonations near or within the LCA (Section 4.5.2.9)

Table 4-1
Model Evaluation Targets and Associated Data-Collection/Data-Analysis Activities
(Page 2 of 2)

Model Evaluation Target	Discussion	Data-Collection/Data-Analysis Activities
Fault transport properties	Faults exert controlling influence on the groundwater flow system in the LCA. Fault damage zone transport properties such as fracture aperture, spacing, and porosity have considerable uncertainty associated with them.	• Sampling LCA completions for RNs (Section 4.5.2.1) • Drilling evidence from ER-2-2, ER-3-3, and ER-4-1 (Section 4.5.2.6)
Permeability anisotropy [a]	Predominantly north–south faults with low-permeability fault cores and damage zones with higher fracture densities parallel to the slip plane create a higher permeability in the north–south direction compared with an east–west direction (N-I, 2013).	• Geochemistry evaluations (Section 4.5.2.7) • WDT in ER-4-1 LCA (Section 4.5.2.4)

[a] This model evaluation target may also be addressed using model sensitivity studies (Section 4.5.3).

Note: R_c calculated based on the maximum of the yield range reported in NNSA/NFO (2015d) and Equation 1 in Pawloski (1999).

- LCA hydraulic properties
- ^{90}Sr mobility in the LCA

Targets that were ranked medium-priority include the following:

- ^{137}Cs mobility in the LCA
- LCA fault transport properties
- LCA permeability anisotropy

Targets identified by the panel as low priority (Kwicklis, 2016) because of their relatively minor impact on the contaminant boundary were as follows:

- ^{14}C mobility
- HST/melt glass/sorption/RN inventory
- Background infiltration rates
- Tuff/fault hydraulic properties
- Test overpressure/damage effects in SZ AA/VA models

The high- and medium-priority model evaluation targets are described in Table 4-1. The low-priority targets are not listed in Table 4-1, and no specific activities are planned to reduce these uncertainties because the expert elicitation panel judged the potential benefit of uncertainty reduction in these targets to be small.

4.5.2 Data Collection and Analysis

Data-collection and analysis activities that address the model evaluation targets were selected based on the Yucca Flat/Climax Mine expert elicitation results (Kwicklis, 2016). Activities were identified that could address each model evaluation goal and rated according to the anticipated ability to reduce the uncertainty, based on expert judgment. These efforts expanded on previous work by the Yucca Flat Guidance Team that focused on determining objectives and selecting locations for three new wells in Yucca Flat (Kwicklis, 2015). The previous efforts included drilling three new wells selected to evaluate the extent of contamination in the LCA, exchange volume size, the integrity of the TCU as a barrier to RN migration, the potential for fracture pathways between the TCU and LCA near major detonations, the role of faults as transport pathways, and test-induced hydraulic overpressures as a driving mechanism for RN transport to the LCA. These uncertainties were identified during the PRT response period as important uncertainties that should be evaluated during model evaluation.

In general, model evaluation activities with the greatest anticipated ability to reduce the uncertainty were selected for the model evaluation process. The only exception is for an MWAT at WW-C-1 for addressing uncertainty in basin flux through the testing area. While this activity was estimated to reduce 54 percent of the uncertainty, formalization of the ER-6-1-2 MWAT reanalysis was estimated to reduce 46 percent of the uncertainty. Although the ER-6-1-2 MWAT reanalysis is anticipated to result in sufficient uncertainty reduction with respect to the regulatory objectives, the final decision to perform an additional MWAT during the CADD/CAP stage will be made in consultation with NDEP. Expert elicitation had also rated WDT in the LCA at ER-2-2 and ER-3-3 high with respect to ability to reduce uncertainty, but these activities are not included for model evaluation because difficulties encountered during drilling required that ER-2-2 be plugged and abandoned and ER-3-3 was unable to sustain flow rates high enough to perform a full WDT.

The following activities were selected as most suitable for addressing the model evaluation targets:

- Sampling LCA completions for RNs
- Formalizing the ER-6-1-2 MWAT reanalysis
- Sampling near-field wells
- Performing WDT activities in the LCA at ER-4-1
- Sampling NASH test cavity at Satellite Well UE-2ce
- Interpreting drilling evidence from ER-2-2, ER-3-3, and ER-4-1
- Evaluating ER-4-1 and other Yucca Flat groundwater geochemistry
- Investigating LCA surface elevations
- Reviewing historical data for detonations near or within the LCA

Following the elicitation process, additional activities to address the model evaluation targets were identified by the modeling team along with subject matter experts. These activities include (1) evaluating ER-4-1 and other Yucca Flat groundwater geochemistry, (2) investigations of the LCA surface elevation to address uncertainty in the number of exchange volumes that extend into the LCA, and (3) reviewing historical data for detonations near or within the LCA to address uncertainty in ^{90}Sr and ^{137}Cs mobility and in the number of exchange volumes that extend into the LCA. Activities (1) and (3) were added in order to increase the likelihood of success to achieve individual uncertainty reduction targets (Table 4-1). Activity (2) was added in recognition of the fact that the number of tests that are estimated to intersect the saturated LCA is a function not only of the assumed exchange volume radius but also the elevation of the LCA surface itself, which has uncertainty associated with it, especially in areas where the LCA surface elevation was not constrained by nearby boreholes.

4.5.2.1 Sampling LCA Completions for RNs

Following the publication of N-I (2013), samples have been collected from wells accessing the saturated LCA and analyzed for RNs according to the NNSS Integrated Sampling Plan (NNSA/NFO, 2015b). This includes sampling the model evaluation wells ER-3-3 and ER-4-1 and several other wells completed in the LCA, including ER-7-1, UE-7nS, ER-6-2, and WW-2 (Figure 4-4). Additional wells (UE-10J, UE-1q, U-3cn-5, UE-1r, UE-1h, and ER-6-1-2) will be sampled during the CADD/CAP stage (Figure 4-4). Sampling LCA completions in Yucca Flat for RN activity ranked high on the list of priorities because it reduces uncertainty in the extent of RN contamination in the LCA, and contributes to uncertainty reduction in ^{137}Cs and ^{90}Sr mobility in the LCA and in the exchange volume size. Sampling the ER-3-3 LCA completion also provides information regarding transport within the Yucca Fault.

4.5.2.2 Formalizing ER-6-1-2 MWAT Reanalysis

The informal analysis by Halford (2012 and 2016) of the transmissivity-width product between wells ER-6-1-2 and ER-7-1 calculated from the 2004 ER-6-1-2 MWAT data will be formally documented and reviewed. The Halford (2012 and 2016) interpretations were shown to have a large impact on the contaminant boundary extent when total flux through the model domain and the flux through the eastern corridor of Yucca Flat in alternative models were used as calibration constraints (Navarro, 2016). The need to formally document and review Halford (2012 and 2016) is motivated by this activity's demonstrated contribution toward reducing uncertainty in the basin flux through the testing area, as well as reducing the uncertainty associated with the LCA hydraulic properties and with the permeability anisotropy. This activity will involve developing an extended LCA groundwater model for Yucca Flat and the surrounding areas that will use steady-state and transient hydraulic heads observed during the ER-6-1-2 MWAT conducted in 2004 to calibrate spatially variable transmissivities for the LCA, including areas well to the south of Yucca Flat that experienced drawdowns during the MWAT.

4.5.2.3 Sampling Near-field Wells

The new near-field wells (ER-2-2 near CALABASH sampled during drilling; ER-3-3 near WAGTAIL; and ER-4-1 near STRAIT) have been sampled; the results will be combined with historical data from near-field LCA wells (e.g., UE-7nS near BOURBON/ARTESIA, U-3cn-5 near BILBY, and ER-7-1 near MICKEY/TORRIDO) to reduce uncertainty in exchange volume size/shape.

4.5.2.4 Well Development and Testing at ER-4-1 LCA

WDT in the LCA at ER-4-1 potentially contributes to uncertainty reductions in the basin flux through the testing areas, exchange volume size/shape, LCA hydraulic properties, permeability anisotropy, and extent of contamination in the LCA (Kwicklis, 2016). Steady-state hydraulic heads from the LCA at ER-4-1 will also provide an additional calibration point for the saturated LCA model.

4.5.2.5 Sampling NASH Test Cavity at Satellite Well UE-2ce

Sampling the lower carbonate aquifer-thrust plate (LCA3) near NASH at Satellite Well UE-2ce is expected to reduce uncertainty in the mobility of ^{90}Sr and the extent of contamination in the LCA. Evaluating ^{90}Sr concentrations at UE-2ce will provide upper bounds on its mobility in a carbonate rock aquifer. As noted in Navarro (2016, Section 3.0), UE-2ce is 183 m south of the NASH working point. It was intermittently pumped between 1977 and 1984, and again in 2008, and was bailed at other times. During pumping, ^{3}H was greater than its MCL, but ^{90}Sr never exceeded its MCL despite ^{90}Sr levels estimated at greater than 10^5 times the MCL in the carbonate source term (N-I, 2013, Figure 2-6). The analysis of new and historical RN data from NASH will potentially result in reductions in uncertainty in ^{90}Sr and ^{137}Cs mobility, and indicate the need to refine the ensemble of transport models considered for calculating the contaminant boundary forecasts.

4.5.2.6 Drilling Evidence from ER-2-2, ER-3-3, and ER-4-1

Drilling evidence from ER-2-2, ER-3-3, and ER-4-1 (e.g., geophysical logs, field chemistry, water level measurements, and water production) is expected to contribute to uncertainty reductions in the exchange volume size/shape; extent of contamination in the LCA and, to a lesser extent, LCA hydraulic properties; and fault transport properties. The three wells drilled in 2016 are within 2.5 to

3.6 R_c laterally of a nearby nuclear detonation (based on the maximum of the announced yield reported in NNSA/NFO [2015d] and Equation 1 in Pawloski [1999]). ER-2-2 was drilled near CALABASH, which was detonated at a depth of 625 m (2,050 ft); ER-3-3 was drilled near WAGTAIL, which was detonated at a depth of 750 m (2,459 ft); and ER-4-1 was drilled near STRAIT, which was detonated at a depth of 780 m (2,567 ft) (NNSA/NFO, 2015d). Inferences regarding the hydraulic conductivity values from drilling data, WDT at ER-3-3, and the results of ^3H analysis from samples taken during drilling are included under this activity.

4.5.2.7 Evaluating ER-4-1 and Other Yucca Flat Groundwater Geochemistry

Groundwater samples collected during WDT at ER-4-1 (north-northwest of WW-C and WW-C-1 between Yucca Fault and Topgallant Fault) will provide geochemical and isotopic evidence regarding the permeability anisotropy target. The intent is to reduce uncertainty in flow direction in the central part of the basin, which can be in a direction different than the hydraulic gradient due to anisotropy in permeability. An additional groundwater geochemistry sample from ER-4-1, combined with existing and other new groundwater geochemical data from other wells, can help evaluate if flow directions are aligned with the gradient or at a large angle to it. This would provide a qualitative, and perhaps quantitative indication of whether anisotropy is strong enough to affect anticipated transport directions.

4.5.2.8 Investigation of LCA Surface Elevations

The recent drilling of wells ER-2-2, ER-4-1 and ER-3-3 indicated some discrepancies between the LCA surface elevation represented in the Yucca Flat/Climax Mine HFM (BN, 2006) and the surface elevation observed at the well locations. These discrepancies highlighted an uncertainty that could impact the number and locations of tests included in the LCA models. This is especially significant if new LCA sources are identified in the southern part of the basin or in areas currently believed to lack deep LCA sources. This uncertainty will be addressed by comparing the LCA surface represented in the Yucca Flat/Climax Mine HFM with the LCA surface elevation estimates based on existing gravity inversion data (Phelps et al., 1999) and on proximity of test locations to control points provided by boreholes completed in the LCA. This information will support uncertainty reduction in exchange volume size/shape that extends into the LCA.

4.5.2.9 Review of Historical Information for Detonations near or within the LCA

Identifying the tests that radiologically impact the saturated LCA depends on the assigned exchange volume size and shape. To address this uncertainty, available information regarding the exchange volume size and shape of tests near the LCA will be reviewed and summarized. This review will include a reevaluation of information regarding RN partitioning in carbonate tests. Historical documents will be reviewed to summarize the tritium exchange ratio (TER), which was the basis for assigning exchange volume radii to tests. Available data regarding the spatial extent of contamination as observed from drillback core will be summarized. Finally, a review of groundwater radiochemical data (both new and old) will be performed to assess contamination of the LCA and the implications to the size and shape of the exchange volume. Evidence for asymmetric distribution of contaminants (favoring upward offset of the exchange volume relative to the working point) and the implications to LCA contamination will be evaluated. Finally, data regarding the ^{90}Sr and ^{137}Cs activities in LCA groundwater and the implications to both the exchange volume size/shape and RN mobility will be summarized.

In addition, LANL and Lawrence Livermore National Laboratory (LLNL) containment scientists will be interviewed regarding the placement of tests near the LCA and the steps they took to evaluate the potential for contamination of the LCA. Because of the potential for catastrophic RN releases to the atmosphere, containment scientists were acutely aware of the excessive carbon dioxide (CO_2) production that would result from detonating tests in the area of the LCA. The steps taken to ensure isolation of tests from the LCA and the implications to LCA contamination will be summarized.

4.5.3 Data Impact Assessment and Model Refinement

The Yucca Flat/Climax Mine Base Case model will be modified and recalibrated to incorporate the results of the model evaluation targets (Table 4-1). Criteria based on the model-evaluation targets will be applied to produce more realistic Base Case and alternative models (i.e., models consistent with the new data and established criteria). These criteria will include the following:

- Improved basin and eastern corridor fluxes estimated from the ER-6-1-2 MWAT reanalysis
- Location and number of detonations that have RN source terms emplaced in the LCA
- Adjusted source term concentrations and/or sorption coefficients of ^{90}Sr and ^{137}Cs
- Extent of contamination now observed versus the forecasted extent
- Transport velocities estimated from ^{14}C data

Application of these criteria will likely result in eliminating certain models from the contaminant boundary ensemble. Also, additional contaminant boundaries may be included in the ensemble as a result of the model evaluation process. The current ensemble is described in Section 2.3.

Additional alternative models were explored based on the recommendations of the PRT (N-I, 2015), and three models with alternative fault conceptualizations led to greater particle breakthrough at 1,000 years compared to the Base Case (Navarro, 2016). These will be explored further, using the more realistic basin groundwater flux constraints:

- Models containing faults without low-permeability cores
- Models containing only faults with trace lengths greater than 3 km
- Models with only the largest basin-forming faults

The sensitivity of the revised Base Case contaminant boundary extent to country rock versus fault permeability will be explored with variations of these alternative conceptualizations. Additionally, alternative conceptualizations of permeability anisotropy will be considered, based on geochemical evidence from ER-4-1 and model sensitivity studies (Section 4.5.2.7). Groundwater flow and transport model uncertainties not explicitly addressed through CADD/CAP data-collection activities described in this plan will be included in the final contaminant boundary ensemble using the uncertainty methods previously used in the groundwater flow and transport model report (e.g., Monte Carlo simulations) (N-I, 2013).

4.6 Waste Management

Waste management details can be found in the *Underground Test Area Project Waste Management Plan* (WMP) (NNSA/NSO, 2009) and site-specific planning and field documents. The UGTA Project Fluid Management Plan (FMP) is included as Attachment 1 of the WMP. The term "waste management" covers the segregation, tracking, characterization, and disposal of wastes generated during field activities. The data-collection activities expected to generate waste include well development, testing, and sampling operations. Also, personal protective equipment and sampling equipment waste are generated. The largest volume of waste generated during sampling activities comprises effluent (fluids) and groundwater. Other wastes—such as sanitary, hydrocarbon, and hazardous waste—are generated as a result of the operation and maintenance of heavy equipment as well as other support functions involved in the specific type of activity.

Management of investigation-derived waste (IDW) is described in the UGTA Project WMP (NNSA/NSO, 2009). Details regarding the characterization, storage, treatment, and disposal of wastes generated at investigation sites are addressed in site-specific field instructions or similar working-level documents. The generated wastes are managed and disposed of in compliance with applicable federal, state, and local laws and regulations. The potential for generating hazardous, radioactive, and mixed waste streams is assessed separately for each well location. Field personnel are trained and procedures implemented to address management of radioactive and hazardous waste streams. Waste characterization is based on process knowledge, fluid management monitoring and sampling, and groundwater sampling. This information is used to assign the appropriate waste type (i.e., sanitary, hydrocarbon, hazardous, radioactive, or mixed) to the IDW.

Waste generation is minimized through a comprehensive compliance program. Waste minimization is achieved through the hazardous materials control, materials substitution, and waste segregation. Hazardous materials are controlled, managed, and tracked in accordance with Occupational Safety and Health Administration (OSHA) requirements, and applicable procedures and protocols. Material substitution is implemented wherever possible to prevent or minimize hazardous waste. Waste such as effluent and personal protective equipment is segregated to the greatest extent possible to minimize the generation of hazardous, radioactive, and/or mixed waste.

4.7 Reporting Requirements

Well completion reports will present data collected during drilling including—but not limited to—well construction information; borehole logs (e.g., geophysics, flow, lithologic, water quality); preliminary water-level measurements; water production; drilling parameters; and the results of RN (i.e., ^{3}H) field monitoring. The ER-4-1 WDT operations along with the analyses of the resulting data (e.g., aquifer test, water chemistry, and isotopic compositions) will be presented in data and analysis reports. In addition, WDT and water-quality measurement activities are reported in morning reports on the UGTA Field Operations website, which is accessible to project personnel and NDEP. The Halford (2012 and 2016) reanalysis of the 2004 ER-6-1-2 MWAT data will be formalized and documented in the model evaluation report. The results of other model evaluation activities—interpreting drilling evidence from ER-2-2, ER-3-3, and ER-4-1; sampling LCA completions for RNs; sampling near-field wells; and sampling NASH at UE-2ce—will be documented in the model evaluation report, which will be reviewed by the PER committee. The results of data impact assessment and model refinement studies will be included in the model evaluation report. Model evaluation results will be presented to the PER committee for review. Presentations will include results of the analysis of the new data, assessment of their impact on groundwater flow and transport forecasts, and any model refinements. These reviews will be designed to ensure that the PER committee knows of all pertinent technical information to support informed recommendations required throughout the CADD/CAP process (Figure 4-3).

5.0 References

ASME/RSI, see American Society of Mechanical Engineers and Institute for Regulatory Science.

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Appendix A

Corrective Action Sites in the Yucca Flat/Climax Mine CAU

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 1 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
01-57-001	U-1a Cavity	LEDOUX	4096072.947	583712.9049	09/27/1990	<20	291	AA	No
01-57-002	U-1c Cavity	YERBA	4097860.015	583658.7614	12/14/1971	<20	332	AA	No
01-57-003	U1d Cavity (2)	SUNDOWN-A	4099521.259	583805.2819	09/20/1990	<20	270	AA	No
		SUNDOWN-B	4099521.259	583805.2819	09/20/1990	<20	256	AA	No
02-57-001	U-2a Cavity	ALPACA	4113517.201	581912.8714	02/12/1965	0.33	225	AA	No
02-57-002	U-2aa Cavity	CLUB	4110380.37	582466.3122	01/30/1964	<20	180	AA	No
02-57-003	U-2ab Cavity	TEE	4110844.814	582817.5969	05/07/1965	7	190	AA	No
02-57-004	U-2ad Cavity	CASHMERE	4109781.997	583277.1919	02/04/1965	<20	232	AA	No
02-57-005	U-2af Cavity	KENNEBEC	4109848.785	582701.9496	06/25/1963	Low	226	AA	No
02-57-006	U-2ag Cavity	MULLET	4109784.292	582800.5676	10/17/1963	Low	60	AA	No
02-57-007	U-2ah Cavity	PONGEE	4109893.661	582808.9986	07/22/1965	<20	134	AA	No
02-57-008	U-2ai Cavities (2)	DRILL (SOURCE-LOWER)	4110167.375	582548.6995	12/05/1964	<20	221	AA	No
		DRILL (TARGET-UPPER)	4110167.375	582548.6995	12/05/1964	3.4	190	AA	No
02-57-009	U-2ak Cavity	CENTAUR	4110502.468	582517.0817	08/27/1965	<20	172	AA	No
02-57-010	U-2aL Cavity	EMERSON	4110900.435	583125.4457	12/16/1965	<20	260	AA	No
02-57-011	U-2am Cavity	COMMODORE	4109742.548	583068.5508	05/20/1967	250	745	LTCU	Yes
02-57-013	U-2an Cavity	TAPESTRY	4110166.632	582427.4523	05/12/1966	<20	249	AA	No
02-57-014	U-2ao Cavity	FLOTOST	4111552.821	583124.961	08/16/1977	<20	275	AA	No
02-57-015	U-2ap Cavity	EFFENDI	4110672.211	583125.6538	04/27/1967	<20	221	AA	No
02-57-016	U-2ar Cavity	ASIAGO	4109018.597	582763.9323	12/21/1976	<20	330	AA	No
02-57-017	U-2as Cavity	CLARKSMOBILE	4108597.705	583534.5538	05/17/1968	20 to 200	473	TM-LVTA	Yes
02-57-018	U-2at Cavity	KNOX	4108214.834	583994.513	02/21/1968	20 to 200	645	LTCU	Yes
02-57-019	U-2au Cavity	ILDRIM	4108532.529	583865.0949	07/16/1969	20 to 200	410	TM-WTA	No
02-57-020	U-2av Cavity	CALABASH	4111174.76	583063.4963	10/29/1969	110	625	LTCU	Yes

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 2 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
02-57-021	U-2aw Cavity	STANYAN	4109984.956	582671.5653	09/26/1974	20 to 200	573	TM-WTA	Yes
02-57-022	U-2ax Cavity	PORTMANTEAU	4112174.199	581323.095	08/30/1974	20 to 200	655	TM-LVTA	Yes
02-57-023	U-2ay-1 Cavity	YANNIGAN-RED	4108186.487	583306.5445	02/26/1970	20 to 200	392	AA	No
02-57-024	U-2ay-2 Cavity	YANNIGAN-WHITE	4108369.262	582860.0437	02/26/1970	20 to 200	395	AA	No
02-57-025	U-2ay-3 Cavity	YANNIGAN-BLUE	4107898.668	582922.3337	02/26/1970	20 to 200	364	AA	No
02-57-026	U-2az-1 Cavity	FLASK-GREEN	4107853.441	583230.5744	05/26/1970	105	529	TM-UVTA	Yes
02-57-027	U-2az-2 Cavity	FLASK-YELLOW	4108380.878	583115.9956	05/26/1970	0.09	335	AA	No
02-57-028	U-2az-3 Cavity	FLASK-RED	4108163.247	582839.4991	05/26/1970	0.035	152	AA	No
02-57-029	U-2b Cavity	ST. LAWRENCE	4113440.47	582202.2951	11/09/1962	Low	166	AA	No
02-57-030	U-2bc Cavity	PARNASSIA	4113069.701	582477.5551	11/30/1971	<20	331	TM-LVTA	No
02-57-031	U-2bd Cavity	VULCAN	4112497.354	582312.2966	06/25/1966	25	322	AA	No
02-57-032	U-2be Cavity	NOOR	4112388.612	581718.793	04/10/1968	20 to 200	382	AA	No
02-57-033	U-2bf Cavity	GOURD-AMBER	4113452.182	581638.5021	04/24/1969	<20	181	AA	No
02-57-034	U-2bg Cavity	THROW	4112641.057	581412.8094	04/10/1968	<20	231	AA	No
02-57-035	U-2bh Cavity	SCUTTLE	4113529.554	582064.8579	11/13/1969	1.7	165	AA	No
02-57-036	U-2bi Cavity	OAKLAND	4113228.967	581411.0334	04/04/1967	<20	166	AA	No
02-57-037	U-2bj Cavity	IMP	4113212.227	581858.8294	08/09/1968	<20	179	AA	No
02-57-038	U-2bL Cavity	GOURD-BROWN	4113006.585	581533.4195	04/24/1969	<20	227	AA	No
02-57-039	U-2bm Cavity	LEXINGTON	4113319.569	582126.3101	08/24/1967	<20	226	AA	No
02-57-040	U-2bn Cavity	CHATTY	4113267.492	581974.085	03/18/1969	<20	195	AA	No
02-57-041	U2bo1 Cavity	BOWL-1	4113288.313	581730.4871	06/26/1969	<20	198	AA	No
02-57-042	U-2bp-1 Cavity	SPIDER-A	4113052.855	583066.3806	08/14/1969	<20	213	AA	No
02-57-043	U-2bp-2 Cavity	SPIDER-B	4112824.492	583052.5597	08/14/1969	<20	228	AA	No
02-57-044	U-2bq-1 Cavity	KYACK-A	4112883.063	582701.9221	09/20/1969	<20	192	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 3 of 32)

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02-57-045	U-2bq-2 Cavity	KYACK-B	4112737.205	582841.7113	09/20/1969	<20	186	AA	No
02-57-046	U-2br Cavity	HAREBELL	4111546.789	582794.0893	06/24/1971	20 to 200	519	TM-LVTA	Yes
02-57-047	U-2bs Cavity	STARWORT	4108930.58	583559.3315	04/26/1973	90	564	LTCU	Yes
02-57-048	U-2bu Cavity	MINIATA	4107503.399	584203.9308	07/08/1971	83	529	LTCU	Yes
02-57-049	U-2bv Cavity	PORTULACA	4111722.178	581103.3803	06/28/1973	20 to 200	466	AA	No
02-57-050	U-2bw Cavity	SUTTER	4112127.097	583090.6978	12/21/1976	<20	200	AA	No
02-57-051	U-2bx Cavity	HULSEA	4112484.966	583028.4665	03/14/1974	<20	195	AA	No
02-57-052	U-2by Cavity	POLYGONUM	4112882.926	582234.7337	10/02/1973	<20	213	AA	No
02-57-053	U-2bz Cavity	WALLER	4112346.685	582708.9652	10/02/1973	<20	311	AA	No
02-57-054	U-2c Cavity	KERMET	4113229.414	582415.1637	11/23/1965	<20	196	AA	No
02-57-055	U-2ca Cavity	STUTZ	4110688.754	576226.1332	04/06/1966	<20	226	TM-LVTA	No
02-57-056	U-2cc Cavity	SAXON	4110802.364	576909.8359	07/28/1966	1.2	154	TM-LVTA	No
02-57-057	U-2cd Cavity	TRAVELER	4110420.518	576560.769	05/04/1966	<20	198	AA	No
02-57-058	U-2ce Cavity	NASH	4111152.169	576725.5423	01/19/1967	39	364	LCA3	No
02-57-059	U-2cg Cavity	HEILMAN	4110451.746	576956.205	04/06/1967	<20	153	AA	No
02-57-060	U-2ch Cavity	POD-A	4110790.823	576139.8519	10/29/1969	16.7 (Total)	249	TM-LVTA	No
02-57-061	U-2ci Cavity	POD-B	4110335.588	576309.9822	10/29/1969		171	TM-LVTA	No
02-57-062	U-2cj Cavity	POD-C	4110228.882	576667.5047	10/29/1969		312	AA	No
02-57-063	U-2ck Cavity	POD-D	4110773.352	577146.7243	10/29/1969		267	TM-LVTA	No
02-57-064	U-2cm Cavity	STODDARD	4108518.984	577436.5611	09/17/1968	31	468	TM-LVTA	Yes
02-57-065	U-2cn Cavity	CRUET	4108701.808	577410.2724	10/29/1969	11	264	TM-WTA	No
02-57-066	U-2co Cavity	KRYDDOST	4108183.966	577489.8373	05/06/1982	<20	335	TM-LVTA	No
02-57-067	U-2cp Cavity	CABOC	4107930.547	577849.9758	12/16/1981	<20	335	TM-LVTA	No
02-57-068	U-2cq Cavity	GORBEA	4107728.606	577956.4219	01/31/1984	20 to 150	388	TM-LVTA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 4 of 32)

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02-57-069	U-2cr Cavity	WEXFORD	4111185.998	577608.7995	08/30/1984	<20	314	TM-LVTA	No
02-57-070	U-2cs Cavity	MARIBO	4108993.077	577919.4155	06/26/1985	<20	381	TM-LVTA	No
02-57-072	U-2cu Cavities (2)	KAWICH-BLACK	4109480.68	577917.6636	02/24/1989	<20	431	TM-LVTA	No
		KAWICH-RED	4109480.68	577917.6636	02/24/1989	<20	370	TM-LVTA	No
02-57-073	U-2db Cavities (3)	CREW	4109730.25	581064.3646	11/04/1968	20 to 200	603	AA	No
		CREW-2ND	4109730.25	581064.3646	11/04/1968	<20	359	AA	No
		CREW-3RD	4109730.25	581064.3646	11/04/1968	<20	359	TM-LVTA	Yes
02-57-074	U-2dc-1 Cavity	TYG-E	4108565.381	581958.887	12/12/1968	<20	198	AA	No
02-57-075	U-2dc-2 Cavity	TYG-D	4108717.598	581809.6566	12/12/1968	<20	207	AA	No
02-57-076	U-2dc-3 Cavity	TYG-C	4108359.79	581901.7108	12/12/1968	<20	228	AA	No
02-57-077	U-2dc-4 Cavity	TYG-A	4108664.672	581603.2462	12/12/1968	<20	228	AA	No
02-57-078	U-2dc-5 Cavity	TYG-B	4108306.973	581695.2911	12/12/1968	<20	251	AA	No
02-57-079	U-2dc-6 Cavity	TYG-F	4108447.669	581501.5705	12/12/1968	<20	265	AA	No
02-57-080	U-2dd-2 Cavity	ARNICA-YELLOW	4107895.081	581115.5946	06/26/1970	<20	309	TM-LVTA	No
02-57-081	U-2dd-3 Cavity	ARNICA-VIOLET	4108252.224	581288.0847	06/26/1970	<20	264	AA	No
02-57-082	U-2de Cavity	COFFER	4110034.651	581048.1127	03/21/1969	<100	465	AA	No
02-57-083	U-2df Cavity	HUTCH	4110732.237	580971.8556	07/16/1969	20 to 200	548	AA	Yes
02-57-084	U-2dg Cavity	CARPETBAG	4109584.265	581377.8518	12/17/1970	220	661	TM-LVTA	Yes
02-57-085	U-2dh-2 Cavity	SAPPHO	4107802.007	581588.5792	03/23/1972	<20	198	AA	No
02-57-086	U-2dh-3 Cavity	KARA	4107737.171	581262.4817	05/11/1972	<20	259	AA	No
02-57-087	U-2di Cavity	CHANTILLY	4109064.991	581029.2718	09/29/1971	<20	331	AA	No
02-57-088	U-2dj Cavities (3)	FLAX-BACKUP	4110785.078	581343.5208	12/21/1972	<20	445	AA	No
		FLAX-SOURCE	4110785.078	581343.5208	12/21/1972	<20	689	TM-LVTA	Yes
		FLAX-TEST	4110785.078	581343.5208	12/21/1972	20 to 200	436	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 5 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
02-57-089	U-2dk Cavity	ZINNIA	4108628.881	580951.8122	05/17/1972	<20	323	AA	No
02-57-090	U-2dL Cavity	CHAENACTIS	4109003.553	580800.9144	12/14/1971	20 to 200	331	AA	No
02-57-091	U-2dm Cavity	LONGCHAMPS	4108785.554	581310.5753	04/19/1972	<20	326	AA	No
02-57-092	U-2dn Cavity	MERIDA	4108113.209	581184.9342	06/07/1972	<20	204	AA	No
02-57-093	U-2do Cavity	GAZOOK	4108265.071	581032.0711	03/23/1973	<20	326	AA	No
02-57-094	U-2dp Cavity	DELPHINIUM	4108721.033	581143.1899	09/26/1972	15	296	AA	No
02-57-095	U-2dq Cavity	SATZ	4107666.286	581917.597	07/07/1978	<20	315	TM-LVTA	No
02-57-096	U-2dr Cavity	CABRILLO	4110124.691	581261.6851	03/07/1975	20 to 200	600	AA	Yes
02-57-097	U-2ds Cavity	GROVE	4108002.199	582129.983	05/22/1974	<20	314	TM-LVTA	No
02-57-098	U-2dt Cavity	TANYA	4108213.15	581458.5226	07/30/1968	20 to 200	381	AA	No
02-57-099	U-2du Cavity	ALVISO	4107667.368	582222.6335	06/11/1975	<20	183	AA	No
02-57-100	U-2dv Cavity	FALLON	4109073.596	581748.3666	05/23/1974	20 to 200	466	AA	Yes
02-57-101	U-2dw Cavities (2)	CRESTLAKE-BRIAR	4108486.577	581198.8435	07/18/1974	<20	374	AA	No
		CRESTLAKE-TANSAN	4108486.577	581198.8435	07/18/1974	<20	272	AA	No
02-57-102	U-2dy Cavity	EDAM	4108089.148	581001.8632	04/24/1975	20 to 200	411	TM-LVTA	No
02-57-103	U-2dz Cavity	BANON	4109127.72	581471.1888	08/26/1976	20 to 150	537	AA	Yes
02-57-104	U-2e Cavity	CUMBERLAND	4112650.712	582416.9197	04/11/1963	Low	227	AA	No
02-57-105	U-2ea Cavity	SEAFOAM	4113172.424	582226.1348	12/13/1973	<20	198	AA	No
02-57-106	U-2eb Cavity	POTRERO	4113011.318	581929.603	04/23/1974	<20	211	AA	No
02-57-107	U-2ef Cavity	GOUDA	4110204.747	583212.6106	10/06/1976	<20	200	AA	No
02-57-108	U-2eg Cavity	RIVOLI	4110493.753	582827.62	05/20/1976	<20	200	AA	No
02-57-109	U-2eh Cavity	LIPTAUER	4111886.341	581420.9921	04/03/1980	20 to 150	417	AA	No
02-57-110	U-2ei Cavity	COULOMMIERS	4112042.063	582725.2779	09/27/1977	20 to 150	530	TM-LVTA	Yes
02-57-111	U-2ek Cavity	CHIBERTA	4109438.551	583282.983	12/20/1975	20 to 200	716	LTCU	Yes

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 6 of 32)

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02-57-112	U-2eL Cavity	MARSILLY	4108615.31	583227.9434	04/05/1977	20 to 150	689	LTCU	Yes
02-57-113	U-2em Cavity	AZUL	4110515.899	583138.6543	12/14/1979	<20	205	AA	No
02-57-114	U-2en Cavity	REBLOCHON	4108996.028	583086.3896	02/23/1978	20 to 150	658	LTCU	Yes
02-57-115	U-2eo Cavity	KLOSTER	4112132.085	582344.3742	02/15/1979	20 to 150	536	TM-LVTA	Yes
02-57-116	U-2ep Cavity	NESSEL	4108720.929	582844.2391	08/29/1979	20 to 150	464	AA	Yes
02-57-117	U-2eq Cavity	RIOLA	4108128.168	583029.4554	09/25/1980	1.07	424	AA	Yes
02-57-118	U-2er Cavity	ISLAY	4113069.273	582807.0095	08/27/1981	<20	294	TM-LVTA	No
02-57-119	U-2es Cavity	AKAVI	4111736.341	582436.8793	12/03/1981	20 to 150	494	TM-LVTA	Yes
02-57-120	U-2et Cavity	CHEEDAM	4113338.418	583086.3849	02/17/1983	<20	343	TM-LVTA	No
02-57-121	U-2eu Cavity	DANABLU	4112739.169	580793.8777	06/09/1983	<20	320	AA	No
02-57-122	U-2ev Cavity	AGRINI	4111503.607	581264.7323	03/31/1984	<20	320	AA	No
02-57-123	U-2ew Cavities (2)	BRANCO	4108745.678	583821.7505	09/21/1983	<20	293	AA	Yes
		BRANCO-HERKIMER	4108745.678	583821.7505	09/21/1983	<20	427	TM-WTA	No
02-57-124	U-2ex Cavity	ROMANO	4110849.196	582336.3945	12/16/1983	20 to 150	515	TM-UVTA	Yes
02-57-125	U-2ey Cavity	NIGHTINGALE	4113701.312	582292.8044	06/22/1988	<150	238	AA	No
02-57-126	U-2ey Cavity	RHYOLITE	4113701.312	582292.8044	06/22/1988	<150	238	AA	No
02-57-127	U-2f Cavity	NARRAGUAGUS	4112437.957	582206.1309	09/27/1963	Low	150	AA	No
02-57-128	U-2fa Cavity	FARALLONES	4110329.18	581101.3319	12/14/1977	20 to 150	667	AA	Yes
02-57-129	U-2fb Cavity	QUARGEL	4109332.57	581302.5467	11/18/1978	20 to 150	542	TM-LVTA	Yes
02-57-130	U-2fc Cavity	FAJY	4111137.214	580961.3029	06/28/1979	20 to 150	536	AA	Yes
02-57-131	U-2fd Cavity	TARKO	4109293	580891.3336	02/28/1980	<20	369	AA	No
02-57-132	U-2fe Cavity	CROWDIE	4111410.563	580807.687	05/05/1983	<20	390	AA	No
02-57-133	U-2ff Cavity	LABAN	4108454.844	580863.7457	08/03/1983	<20	326	AA	No
02-57-134	U-2g Cavity	SATSOP	4112358.914	581916.6783	08/15/1963	Low	225	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 7 of 32)

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02-57-135	U-2ga-S Cavity	CORNUCOPIA	4111105.184	582418.3624	07/24/1986	<20	380	AA	No
02-57-136	U-2gb Cavity	PANAMINT	4109149.479	583390.5833	05/21/1986	<20	480	TM-WTA	Yes
02-57-137	U-2ge Cavity	BORATE	4111004.326	581745.8995	10/23/1987	20 to 150	543	AA	Yes
02-57-138	U-2gf Cavity	SCHELLBOURNE	4109072.669	582348.6841	05/13/1988	<150	463	AA	Yes
02-57-139	U-2gg Cavity	INGOT	4111118.918	582789.5003	03/09/1989	20 to 150	500	TM-WTA	Yes
02-57-140	U-2gh Cavity	METROPOLIS	4107763.999	583867.494	03/10/1990	20 to 150	469	TM-LVTA	Yes
02-57-141	U-2h Cavity	CARMEL	4112435.541	581626.8666	02/21/1963	Low	163	AA	No
02-57-142	U-2j Cavity	ALVA	4112899.615	581336.9597	08/19/1964	4.4	166	AA	No
02-57-143	U-2L Cavity	AHTANUM	4113384.869	581550.3578	09/13/1963	Low	226	AA	No
02-57-144	U-2m Cavity	FENTON	4113068.77	581355.306	04/23/1966	1.4	167	AA	No
02-57-145	U-2n Cavity	ACE	4111750.511	581978.8141	06/11/1964	3	266	AA	No
02-57-146	U-2p Cavity	PAR	4112054.29	581887.2247	10/09/1964	38	406	AA	No
02-57-147	U-2q Cavity	CREPE	4107978.425	584019.4362	12/05/1964	20 to 200	404	TM-LVTA	Yes
02-57-148	U-2r Cavity	PLAID II	4109283.765	582582.5826	02/03/1966	<20	269	AA	No
02-57-149	U-2t Cavity	DUMONT	4107611.36	583624.5617	05/19/1966	20 to 200	671	LTCU	Yes
02-57-150	U-2u Cavity	PACKARD	4111683.387	582897.4602	01/15/1969	10	247	AA	No
02-57-151	U-2v Cavity	AGILE	4109345.591	582856.6698	02/23/1967	20 to 200	733	TM-LVTA	Yes
02-57-152	U-2x Cavity	LANPHER	4108103.524	583645.7169	10/18/1967	20 to 200	715	LTCU	Yes
02-57-153	U-2y Cavity	HUPMOBILE	4111424.327	582898.4104	01/18/1968	7.4	247	AA	No
02-57-154	U2bo2 Cavity	BOWL-2	4113098.817	581685.5287	06/26/1969	<20	229	AA	No
03-57-001	U-3aa Cavity	BOOMER	4100664.27	585775.9835	10/01/1961	Low	101	AA	No
03-57-002	U-3ab Cavity	ERMINE	4100671.253	585851.8608	03/06/1962	Low	73	AA	No
03-57-003	U-3ac Cavity	SHREW	4100678.458	585927.6469	09/16/1961	Low	98	AA	No
03-57-004	U-3ad Cavity	PLATYPUS	4100665.96	586007.9021	02/24/1962	Low	58	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 8 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-005	U-3ae Cavity	MINK	4100692.428	586079.4011	10/29/1961	Low	192	AA	No
03-57-006	U-3af Cavity	COYPU	4100720.095	586148.7532	04/10/1963	Low	75	AA	No
03-57-007	U-3ag Cavity	CHINCHILLA	4100747.764	586218.1937	02/19/1962	1.9	150	AA	No
03-57-008	U-3ah Cavity	FISHER	4100394.887	586386.6781	12/03/1961	13.4	364	AA	No
03-57-009	U-3ai Cavity	HOGNOSE	4100181.5	586090.0275	03/15/1962	Low	240	AA	No
03-57-010	U-3aj-S Cavity	RACCOON	4100361.674	585783.4109	06/01/1962	Low	164	AA	No
03-57-011	U-3ak Cavity	RINGTAIL	4100097.945	586599.7846	12/17/1961	Low	363	AA	No
03-57-012	U-3aL Cavity	PAMPAS	4099884.434	586302.507	03/01/1962	9.5	363	AA	No
03-57-013	U-3am-S Cavity	AARDVARK	4102537.434	586124.4541	05/12/1962	40	434	LTCU	Yes
03-57-014	U-3an Cavity	WAGTAIL	4102455.853	585520.4065	03/03/1965	20 to 200	750	LTCU	Yes
03-57-015	U-3ao Cavity	AGOUTI	4100543.036	585790.3755	01/18/1962	6.4	261	AA	No
03-57-016	U-3ap Cavity	STOAT	4100253.078	585731.0615	01/09/1962	5.1	302	AA	No
03-57-017	U-3aq Cavity	DORMOUSE	4100493.944	585335.6199	01/30/1962	Low	363	AA	No
03-57-018	U-3ar Cavity	ARMADILLO	4100131.758	585385.9672	02/09/1962	7.1	240	AA	No
03-57-019	U-3as Cavity	CHINCHILLA II	4100503.252	585565.0645	03/31/1962	Low	137	AA	No
03-57-020	U-3at Cavity	JERBOA	4100246.526	586493.2284	03/01/1963	Low	301	AA	No
03-57-021	U-3au-S Cavity	HAYMAKER	4099915.328	585718.2983	06/27/1962	67	408	AA	Yes
03-57-022	U-3av Cavity	WOLVERINE	4100714.846	585949.1544	10/12/1962	Low	73	AA	No
03-57-023	U-3aw Cavity	PACKRAT	4100368.76	585354.3145	06/06/1962	Low	262	AA	No
03-57-024	U-3ax Cavity	PACA	4100475.859	586623.2176	05/07/1962	Low	258	AA	No
03-57-025	U-3ay Cavity	CHIPMUNK	4100741.314	586020.7421	02/15/1963	Low	59	AA	No
03-57-026	U-3az Cavity	DORMOUSE PRIME	4100248.669	586756.5492	04/05/1962	10.6	261	AA	No
03-57-027	U-3ba Cavity	TENDRAC	4101046.5	586234.8006	12/07/1962	Low	303	AA	No
03-57-028	U-3bb Cavity	PEBA	4101412.508	586233.2014	09/20/1962	Low	241	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 9 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-029	U-3bc Cavity	HUTIA	4100212.414	585616.0334	06/06/1963	Low	135	AA	No
03-57-030	U-3bd Cavity	MERRIMAC	4101411.23	585867.8231	07/13/1962	Intermediate	413	AA	Yes
03-57-031	U-3be Cavity	DAMAN I	4100082.696	586160.4944	06/21/1962	Low	260	AA	No
03-57-032	U-3bf Cavity	FERRET	4101778.181	586231.3384	02/08/1963	Low	326	TM-UVTA	No
03-57-033	U-3bg Cavity	ACUSHI	4100431.391	586971.321	02/08/1963	Low	261	AA	No
03-57-034	U-3bh Cavity	HYRAX	4100187.645	586972.4938	09/14/1962	Low	217	AA	No
03-57-035	U-3bj Cavity	BANDICOOT	4099700.039	586974.4841	10/19/1962	12.5	241	AA	No
03-57-036	U-3bk Cavity	MATACO	4100432.576	587215.7032	06/14/1963	Low	196	AA	No
03-57-037	U-3bL Cavity	BOBAC	4100430.219	586727.5614	08/24/1962	Low	206	AA	No
03-57-038	U-3bm Cavity	GUNDI	4099942.947	586729.6237	11/15/1962	Low	241	AA	No
03-57-039	U-3bn Cavity	CASSOWARY	4099699.528	586730.1631	12/16/1964	<20	150	AA	No
03-57-040	U-3bo Cavity	STURGEON	4100188.495	587216.6196	04/15/1964	<20	150	AA	No
03-57-041	U-3bp Cavity	GERBIL	4099944.625	587216.5554	03/29/1963	Low	280	AA	No
03-57-042	U-3bq Cavity	ANCHOVY	4099700.88	587217.7347	11/14/1963	Low	260	AA	No
03-57-043	U-3br Cavity	BELEN	4101401.219	585383.3747	02/04/1970	20 to 200	421	AA	Yes
03-57-044	U-3bs Cavity	PUCE	4101888.82	585381.0282	06/10/1966	<20	486	AA	Yes
03-57-045	U-3bt Cavity	BONEFISH	4101890.548	585869.1784	02/18/1964	<20	301	AA	No
03-57-046	U-3bu Cavity	NUMBAT	4100433.431	587459.5554	12/12/1962	Low	232	AA	No
03-57-047	U-3bv Cavity	HARKEE	4100189.564	587459.7651	05/17/1963	Low	241	AA	No
03-57-048	U-3bw Cavity	PEKAN	4099945.485	587460.9552	08/12/1963	Low	302	AA	No
03-57-049	U-3bx Cavity	BARBEL	4099711.145	587438.2076	10/16/1964	<20	259	AA	No
03-57-050	U-3by Cavity	FERRET PRIME	4099455.335	586730.977	04/05/1963	Low	241	AA	No
03-57-051	U-3bz Cavity	GRUNION	4099456.285	586974.7669	10/11/1963	Low	261	AA	No
03-57-052	U-3cb Cavity	CARP	4099457.98	587461.9938	09/27/1963	Low	329	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 10 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-053	U-3cd Cavity	DOVEKIE	4098848.223	587464.4731	01/21/1966	<20	333	AA	No
03-57-054	U-3cf Cavity	HOOPOE	4100674.746	585889.8884	12/16/1964	<20	70	AA	No
03-57-055	U-3cg Cavity	TEJON	4100665.883	585967.6165	05/17/1963	Low	75	AA	No
03-57-056	U-3ch Cavity	SARDINE	4099697.423	586242.2442	12/04/1963	Low	262	AA	No
03-57-057	U-3cj Cavity	SIENNA	4099456.794	587218.2058	01/18/1966	<20	275	AA	No
03-57-058	U-3cn Cavity	BILBY	4102015.745	586904.8732	09/13/1963	249	714	OSBCU	Yes
03-57-059	U-3co Cavity	PIPEFISH	4099698.03	586486.386	04/29/1964	<20	262	AA	No
03-57-060	U-3cp Cavity	CANVASBACK	4102566.152	587451.4518	08/22/1964	<20	448	LTCU	Yes
03-57-061	U-3cr Cavity	BARRACUDA	4100190.39	587764.4586	12/04/1963	Low	263	AA	No
03-57-062	U-3ct Cavity	MERLIN	4101039.976	586725.1312	02/16/1965	10.1	296	AA	No
03-57-063	U-3cu Cavity	BITTERLING	4099642.201	587766.1448	06/12/1964	<20	193	AA	No
03-57-064	U-3cv Cavity	MINNOW	4099946.309	587765.3906	05/15/1964	<20	241	AA	No
03-57-065	U-3cx Cavity	CYCLAMEN	4100913.98	585476.425	05/05/1966	12	305	AA	No
03-57-066	U-3cy Cavity	PIKE	4100921.277	587823.2151	03/13/1964	<20	115	AA	No
03-57-067	U-3cz Cavity	SOLENDON	4101586.5	586235.3391	02/12/1964	<20	150	AA	No
03-57-068	U-3d Cavity	PASCAL-B	4100743.107	585825.8747	08/27/1957	1 gram	152	AA	No
03-57-069	U-3da-S Cavity	SCAUP	4101851.353	587895.5381	05/14/1965	<20	427	LTCU	Yes
03-57-070	U-3db Cavity	GUNDI PRIME	4100798.771	587457.6442	05/09/1963	Low	272	AA	No
03-57-071	U-3dd Cavity	KESTREL	4098175.933	586857.0711	04/05/1965	<20	447	AA	Yes
03-57-072	U-2dd-1 Cavity	CAN-GREEN	4107725.693	581475.8476	04/21/1970	20 to 200	274	AA	No
03-57-073	U-2dd-4 Cavity	CAN-RED	4108083.383	581646.7218	04/21/1970	20 to 200	399	LTCU	No
03-57-074	U-3de Cavity	TUNA	4101158.858	585871.7205	12/20/1963	Low	414	AA	Yes
03-57-075	U-3df Cavity	CORMORANT	4097259.615	586251.0802	07/17/1964	<20	272	AA	No
03-57-076	U-3dg Cavity	SCREAMER	4097875.444	588077.3386	09/01/1965	<20	302	TM-WTA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 11 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-077	U-3dh Cavity	BUFF	4103354.215	586229.7486	12/16/1965	20 to 200	500	LTCU	Yes
03-57-078	U-3di Cavity	GUANAY	4097261.745	586860.8483	09/04/1964	<20	261	AA	No
03-57-079	U-3dj Cavity	TROGON	4100434.144	587763.9744	07/24/1964	<20	193	AA	Yes
03-57-080	U-3dk Cavity	PARROT	4099184.775	587768.3115	12/16/1964	1.3	180	AA	No
03-57-081	U-3dL Cavity	HADDOCK	4102747.262	586841.9594	08/28/1964	<20	364	LTCU	No
03-57-082	U-3dm Cavity	CINNAMON	4099148.552	586122.2451	03/07/1966	<20	120	AA	No
03-57-083	U-3dn Cavity	PERSIMMON	4097264.245	587469.9912	02/23/1967	<20	299	AA	No
03-57-084	U-3do Cavity	COURSER	4103358.534	587448.674	09/25/1964	0	359	LTCU	No
03-57-085	U-3dp Cavity	MAUVE	4097256.119	585336.8784	08/06/1965	<20	321	AA	No
03-57-086	U-3dr Cavity	BORDEAUX	4096647.996	585643.4755	08/18/1967	<20	332	AA	No
03-57-087	U-3ds Cavity	PURPLE	4096351.485	588082.3405	03/18/1966	<20	333	TM-WTA	No
03-57-088	U-3dt Cavity	TURNSTONE	4099028.521	586656.2765	10/16/1964	<20	126	AA	No
03-57-089	U-3du Cavity	FINFOOT	4099453.678	586243.3953	03/07/1966	<20	196	AA	No
03-57-090	U-3dw Cavity	TERN	4100311.928	587672.6595	01/29/1965	<20	211	AA	No
03-57-091	U-3dx Cavity	MUSCOVY	4097270.022	589298.4249	04/23/1965	<20	180	TM-WTA	No
03-57-092	U-3dy Cavity	PETREL	4100066.704	587338.0326	06/11/1965	1.3	181	AA	No
03-57-093	U-3dz Cavity	KNIFE B	4098203.124	585912.3196	11/15/1968	<20	363	AA	No
03-57-094	U-3e Cavity	PASCAL-C	4100845.177	586098.389	12/06/1957	0.038	76	AA	No
03-57-095	U-3eb Cavity	TANGERINE	4100443.761	586239.9698	08/12/1966	<20	88	AA	No
03-57-096	U-3ec Cavity	OCHRE	4100156.656	586850.4335	04/29/1966	<20	126	AA	No
03-57-097	U-3ed Cavity	MOA	4099458.451	587614.7088	09/01/1965	<20	194	AA	No
03-57-098	U-3ee Cavity	POMMARD	4100617.467	587884.6224	03/14/1968	1.5	209	AA	No
03-57-099	U-3hp Cavity	JARA	4095737.834	586804.9394	06/06/1974	<20	378	AA	Yes
03-57-100	U-3ef Cavity	MUSHROOM	4099703.456	587948.7325	03/03/1967	<20	180	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 12 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-102	U-3eh Cavity	FUTTOCK	4102594.684	586872.3351	06/18/1975	<20	187	AA	No
03-57-103	U-3ei Cavity	MORRONES	4103176.462	587662.6011	05/21/1970	20 to 200	483	LTCU	Yes
03-57-104	U-3ej Cavity	VISE	4101221.16	586237.1986	01/30/1969	20 to 200	454	TM-LVTA	Yes
03-57-105	U-3ek Cavity	TOMATO	4097271.588	589572.6126	04/07/1966	<20	226	TM-LVTA	No
03-57-106	U-3eL Cavity	PLANER	4096956.975	586861.6623	11/21/1969	<20	378	AA	Yes
03-57-107	U-3em Cavity	UMBER	4098481.256	586855.9832	06/29/1967	10	310	AA	No
03-57-108	U-3en Cavity	SEPIA	4100857.706	586878.45	11/12/1965	<20	241	AA	No
03-57-109	U-3eo Cavity	FAWN	4101344.937	586861.5272	04/07/1967	<20	271	AA	No
03-57-110	U-3ep Cavity	ABSINTHE	4100310.123	587154.6215	05/26/1967	<20	119	AA	No
03-57-111	U-3eq Cavity	BRUSH	4100067.658	587612.5786	01/24/1968	<20	118	AA	No
03-57-112	U-3er Cavity	KNIFE C	4098215.765	589508.3553	10/03/1968	<20	301	LTCU	No
03-57-113	U-3es Cavity	CHOCOLATE	4097440.331	585549.2518	04/21/1967	<20	240	AA	No
03-57-114	U-3et Cavity	KHAKI	4100539.671	587336.6165	10/15/1966	<20	233	AA	No
03-57-115	U-3eu Cavity	CERISE	4100068.76	587932.5713	11/18/1966	<20	211	AA	No
03-57-116	U-3ev-2s Cavity	SNUBBER	4101433.55	589893.2384	04/21/1970	12.7	344	LTCU	No
03-57-117	U-3ew Cavity	GIBSON	4098026.829	587772.4061	08/04/1967	<20	241	AA	No
03-57-118	U-3ex Cavity	GILROY	4099182.12	587006.4941	09/15/1967	<20	240	AA	No
03-57-119	U-3ey Cavity	WEMBLEY	4099183.631	587432.8089	06/05/1968	<20	238	AA	No
03-57-120	U-3ez Cavity	SIDECAR	4099186.187	588255.9143	12/13/1966	<20	240	TM-WTA	No
03-57-121	U-3fa Cavity	SAZERAC	4098814.993	586520.232	10/25/1967	<20	301	AA	No
03-57-122	U-3fb Cavity	KNIFE A	4098849.789	587829.8727	09/12/1968	<20	332	TM-LVTA	No
03-57-123	U-3fc Cavity	PICCALILLI	4098791.788	588683.268	11/21/1969	20 to 200	394	LTCU	Yes
03-57-124	U-3fd Cavity	LAGUNA	4097749.016	586858.8728	06/23/1971	20 to 200	455	TM-WTA	Yes
03-57-125	U-3fe Cavity	LOVAGE	4096042.78	586864.5457	12/17/1969	<20	378	AA	Yes

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 13 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-126	U-3ff Cavity	PLOMO	4098797.261	590145.962	05/01/1974	<20	149	TM-LVTA	No
03-57-127	U-3fh Cavity	STILT	4099401.222	588681.5049	12/15/1967	<20	333	TM-LVTA	No
03-57-128	U-3fj Cavity	TORCH	4099949.739	588679.2228	02/21/1968	<20	240	TM-WTA	No
03-57-129	U-3fk Cavity	SEVILLA	4099952.744	589533.116	06/25/1968	<20	359	TM-LVTA	No
03-57-130	U-3fm Cavity	COGNAC	4100821.13	585324.1363	10/25/1967	<20	240	AA	No
03-57-131	U-3fn Cavity	BEEBALM	4101876.565	586326.3681	05/01/1970	<20	390	TM-WTA	No
03-57-132	U-3fq Cavity	CANJILON	4103355.512	586595.1322	12/16/1970	<20	302	TM-LVTA	No
03-57-133	U-3fr Cavity	FIZZ	4100422.825	586199.8068	03/10/1967	<20	118	AA	No
03-57-134	U-3fs Cavity	WELDER	4100467.121	586202.3791	10/03/1968	<20	118	AA	No
03-57-135	U-3fu Cavity	BEVEL	4101117.085	586984.1881	04/04/1968	<20	241	AA	No
03-57-136	U-3fv Cavity	MALLET	4095437.96	588085.8803	01/31/1968	<20	240	AA	No
03-57-137	U-3fw Cavity	ADZE	4096295.132	589301.5009	05/28/1968	<20	240	TSA	No
03-57-138	U-3fx Cavity	AUGER	4100620.893	588860.0138	11/15/1968	<20	240	TM-LVTA	No
03-57-139	U-3fy Cavity	SPUD	4095440.527	589000.1205	07/17/1968	<20	240	TM-LVTA	No
03-57-140	U-3fz Cavity	HATCHET	4098481.546	587100.075	05/03/1968	<20	240	AA	No
03-57-141	U-3ga Cavity	FUNNEL	4100447.172	586161.0498	06/25/1968	<20	119	AA	No
03-57-142	U-3gb Cavity	FILE	4097196.797	585702.7821	10/31/1968	<20	229	AA	No
03-57-143	U-3gc Cavity	BARSAC	4097746.934	586188.4664	03/20/1969	<20	304	AA	No
03-57-144	U-3gd Cavity	AJO	4098720.625	585773.3694	01/30/1970	<20	304	AA	No
03-57-145	U-3ge Cavity	SAPELLO	4096950.295	584957.0295	04/12/1974	<20	181	AA	No
03-57-146	U-3gf Cavity	WINCH	4096341.448	585126.7688	02/04/1969	<20	240	TM-WTA	No
03-57-147	U-3gg Cavity	TORTUGAS	4102586.698	584708.7392	03/01/1984	20 to 150	639	LTCU	Yes
03-57-148	U-3gh Cavity	SCISSORS	4095733.01	585402.8627	12/12/1968	<20	240	AA	No
03-57-149	U-3gi Cavity	TULOSO	4098785.835	586976.8566	12/12/1972	<20	271	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 14 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-150	U-3gj Cavity	ALIMENT	4096664.297	590215.0395	05/15/1969	<20	240	OSBCU	No
03-57-151	U-3gk Cavity	SHAVE	4097056.971	589390.5339	01/22/1969	<20	241	UTCU	No
03-57-152	U-3gL Cavity	NIPPER	4095620.465	588085.2281	02/04/1969	<20	241	AA	No
03-57-153	U-3gm Cavity	HOREHOUND	4094527.759	589307.6767	08/27/1969	<20	332	LTCU	No
03-57-154	U-3gn Cavity	PLIERS	4097683.576	585487.8104	08/27/1969	<20	239	AA	No
03-57-155	U-3go Cavity	TAPPER	4096284.228	586193.5718	06/12/1969	<20	303	AA	No
03-57-156	U-3gq Cavity	BAY LEAF	4100523.28	586160.719	12/12/1968	<20	130	AA	No
03-57-157	U-3gr Cavity	MANZANAS	4096692.643	589603.6515	05/21/1970	<20	241	TSA	No
03-57-158	U-3gs Cavity	APODACA	4096936.17	589602.7647	07/21/1971	<20	241	LTCU	No
03-57-159	U-3gt Cavity	BIT-A	4100523.505	586226.2611	10/31/1968	<20	148	AA	No
		BIT-B	4100523.505	586226.2611	10/31/1968	<20	118	AA	No
03-57-160	U-3gu Cavity	MESCALERO	4100370.892	586220.7025	01/05/1972	<20	120	AA	No
03-57-161	U-3gv Cavity	BONARDA	4101519.982	584560.1703	09/25/1980	20 to 150	381	TM-WTA	No
03-57-162	U-3gx Cavity	ABEYTAS	4098590.685	587815.8388	11/05/1970	20 to 200	393	TM-LVTA	Yes
03-57-163	U-3gz Cavity	CUMARIN	4099402.018	588894.7911	02/25/1970	20 to 200	408	LTCU	Yes
03-57-164	U-3ha Cavity	CORAZON	4095520.12	585525.8529	12/03/1970	<20	241	AA	No
03-57-165	U-3hb Cavity	JIB	4095440.295	588756.0273	05/08/1974	<20	180	TM-UVTA	No
03-57-166	U-3hc Cavity	SPRIT	4099305.079	587310.4963	11/10/1976	<20	183	AA	No
03-57-167	U-3hd Cavity	EMBUDO	4099001.445	587646.75	06/16/1971	<20	303	AA	No
03-57-168	U-3he Cavity	BARRANCA	4098207.38	587131.5418	08/04/1971	<20	271	AA	No
03-57-169	U-3hf Cavity	FRIJOLES-GUAJE	4098025.919	587513.0946	09/22/1971	<20	257	AA	No
03-57-170	U-3hg Cavity	PEDERNAL	4096550.448	588234.3782	09/29/1971	<20	379	TM-LVTA	Yes
03-57-171	U-3hh Cavity	JAL	4095433.359	586866.97	03/19/1970	<20	301	AA	No
03-57-172	U-3hi-A Cavity	CULANTRO-A	4096963.2	588629.0288	12/10/1969	<20	134	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 15 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-173	U-3hi-B Cavity	CULANTRO-B	4096986.32	588781.3742	12/10/1969	<20	149	AA	No
03-57-174	U-3hj Cavity	SCUPPER	4097258.975	586068.2568	08/19/1977	<20	450	AA	Yes
03-57-175	U-3hk-a Cavity	IPECAC-A	4096993.908	588690.1871	05/27/1969	<20	124	AA	No
03-57-176	U-3hk-b Cavity	IPECAC-B	4096979.291	588872.8225	05/27/1969	<20	124	AA	No
03-57-177	U-3hk-d Cavity	SEAWEED B	4096729.981	589041.2891	10/16/1969	<20	119	AA	No
03-57-178	U-3hk-c Cavity	SEAWEED-E	4096857.911	589010.0485	10/01/1969	<20	124	AA	No
03-57-179	U-3hk-e Cavity	SEAWEED-C	4096601.958	589010.9599	10/01/1969	<20	119	AA	No
03-57-180	U-3hk-f Cavity	SEAWEED-D	4096499.228	588927.5113	10/01/1969	<20	119	AA	No
03-57-181	U-3hL Cavity	PENASCO	4096959.145	587471.0974	11/19/1970	<20	271	AA	No
03-57-182	U-3ho Cavity	TRUCHAS-CHAMISAL	4096871.903	587349.4832	10/28/1970	<20	118	AA	No
03-57-183	U-3hm Cavity	TRUCHAS-RODARTE	4096958.11	587166.3792	10/28/1970	<20	266	AA	No
03-57-184	U-3hn Cavity	TRUCHAS-CHACON	4096871.385	587288.5421	10/28/1970	<20	119	AA	No
03-57-185	U-3hq Cavity	PRATT	4096649.904	586192.2517	09/25/1974	<20	314	AA	No
03-57-186	U-3hr Cavity	CARRIZOZO	4095976.589	585341.4117	12/03/1970	<20	279	TM-WTA	No
03-57-187	U-3hs Cavity	DEXTER	4096783.816	587425.3969	06/23/1971	<20	120	AA	No
03-57-188	U-3ht Cavity	ATARQUE	4096704.975	587547.8395	07/25/1972	<20	294	AA	No
03-57-189	U-3hu Cavity	KEEL	4096570.368	587319.762	12/16/1974	<20	305	AA	No
03-57-190	U-3hv Cavity	COLMOR	4096662.299	587110.7013	04/26/1973	<20	246	AA	No
03-57-191	U-3hx Cavity	COWLES	4095434.382	587171.7429	02/03/1972	<20	302	AA	No
03-57-192	U-3hy Cavity	ELIDA	4095430.684	586105.174	12/19/1973	<20	381	AA	Yes
03-57-193	U-3hz Cavity	FRIJOLES-PETACA	4097750.466	587194.0725	09/22/1971	<20	226	AA	No
03-57-194	U-3j Cavity	PASCAL-A	4101045.552	585869.1363	07/26/1957	0.056	152	AA	No
03-57-195	U-3ja Cavity	ESTACA	4096029.431	587572.1759	10/17/1974	<20	321	TM-UVTA	No
03-57-196	U-3jb Cavity	BOBSTAY	4096160.856	587406.203	10/26/1977	<20	381	TM-WTA	Yes

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 16 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-197	U-3jc Cavity	CEBOLLA	4096112.906	587199.8175	08/09/1972	<20	287	AA	No
03-57-198	U-3jd Cavity	MESITA	4096013.555	587463.7821	05/09/1973	<20	149	AA	No
03-57-199	U-3je Cavity	HOSPAH	4098173.897	586278.4145	12/14/1971	<20	302	AA	No
03-57-200	U-3jf Cavity	SHALLOWS	4098482.766	587465.7603	02/26/1976	<20	245	AA	No
03-57-201	U-3jg Cavity	ANGUS	4095843.042	586362.6815	04/25/1973	<20	453	AA	Yes
03-57-202	U-3jh Cavity	BACKGAMMON	4094640.671	586763.0529	11/29/1979	<20	229	AA	No
03-57-203	U-3ji Cavity	PAJARA	4094366.415	586764.0815	12/12/1973	<20	278	AA	No
03-57-204	U-3jj Cavity	CAPITAN	4094492.026	586938.8326	06/28/1972	<20	134	AA	No
03-57-205	U-3jk Cavity	VELARDE	4094609.631	587035.9669	04/25/1973	<20	277	AA	No
03-57-206	U-3jL Cavity	PUYE	4097897.133	585639.3786	08/14/1974	<20	430	AA	Yes
03-57-207	U-3jm Cavity	JICARILLA	4096051.451	587416.0525	04/19/1972	<20	148	AA	No
03-57-208	U-3jn Cavity	ALGODONES	4101644.326	585604.2912	08/18/1971	20 to 200	528	TM-UVTA	Yes
03-57-209	U-3jp Cavity	OCATE	4095817.636	587572.9423	03/30/1972	<20	210	AA	No
03-57-210	U-3jq Cavity	MONERO	4102509.512	588670.6032	05/19/1972	<20	537	OSBCU	Yes
03-57-211	U-3jr Cavity	SPAR	4095955.72	587213.4488	12/19/1973	<20	148	AA	No
03-57-212	U-3js Cavity	ONAJA	4095921.805	587109.0653	03/30/1972	<20	279	AA	No
03-57-213	U-3jt Cavity	CUCHILLO	4095731.7	587201.4292	08/09/1972	<20	199	AA	No
03-57-214	U-3ju Cavity	FRIJOLES-ESPUELA	4097836.587	587422.2642	09/22/1971	<20	149	AA	No
03-57-215	U-3jv Cavity	RIB	4097263.582	587287.5231	12/14/1977	<20	213	AA	No
03-57-216	U-3jw Cavity	FRIJOLES-DEMING	4097714.784	587434.9098	09/22/1971	<20	150	AA	No
03-57-217	U-3jx Cavity	SOLANO	4095672.622	587411.5983	08/09/1972	<20	134	AA	No
03-57-218	U-3jy Cavity	BERNAL	4096529.826	586710.7812	11/28/1973	<20	285	AA	No
03-57-219	U-3k Cavity	COLFAX	4100720.157	585805.6533	10/05/1958	0.0055	107	AA	No
03-57-220	U-3kb Cavity	MARSH	4097930.704	586355.4435	09/06/1975	<20	427	AA	Yes

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 17 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-221	U-3kc Cavity	BILGE	4095554.716	586713.2915	02/19/1975	<20	318	AA	No
03-57-222	U-3kd Cavity	DECK	4097567.168	587042.3174	11/18/1975	<20	326	AA	No
03-57-223	U-3kf Cavity	FOREFOOT	4101405.231	586617.52	06/02/1977	<20	194	AA	No
03-57-224	U-3kg Cavity	PUDDLE	4095436.947	587903.0201	11/26/1974	<20	184	AA	No
03-57-225	U-3ki Cavity	COVE	4096040.436	586102.7122	02/16/1977	<20	335	AA	No
03-57-226	U-3kj Cavity	JACKPOTS	4097594.041	586035.4025	06/01/1978	<20	304	AA	No
03-57-227	U-3kk Cavity	CERNADA	4096256.094	586773.9123	09/24/1981	<20	213	AA	No
03-57-228	U-3km Cavity	OARLOCK	4096802.786	586344.0851	02/16/1977	<20	318	AA	No
03-57-229	U-3kn Cavity	CONCENTRATION	4098602.13	586720.2433	12/01/1978	<20	247	AA	No
03-57-230	U-3kp Cavity	SEAMOUNT	4097595.617	586646.6641	11/17/1977	<20	370	AA	No
03-57-231	U-3kq Cavity	MEMORY	4098383.879	585332.9802	03/14/1979	<20	365	AA	No
03-57-232	U-3kr Cavity	CLAIRETTE	4096512.184	586025.4888	02/05/1981	<20	354	AA	No
03-57-233	U-3ks Cavity	OFFSHORE	4096961.645	588171.994	08/08/1979	20 to 150	397	LTCU	Yes
03-57-234	U-3kt Cavity	EBBTIDE	4098931.322	585026.2733	09/15/1977	<20	379	AA	No
03-57-235	U-3ku Cavity	VERDELLO	4096758.937	586862.3596	07/31/1980	<20	366	AA	No
03-57-236	U-3kv Cavity	VICTORIA	4095924.838	587992.7234	06/19/1992	<20	244	AA	No
03-57-237	U-3kw Cavity	FREEZEOUT	4095114.986	587325.1582	05/11/1979	<20	335	AA	No
03-57-238	U-3kx Cavity	CANFIELD	4101529.092	587150.3269	05/02/1980	<20	351	TM-LVTA	No
03-57-239	U-3ky Cavity	HURON KING	4097885.937	585837.5203	06/24/1980	<20	320	AA	No
03-57-240	U-3kz Cavity	ALEMAN	4102951.327	584403.0639	09/11/1986	<20	503	TM-LVTA	Yes
03-57-241	U-3La Cavity	BOUSCHET	4102952.984	584779.1275	05/07/1982	20 to 150	564	LTCU	Yes
03-57-242	U-3Lb Cavity	NAVATA	4101239.15	587029.1741	09/29/1983	<20	183	AA	No
03-57-243	U-3Lc Cavity	SABADO	4095073.999	588666.4236	08/11/1983	<20	320	UTCU	No
03-57-244	U-3Ld Cavity	VILLITA	4095328.426	587354.9049	11/10/1984	<20	372	AA	Yes

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 18 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-245	U-3Lf Cavity	CERRO	4097507.707	587484.379	09/02/1982	<20	229	AA	No
03-57-246	U-3Lg Cavity	FLORA	4095644.032	586104.4289	05/22/1980	<20	335	AA	No
03-57-247	U-3Lh Cavity	TENAJA	4097189.562	588003.8694	04/17/1982	<20	356	TM-LVTA	No
03-57-248	U-3Li Cavity	MOGOLLON	4096584.05	584790.7627	04/20/1986	<20	259	TM-UVTA	No
03-57-249	U-3Lj Cavity	TREBBIANO	4101733.327	584559.1031	09/04/1981	<20	305	TM-UVTA	No
03-57-250	U-3Lk Cavity	MONAHANS-A	4094336.359	587035.6592	11/09/1988	<20	290	AA	No
03-57-251	U-3LL Cavity	TORNERO	4096477.877	584913.0113	02/11/1987	<20	298	TM-WTA	No
03-57-252	U-3Lm Cavity	SEYVAL	4097929.176	586020.1639	11/12/1982	<20	366	AA	No
03-57-253	U-3Lo Cavity	COALORA	4101520.87	584803.8992	02/11/1983	<20	274	TM-UVTA	No
03-57-254	U3Lp Cavity (2)	WHITEFACE-A	4098173.254	586095.5219	12/20/1989	<20	197	AA	No
		WHITEFACE-B	4098173.254	586095.5219	12/20/1989	<20	183	AA	No
03-57-255	U-3Lr Cavity	VAUGHN	4101734.108	584803.1826	03/15/1985	20 to 150	426	TM-LVTA	Yes
03-57-256	U-3Ls Cavity	MUGGINS	4096706.062	584820.7705	12/09/1983	<20	244	TM-UVTA	No
03-57-257	U-3Lt Cavity	MINERO	4096617.421	584910.0993	12/20/1984	<20	245	TM-UVTA	No
03-57-258	U-3Lu Cavity	WACO	4094930.55	588508.1812	12/01/1987	<20	183	AA	No
03-57-259	U-3Lv Cavity	DUORO	4095335.675	585069.3372	06/20/1984	20 to 150	381	TM-UVTA	Yes
03-57-260	U-3Lw Cavity	CORREO	4097190.289	588201.6418	08/02/1984	<20	334	TM-LVTA	No
03-57-261	U-3Lz Cavity	CHAMITA	4095548.911	585068.6193	08/17/1985	<20	332	TM-UVTA	No
03-57-262	U-3m Cavity	LUNA	4100764.733	585846.9098	09/21/1958	0.0015	148	AA	No
03-57-263	U-3mc Cavity	ABO	4100914.191	585628.8484	10/30/1985	<20	196	AA	No
03-57-264	U-3me Cavity	KINIBITO	4101200.903	584805.0638	12/05/1985	20 to 150	579	LTCU	Yes
03-57-265	U-3mf Cavity	TAHOKA	4102054.408	584802.0141	08/13/1987	20 to 150	639	LTCU	Yes
03-57-266	U-3mg Cavity	PANCHUELA	4095137.528	585070.0813	06/30/1987	<20	319	AA	No
03-57-267	U-3mh Cavity	LAREDO	4098948.742	589992.7735	05/21/1988	<150	351	LTCU	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 19 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
03-57-268	U-3mk Cavity	BOWIE	4102847.689	589522.6431	04/06/1990	<20	213	TM-LVTA	No
03-57-269	U-3mL Cavity	DIVIDER	4097638.538	589952.617	09/23/1992	<20	340	LTCU	No
03-57-270	U-3mn Cavity	ABILENE	4096752.217	584942.5572	04/07/1988	<20	245	TM-UVTA	No
03-57-271	U-3mt Cavity	LUBBOCK	4102328.664	584800.7737	10/18/1991	20 to 150	457	LTCU	Yes
03-57-272	U-3n Cavity	BERNALILLO	4100800.629	585896.4356	09/17/1958	0.015	139	AA	No
03-57-273	U-3p Cavity	SAN JUAN	4100825.823	585951.8503	10/20/1958	Zero	71	AA	No
03-57-274	U-3q Cavity	OTERO	4100839.075	586011.2102	09/12/1958	0.038	146	AA	No
03-57-275	U-3r Cavity	VALENCIA	4100806.513	586191.0932	09/26/1958	0.002	148	AA	No
04-57-001	U-4a Cavity	STRAIT	4107187.396	584113.334	03/17/1976	200 to 500	782	OSBCU	Yes
04-57-002	U-4aa Cavity	TRUMBULL	4105588.646	580371.0118	09/26/1974	<20	263	TM-LVTA	No
04-57-003	U-4ab Cavity	TEMESCAL	4105589.597	580645.2819	11/02/1974	<20	263	AA	No
04-57-004	U-4ac Cavity	BELLOW	4105512.957	580508.4288	05/16/1984	<20	207	TM-LVTA	No
04-57-005	U-4af Cavity	CARNELIAN	4106077.452	580704.5212	07/28/1977	<20	208	AA	No
04-57-006	U-4ah Cavity	KARAB	4104708.784	581547.3758	03/16/1978	<20	331	LTCU	No
04-57-007	U-4ai Cavity	BURZET	4104583.241	582591.5312	08/03/1979	20 to 150	450	AA	Yes
04-57-008	U-4aj Cavity	MONTEREY	4106615.338	582119.6676	07/29/1982	20 to 150	400	TM-LVTA	Yes
04-57-009	U-4ak Cavity	TILCI	4103738.104	582723.9879	11/11/1981	20 to 150	445	AA	Yes
04-57-010	U-4aL Cavity	MANTECA	4104163.597	582417.7578	12/10/1982	20 to 150	411	AA	Yes
04-57-011	U-4am Cavity	VILLE	4105055.144	581337.9965	06/12/1985	<20	291	TM-LVTA	No
04-57-012	U-4an Cavities (3)	COSO-BRONZE	4106844.466	582201.1496	03/08/1991	<20	333	TM-WTA	No
		COSO-GRAY	4106844.466	582201.1496	03/08/1991	<20	442	LTCU	Yes
		COSO-SILVER	4106844.466	582201.1496	03/08/1991	<20	475	LTCU	Yes
04-57-013	U-4ar Cavity	BRETON	4104885.761	582473.9974	09/13/1984	20 to 150	483	TM-LVTA	Yes
04-57-014	U-4as Cavity	ROQUEFORT	4107423.898	577987.6722	10/16/1985	20 to 150	415	TM-LVTA	Yes

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 20 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
04-57-015	U-4at Cavities (3)	PALISADE-1	4107165.043	578034.3177	05/15/1989	<20	335	TM-LVTA	No
		PALISADE-2	4107165.043	578034.3177	05/15/1989	<20	390	TM-LVTA	Yes
		PALISADE-3	4107165.043	578034.3177	05/15/1989	<20	404	TM-LVTA	Yes
04-57-016	U-4au Cavity	BULLFROG	4104804.312	582711.0562	08/30/1988	<150	489	TM-WTA	Yes
04-57-017	U-4av Cavity	BRISTOL	4105974.433	582602.4525	11/26/1991	<20	457	LTCU	Yes
04-57-018	U-4b Cavity	MACKEREL	4105895.62	584282.0998	02/18/1964	<20	334	TM-LVTA	No
04-57-019	U-4c Cavity	ZAZA	4106241.528	584056.0188	09/27/1967	20 to 200	667	LTCU	Yes
04-57-020	U-4d Cavity	LATIR	4106851.149	584084.3385	02/27/1974	20 to 200	641	LTCU	Yes
04-57-021	U-4e Cavity	TOPGALLANT	4107063.687	583778.8378	02/28/1975	20 to 200	713	LTCU	Yes
04-57-022	U-4f Cavity	TRANSOM	4105022.835	584121.2192	05/10/1978	Zero	640	LTCU	Yes
04-57-023	U-4g Cavity	ICEBERG	4106577.407	584237.3445	03/23/1978	20 to 150	640	LTCU	Yes
04-57-024	U-4h Cavity	SCANTLING	4107490.57	583929.7483	08/19/1977	20 to 150	701	OSBCU	Yes
04-57-025	U-4i Cavity	GLENCOE	4104481.756	582934.6654	03/22/1986	29	610	OSBCU	Yes
04-57-026	U-4j Cavity	JORNADA	4105419.793	584241.432	01/28/1982	139	639	LTCU	Yes
04-57-027	U-4L Cavity	QUINELLA	4106652.46	583908.3143	02/08/1979	20 to 150	579	LTCU	Yes
04-57-028	U-4n Cavity	HEARTS	4105059.973	584107.0719	09/06/1979	140	640	LTCU	Yes
04-57-029	U-4o Cavity	TECHADO	4107004.301	584388.5083	09/22/1983	<150	532	LTCU	Yes
04-57-030	U-4p Cavity	ROUSANNE	4107286.573	584423.185	11/12/1981	20 to 150	517	LTCU	Yes
04-57-031	U-4q Cavity	CAPROCK	4106730.707	584511.394	05/31/1984	20 to 150	600	LTCU	Yes
04-57-032	U-4r Cavity	VERMEJO	4104740.007	584108.4813	10/02/1984	<20	350	TM-UVTA	No
04-57-033	U-4s Cavity	TULIA	4104808.73	583901.0431	05/26/1989	<20	398	TM-UVTA	Yes
04-57-034	U-4t Cavity	GASCON	4106430.596	584512.4443	11/14/1986	20 to 150	593	LTCU	Yes
04-57-035	U-4u Cavity	DALHART	4105161.389	584419.1129	10/13/1988	<150	640	LTCU	Yes
06-57-001	U-6a Cavity	RUSSET	4091959.298	583968.0098	03/05/1968	<20	120	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 21 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
06-57-002	U-6d Cavity	PRESIDIO	4093458.41	588513.3235	04/22/1987	<20	320	TM-LVTA	No
06-57-003	U-6e Cavity	AUSTIN	4094534.029	588509.5649	06/21/1990	<20	351	TM-LVTA	No
06-57-004	U-6g Cavity	HARLINGEN-A	4094337.843	587309.3172	08/23/1988	<20	290	AA	No
06-57-005	U-6h Cavity	HARLINGEN-B	4094063.589	587310.5411	08/23/1988	<20	290	AA	No
06-57-006	U-6i Cavity	MONAHANS-B	4094062.654	587036.3346	11/09/1988	<20	290	AA	No
07-57-001	U-7a Cavity	FOREST	4107196.967	585911.2111	10/31/1964	<20	387	LTCU	No
07-57-002	U-7aa Cavity	TAJIQUE	4103061.041	589521.8941	06/28/1972	<20	332	LTCU	No
07-57-003	U-7ab Cavity	REDMUD	4104124.906	588664.94	12/08/1976	<20	427	LTCU	No
07-57-004	U-7ac Cavity	ESCABOSA	4103627.654	585984.968	07/10/1974	20 to 200	639	LTCU	Yes
07-57-005	U-7ad Cavity	MIERA	4106800.81	586405.085	03/08/1973	20 to 200	568	OSBCU	Yes
07-57-006	U-7ae Cavity	STRAKE	4104930.542	588189.7278	08/04/1977	20 to 150	518	LTCU	Yes
07-57-007	U-7af Cavity	POTRILLO	4105518.347	586374.485	06/21/1973	20 to 200	567	OSBCU	Yes
07-57-008	U-7ag Cavity	OBAR	4107382.476	586215.6289	04/30/1975	20 to 200	569	OSBCU	Yes
07-57-009	U-7ah Cavity	MIZZEN	4105820.27	585581.8015	06/03/1975	20 to 200	637	LTCU	Yes
07-57-010	U-7ai Cavity	KEELSON	4102988.488	586139.3277	02/04/1976	20 to 200	639	LTCU	Yes
07-57-011	U-7aj-S Cavity	RUDDER	4106448.2	585543.8855	12/28/1976	20 to 150	639	OSBCU	Yes
07-57-012	U-7ak Cavity	ESROM	4107124.063	585451.3692	02/04/1976	20 to 200	655	LTCU	Yes
07-57-013	U-7aL Cavity	DRAUGHTS	4103509.435	587051.9378	09/27/1978	20 to 150	442	OSBCU	Yes
07-57-014	U-7am Cavity	BULKHEAD	4105822.831	586312.7988	04/27/1977	20 to 150	594	OSBCU	Yes
07-57-015	U-7an Cavity	BILLET	4103654.365	584918.3308	07/27/1976	20 to 150	636	LTCU	Yes
07-57-016	U-7ao Cavity	PINEAU	4105155.091	587076.3974	07/16/1981	<20	207	TM-UVTA	No
07-57-017	U-7ap Cavity	CREWLINE	4105756.615	584804.3148	05/25/1977	20 to 150	564	LTCU	Yes
07-57-018	U-7aq Cavity	SANDREEF	4103286.745	584371.4415	11/09/1977	20 to 150	701	LTCU	Yes
07-57-019	U-7at Cavity	CHESS	4107259.108	587434.9408	06/20/1979	<20	335	LTCU	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 22 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
07-57-020	U-7au Cavity	RUMMY	4104139.587	584246.2041	09/27/1978	20 to 150	640	LTCU	Yes
07-57-021	U-7av Cavity	LOWBALL	4104020.38	584917.3181	07/12/1978	20 to 150	565	LTCU	Yes
07-57-022	U-7ax Cavity	BACCARAT	4107016.301	587740.5798	01/24/1979	<20	326	OSBCU	No
07-57-023	U-7ay Cavity	TOPMAST	4106282.559	587042.2831	03/23/1978	<20	458	OSBCU	No
07-57-024	U-7b Cavity	AUK	4103970.082	588056.0091	10/02/1964	<20	452	LTCU	Yes
07-57-025	U-7ba Cavity	BASEBALL	4104953.737	584822.3353	01/15/1981	20 to 150	564	LTCU	Yes
07-57-026	U-7bd Cavity	PALIZA	4104379.534	588028.0055	10/01/1981	20 to 150	472	LTCU	Yes
07-57-027	U-7be Cavity	PYRAMID	4106522.895	586070.2209	04/16/1980	20 to 150	579	OSBCU	Yes
07-57-028	U-7bg Cavity	ALIGOTE	4106628.641	588421.4491	05/29/1981	<20	320	LTCU	No
07-57-029	U-7bh Cavity	FAHADA	4106743.938	588274.7617	05/26/1983	<20	384	OSBCU	No
07-57-030	U-7bi Cavity	DOLCETTO	4105295.424	588852.8193	08/30/1984	<20	365	LTCU	No
07-57-031	U-7bk Cavity	MULESHOE	4107137.432	587588.3385	11/15/1989	<20	244	LTCU	No
07-57-032	U-7bL Cavity	TAJO	4106222.876	587408.1728	06/05/1986	20 to 150	518	LTCU	Yes
07-57-033	U-7bm Cavity	DUTCHESS	4103607.022	588879.7421	10/24/1980	<20	427	LTCU	No
07-57-034	U-7bo Cavity	MUNDO	4107096.548	586788.6198	05/01/1984	20 to 150	566	OSBCU	Yes
07-57-035	U-7bp Cavity	ATRISCO	4104668.581	588221.1756	08/05/1982	138	640	OSBCU	Yes
07-57-036	U-7br Cavity	BORREGO	4105421.112	584805.4631	09/29/1982	<150	563	LTCU	Yes
07-57-037	U-7bs Cavity	HERMOSA	4105821.449	585916.3269	04/02/1985	20 to 150	638	LTCU	Yes
07-57-038	U-7bu Cavity	TURQUOISE	4103371.559	584731.009	04/14/1983	<150	533	LTCU	Yes
07-57-039	U-7bv Cavity	PONIL	4105294.735	588639.5028	09/27/1985	<20	365	LTCU	No
07-57-040	U-7by Cavity	MIDLAND	4106799.34	586705.2079	07/16/1987	20 to 150	487	OSBCU	Yes
07-57-041	U-7ca Cavity	TEXARKANA	4103850.715	588757.2518	02/10/1989	20 to 150	504	OSBCU	Yes
07-57-042	U-7cb Cavity	FLOYDADA	4105020.139	588640.4301	08/15/1991	<20	503	OSBCU	Yes
07-57-043	U-7e Cavity	PIRANHA	4104937.38	585827.7257	05/13/1966	20 to 200	549	LTCU	Yes

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 23 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
07-57-044	U-7f Cavity	BRONZE	4106156.111	585854.2633	07/23/1965	20 to 200	531	LTCU	Yes
07-57-045	U-7g Cavity	CHARCOAL	4103967.26	587324.6711	09/10/1965	20 to 200	455	LTCU	Yes
07-57-046	U-7h Cavity	CABRESTO	4103963.201	586075.2507	05/24/1973	<20	198	AA	No
07-57-047	U-7j Cavity	LIME	4106708.723	587009.9829	04/01/1966	<20	561	OSBCU	Yes
07-57-048	U-7k Cavity	TAN	4102895.197	585682.8421	06/03/1966	20 to 200	561	TM-LVTA	Yes
07-57-049	U-7i Cavity	LAMPBLACK	4105488.983	587134.0158	01/18/1966	20 to 200	561	OSBCU	Yes
07-57-050	U-7m Cavity	MICKEY	4103974.184	589229.1632	05/10/1967	20 to 200	500	LTCU	Yes
07-57-051	U-7n Cavity	BOURBON	4106409.299	588443.5659	01/20/1967	20 to 200	560	LCA	Yes
07-57-052	U-7o Cavity	DAIQUIRI	4106765.396	585608.2989	09/23/1966	<20	561	LTCU	Yes
07-57-053	U-7p Cavity	BLENTON	4104364.2	587566.9817	04/30/1969	20 to 200	558	LTCU	Yes
07-57-054	U-7r Cavity	SHAPER	4104880.042	586925.5457	03/23/1970	20 to 200	561	OSBCU	Yes
07-57-055	U-7s Cavity	GRAPE A	4104581.677	588663.3448	12/17/1969	20 to 200	551	OSBCU	Yes
07-57-056	U-7t Cavity	THISTLE	4105341.937	588294.6695	04/30/1969	20 to 200	561	OSBCU	Yes
07-57-057	U-7u Cavity	COBBLER	4105485.177	585612.4854	11/08/1967	<20	667	LTCU	Yes
07-57-058	U-7v Cavity	GRAPE B	4106188.98	586433.1236	02/04/1970	20 to 200	554	LTCU	Yes
07-57-059	U-7w Cavity	TORRIDO	4103669.189	589230.2515	05/27/1969	20 to 200	515	OSBCU	Yes
07-57-060	U-7x Cavity	ARTESIA	4106438.201	588077.4631	12/16/1970	20 to 200	485	LTCU	No
07-57-061	U-7y Cavity	TIJERAS	4103166.674	588363.2008	10/14/1970	20 to 200	561	OSBCU	Yes
07-57-062	U-7z Cavity	OSCURO	4104402.83	585555.3682	09/21/1972	20 to 200	560	LTCU	Yes
08-57-001	U-8a Cavity	DISCUS THROWER	4115036.274	580014.5517	05/27/1966	22	337	TM-LVTA	No
08-57-002	U-8b Cavity	CYATHUS	4114456.704	580553.2159	03/06/1970	8.7	294	TM-LVTA	No
08-57-003	U-8c Cavity	NORBO	4115221.574	581312.3095	03/08/1980	<20	271	OSBCU	No
08-57-004	U8e Cavity (2)	CREMINO	4114226.862	580962.9507	09/27/1978	<20	210	AA	No
		CREMINO-CAERPHILLY	4114226.862	580962.9507	09/27/1978	<20	420	TM-LVTA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 24 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
08-57-005	U-8j Cavity	COTTAGE	4115219.692	580794.3122	03/23/1985	20 to 150	515	OSBCU	No
08-57-006	U-8k Cavity	VIDE	4114930.281	581169.5241	04/30/1981	<20	323	OSBCU	No
08-57-007	U-8L Cavity	SECO	4115437.274	581210.087	02/25/1981	<20	200	OSBCU	No
08-57-008	U-8m Cavity	FRISCO	4114641.13	580903.0327	09/23/1982	20 to 150	451	OSBCU	No
08-57-009	U8n Cavity (2)	KAWICH A-BLUE	4114700.787	580552.3893	12/09/1988	<20	384	OSBCU	No
		KAWICH A-WHITE	4114700.787	580552.3893	12/09/1988	<20	369	LTCU	No
08-57-010	U-8d Cavity	BANEBERRY	4114452.019	579922.0876	12/18/1970	10	278	TM-LVTA	No
09-57-001	U-9 ITS T-28 Cavity	AVENS-ANDORRE	4111030.055	585227.6656	12/16/1970	<20	379	LTCU	No
09-57-002	U-9 ITS U-24 Cavity	AVENS-ALKERMES	4110543.119	585351.2646	12/16/1970	<20	306	TM-LVTA	No
09-57-003	U9itsv26 Cavity	ARABIS-RED	4110787.105	585471.995	03/06/1970	<20	250	TM-LVTA	No
09-57-004	U9iv24 Cavity	FOB-RED	4110543.575	585472.8659	01/23/1970	<20	266	TM-LVTA	No
09-57-005	U9iv27 Cavity	FOB-GREEN	4110908.925	585471.5589	01/23/1970	<20	244	TM-LVTA	No
09-57-006	U-9 ITS W-21 Cavity	AVENS-ASMALTE	4110178.352	585596.0488	12/16/1970	<20	308	LTCU	No
09-57-007	U-9 ITS X-20 Cavity	HOD-B (RED)	4110056.556	585718.9875	05/01/1970	<20	265	TM-LVTA	No
09-57-008	U-9 ITS X-23 Cavity	HOD-A (GREEN)	4110422.569	585717.3974	05/01/1970	<20	241	TM-LVTA	No
09-57-009	U-9 ITS X-24 Cavity	SCREE-ACAJOU	4110550.269	585716.8981	10/13/1970	<20	249	TM-LVTA	No
09-57-010	U-9 ITS X-27 Cavity	PITON-B	4110909.524	585716.2643	05/28/1970	<20	230	TM-LVTA	No
09-57-011	U-9 ITS X-28 Cavity	ARABIS-GREEN	4111031.671	585715.1996	03/06/1970	<20	259	TM-LVTA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 25 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
09-57-012	U-9 ITS X-29 Cavity	AVENS-CREAM	4111153.273	585715.1174	12/16/1970	<20	293	LTCU	No
09-57-013	U9iy27 Cavity	FOB-BLUE	4110909.985	585837.8605	01/23/1970	<20	101	TM-LVTA	No
09-57-014	U-9 ITS Y-30 Cavity	PITON-A	4111275.888	585836.2651	05/28/1970	<20	237	TM-LVTA	No
09-57-015	U-9 ITS Z-21 Cavity	SCREE-ALHAMBRA	4110179.635	585962.0247	10/13/1970	<20	192	TM-LVTA	No
09-57-016	U-9 ITS Z-24 Cavity	SCREE-CHAMOIS	4110541.657	585960.731	10/13/1970	<20	101	TM-LVTA	No
09-57-017	U9iz25 Cavity	HOD-C (BLUE)	4110666.917	585960.2529	05/01/1970	<20	101	TM-LVTA	No
09-57-018	U-9 ITS Z-26 Cavity	ARABIS-BLUE	4110788.735	585959.5434	03/06/1970	<20	101	TM-LVTA	No
09-57-019	U-9 ITS Z-27 Cavity	NAMA-MEPHISTO	4110910.67	585959.4544	08/05/1971	<20	244	TM-LVTA	No
09-57-020	U-9 ITS-XY-31 Cavity	NAMA-AMARYLIS	4111397.643	585774.894	08/05/1971	<20	273	LTCU	No
09-57-021	U9itsw22 Cavity	HAPLOPAPPUS	4110299.997	585611.1584	06/28/1972	<20	184	TM-LVTA	No
09-57-022	U9itsw24.5 Cavity	SOLANUM	4110620.101	585655.6963	12/14/1972	<20	183	TM-LVTA	No
09-57-023	U-9a Cavity	MAD	4109333.714	584422.0642	12/13/1961	0.5	182	AA	No
09-57-024	U-9aa Cavity	TAUNTON	4109497.02	584309.7358	12/04/1962	Low	228	AA	No
09-57-025	U-9ab Cavity	KAWEAH	4108639.061	584699.7388	02/21/1963	3	227	AA	No
09-57-026	U-9ac Cavity	TOYAH	4109251.509	584776.8321	03/15/1963	Low	131	AA	No
09-57-027	U-9ad Cavity	MISSISSIPPI	4110752.353	584268.7569	10/05/1962	115	494	TM-LVTA	Yes
09-57-028	U-9ae Cavity	STONES	4107616.934	585300.5597	05/22/1963	Intermediate	393	TM-LVTA	No
09-57-029	U-9af Cavity	MANATEE	4109079.649	585206.4305	12/14/1962	Low	60	AA	No
09-57-030	U-9ah Cavity	PLEASANT	4109501.781	584894.7814	05/29/1963	Low	211	AA	No
09-57-031	U-9ai Cavity	APSHAPA	4109125.334	585203.8366	06/06/1963	Low	89	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 26 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
09-57-032	U-9aj Cavity	GARDEN	4108287.94	585997.3058	10/23/1964	<20	150	TM-LVTA	No
09-57-033	U-9ak #1 Cavity	NATCHES	4109163.652	585623.9425	08/23/1963	Low	59	AA	No
09-57-034	U-9ak Cavity	KOHOCTON	4109163.639	585611.7711	08/23/1963	Low	255	TM-LVTA	No
09-57-035	U-9aL Cavity	AJAX	4110204.063	584316.0786	11/11/1966	<20	238	AA	No
09-57-036	U-9ao Cavity	FORE	4111072.723	584373.9166	01/16/1964	20 to 200	491	TM-LVTA	No
09-57-037	U-9ap Cavity	RACK	4109015.794	584472.8677	08/15/1968	<20	200	AA	Yes
09-57-038	U-9aq Cavity	TORNILLO	4108474.86	585754.3492	10/11/1963	0.38	150	AA	No
09-57-039	U-9ar Cavity	DRIVER	4108637.694	585180.8654	05/07/1964	<20	148	AA	No
09-57-040	U-9at Cavity	MUSTANG	4109966.962	584582.0206	11/15/1963	Low	166	AA	No
09-57-041	U-9au Cavity	BOGEY	4108557.371	585750.756	04/17/1964	<20	119	AA	No
09-57-042	U-9av Cavity	EAGLE	4109827.976	584850.6324	12/12/1963	5.3	165	AA	No
09-57-043	U-9aw Cavity	BACKSWING	4108316.295	585304.239	05/14/1964	<20	163	AA	No
09-57-044	U-9ax Cavity	GREYS	4108529.158	584748.8212	11/22/1963	Intermediate	301	AA	No
09-57-045	U-9ay Cavity	OCONTO	4109324.572	585529.5582	01/23/1964	10.5	265	TM-LVTA	No
09-57-046	U-9az Cavity	TINDERBOX	4110815.794	584984.5859	11/22/1968	<20	440	LTCU	No
09-57-048	U-9b Cavity	WHITE	4109137.477	584136.9784	05/25/1962	Low	193	AA	No
09-57-049	U-9ba Cavity	HANDICAP	4109714.598	585521.7817	03/12/1964	<20	144	AA	No
09-57-050	U-9bb Cavity	BUNKER	4109948.962	585874.4763	02/13/1964	<20	226	TM-LVTA	No
09-57-051	U-9bc Cavity	HOOK	4109608.434	586101.1071	04/14/1964	<20	204	TM-LVTA	No
09-57-052	U-9bd Cavity	SPOON	4107925.864	586503.2126	09/11/1964	<20	180	TM-LVTA	No
09-57-053	U-9be Cavity	FADE	4107635.657	586214.73	06/25/1964	<20	205	TM-LVTA	No
09-57-054	U-9bf Cavity	LINKS	4107923.83	585924.2465	07/23/1964	<20	120	AA	No
09-57-055	U-9bg Cavity	CHENILLE	4107665.943	586062.2052	04/22/1965	<20	141	TM-WTA	No
09-57-056	U-9bh Cavity	WOOL	4108514.507	586561.7699	01/14/1965	<20	216	TM-LVTA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 27 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
09-57-057	U-9bi-1 Cavity	TERRINE-WHITE	4108666.851	585671.4564	12/18/1969	20 to 200	457	TM-LVTA	Yes
09-57-058	U-9bi-2 Cavity	TERRINE-YELLOW	4108695.619	586218.9118	12/18/1969	20 to 200	418	LTCU	No
09-57-059	U-9bj Cavity	TICKING	4107804.129	586457.8995	08/21/1965	<20	210	TM-LVTA	No
09-57-060	U-9bk Cavity	SUEDE	4108113.553	586412.6113	03/20/1965	<20	143	TM-LVTA	No
09-57-061	U-9bm Cavity	SEERSUCKER	4108315.157	586011.5112	02/19/1965	<20	144	TM-LVTA	No
09-57-062	U-9bn Cavity	TWEED	4108458.823	586303.2529	05/21/1965	<20	284	TM-LVTA	No
09-57-063	U-9bo Cavity	ORGANDY	4108155.447	586700.1575	06/11/1965	<20	173	TM-LVTA	No
09-57-064	U-9bp Cavity	IZZER	4108061.248	585908.4522	07/16/1965	<20	164	AA	No
09-57-065	U-9br Cavity	MAXWELL	4108200.139	586319.4056	01/13/1966	<20	183	TM-LVTA	No
09-57-066	U-9bs Cavity	ELKHART	4107618.619	585696.7655	09/17/1965	<20	220	TM-WTA	No
09-57-067	U-9bt Cavity	TEMPLAR	4107877.723	585983.4503	03/24/1966	0.37	150	TM-WTA	No
09-57-068	U-9bu Cavity	HULA	4107860.434	585132.1138	10/29/1968	<20	198	AA	No
09-57-069	U-9bv Cavity	SWITCH	4109235.52	586209.1274	06/22/1967	3.1	302	LTCU	No
09-57-070	U-9bx Cavity	NOGGIN	4110384.964	584553.7535	09/06/1968	20 to 200	582	TM-LVTA	Yes
09-57-071	U-9by Cavity	VALISE	4110731.526	585111.0358	03/18/1969	<20	91	AA	No
09-57-072	U-9bz Cavity	BIGGIN	4110084.832	585170.0666	01/30/1969	<20	242	TM-LVTA	No
09-57-073	U-9c Cavity	STILLWATER	4109402.035	584075.349	02/08/1962	3.07	181	AA	No
09-57-074	U-9cb Cavity	CUP	4111668.579	584919.7648	03/26/1965	20 to 200	541	LTCU	Yes
09-57-075	U-9cc Cavity	PLAYER	4108315.421	585151.8672	08/27/1964	<20	90	AA	No
09-57-076	U-9ce Cavity	CLYMER	4111224.341	584068.9872	03/12/1966	<20	397	AA	No
09-57-077	U-9cf Cavity	VAT	4110083.874	584987.1691	10/10/1968	<20	195	AA	No
09-57-078	U-9cg Cavities (2)	GRUYERE	4111392.698	584373.1109	08/16/1977	<20	207	AA	No
		GRUYERE-GRADINO	4111392.698	584373.1109	08/16/1977	<20	320	AA	No
09-57-079	U-9ch Cavity	CATHAY	4107922.471	585451.9018	10/08/1971	<20	378	TM-LVTA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 28 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
09-57-080	U-9ci Cavity	ARSENATE	4108776.34	585887.664	11/09/1972	<20	250	TM-LVTA	No
09-57-081	U-9cj Cavity	ALUMROOT	4111605.69	584280.9179	02/14/1973	<20	183	AA	No
09-57-082	U-9ck Cavity	SILENE	4108043.275	585131.5125	06/28/1973	<20	198	AA	No
09-57-083	U-9cL Cavity	TELEME	4107973.316	586899.2009	02/06/1975	<20	305	LTCU	No
09-57-084	U-9cm Cavity	LEYDEN	4108324.416	587086.8828	11/26/1975	<20	326	LTCU	No
09-57-085	U-9cn Cavity	KESTI	4107989.94	587294.9713	06/16/1982	<20	288	LTCU	No
09-57-086	U-9cp Cavity	CAMPOS	4109295.183	585934.6184	02/13/1978	<20	320	TM-LVTA	No
09-57-087	U-9cq Cavity	DAUPHIN	4107684.5	587113.4829	11/14/1980	<20	320	LTCU	No
09-57-088	U-9cr Cavity	NIZA	4109569.138	585750.8618	07/10/1981	<20	341	LTCU	No
09-57-089	U-9cs Cavity	ARMADA	4107683.376	586778.3182	04/22/1983	<20	265	LTCU	No
09-57-090	U-9cv Cavities (3)	GALENA-GREEN	4109051.897	585981.1646	06/23/1992	<20	400	OSBCU	No
		GALENA-ORANGE	4109051.897	585981.1646	06/23/1992	<20	380	OSBCU	No
		GALENA-YELLOW	4109051.897	585981.1646	06/23/1992	<20	290	LTCU	No
09-57-091	U-9cw Cavity	CEBRERO	4107642.95	587494.231	08/14/1985	<20	183	TM-LVTA	No
09-57-092	U-9d Cavity	BRAZOS	4108841.256	584416.2444	03/08/1962	8.4	256	AA	No
09-57-093	U-9e Cavity	HATCHIE	4109271.421	585320.964	02/08/1963	Low	61	AA	No
09-57-094	U-9f Cavity	TIOGA	4109557.32	585176.1068	10/18/1962	Low	59	AA	No
09-57-095	U-9g Cavity	CODSAW	4109438.541	585455.1091	02/19/1962	Low	212	TM-WTA	No
09-57-096	U-9h Cavity	CIMARRON	4109584.063	584459.6235	02/23/1962	11.9	305	AA	No
09-57-098	U-9i Cavity	ANACOSTIA	4108930.66	586179.9933	11/27/1962	5.2	228	TM-LVTA	No
09-57-099	U9itss25 Cavity	BALTIC	4110663.916	585107.0108	08/06/1971	<20	412	TM-LVTA	No
09-57-100	U9itsyz26 Cavities (2)	CANNA-LIMOGES	4110788.425	585863.8811	11/17/1972	<20	213	TM-LVTA	No
		CANNA-UMBRINUS	4110788.425	585863.8811	11/17/1972	<20	183	TM-LVTA	No
09-57-101	U-9j Cavity	HOOSIC	4109093.669	585746.7243	03/28/1962	3.4	187	TM-LVTA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 29 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
09-57-102	U-9k Cavity	DEAD	4108506.373	585961.7599	04/21/1962	Low	194	AA	No
09-57-103	U-9L Cavity	PASSAIC	4108347.588	584853.7131	04/06/1962	Low	233	AA	No
09-57-104	U-9m Cavity	EEL	4108895.107	584564.1658	05/19/1962	4.5	218	AA	No
09-57-105	U-9n Cavity	HUDSON	4109401.084	584767.1549	04/12/1962	Low	151	AA	No
09-57-106	U-9p Cavity	BLACK	4108440.051	585407.3865	04/27/1962	Low	218	AA	No
09-57-107	U-9q Cavity	ROANOKE	4108902.888	584244.1563	10/12/1962	Low	177	AA	No
09-57-108	U-9r Cavity	ARIKAREE	4109443.289	584461.9221	05/10/1962	Low	166	AA	No
09-57-109	U-9u Cavity	RARITAN	4109748.888	584775.3845	09/06/1962	Low	156	AA	No
09-57-110	U-9v Cavity	SACRAMENTO	4108315.484	584551.4968	06/30/1962	Low	149	AA	No
09-57-111	U-9w Cavity	KOOTANAI	4108678.584	585537.621	04/24/1963	Low	182	AA	No
09-57-112	U-9w-1 Cavity	PAISANO	4108670.911	585546.7613	04/24/1963	Low	58	AA	No
09-57-113	U-9x Cavity	ALLEGHENY	4108246.971	585852.9825	09/29/1962	Low	211	TM-WTA	No
09-57-114	U-9y Cavity	WICHITA	4109672.006	583732.5005	07/27/1962	Low	150	AA	No
09-57-115	U-9z Cavity	YORK	4108458.148	585255.0029	08/24/1962	Low	226	AA	No
09-57-116	U-9 ITS AA-25 Cavity	PITON-C	4110667.277	586082.4755	05/28/1970	<20	101	TM-LVTA	No
10-57-001	U-10a Cavity	DUB	4114632.663	583691.0194	06/30/1964	11.7	258	AA	No
10-57-002	U-10aa Cavity	RIVET I	4113608.765	584575.5681	01/18/1967	<20	152	AA	No
10-57-003	U-10ab Cavity	VITO	4113624.521	584719.0809	07/14/1967	<20	97	AA	No
10-57-004	U-10ad Cavity	VIGIL	4114080.242	584413.9389	11/22/1966	<20	94	AA	No
10-57-005	U-10af Cavity	YARD	4112276.154	584035.1354	09/07/1967	20 to 200	521	TM-LVTA	Yes
10-57-006	U-10ag Cavity	WORTH	4112632.773	584403.4962	10/25/1967	<20	197	AA	No
10-57-007	U-10ah Cavity	STACCATO	4112633.188	583934.2423	01/19/1968	20 to 200	443	AA	No
10-57-008	U-10ai Cavity	POLKA	4112953.74	584013.5451	12/06/1967	<20	195	AA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 30 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
10-57-009	U-10aj-A Cavity	TUB-F	4113818.359	584972.8559	06/06/1968	<20	189	AA	No
10-57-010	U-10aj-B Cavity	TUB-B	4113643.272	584851.2862	06/06/1968	<20	189	AA	No
10-57-011	U-10aj-C Cavity	TUB-A	4113874.213	584933.3121	06/06/1968	<20	189	AA	No
10-57-012	U-10aj-D Cavity	TUB-D	4113817.114	584728.1534	06/06/1968	<20	273	TM-LVTA	No
10-57-013	U-10aj-F Cavity	TUB-C	4113644.413	585096.2613	06/06/1968	<20	189	AA	No
10-57-014	U-10ak Cavity	CROCK	4112754.31	585617.1283	05/08/1968	<20	182	AA	No
10-57-015	U-10am-1 Cavity	TUN-A	4113866.751	581667.2466	12/10/1969	<20	200	AA	No
10-57-016	U-10am-2 Cavity	TUN-B	4114064.791	581666.5686	12/10/1969	<20	194	AA	No
10-57-017	U-10am-3 Cavity	TUN-C	4113867.122	581865.3376	12/10/1969	<20	194	TM-LVTA	No
10-57-018	U-10am-4 Cavity	TUN-D	4114065.168	581865.2764	12/10/1969	<20	256	OSBCU	No
10-57-019	U-10an Cavity	LABIS	4113487.206	585261.9473	02/05/1970	25	442	LTCU	No
10-57-020	U-10ap-1 Cavity	CORNICE-YELLOW	4113708.214	585556.462	05/15/1970	20 to 200	390	OSBCU	No
10-57-021	U-10ap-3 Cavity	CORNICE-GREEN	4113260.758	585262.4642	05/15/1970	20 to 200	443	LTCU	No
10-57-022	U-10aq Cavity	BRACKEN	4113546.957	585803.002	07/09/1971	<20	305	LTCU	No
10-57-023	U-10ar Cavity	LAGOON	4115229.45	583978.4085	10/14/1971	<20	305	AA	No
10-57-024	U-10as Cavities (3)	PINEDROPS-BAYOU	4114603.892	584188.1458	01/10/1974	<20	343	TM-LVTA	No
		PINEDROPS-SLOAT	4114603.892	584188.1458	01/10/1974	<20	213	AA	No
		PINEDROPS-TAWNY	4114603.892	584188.1458	01/10/1974	<20	282	TM-LVTA	No
10-57-025	U-10at Cavity	DIANTHUS	4113664.845	583714.4935	02/17/1972	<20	305	AA	No
10-57-026	U-10av Cavity	KASHAN	4113279.782	583741.7648	05/24/1973	<20	265	AA	No
10-57-027	U-10aw Cavity	NATOMA	4115017.395	583909.0563	04/05/1973	<20	244	AA	No
10-57-028	U-10ax Cavity	AKBAR	4113279.32	585768.2558	11/09/1972	<20	267	TM-LVTA	No
10-57-029	U-10ay Cavity	CHEVRE	4114333.976	584024.5459	11/23/1976	<20	317	AA	No
10-57-030	U-10b Cavity	HANDCAR	4114617.113	582746.6847	11/05/1964	12	403	LCA	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 31 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
10-57-031	U10ba Cavity (2)	DOFINO	4114831.737	583994.4516	03/08/1977	<20	183	AA	No
		DOFINO-LAWTON	4114831.737	583994.4516	03/08/1977	<20	282	AA	No
10-57-032	U10bb Cavity (2)	PORTOLA	4115078.491	584116.3697	02/06/1975	<20	198	AA	No
		PORTOLA-LARKIN	4115078.491	584116.3697	02/06/1975	<20	275	AA	No
10-57-033	U-10bc Cavity	ASCO	4112448.477	585634.0913	04/25/1978	<20	183	TM-LVTA	No
10-57-034	U-10bd Cavity	PERA	4112493.092	585329.2047	09/08/1979	<20	200	TM-LVTA	No
10-57-035	U-10be Cavity	ORKNEY	4117302.715	583880.0528	05/02/1984	<20	210	AA	No
10-57-036	U-10bf Cavity	QUESO	4116344.882	584447.1488	08/11/1982	<20	216	AA	No
10-57-037	U-10bg Cavity	HAVARTI	4112356.888	585606.9587	08/05/1981	<20	200	TM-LVTA	No
10-57-038	U-10bh Cavities (3)	HAZEBROOK-APRICOT (ORANGE)	4115384.791	584389.5816	02/03/1987	<20	262	AA	No
		HAZEBROOK-CHECKERBERRY (RED)	4115384.791	584389.5816	02/03/1987	<20	226	AA	No
		HAZEBROOK-EMERALD (GREEN)	4115384.791	584389.5816	02/03/1987	<20	186	AA	No
10-57-039	U-10c Cavity	TURF	4111878.235	583807.6566	04/24/1964	20 to 200	506	TM-LVTA	Yes
10-57-040	U-10ca Cavity	JARLSBERG	4116706.259	585654.7833	08/27/1983	<20	200	TM-LVTA	No
10-57-041	U-10cb Cavity	NORMANNA	4116600.116	585625.8617	07/12/1984	<20	200	LTCU	No
10-57-042	U-10cc Cavity	BRIE	4116773.608	585567.6426	06/18/1987	<20	203	LTCU	No
10-57-043	U-10ds Cavity	DUFFER	4113713.125	585296.8646	06/18/1964	<20	447	LTCU	No
10-57-044	U-10ds-1 Cavity	MARVEL	4113693.329	585303.2808	09/21/1967	2.2	176	AA	No
10-57-045	U-10e Cavity	KLICKITAT	4112035.398	585162.8771	02/20/1964	70	492	LTCU	Yes
10-57-046	U-10f Cavity	SANTEE	4111848.395	583975.3677	10/27/1962	Low	319	AA	No
10-57-047	U-10g Cavity	CASSELMAN	4111801.691	584120.6009	02/08/1963	Low	303	AA	No
10-57-048	U-10i Cavity	BYE	4115505.814	584663.1284	07/16/1964	20 to 200	391	LTCU	No

Table A.1-1
Corrective Action Sites in the Yucca Flat/Climax Mine CAU
(Page 32 of 32)

CAS Number [a]	CAS Description [a]	Test Name [b]	UTM Northing (NAD83) [c]	UTM Easting (NAD83) [c]	Date Expended [b]	Announced Yield Range (kt) [b]	Working Point Depth (m) [c]	Working Point HSU [d]	Saturated Working Point [e]
10-57-049	U-10k Cavity	CORDUROY	4113561.227	584060.7621	12/03/1965	20 to 200	679	OSBCU	Yes
10-57-050	U-10m Cavity	REO	4112737.932	585282.3217	01/22/1966	<20	208	AA	No
10-57-051	U-10n Cavity	MUDPACK	4114997.993	582745.0709	12/16/1964	2.7	152	TM-LVTA	No
10-57-052	U-10p Cavity	KANKAKEE	4114318.377	584361.9185	06/15/1966	20 to 200	455	LCA	No
10-57-053	U-10q Cavity	STANLEY	4111789.017	584417.4574	07/27/1967	20 to 200	484	TM-LVTA	Yes
10-57-054	U-10r Cavity	WASHER	4112673.114	584520.6704	08/10/1967	<20	468	LTCU	Yes
10-57-055	U-10s Cavity	ROVENA	4114001.187	584463.5669	08/10/1966	<20	194	AA	No
10-57-056	U-10t Cavity	SHUFFLE	4112218.909	585436.5123	04/18/1968	20 to 200	493	ATCU	Yes
10-57-057	U-10u Cavity	NEWARK	4114001.718	584615.9277	09/29/1966	<20	229	AA	No
10-57-058	U-10w Cavity	SIMMS	4114144.571	584511.2292	11/05/1966	2.3	199	AA	No
10-57-059	U-10x Cavity	WARD	4113874.946	584521.0392	02/08/1967	<20	260	AA	No
10-57-060	U-10y Cavity	RIVET III	4113690.054	584383.6652	03/02/1967	<20	274	AA	No
10-57-061	U-10z Cavity	RIVET II	4113571.806	584441.6797	01/26/1967	<20	198	AA	No
15-57-001	U-15a Cavity	HARD HAT	4120380.606	583374.5823	02/15/1962	5.7	287	MGCU	Yes
15-57-002	U-15a.01 Cavity	PILE DRIVER	4120473.577	583708.5883	06/02/1966	62	463	MGCU	Yes
15-57-003	U-15e Cavity	TINY TOT	4120066.936	583585.9376	06/17/1965	<20	111	MGCU	No

[a] FFACO, 1996, as amended
[b] NNSA/NFO, 2015
[c] Modified from NNSA/NFO, 2015; to NAD83 coordinate system and to depth in meters
[d] Pawloski et al., 2008
[e] DOE/NV, 1997

A.1.0 References

DOE/NV, see U.S. Department of Energy, Nevada Operations Office.

FFACO, see *Federal Facility Agreement and Consent Order.*

Federal Facility Agreement and Consent Order. 1996 (as amended March 2010). Agreed to by the State of Nevada; U.S. Department of Energy, Environmental Management; U.S. Department of Defense; and U.S. Department of Energy, Legacy Management. Appendix VI, which contains the Underground Test Area Strategy, was last modified June 2014, Revision No. 5.

NNSA/NFO, see U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office.

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Appendix B

Yucca Flat/Climax Mine CAI Stage Activity Summary

Table B.1-1
CAIP Characterization Activities
(Page 1 of 8)

Scientific Objectives Presented in DOE/NV (2000)	Investigations Addressing Objectives
Mineralogy Study of the Tuff Confining Unit (TCU)	
• Estimate the lateral continuity and hydraulic characteristics of the TCU. • Determine the geochemistry of the alteration minerals. • Quantification of the alteration minerals. • Define the spatial variability of the alteration minerals. • Determine the extent of hydrothermal alteration.	• The TCU lateral distribution and continuity were determined from mineralogy studies (Prothro, 2005; WoldeGabriel et al., 2004) and borehole and geophysical data (BN, 2006). The thickness, extent and spatial distribution is represented in the Yucca Flat/Climax Mine HFM (BN, 2006). • The TCU was generally too impermeable to conduct constant rate pumping tests. Hydraulic characteristics of the TCU estimated from slug tests are documented in Halford et al. (2005) and SNJV (2006b), which includes core-scale permeability and porosity measurements. Additional TCU core-scale property measurements are reported in DBS&A (2008) and N-I (2013). These measurements show a large range of hydraulic conductivity at the core-scale within the TCU. The TCU hydrogeologic character is also discussed in Drellack et al. (2010) and Prothro (2008), which describes fracture characteristics. The characteristics of faults in the TCU are discussed in Sweetkind and Drake (2007) and Prothro et al. (2009). • Bulk rock chemistry and mineralogy of the TCU and other tuffaceous rocks are discussed in WoldeGabriel et al. (2004). The mineralogy of fracture-lining minerals in the TCU and their isotopic characteristics (^{13}C and ^{18}O) are reported in Dickerson et al. (2004). The isotopic data indicate that fracture-lining minerals formed under nonhydrothermal conditions are indicative of downwardly percolating water. Altered volcanic rocks that form the TCU beneath Yucca Flat consist mainly of three major mineral assemblages: zeolite, felsic minerals, and clay minerals (Prothro, 2005). Based on the dominant mineral assemblage, the TCU can be subdivided into three zones: (1) an upper zone, which comprises both the upper and lower tuff confining units (UTCU and LTCU); (2) a middle zone, which correlates to the Oak Spring Butte confining unit (OSBCU); and (3) a basal argillic zone, which correlates to the argillic tuff confining unit (ATCU). • Mineralogic data (X-ray diffraction) from 17 holes, along with lithologic, stratigraphic, and geophysical log data from approximately 500 drill holes, were interpreted to develop a three-layer mineralogic model for the TCU (Prothro, 2005; BN, 2006), which illustrates the lateral continuity and spatial distribution of the different units within the TCU. These models show that all three zones are extensive beneath the eastern half of Yucca Flat within the Yucca Flat basin proper. Only the basal argillic zone occurs beneath western Yucca Flat within the western sub-basin. All three zones appear to be absent along the buried ridge that separates Yucca Flat basin proper from the western sub-basin. The LTCU is, on average, the thickest of the three zones, averaging 213 m (700 ft), followed by the OSBCU at 126 m (413 ft), and finally the ATCU at 27 m (89 ft) (Prothro, 2005; Drellack et al., 2010).

Table B.1-1
CAIP Characterization Activities
(Page 2 of 8)

Scientific Objectives Presented in DOE/NV (2000)	Investigations Addressing Objectives
Geophysical Interpretation of the Paleozoic Framework	
• Determine depths to the Paleozoic rocks beneath Yucca Flat through a new and refined inversion based on gravity and borehole data. • Produce a modified gravity map that represents separately the gravity field of the Paleozoic rocks. • Produce new cross-sections of the Paleozoic rocks. • Characterize the 3-D configuration of the Climax Mine and Gold Meadows stocks.	• Numerous geophysical investigations have been conducted in Yucca Flat since the 1960s and include seismic, resistivity, magnetic, and gravity. USGS analyzed existing gravity data using 3-D inversion (Phelps and McKee, 1999; Phelps et al., 1999 and 2000), and collected additional gravity data in the southern portion of the model area including CP Basin and Massachusetts Mountain (Phelps et al., 2005). Phelps et al. (2000) presents maps depicting the gravity field of the Paleozoic basement rocks and interpretive cross-sections showing the structure of these rocks. A magnetotelluric (MT) survey was also conducted in the Yucca Flat vicinity in 2003 (Phelps et al., 2004). Phelps et al. (2004) interpreted the magnetic data to show the configuration of granitic rocks at Climax Mine and Gold Meadows stock. • Results of geophysical investigations conducted in Yucca Flat were reviewed during HFM construction (BN, 2006) and, where appropriate, integrated into the HFM. Information from geophysical investigations was integrated with surface geology and drill-hole data to develop a structural model of the basin and determine the distribution of HSUs, including the pre-Tertiary (Paleozoic) rocks. The geophysical data were also used during development of alternative scenarios (Phelps and Graham, 2002; BN, 2006). The geophysical methods conducted in Yucca Flat and used during HFM construction are discussed in BN (2006).

Table B.1-1
CAIP Characterization Activities
(Page 3 of 8)

Scientific Objectives Presented in DOE/NV (2000)	Investigations Addressing Objectives
Hydrogeologic Investigation of Wells ER-6-1 and ER-6-2	
• Provide for long-term water-quality monitoring of the uppermost part of the LCA to detect the presence of RNs transported in groundwater. • Provide for multilevel head monitoring and hydraulic testing.	• Long-term water-quality monitoring of the uppermost part of the LCA to detect RNs potentially transported in groundwater took place throughout the CAI stage as part of the UGTA and Routine Radiological Environmental Monitoring Plan (RREMP) programs, with current plans for continued sampling presented in NNSA/NFO (2015). • Single-well tests were performed in the LCA to measure hydraulic properties, including hydraulic conductivities, at ER-3-1, ER-6-1, ER-6-2 (SNJV, 2005d), ER-7-1 (SNJV, 2004a), ER-8-1, ER-12-2 (SNJV, 2004b), and in the TCU at ER-2-1 (SNJV, 2004c). • An MWAT at ER-6-1-2 was performed with measurable responses at continuously monitored wells (ER-7-1 and ER-3-1) and periodically measured wells (UE-7nS and U3-cn-5). Continuously monitored well (UE-1h) did not respond (SNJV, 2005a). • Multilevel head monitoring revealed that the shallow piezometer completion in the TCU at ER-6-1-2 did not respond to pumping of the LCA at ER-6-1-2 during the MWAT (SNJV, 2005a). • Tracer tests involving multiple nonreactive tracers were performed in the LCA at the ER-6-1 well cluster to characterize transport properties (SNJV, 2005c and 2007). • Historical hydrologic and transport data from Yucca Flat and the larger NNSS region were located, compiled and analyzed along with data collected during the CAI stage to create parameter distributions for various HSUs in Yucca Flat (SNJV, 2006b).

Table B.1-1
CAIP Characterization Activities
(Page 4 of 8)

Scientific Objectives Presented in DOE/NV (2000)	Investigations Addressing Objectives
Isotope/Geochemistry Mass Balance Studies	
• Develope a consistent and complete set of groundwater chemistry data for the Yucca Flat groundwater flow system. • Characterize mineralogy of fracture-coating phases from boreholes. • Characterize trace element leaching rates. • Characterize (micrographic) the mineralogy of fracture-coating phases in support of the fracture diffusion experiments conducted by LANL. • Identify groundwater flow and reaction paths. • Calculate groundwater ages and evaluate flow velocities.	• New Yucca Flat/Climax Mine wells were sampled and analyzed for a comprehensive suite of analytes. Data were combined with historical data from preexisting wells in Yucca Flat/Climax Mine and used with inverse geochemical models to investigate the origin of groundwater at selected wells within the basin and identify flow paths into, within, and exiting Yucca Flat (SNJV, 2005b and 2006a). • The mineralogy and isotopic composition of TCU fracture-lining minerals were studied (Dickerson et al., 2004). • Laboratory studies of RN migration in naturally fractured cores investigated the role of fracture-lining minerals on cores from the tuffs and LCA (Ware et al., 2005; Reimus et al., 2006; Zavarin et al., 2007; SNJV, 2007). • Groundwater flow and reaction paths and mixing were investigated with the geochemical inverse models NETPATH and PHREEQC in SNJV (2006a). • Carbon-14 (^{14}C) data were used to calculate groundwater ages (residence times) (N-I, 2013, Appendix L; and Kwicklis and Farnham, 2014). Groundwater velocities between wells in the LCA and overlying alluvial and volcanic aquifers were calculated with inverse geochemical models and ^{14}C in SNJV (2006a).
Analysis of Existing Tracer Test Data	
• Determine hydraulic and transport parameters (i.e., hydraulic conductivity, effective porosity, dispersivity, and matrix diffusion) for the LCA using existing test data. Reanalysis of these tests, in light of the current understanding of tracer transport processes (HSU properties). • Use current analysis methods to provide information more comparable to recent tests for use in determining representative parameters for predictive modeling of RN transport.	• A forced-gradient tracer test was performed in the LCA in Yucca Flat between Wells ER-6-1 and ER-6-1-2 over a transport distance of 64 m using multiple tracers (SNJV, 2004d; SNJV, 2005c). Tracers were released in both upper and lower zones of ER-6-1 identified during flow logging. • ER-6-1 to ER-6-1-2 tracer arrival data SNJV (2005c) were interpreted to provide estimates of transport porosity (0.006 to 0.025) and dispersivity (19 to 34 m) in the LCA, depending on the tracer and borehole intervals tested (Reimus at al., 2006; SNJV, 2006c; Reimus, 2007). Matrix diffusion was difficult to identify or quantify due to the short test duration, low diffusion coefficients, and short transport distance (Reimus et al., 2006; SNJV, 2006c). • Tracer data from field tracer experiments at the Amargosa Tracer Site and Waste Isolation Pilot Plant in carbonate rock and from the BULLION and C-holes sites in tuff were reviewed as analogs for transport behavior in Yucca Flat and used to compute distributions of effective transport porosity, dispersivity, and matrix diffusion (SNJV, 2007).

Table B.1-1
CAIP Characterization Activities
(Page 5 of 8)

Scientific Objectives Presented in DOE/NV (2000)	Investigations Addressing Objectives
Laboratory Studies of Transport Processes	
• Obtain laboratory estimates of RN transport parameters (e.g., matrix diffusion, dispersion, and sorption), and the uncertainty associated with these parameters. This information will be used in the CAU-scale fate and transport model. • Gain experimental insights into colloid transport processes, and obtain estimates of parameters describing those processes. Information will be used to improve the CAU-scale model.	• Replicate rock wafer experiments were conducted on four cores (eight experiments total) taken from high-flow zones in the LCA at ER-6-1 to obtain estimates of matrix diffusion coefficients for various solute tracers planned for use in the field tracer experiment (Reimus et al., 2006; SNJV, 2006c). The diffusion wafer experiments indicated that solute matrix diffusion coefficients in the low-porosity LCA rocks are quite small (1 to 20 $\times$ 10^{-10} m^2/s) due to low porosity and low tortuosity. • Hershey et al. (2003) performed and evaluated laboratory diffusion experiments with bromine (Br) and ^{14}C through three LCA cores obtained from two NNSS wells. The effective matrix diffusion coefficient for Br ranged from 5.2 $\times$ 10^{-10} to 6.9 $\times$ 10^{-10} square meters per second (m^2/s). The reported effective porosities ranged from 0.0170 to 0.0256, and the calculated tortuosities ranged from 0.25 to 0.33. According to SNJV (2007), these tortuosities appear to be uncharacteristically large for such low-porosity rock samples in comparison to other diffusion cell experiments on NNSS samples and from other published diffusion experiments in the literature. • Batch experiments and fracture transport experiments were done to characterize fracture retardation and matrix sorption coefficients for various RNs, including C, Cs, americium (Am), Sr, europium (Eu), Ni, Np, samarium (Sm), Tc, U, and Pu in alluvium, tuffs, and LCA rock (Ware et al., 2005; Zavarin et al., 2005 and 2007; Reimus et al., 2006; SNJV, 2007). • Zavarin et al. (2007) summarizes laboratory experiment results reported in Zavarin et al. (2005) and Ware et al. (2005) that examined RN transport in tuff and carbonate fractures. In some of the LANL and LLNL experiments in volcanic tuff, it was apparent that ^{137}Cs, ^{239}Pu, and Sm did not migrate as free solutes, but rather as solutes sorbed to colloids, as a combination of free solutes and solutes sorbed to colloids, or as colloidal precipitates (Zavarin et al., 2007). This behavior was also evident for ^{14}C in a few of the tuff experiments, and for ^{239}Pu and Sm in the carbonate fracture experiments. In LANL experiments, either silicate or calcite colloids (the latter would explain the colloidal behavior of ^{14}C) appear to have formed in the synthetic ER-2-1 water unintentionally, and to sorb ^{137}Cs and ^{239}Pu quite strongly. The ^{239}Pu concentrations used in LANL experiments were also high enough to have potentially created Pu colloids over time. The fact that ^{137}Cs and ^{239}Pu were two of the more strongly sorbing solutes in the LANL tuff batch sorption and desorption experiments (Ware et al., 2005) also suggests that the unretarded transport of these RNs is associated with colloid-facilitated transport (SNJV, 2007). • Column studies of colloid-facilitated RN transport in the LCA was further investigated by Zavarin et al. (2013), who found that for extremely high colloid loads this process could be significant. • The importance of colloid-facility Pu transport in the LCA relative to other RNs for defining the contaminant boundary in Yucca Flat was investigated by N-I (2013, Appendix M).

Table B.1-1
CAIP Characterization Activities
(Page 6 of 8)

Scientific Objectives Presented in DOE/NV (2000)	Investigations Addressing Objectives
Rainier Mesa Colloid Studies	
• Understand the hydrologic source term (HST) in saturated tuffs in Yucca Flat by studying the HST emanating from similar tuffs at Rainier Mesa, where many tests were detonated in tuffs saturated with perched water. The water present in or discharging from the tunnels contains RNs from nearby nuclear tests that are hydraulically connected to the tunnel via their damage zones, and thus provide insights as to the mobile source term under Yucca Flat. • Investigate physical, geochemical, and radiochemical controls on the movement of actinides introduced from underground weapons testing under ambient flow conditions such as those found in the tunnel complexes. • Investigate colloid-facilitated RN transport under natural flow conditions, avoiding the mechanical stresses and high velocities associated with high-volume pumping. The water samples will be collected from natural discharges from fractures in the tunnel ceiling and walls to provide a realistic measure of the ambient colloidal load, sizing, and mineralogy.	• Perched groundwater samples from the flooded tunnels were taken by sampling water behind the cement plugs near the portal at N- and T-tunnels (Zavarin, 2006a). Samples were also acquired from vent holes #2 and #10 at N-tunnel (Zavarin, 2011 and 2013). • Water from the vent holes was characterized for RNs, redox potential, and colloids (Roback et al., 2007). • Groundwater from behind the plugs at flooded N- and T-tunnels was sampled and characterized for RNs (Zavarin, 2009a). • Data relevant to the HST at Rainier Mesa was summarized in Tompson et al. (2011) and helped guide the development of HST understanding for the Yucca Flat HST applied in the Yucca Flat flow and transport models (N-I, 2013, Appendix C).

Table B.1-1
CAIP Characterization Activities
(Page 7 of 8)

Scientific Objectives Presented in DOE/NV (2000)	Investigations Addressing Objectives
Analysis of Data for Phenomenological Models	
• Estimate dimensions of near-field physical components. • Identify the geologic features of the near-field environment. • Identify the hydrologic features of the near-field environment. • Estimate RN concentrations and distributions within the near-field environment. • Define the composition and texture of the melt glass.	• Historical studies around nuclear explosions indicate that near-field physical, geologic and hydrologic components influencing the distribution and concentration of various RNs following a nuclear test include (Tompson et al., 2008 and 2011): - Cavity with radius (R_c) estimated based on explosive yield, depth of burial, rock type, and overburden density (Pawloski., 1999). - Crushed and compressed zone extending from the cavity wall outward to about 2 to 3 R_c. - Collapse chimney extending upward from the cavity, potentially as far as ground surface to create a collapse crater. - Melt-glass zone mixed with rubble filling the lower half of the cavity, with melt-glass mass determined by the 700-metric-ton-per-kiloton-yield correlation presented by Pawloski (1999). The hydrologic characteristics of these features are imperfectly known, but in general, these features appear to possess higher-than-background permeability except for the glass-lined lower part of the cavity and the cavity walls, based on (1) loss of drilling fluid from post-test drilling, (2) chimney pressurization and tracer studies done during the weapons testing era, and (3) drill-backs and mine-backs at Rainier Mesa during the testing era that examined the changes in the degree of microfracturing with radial distance from the working point. • Additional considerations for UZ tests such as enhanced infiltration due to capture of surface runoff by craters were considered in McNab (2008), SNJV (2009), and N-I (2013). SNJV (2009) also extensively explored the impact of air/water partitioning on ^{14}C migration to the water table. Carle et al (2008) investigated the impact of noncondensible gas (CO_2) generated from thermal decomposition of carbonate rock, as well as steam production from test-generated heat, on RN transport. Carle et al. (2008) also considered the potential remobilization of RNs incorporated into the decomposition products of carbonate-hosted tests. • Table D-2 of N-I (2013) presents a summary of near-field wells and associated underground nuclear detonations in the Yucca Flat/Climax Mine CAU that were sampled during CAI. The wells include UE-3 4 (ALEMAN), U-7ba PS 1 AS (BASEBALL), U-3cn PS2 (OSBCU) and U-3cn-5 (LCA) at BILBY, UE-7nS (BOURBON), U-4u PS 2A (DALHART), U-4t PS 3A and UE-4t 1 and 2 (GASCON), 1U-2gg PSE 3A (INGOT), U-E-2ce (NASH), and ER-7-1 (TORRIDO). Of these, U-3cn-5, UE-7nS, UE-2ce and ER-7-1 monitor the LCA or LCA3. Of these, Well ER-7-1 was drilled specifically as part of CAI and is 200 m (about 3 R_c) from the TORRIDO working point. Table D-1 of N-I (2013) summarizes sampling data for these and other wells during and prior to CAI (Zavarin, 2006b, 2009b and c, and 2010; N-I, 2013, Appendix D).

Table B.1-1
CAIP Characterization Activities
(Page 8 of 8)

Scientific Objectives Presented in DOE/NV (2000)	Investigations Addressing Objectives
	• Rose et al. (2011) describe the results of a study at the CHANCELLOR detonation in tuffs on Pahute Mesa wherein groundwater and associated glass and cavity debris were compared to refine RN glass/water partitioning coefficients used for hydrologic source-term modeling in Yucca Flat (N-I, 2013, Appendix C). Although not done specifically as part of the Yucca Flat/Climax Mine CAI, the results of Rose et al. (2011) help to meet the requirements of this CAI activity goal. • HST models developed for Yucca Flat included historical observations on rock damage surrounding nuclear tests, near-field water samples from post-shot wells and nearby satellite wells, and insights gained from post-shot characterization at Rainier Mesa to develop hydrologic source-term models for Yucca Flat (McNab, 2008; Pawloski et al., 2008; Tompson et al., 2008; Carle et al., 2008; SNJV, 2009). • Data relevant to the HST at Rainier Mesa, including data from mine-back at the Rainier Test, is summarized in Tompson et al. (2011) and helped guide the development of HST understanding for the Yucca Flat HST applied in the Yucca Flat flow and transport models (N-I, 2013, Appendix C).

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Appendix C

NNSA/NFO Responses to Formal Peer Review

R.F. Boehlecke (NNSA/NFO) to C. Andres (NDEP)
(37 Pages)

C. Andres (NDEP) to R.F. Boehlecke (NNSA/NFO)
(2 Pages)

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REQUEST TO PROCEED TO DECISION #4 OF THE FEDERAL FACILIYTY AGREEMENT AND CONSENT ORDER (FFACO) UNDERGROUND TEST AREA (UGTA) STRATEGY FOR CORRECTIVE ACTION UNIT (CAU) 97: YUCCA FLAT/CLIMAX MINE

Following the FFACO process, an external peer review of the Yucca Flat/Climax Mine (YF/CM) flow and transport model and supporting data has been completed and the YF/CM Modeling Team addressed the peer reviewer's concerns and recommendations. The Executive Summary of the Navarro response to the peer review document summarizing the peer reviewer's concerns and recommendations and the YF/CM Modeling Team's responses, is presented as Attachment 1 to this letter.

The YF/CM Modeling Team responses were reviewed at varying stages by the YF/CM Pre-emptive review (PER) committee. Through an iterative process of receiving comments, revising the document, and performing additional analyses, the PER committee determined that the YF/CM Modeling Team adequately addressed their concerns and the PER process was closed out (Attachment 2 to this letter).

With the completion of the external peer review and the UGTA modeling team responses to the peer reviewer's recommendations, the National Nuclear Security Administration Nevada Field Office (NNSA/NFO) requests approval to proceed to Decision #4 of the FFACO UGTA Strategy. Attachment 3 to this letter provides further justification for proceeding to Decision #4 and also identifies activities to be addressed as Model Evaluation studies.

Please direct comments and questions to Bill Wilborn, of my staff, at (702) 295-3188.

/s/ Robert F. Boehlecke

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Executive Summary

The Underground Test Area (UGTA) Corrective Action Unit (CAU) 97, Yucca Flat/Climax Mine (YF/CM), in the northeast part of the Nevada National Security Site (NNSS) requires environmental corrective action activities to assess contamination resulting from underground nuclear testing. These activities are necessary to comply with the UGTA corrective action strategy defined in Appendix VI, Revision No. 4, of the *Federal Facility Agreement and Consent Order* (FFACO) (1996, as amended). The *Phase I Flow and Transport Model Document for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada* (N-I, 2013a) was developed and subjected to an external peer review as required by the corrective action investigation (CAI) stage of the UGTA strategy. The YF/CM Peer Review Committee (PRC) raised a number of questions and provided recommendations for supplemental analyses (in the *External Peer Review Team Report for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada* [N-I, 2015]).

The purpose of this document is to provide responses to the PRC recommendations addressing the uncertainties identified by the PRC so that sufficient confidence in the contaminant boundary forecasts is established to advance to the Corrective Action Decision Document (CADD)/Corrective Action Plan (CAP) stage and initiate model evaluations. The PRC summarized their concerns and recommendations, and presented discussions of each of these uncertainties in their report (N-I, 2015). The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) responses are summarized in Table ES-1.

In the process of responding to the comments and recommendations, the YF/CM modeling team reanalyzed existing data and models, ran new models recommended by the PRC, drilled three new wells (ER-2-2, ER-3-3, and ER-4-1), and sampled additional wells. The new wells were drilled near deeply buried, large-yield detonations (ER-2-2 and ER-4-1) or near faults (ER-2-2 and ER-3-3) to investigate the extent of contamination associated with tests near the lower carbonate aquifer (LCA) or faults. No new detections of elevated tritium (^3H) concentrations in the LCA were observed in the resampled wells or in the LCA during drilling of the three new wells, supporting the observation that ^3H contamination of the LCA is of limited areal extent and that simulations documented in the Phase I flow and transport model document (N-I, 2013a) adequately bound radionuclide (RN) transport.

The overall conclusion from this effort is that the original YF/CM flow and transport models documented in the Phase I flow and transport model document conservatively bounded the contaminant migration in YF/CM, and that the new models recommended by the PRC did not lead to the development of credible transport scenarios with different transport pathways or contamination over a larger spatial extent.

Table ES-1
Responses to YF/CM PRC Comments
(Page 1 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.1.1 Western Boundary			
1	Expand the model domain to include Rainier Mesa and use head and perched spring data from that area for calibration.	This uncertainty focuses on the model prediction that flow direction in some areas of the western part of the system is northerly, which the PRC states is opposite to the direction presented in the conceptual model and opposite to the flow simulated by the regional model of the Death Valley Regional Flow System (DVRFS).	Model studies were conducted to show that recharge from Rainier Mesa does not influence the transport model results. The alternate model studies included (1) applying a fixed amount of flow from Rainier Mesa into northwestern Yucca Flat, (2) treating this flow as a calibration target, (3) penalizing the model for northward flow in this area, and (4) using as calibration targets pseudo-points based on the Fenelon et al. (2012) conceptual model. These simulations led to less-extensive transport results compared to the base-case model and further did not eliminate the northerly flow in the northwestern part of the model. Hence, there is no benefit in extending the western model domain or in using head and perched spring data from that area.
2.1.2 Southern Boundary			
2	Extend model domain to the south to capture contaminant boundaries that extend beyond the current model domain.	The concern under this uncertainty is that some simulations predict the southern extent of the contaminant boundary to fall beyond the model domain.	It is not necessary to extend the southern model boundary because simulations that reach the boundary are known to be conservative, and reduction of the contaminant boundary extent is anticipated during model evaluation (CADD/CAP) as the conservative models are either refined or removed from the ensemble. The contaminant boundaries associated with this model are known to be conservative for the following reasons: (1) recent estimates of the water flux through the high-permeability corridor are considerably less (~20 kilograms per second [kg/s]) than that estimated for the base-case model (~148 kg/s); (2) although contamination is forecasted, it is not observed in the LCA wells (e.g., U-3cn 5, ER-7-1, and UE-7nS) located in the high-permeability eastern corridor along pathways that impacted the southern boundary; (3) although ^{3}H above its *Safe Drinking Water Act* (SDWA) maximum contaminant level (MCL) (CFR, 2015) is forecasted, it is not observed above the minimum detection limit (MDL) (1,500 to 1,800 picocuries per liter [pCi/L]) in the LCA in the three new wells (ER-2-2, ER-3-3, and ER-4-1); and (4) carbon-14 (^{14}C) data suggest longer travel times. An example simulation using the 20 kg/s flux produced a contaminant boundary well north of the southern model boundary. Hence, the current southern boundary is sufficient.

Table ES-1
Responses to YF/CM PRC Comments
(Page 2 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.1.3 Northern Boundary			
3	Investigate inflow from the north with multi-well aquifer testing and water sampling.	The concern under this uncertainty is that significant flow from the north is possible and could be an important factor in RN transport out of Yucca Flat.	Recent reanalysis of the ER-6-1 multiple-well aquifer test (MWAT) data (Halford, 2012 and 2016) and historically reported results (Winograd and Thordarson, 1975; Harrill et al., 1988) indicate that the current base-case model overestimates flow from the north. Alternate models with lower flux constraints reduce the northern flux significantly, leading to a reduction in the southern extent of the contaminant boundary. Hence, the current understanding of the northern boundary flux is sufficient and an MWAT in the north is unnecessary.
2.1.4 Water Table Boundary and AA/VA Flow Direction			
4	Contour simulated water levels in the AA/VA, compare with available data and include the resulting uncertainty in flux to the LCA in future modeling.	This concern is that it is difficult to determine the simulated groundwater flow direction in the shallow aquifer from the information presented, especially with regard to flow toward faults. Present-day flow directions can differ from those indicated by the pre-development hydraulic heads estimated in Fenelon et al. (2012) due to the effects of nuclear testing.	As requested, a contour map of simulated pre-testing hydraulic heads (with inferred flow directions) was developed and compared to pre-development heads and flow directions shown in Fenelon et al. (2012). The modeled heads differ from the Fenelon et al. (2012, Plate 3) pre-development heads and flow directions. The strongest hydraulic gradients in the alluvial aquifer/volcanic aquifer (AA/VA) flow system are downward to the LCA, which are not evident in map view. Flow directions depend on whether faults are assumed to be permeable. The saturated zone (SZ) AA/VA system model assumes faults are permeable through the tuff-confining unit (TCU) and, therefore, water and RNs enter the LCA at many places in the model. The Fenelon et al. (2012) conceptual model assumes that faults serve no hydrologic role other than to offset aquifers. In their conceptualization, groundwater and RNs from the alluvium and tuffs reach the LCA only where alluvial aquifers (AAs) and volcanic aquifers (VAs) are offset across faults. The SZ AA/VA model is based on a scenario more conducive for transport to the LCA and is therefore sufficient.

Table ES-1
Responses to YF/CM PRC Comments
(Page 3 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.1.5 Hydraulic Connection between Aquifers			
5	Evaluate uncertainty in flux to the LCA associated with the inconsistency of the boundary between the LCA and AA/VA models. Couple the AA/VA and LCA models and use all the head data within the combined multi-aquifer system for calibration.	This uncertainty concerns the use of loose coupling between the AA/VA and the LCA models, and the possible resulting underestimation of recharge to the LCA model.	It is not necessary to couple the AA/VA and LCA models to develop a combined multi-aquifer system model. The modeling team does not agree with the premise of the comment that the SZ AA/VA and SZ LCA models are inconsistent. Consistency in heads between the SZ AA/VA system model and the SZ LCA model was enforced by applying steady-state heads from the LCA model to the base of the SZ AA/VA model along faults. Small increases in LCA heads that might have occurred due to testing induced overpressures in the tuffs contribute little uncertainty to the overall downward gradient dominated by the overpressures in the tuff and can be justifiably ignored, as demonstrated by sensitivity studies presented in Appendix I of N-I (2013), which examined the effect of ignoring hydraulic transients in the LCA due to testing in the shallower tuffs and alluvium. In conclusion, joint calibration of the AA/VA and LCA models (development of a combined multi-aquifer system model) is not necessary.
2.2.1 Poorly Posed Calibration			
6	Expand the model domain to couple the aquifer systems, extend the domain to the groundwater divide to the west, include more target data from the available dataset as well as through additional data collection, and simplify the parameterization.	This uncertainty focuses on the fact that the LCA model optimization is underconstrained with respect to the number of adjustable parameters in the model.	Extending the LCA model domain to include AA/VA is not necessary, because the number of parameters to be estimated and the number of observations used for parameter estimation remain unchanged whether the models are fully coupled or loosely coupled through their common boundary conditions. There is no advantage to a coupled model with extended LCA model domain to include AA/VA because of the greater structural complexity represented by a coupled model with extended LCA model domain to include AA/VA, the increased refinement needed for high-gradient zones, and the increased number of unknown parameters. In addition, the base-case model presented in N-I (2013) is more conservative with respect to transport forecasts than an alternate model that includes the additional wells recommended by the PRC (N-I, 2015, Section 6.2.1). The alternate case did not calibrate as well, and the added calibration targets led to a contaminant boundary more northerly than the N-I (2013) transport model. Therefore, no further action is needed to address this recommendation.

Table ES-1
Responses to YF/CM PRC Comments
(Page 4 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.2.2 Lack of Steady-State Head Data			
7	Calibrate a coupled model of the aquifers, include more calibration targets, resurvey the well heads to ensure accuracy of the targets, and completely represent the data that were used to develop steady state targets in the residual analysis.	The focus of this uncertainty is that steady-state heads from different wells are not concurrent; they are sparse, affected by detonations, and many come from sections with long well screens.	There is no need to couple the SZ AA/VA and SZ LCA (see Responses #5 and #6). The current land surface accuracy for the Yucca Flat LCA wells is generally less than 1 foot (ft) and is much smaller than the hydraulic head changes across Yucca Flat that are ~50 ft (Fenelon et al., 2012). Alternative approaches to represent head data variability led to transport results that were not more extensive than those for the N-I (2013) transport models. The alternate models included (1) using mean water levels calculated by the U.S. Geological Survey (USGS), (2) using multiple steady-state targets to encompass temporal variability, (3) using pseudo-points to honor head contours reported in Fenelon et al. (2012), and (4) using weights based on data quality. Therefore, no further action is needed under this recommendation.
2.2.3 Use of Parameter Bounds			
8	Reduce the number of parameters through re-parameterization, remove bounds from the parameters, include more calibration targets, and adjust the model conceptualization and construction if the estimated parameter values are not reasonable.	This uncertainty addresses the concern that placing bounds on parameters during an estimation process can lead to models that are not realistic or that underpredict transport.	The conceptual flow model and parameter bounds documented in N-I (2013) were carefully determined and are consistent with available flow system information. The effects of reducing the number of adjustable parameters with respect to fault properties was explored (see Response #19). These model studies supplemented with current estimates of water flux (Halford, 2016) through Yucca Flat and RN data demonstrate that the base-case model (N-I, 2013) does not underpredict transport (see Response #2). Hence, it is not necessary to further address this recommendation.
2.2.4 Omission of Available Calibration Data			
9	Include as many calibration targets as possible (also use multiple targets at individual locations for the steady state calibration to incorporate the transient nature of the data into the steady state calibration uncertainty), include hydrogeologic features to facilitate a fit to those targets, and present residuals related to all of the measurements. Critically review all available calibration data.	The concern raised is that there are head measurements available from some wells that were not used in the LCA calibration.	Several alternate models were developed to evaluate this recommendation as follows: (1) including the additional wells recommended by the PRC, (2) using multiple targets at locations with transient water levels not associated with anthropogenic activities, and (3) assigning weights based on data quality. The alternate models did not lead to transport in excess of the base case. Hence, further addressing this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 5 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.2.5 Using the Jacobian to Determine Weights for Targets			
10	Determine weights by evaluating the quality of the target data based on well construction and measurement procedures.	This uncertainty was focused on determining target weights from data quality rather than mathematical constructions.	The base-case model is more conservative than the alternate model using calibration weights. The modeling team performed a critical review of the LCA water-level data quality. The LCA model was recalibrated using the temperature corrected data and steady-state calibration weights that consider data quality. This alternate model achieved a poorer calibration and forecasted a contaminant boundary more northerly than the current base case. Hence, it is not necessary to further address this recommendation.
2.2.6 Field Measurements of Hydraulic Conductivity Not Honored in the Calibrated Model			
11	After estimating parameters without bounds, compare the values to equivalent field values; if they are unreasonable, adjust the model conceptualization and/or construction.	This uncertainty was motivated by the fact that estimated parameter values do not match all the field measurements.	The base-case model takes into account the available hydraulic conductivity data. Great care has been exercised in choosing the underlying conceptual flow model, and in setting bounds on parameters that are plausible and consistent with the available information. Small-scale hydraulic conductivity estimates are expected to display more variability than volume-averaged estimates needed on a larger scale. In response to PRC comments regarding spatial distribution of hydraulic conductivity measurements, an LCA model was recalibrated using rezonation of the SZ LCA, which divided the three north–south zones into northern and southern components. This model achieved poorer calibration than the base case and also forecasted less transport. The suggested alternatives have been adequately addressed, and model conceptualization and/or construction does not require adjustment.

Table ES-1
Responses to YF/CM PRC Comments
(Page 6 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.3.1.1 Limited Characterization of Aquifer Properties			
12	Conduct MWATs in the central and western parts of Yucca Flat.	This uncertainty concerns the scale dependence of hydraulic conductivity measurements.	A model simulation was created that expanded bounds on country rock and fault permeability to encompass the measured values and allow larger values to be assigned during calibration. This model achieved poorer calibration than the base case and forecasted less transport. During the drilling of three new wells (ER-2-2, ER-3-3, and ER-4-1) within the central part of Yucca Flat, water levels in the neighboring wells that were instrumented did not show any responses to the drilling activities. Additionally, water pumping rates out of these wells have been below 100 gallons per minute (gpm). These observations support the conceptual model of permeabilities being lower at least in the neighborhood of each well. Because the LCA in the central and western parts of the basin did not respond to the 2004 ER-6-1-2 MWAT, calibrated permeabilities in this part of the basin were constrained solely by steady-state heads, which indicate west-to-east flow in this part of the basin. Consequently, the calibrated permeabilities reflect the lower west–east permeability across the faults and fractures, which have a dominant north–south orientation. Matching the observed hydraulic head data in the western and central portions of Yucca Flat required the model to select lower permeability values than those for the eastern portion. Further, majority of the source locations are not in these portions of the basin—if tests within 3 R_c of the top of LCA are considered, only 9 out of 39 locations lie within central and western Yucca Flat. Hence, refining parameter measurements for those portions of Yucca Flat will lead to relatively small gains in reducing the uncertainty in the contaminant forecasts.
2.3.1.2 Model Permeabilities Inconsistent with Field Measurements			
13	Use available hydraulic properties data to delineate permeability zones in the model. Honor the measured hydraulic conductivities. Reevaluate the choice of the “fast” scenario.	This uncertainty is focused on the apparent mismatch between the permeability values used in the model versus pumping-scale data.	Pumping tests tend to select the higher-permeability zones and do not necessarily represent large-scale averages. The alternate flow models considering a north–south subdivision of the country rock, and those with expanded permeability bounds, do not calibrate to the data as well as the base-case model, and forecast less southern extent for the contaminant boundary compared to the base case. The issue has been adequately addressed through additional modeling, and it is not necessary to modify the base-case model.

Table ES-1
Responses to YF/CM PRC Comments
(Page 7 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.3.1.3 Preferential Flow			
14	Thoroughly evaluate existing data for indications of karst and install new wells to investigate for karst. If karst features cannot be ruled out, include alternative models that have continuous high hydraulic conductivity pathways from the northern to the southern end of Yucca Flat and passing through source zones.	This uncertainty addresses local-scale permeable pathways in the country rock.	Available subsurface and outcrop evidence, as well as hydrogeologic reasoning, indicates that extensive solution channels that could provide basin-scale transport pathways in Yucca Flat do not exist. Although karst features have been observed sporadically in boreholes (e.g., identified by a drop in the drill string while deepening Well UE-10j and later confirmed with video logs) and outcrops, karst features are relatively rare in the extensive limestone outcrops exposed in the surrounding mountain blocks, and an integrated set of saturated solution channels throughout the Yucca Flat basin is unlikely. Hence, karst is not believed to have created extensive permeable pathways in Yucca Flat, and further work suggested in this recommendation is not necessary.
2.3.2 Faults			
15	Extend the range of permeability considered for modeling faults well above the highest measured value and include alternative models without impermeable fault cores.	This uncertainty focuses on flow and transport through faults, and includes several sub-comments that are addressed in Responses #15 through #19.	Extrapolating small discrete measurements over an entire fault zone spanning a potentially 36-kilometer (km) feature is not realistic, and cannot be reconciled with the observed gradient and realistic flow rates through the LCA within Yucca Flat. Permeabilities from cross-hole response are more representative of large scale values and are used for bounding parameter distributions. An alternate model without low-permeability fault cores resulted in slightly greater transport to the southern boundary—12% of the cases considered in the probabilistic transport analysis using the alternate models reached the southern boundary of the model as compared to 10% for the base case. As discussed under Response #2, these models are known to be conservative, incorporating north–south fluxes far greater than the current estimates. Hence, it is not necessary to extend the range of permeabilities beyond the values already considered in the base-case model.
16	Assign increased permeability to the material that is currently simulated as country rocks near major faults in the analysis of uncertainty.	This uncertainty focuses on flow and transport through faults, and includes several sub-comments that are addressed in Responses #15 through #19.	This recommendation is implicitly included in the model. The grid spacing at the explicitly simulated faults in a direction perpendicular to the fault plane in the current model is 125 meters (m); thus, 125 m of country rock on each side of the fault center is included in the volume that is assigned damage zone properties. Hence, further work suggested in this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 8 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
17	Explore greater fault permeability in the AA/VA model, and characterize AA/VA fault behavior.	This uncertainty focuses on flow and transport through faults, and includes several sub-comments that are addressed in Responses #15 through #19.	The LCA transport results were not significantly impacted by alternate AA/VA models including a wide range of lateral permeabilities with an upper bound of 5 × 10^{-12} square meters (m^2), as well as incorporating breaching scenarios. Other modeling cases were run such as one in which the entire RN inventory from eight key tests was initially placed directly into the LCA to simulate the effects of breaching scenarios (N-I, 2013). These cases did not significantly impact the contaminant boundary even though the models assumed that significant amounts of ^3H from deeply buried tests are initially distributed in the LCA. Available data do not support the type of breaching proposed by PRC. The three new wells drilled in Yucca Flat (ER-2-2, ER-3-3, and ER-4-1) targeted detonations within a few cavity radii (R_c) (estimated based on the maximum yields reported in NNSA/NFO [2015] and the equation in Pawloski [1999]) of faults to determine the impact of faults on transport to the LCA. The absence of ^3H in the LCA in these wells indicates that nearby faults were not significant transport pathways to the LCA, in spite of their proximity to the working points. Hence, it is not necessary to extend the range of permeabilities considered in the AA/VA model or to further characterize fault behavior.
18	Evaluate the contaminant boundary using an alternative flow model in which all faults in the volcanic rocks serve as permeable pathways to the LCA.	This uncertainty focuses on flow and transport through faults, and includes several sub-comments that are addressed in Responses #15 through #19.	As discussed for Response #17, the LCA transport results were not significantly impacted by alternate AA/VA models including a wide range of lateral fault permeabilities, or by incorporating breaching scenarios. Therefore, no further action is needed under this recommendation.
19	Include an alternative model which has no or many fewer minor faults; this may require allowing flow and transport to occur between the AA/VA and LCA via the TCU in addition to the major faults.	This uncertainty focuses on flow and transport through faults, and includes several sub-comments that are addressed in Responses #15 through #19.	See Responses #17 and #18. The alternate models did not significantly increase transport compared to the base-case model. Hence, further work suggested in this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 9 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.3.3 Tuff Confining Unit			
20	Evaluate the uncertainty in the contaminant boundary due to flow across the TCU that is not impermeable, but rather honors the available data on hydraulic properties of the TCU.	This uncertainty focuses on the process of flow across the TCU.	Interruption of the lateral continuity of the TCU by faults, and in certain model scenarios by local vertical pathways to the LCA created by the force of the nuclear detonations (the “breaching scenario”), is already incorporated in the SZ AA/VA conceptual models documented in N-I (2013). A wide range of lateral permeabilities (10^{-17} to 10^{-12} m^2)—consistent with available Yucca Flat-specific TCU hydrologic testing data—were assumed or calibrated (N-I, 2013, Figure 4-12). The upper limit of this range has been extended to 5 × 10^{-12} m^2 in model runs in response to the PRC comments. Three breaching cases that allow transport across the lower boundary in non-faulted locations have already been run (N-I, 2013). In these breaching cases, hydrofracturing along the lower TCU boundary was allowed and, if this occurred, the rock was assigned high permeability (10^{-12} m^2) and low porosity (0.01) between the detonation and the LCA. These model runs did not significantly impact the contaminant boundary. Moreover, the available ^3H data from large-yield, deeply buried detonations such as BILBY, CALABASH, STRAIT, and WAGTAIL indicate that the type of breaching proposed by the PRC does not occur. Hence, further work suggested in this recommendation is not necessary.
21	Develop new data and field testing to determine the lateral continuity of the TCU as an effective hydraulic barrier to vertical transport.	This uncertainty focuses on the process of flow across the TCU.	The SZ AA/VA model alternatives considered the possibility that nuclear testing created fracture pathways to the top of the LCA (N-I, 2013, Section 4.0). This so-called breaching hypothesis was investigated by the new wells drilled into the LCA near the CALABASH, STRAIT, and WAGTAIL detonations. Two of the wells (ER-2-2 near CALABASH and ER-3-3 near WAGTAIL) also investigated whether faults were significant transport pathways for TCU-hosted detonations to the LCA. No ^3H was detected above the MDL (1,500 to 1,800 pCi/L) in the LCA water produced during drilling, indicating that the transport pathways hypothesized by the PRC do not exist at these wells (ER-2-2, ER-3-3, and ER-4-1). Hence, further work suggested in this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 10 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.3.4 Effective Porosity			
22	Evaluate uncertainty in the contaminant boundary due to effective fracture porosity of the TCU.	This uncertainty is motivated by lack of sufficient data regarding effective porosity in the TCU.	The base-case model presented in N-I (2013) is sufficiently conservative. Damage zones or chimneys in the TCU were assumed to have a fracture porosity of 0.01. In response to PRC comments, additional simulations were run with an assumed fracture porosity of 5×10^{-04} to assess potential significance of continuous fracture networks on simulated RN fluxes to the LCA. These simulations indicated that the breakthrough of ^{14}C and other long-lived RNs to the LCA is smaller when fracture flow combined with fracture-matrix diffusion is considered, but that there may be some earlier breakthrough of ^{3}H compared with the base case. However, because the contaminant boundary is defined by ^{3}H initially emplaced within the LCA, the effect of some early ^{3}H breakthrough from the TCU is not expected to alter the range of N-I (2013) contaminant boundaries. Hence, further work suggested in this recommendation is not necessary.
2.3.5 Potential for Flow of Surface Water into Fractures in the Alluvium			
23	Model faults as local zones of preferential flow through the unsaturated and saturated alluvium. Gather field data to ascertain the degree to which fissures contribute to enhanced local recharge.	This uncertainty concerns open fractures and faults at the surface that could act as conduits for flow of surface water to water table.	Most of these surface cracks generated by nuclear testing have since become sealed due to infilling by sediments and from weathering, but as indicated by recent photos in Appendix C of the PRC report (N-I, 2015), there are isolated areas along major faults where infilling of these cracks is incomplete. Field observations of these open surface cracks taken before and after the August 4, 2014, storm suggest that these cracks have not been areas of preferential water movement during runoff events. The practice during the nuclear testing period was to avoid major fault zones, so if preferential flow into these areas were to occur, it would pass between detonations and would not be available to flow into craters that formed above the detonations elsewhere. Hence, further work suggested in this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 11 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.3.6 Anisotropy and Preferential Flow in the Unsaturated Zone			
24	Determine the maximum depth of recent infiltration along possible flow pathways to detonation cavities at craters with high rates of recharge.	This uncertainty is motivated by concerns about preferential infiltration from crater bottoms.	This issue was determined to be a low priority because unsaturated zone (UZ) detonations did not contribute significantly to the contaminant boundary. Roughly 90% of UZ detonations are above the SZ AA/VA model, and the 10% that are above the SZ LCA are in the extreme northern end of the basin. This means that regardless of crater infiltration rates and wetting front velocity, the contaminant boundary will be defined by other, more deeply buried detonations further downgradient. Hence, further work to address this recommendation is not necessary.
2.4.1 No Uncertainty Associated with the RST			
25	Include uncertainties in radiologic source term (RST) in modeling.	This uncertainty focuses on the RST.	RST uncertainty, as documented in Bowen et al. (2001), has been explicitly incorporated in the source term via screening analyses documented in Appendix C of N-I (2013). Source term uncertainty has already been examined to varying degrees in each of the three model types (UZ, SZ AA/VA, and SZ LCA models) through uncertainty analysis in melt-glass partitioning factors, exchange volume size, alternate conceptual models (constant mass or constant concentration), and inventory uncertainty. The RST uncertainty approach used in the screening analysis, with the exception of melt glass dissolution, was also used in determining initial LCA model inventories for the detonations with initial inventories within the SZ LCA. Comparison of unclassified and classified R_c, inventory, and yield for the 39 deep tests likely to impact the contaminant boundary has been completed. The results showed that R_c is generally smaller than unclassified estimates based on maximum yield, thus reducing the number of tests intersecting the SZ LCA (cavity dimension based on maximum announced yield identified in NV-209-REV 16 [NNSA/NFO, 2015] and Equation 1 in UCRL-ID-136003 [Pawloski, 1999]). The initial source term concentrations and the total inventory deposited in the SZ LCA are not substantially impacted. These results were presented to the Nevada Division of Environmental Protection (NDEP) on June 5, 2015. The results suggest that the contaminant boundary would not be greatly impacted if classified source terms had been used. Hence, further work suggested in this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 12 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.4.2 Uncertainties in Partition Factors Are Not Well Defined Particularly for Cavities in Carbonate Rock			
26	Develop support for partition factors used.	This uncertainty concerns the partition factors appropriate for modeling the concentration of RNs in cavities in silicic as well as carbonate rocks.	The International Atomic Energy Agency (IAEA) RN partitioning recommendations were developed using a combination of underground nuclear test data from the NNSS, Mururoa/Fangataufu, and other underground nuclear testing locations (IAEA, 1998a, b, and c); and hence are consistent with data from the NNSS. Supporting work on partitioning factors for tests detonated in carbonate rock were performed by the UGTA Activity, including extensive work done on NASH and KANKAKEE debris (Carle et al., 2008). The partition factors are consistent with observations and do not need to be revised.
2.4.3 Water Flow into Cavities			
27	Measure and monitor enhanced-recharge-driven transport in and below detonation craters.	This uncertainty addresses the hydraulic properties beneath detonation cavities in the TCU and the potential for rapid transport.	There is no need to further characterize, measure, or monitor enhanced, recharge-driven transport below detonation craters near UZ-hosted tests. Roughly 90% of the UZ detonations were located above the SZ AA/VA domain, which provides additional barriers to RN transport to the SZ LCA. The effectiveness of the SZ AA/VA system as a barrier to RN migration from the UZ to the SZ LCA was demonstrated in N-I (2013) by comparing RN fluxes with and without the UZ RN fluxes present. The results in both cases were the same. The 10% of the UZ-hosted detonations that lie directly above the SZ LCA occur in the northern parts of the LCA model (NASH, HANDCAR, KANKAKEE) or are monitored by a nearby well that shows no evidence of RN transport (BOURBON). Therefore, because a considerable amount of work has already been done to demonstrate that these sources do not impact the contaminant boundary, additional crater studies are not considered necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 13 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.4.4 Uncertainty in Exchange Volume Not Fully Captured			
28	Extend the uncertainty analysis to include exchange volumes of at least 5 R_c.	The concern of this uncertainty is that fracturing associated with nuclear detonations could extend further than that included in the model.	The general configuration of detonation-altered zones and properties described in Appendix C of N-I (2013) are largely based on information compiled in the Office of Technology Assessment (OTA) report (OTA, 1989). The exchange volume is related to the size of the damage zone, but is also related to volatility and molecular weight of the RNs comprising the hydrologic source term (HST) and whether the exchange volume is located in a saturated or unsaturated environment. N-I (2013) used Yucca Flat specific data and HST modeling (Tompson, 2008) as well as cavity data from the RAINIER and CHANCELLOR detonations to estimate RN-specific exchange volumes. Only ^{14}C has a maximum exchange volume size of 5 R_c within the SZ, and the initial concentration of ^{14}C is only slightly above the SDWA MCL (CFR, 2015) assuming a 1 R_c exchange volume (N-I, 2012, Figure 2-6). Using a 5 R_c for ^{14}C would lower the initial concentration below the MCL. Using the recommended 5 R_c exchange volume for all detonations and all RNs would create lower initial concentrations that are most likely unrealistic and would impart an additional element of non-conservatism. ^{3}H measurements and water production rates observed during drilling of Wells ER-2-2, ER-3-3, and ER-4-1 have indicated that the TCU is largely uncontaminated and unfractured at distances of 2.5 to 3 R_c from the working point (based on the maximum announced yield of the nearby tests). This indicates that the exchange volumes used in N-I (2013) are adequate for contaminant boundary calculations.

Table ES-1
Responses to YF/CM PRC Comments
(Page 14 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.4.5 Possible Chimney and Cavity Pathways to the LCA			
29	Expand the uncertainty analysis to include a greater range of permeability enhancement assigned to the damage zone. Where possible, consider using shot holes to test field permeability of the damage zones.	This uncertainty addresses the size of the exchange volume and damage zone associated with an underground test.	Historical studies with air injection and gas tracers have been used to characterize cavities and chimneys in the TCU at Rainier Mesa (Peterson et al., 1977a and b, and 1978). Because the rocks are partially water-filled, estimated air-permeabilities and porosities are minimum estimates of the single-phase values. The results indicated that the air-permeabilities were on the order of 8 to 150 Darcies (roughly 8×10^{-12} to 1.5×10^{-10} m^2) in the upper parts of the chimney above the injection hole, and sometimes much less (0.001 to 12 Darcies, roughly 10^{-15} to 1.2×10^{-11} m^2) in the lower part of the chimney that included the cavity region. Air-filled porosity (accessible void volume) was on the order of 0.09 to 0.17. For comparison, the average air permeability of the surrounding media was estimated to be about 1 Darcy (roughly 10^{-12} m^2) in the vitric tuff and 0.001 to 0.36 Darcies (10^{-15} to 3.6×10^{-13} m^2) in the adjacent undamaged zeolitic rocks. The chimney/cavity systems, therefore, had enhanced permeability relative to the surrounding rock. Low water production rates and lack of measured ^{3}H during drilling of the three new wells in Yucca Flat (ER-2-2, ER-3-3, and ER-4-1) indicated lack of enhanced permeability near and below the working point. Drilling results indicate little to no transport into the LCA from the nearby underground tests. This supports the conclusion that damage zone permeability does not produce significant vertical transport in the region surrounding deeply buried large underground tests near the interface with the LCA, or faults that intersect the LCA. Further work suggested in this recommendation is not necessary.
2.5.1 Values Used for Pu Retardation Are Not Well Supported and May Be Too High			
30	Decrease Pu K_d values used for modeling. Collect more data to understand Pu retardation, and further evaluate existing data.	This uncertainty is associated with the concern that the sorption coefficient distributions used in the transport model for plutonium (Pu) may not be sufficiently conservative.	To address this recommendation, the range of Pu distribution coefficient (K_d) values for the LCA was decreased from 900 to 10,000 milliliters per gram (mL/g) to 0.76 to 1,096 mL/g (Sutton, 2009). Although Pu contamination for the reduced K_d case was more extensive, the effect was insignificant because the contaminant boundary remained dominated by ^{3}H. Hence, further work suggested in this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 15 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.5.2 Melt-Glass Dissolution Is Largely Neglected			
31	Include melt-glass dissolution in UZ models. Consider additional processes affecting cavity-debris behavior in the LCA, and include an instant-release case.	This uncertainty concerns the initial inventory assigned to each detonation and melt-glass dissolution.	This uncertainty is considered a low priority that does not require further analysis. Melt-glass dissolution in the UZ is not important to contaminant transport because dry conditions follow the detonation, and the wetting front from crater infiltration will not arrive until long after melt glass has cooled (in some cases, hundreds of years). Significant glass dissolution occurs only at elevated temperatures, and transport of liberated Pu due to glass dissolution is limited by sorption and filtration of colloids (Zavarin et al., 2015). Additionally, UZ detonations were shown in N-I (2013) to be secondary to other detonations for defining the contaminant boundary, so late-time melt-glass dissolution would have only a minor impact. The parametric uncertainties associated with calculating the HST for the SZ LCA included inventory uncertainty and melt-glass partition fractions. The inventory uncertainty varied from a factor of 0.1 to 10 depending on the RN group (i.e., residual ^{3}H, activation products, fission products, or unspent fuel), and melt-glass fractions varied from 0 to 100% depending on the RN. The uncertainty associated with initial inventory and melt-glass partition factors is much larger than the total expected melt-glass dissolution, and immediately releasing a small percentage of the RNs incorporated in melt-glass to the LCA will not significantly change the contaminant boundary. Hence, further work suggested by this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 16 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.6.1 Field Measured ^{3}H Concentrations Are Not Simulated in the N-I (2013) Model			
32	Simulate sub-regions of the model with smaller mesh size and more particles to understand mismatches.	This uncertainty focuses on the non-zero levels of ^{3}H concentrations detected in Wells ER-2-1, UE-6e, UE-6d, TW-B, and WW-A.	Past ^{3}H detections in the SZ AA/VA system and LCA were explained with a combination of modeling and groundwater sampling. Since the completion of N-I (2013), several wells have been resampled (ER-6-2, UE-7nS, WW-3, WW-2, ER-2-1, UE-6d, UE-6e, and TW-B). Five of these wells (ER-2-1, ER-6-2, TW-B, UE-6d, and UE-6e) were identified by the PRC as of special concern (N-I, 2013, Table 6-4) based on previous ^{3}H measurements. The ^{3}H detected at WW-A is attributed to RN migration from the HAYMAKER detonation induced by pumping from WW-A while functioning as a water-supply well. The ^{3}H detected in ER-2-1 samples is consistent with contaminated water moving outward from an initial exchange volume of 4 R_c or less (two SZ detonations are within a lateral distance of 4.1 R_c from ER-2-1). Sampling wells with anomalous historical results has been completed and the results explained. Wells UE-6d, UE-6e, and TW-B are currently below the low-level detection limit (~2 pCi/L), indicating that past ^{3}H occurrences, although unexplained, were not the leading edges of a contaminant plume. Hence, further work suggested by this recommendation is not necessary.
33	Incorporate processes that could lead to observed lateral transport of ^{3}H in the AA/VA.	This uncertainty focuses on the non-zero levels of ^{3}H concentrations detected in Wells ER-2-1, UE-6e, UE-6d, TW-B, and WW-A.	The ^{3}H detected at WW-A was the result of 27 years of pumping for water supply, a factor that induced ^{3}H migration from the HAYMAKER test ~0.5 km away from WW-A. Even this explanation required the presence of hydrodynamic dispersion in the alluvium, in addition to pumping. Wells UE-6d, UE-6e, and TW-B are currently below the low-level detection limit (~2 pCi/L), indicating that past ^{3}H occurrences, although unexplained, were not the leading edges of a contaminant plume. Hence, further work suggested by this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 17 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
34	Evaluate whether timing of sampling or nature of completion of non-detect wells may be such the ^{3}H occurrences were missed.	This uncertainty focuses on the adequacy of sampling locations and frequency in the LCA.	Sampling frequency and completion depth intervals relative to potential contamination sources were examined. Near-field wells such as ER-7-1, UE-7nS, and U-3cn 5 tended to have shallow completion depths in the LCA and relatively frequent measurements, so that transient RN fluxes to the LCA from the overlying tuffs were likely to be observed if they occurred. These wells all have measured ^{3}H concentrations that are slightly above to below detection, indicating that RN movement from the nearby tests to the LCA was at most very minor. Far-field wells such as WW-C, WW-C-1, TW-D, UE-1q, and ER-6-1 also have shallow completion depths, and in most cases had near-yearly sample collection. These wells have experienced only very low levels of ^{3}H over many decades. The samples from these far-field wells are presently free of measurable ^{3}H, confirming that the southern half of Yucca Flat basin is uncontaminated. Hence, further work under this recommendation is not necessary.
35	Gather field data to define the current extent of contamination, then adjust the model to better represent the field system.	This uncertainty focuses on the adequacy of sampling locations and frequency in the LCA.	Since the completion of N-I (2013), several wells have been resampled (ER-6-2, UE-7nS, WW-3, WW-2, ER-2-1, UE-6d, UE-6e, and TW-B). Five of these wells (ER-2-1, ER-6-2, TW-B, UE-6d, and UE-6) were identified by the PRC as of special concern (N-I, 2013, Table 6-4) based on previous ^{3}H measurements. Additionally, three new wells (ER-2-2, ER-3-3, and ER-4-1) were drilled near deeply buried, large-yield detonations (ER-2-2 and ER-4-1) or near faults (ER-2-2 and ER-3-3) to investigate the extent of contamination associated with tests near the LCA or faults. No new detections of elevated ^{3}H concentrations in the LCA were observed in the resampled wells or in the LCA during drilling of the three new wells, although elevated ^{3}H (~10 million pCi/L) was observed in the Tertiary volcanics above the TCU at ER-2-2 (within 2 R_c of the CALABASH test). Hence, further work under this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 18 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.6.2 Crater-Infiltration Data Are Not Well Matched in the Model			
36	Ensure that the crater-recharge model is conservative.	This uncertainty addresses the rate of surface flux into the UZ by enhanced recharge through craters.	The differences between the long-term (1,000-year) infiltration rates estimated for the HYRAX, LAGUNA, and BYE craters in N-I (2013, Table E-1) and independent estimates calculated by the reviewers or published in the open literature from field data result from the fact that the observations were performed during a time period of higher than normal precipitation, which biases the observed data above the long term trend. Hence, further work under this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 19 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.6.3 Geochemical and Environmental Isotope Not Fully Evaluated			
37	Justify the choice of initial chloride concentrations. Explain differences in interpretations of ^{14}C in the Yucca Flat and Ash Meadows LCA flow systems. Avoid interpreting ages from dissolved organic carbon-14 data.	This uncertainty addresses the interpretation of ^{36}Cl and ^{14}C data.	The assumption that the chloride concentration of LCA recharge is ~7 milligrams per liter (mg/L) is based on the mean chloride concentration of dozens of tunnel seeps in tuffs at Rainier Mesa. The use of this value in recharge to the LCA in Yucca Flat is reasonable in that water in the tuffs at Rainier Mesa (a regional recharge area) has undergone no or minimal chloride leaching (as in the LCA) or evaporative enrichment after discharge (as do perched spring data). Furthermore, the use of 7 mg/L to correct the LCA samples that appear to have been affected by halite dissolution allows for a range in $^{36}Cl/Cl$ ratios similar to those measured in packrat middens between 10,000 and 40,000 years ago (a range that is neither too high or too low) and which matches the temporal variations in the packrat midden data (Kwicklis and Farnham, 2014). While this does not prove the use of 7 mg/L is correct, it is at least internally consistent with the ranges and timing of $^{36}Cl/Cl$ variations estimated from the packrat midden data. Three explanations for possible higher rates of isotope exchange in the Devils Hole flow system compared with Yucca Flat are as follows: (1) Flow in the Devils Hole system experiences more vertical variations due to faults and stratigraphic offsets, and undergoes a larger range of temperature and pressure variations that would promote calcite dissolution and re-precipitation. (2) Degassing of carbon dioxide (CO_2) under atmospheric conditions at Devils Hole promotes deposition of fine-grained, porous calcite, with which later groundwater then interacts. (3) Dolomite dissolution, combined with calcite precipitation, effectively serves as a carbon isotope exchange mechanism. None of these processes that potentially occur at Devils Hole apply to the LCA in Yucca Flat. Hence, further work under this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 20 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.6.4 Interpretation of Temperature Data			
38	Explain temperature at the water table, use temperature data to inform calibration of the coupled flow model, and incorporate water fluxes indicated by temperature data into determination of the contaminant boundary.	This uncertainty concerns the interpretation of temperature data in the Yucca Flat area.	Further work as suggested in this recommendation will not reduce the model uncertainty. The work to explain groundwater temperature patterns is described in detail in Appendix H of N-I (2013). From the data and associated models, it was interpreted that drainage from the AA/VA might be occurring near the major basin-bounding faults, consistent with the groundwater ^{14}C age distribution in the LCA. The possible range of groundwater inflow from the north was limited to 0 to 50 kg/s based on temperature profiles from Wells UE-10j and ER-8-1. The temperature data support recent assessments of small basin-wide fluxes and slow travel times as indicated by inorganic ^{14}C data. Further work under this recommendation is not necessary.
2.6.5 Realistic Geologic Features			
39	Incorporate more realistic geologic features as computational capabilities, software, and data improve.	This uncertainty addresses geological simplifications incorporated in the hydrostratigraphic model.	The base case model and the alternate conceptualizations presented in Responses #11 through #21, #42, and #44 encompass these uncertainties.
2.6.6 Other Sources of Data Are Available but Unused			
40	Review and use data from surrounding DOE and DOD facilities to further constrain water levels, boundary fluxes, and estimates of hydraulic properties. Among other approaches discussed in previous sections of this report, the peer review team recommends building confidence in the Yucca Flat model by using the Yucca Flat modeling approach to simulate single-test detonations outside Yucca Flat in similar geological units where there has been groundwater monitoring (e.g., the 40-kt RULISON test in 1969 in Colorado, the 200- to 1,000-kt FAULTLESS test in 1968 in central Nevada, or the 12-kt SHOAL test in 1963 in northern Nevada).	This uncertainty addresses sources of data from outside the CAU area that could potentially be used in the conceptual model.	All available data that may be used to constrain water levels within Yucca Flat, including data from surrounding DOE and U.S. Department of Defense (DoD) facilities, were evaluated and applied where applicable. The uniqueness of the different testing environments makes direct extrapolation of the results of offsite nuclear testing to Yucca Flat inappropriate. Hence, further work under this recommendation is not necessary. Due to the uniqueness of the different testing environments, direct extrapolation of the results of offsite nuclear testing is unlikely to add new insights to the processes already included in the Yucca Flat flow and transport model.

Table ES-1
Responses to YF/CM PRC Comments
(Page 21 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.7.1 Current Evaluation Does Not Capture the 95th Percentile			
41	Generate flow models that represent combinations of values from the upper end of their parameter distributions and explore whether calibration is successful.	This uncertainty addresses the perception that some of the extreme parameter values may not be sampled in the uncertainty analysis.	The uncertainty analysis in N-I (2013) and the alternate models presented in the response to the PRC comments together provide reasonable bounds for plausible transport scenarios. Several examples where parameters were manually changed to investigate the impact to the model are already presented (Responses #15 through #19). It is not reasonable to manually pick the upper end of multiple distributions simply to enhance the transport prediction. Using biased sampling of transport parameters may result in unrealistic predictions and misallocation of monitoring or remediation resources. Hence, further work under this recommendation is not necessary.
2.7.2 Expected Alternative Flow Models Were Not Included			
42	Include alternative flow models with fast flow fields from many detonation locations.	This uncertainty addresses the concern that some of the alternate conceptual models were not included in the uncertainty analysis.	The LCA model has already appropriately included fast path cases. As demonstrated by the Null Space Monte Carlo (NSMC) analysis (N-I, 2013), and also discussed in Responses #8 and #13, a wide range of parameter combinations were simulated, each matching observed water-level observations. As reported in Response #44, several additional fast path cases as well as particle starting locations at 39 detonations within 3 R_c of the saturated LCA (based on the maximum of the announced yield range [NNSA/NFO, 2015] and the equation published in Pawloski [1999]) were considered. The PRC identified 10 alternative cases they felt should be simulated; reasonable transport models based on these recommendations did not lead to significantly higher contaminant transport than the base case, or led to cases that did not match observed water levels and were not acceptable alternatives. Hence, further work under this recommendation is not necessary.
2.7.3 Limited Number (100) of NSMC Realizations			
43	Employ the approach described in Section 6.7.1 of N-I (2015) to capture fast flow fields without excessive numbers of simulations.	This uncertainty addresses the possibility that the effect of most permeable pathways was not captured by the range of uncertainty used in the model.	Fast flow path cases that produced more extensive transport, did not match observed water levels in the basin, and therefore are not acceptable alternatives. For example, the LCA model recalibrations specifying large faults as a high-permeability features produced faster transport than the base case, but were largely unsuccessful in matching steady-state heads in western Yucca Flat. Hence, further work under this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 22 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.7.4 Limited Calibrated Flow Models Used to Evaluate Transport Uncertainty			
44	Include more fast flow field models coupled with transport parameter values from the end of the distribution that enhances transport.	This uncertainty addresses the concern that the model did not include continuous high-conductivity pathways.	The modeling team disagrees with the approach proposed by the PRC that transport parameters be hand-drawn from parts of the distribution that maximizes transport. Biased sampling of conservative parameters creates unreasonable transport cases and results in extremely unlikely predictions above the 95th percentile. Using such unlikely predictions may result in misallocation of monitoring and/or remediation resources. A set of 39 possible contaminant sources (all detonations within 3 R_c of the SZ LCA) was used to identify alternate fast flow fields for transport uncertainty evaluation. Ten alternate model cases were selected for transport and contaminant boundary calculations in the LCA. These results along with LCA ^3H concentrations obtained from drilling Wells ER-2-2, ER-3-3, and ER-4-1, and the lower basin flux data (Halford, 2016) support the conclusion that the transport parameters distributions used to develop the contaminant boundary ensemble (N-I, 2013) adequately bound the range of uncertainty.
2.7.5 Limited Alternate Models Used to Evaluate Relevant Detonations			
45	Include more flow fields in the uncertainty evaluation with bias to capture the 95th percentile, and include all sources with enhanced transport.	This uncertainty focuses on the concern that some potentially important contaminant sources were excluded from the model.	This uncertainty was addressed using particle tracking studies followed by developing a contaminant boundary forecast for the particle track case with the largest total particle breakthrough at the southern boundary. Particle tracking studies included the 39 detonations within 3 R_c of the SZ LCA and the 83 NSMC flow fields that achieved an acceptable calibration from N-I (2013). The percentage of particles arriving near the model's southern boundary within 1,000 years varied from 13 to 82%. The 95th percentile contaminant boundary for the simulation with the largest total particle breakthrough was similar to that for the base case. Further work in the direction suggested in this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 23 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.7.6 Limited Range of Transport Parameters Values Used to Evaluate Transport Uncertainty			
46	Include Pu isotopes with combinations of lower K_d values and higher mass in the source term, expand the evaluated uncertainty range of matrix diffusion, and include higher values of dispersivity.	This uncertainty addresses the concern that the ranges considered in the model for some of the transport parameters were not sufficiently wide.	Alternative transport simulations using reduced Pu K_ds for the LCA matrix, reduced Pu retardation factors (R_d) for the LCA fractures, and increased dispersivity values did not lead to transport in excess of the base case. Reducing the range of Pu LCA matrix K_ds from the 900 to 10,000 mL/g values used for contaminant boundary calculations (N-I, 2013) to 0.76 to 1,096 mL/g (Sutton, 2009) produced more extensive Pu contamination; but because the contaminant boundary remained dominated by ^3H, the impact to the contaminant boundary was insignificant. Increased dispersivity resulted in more diffuse transport and a wider contaminant boundary with less MCL exceedances near the model's southern boundary compared to the base case. Larger Pu mass in the source term is not consistent with known concentrations in near-field samples or with published literature (Responses #25 and #26). Use of higher dispersivity values did not result in contaminant boundaries substantially different from those calculated in the base case. Further work suggested in this recommendation is not necessary.
2.7.7 Mesh Refinement Not Necessarily Conservative			
47	Evaluate higher level meshes to determine definitively the mesh-refinement level for which there is no change in the contaminant boundary.	This uncertainty focuses on the effects of the mesh size on model predictions.	Comparison of calibrated transport model results for 125-m spacing (Level 2 mesh) and 62.5-m spacing (Level 3 mesh) demonstrates that while transport from some locations was enhanced, transport from other locations was reduced; and the overall particle paths and travel times do not change significantly with mesh refinement. Further work in the direction suggested in this recommendation is not necessary.

Table ES-1
Responses to YF/CM PRC Comments
(Page 24 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.8.1 New Concerns and Approaches Will Likely Arise			
48	Engage external experts in periodic peer review.	This uncertainty is motivated by a desire for UGTA to employ external reviewers more frequently throughout the life of the project.	All UGTA Activity products are reviewed by a pre-emptive review committee that includes experts in a variety of fields (e.g., geology, radiochemistry, and hydrology) and an ex officio NDEP member. Additional reviewers are added as necessary. This committee is highly knowledgeable regarding the YF/CM CAU and different aspects of the flow and transport model. New contractors are introduced throughout the life of each CAU and, therefore, bring new perspectives to the work. The current process of using internal pre-emptive reviews with a final external peer review meets the requirements of the FFACO (1996, as amended) and will not be changed.
2.8.2 Climate Change			
49	Evaluate whether long-term climate change and associated extreme weather events would have a significant impact on transport of radionuclides.	This uncertainty addresses the concern that the climate may change radically over the 1,000-year time frame of concern.	A preliminary assessment indicates that the U.S. Southwest will experience warmer and drier conditions. If true, then current models are already conservative. By continued execution of the UGTA strategy (FFACO, 1996 as amended), any such assessment of regional scale climate change will occur when monitoring indicates a need for this action.

Table ES-1
Responses to YF/CM PRC Comments
(Page 25 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.9.1 The Extent of Contamination Is Poorly Defined at Present			
50	Determine the bounds of contaminant migration in both the AA/VA and LCA.	This uncertainty focuses on the need to define the bounds of contaminant migration.	Since the completion of N-I (2013), eight wells have been resampled (ER-2-1, ER-6-2, TW-B, UE-6d, UE-6e, UE-7nS, WW-2, and WW-3). Five of these wells (ER-2-1, ER-6-2, TW-B, UE-6d, and UE-6) were identified by the PRC as of special concern (N-I, 2013, Table 6-4) based on previous ^{3}H measurements. Additionally, three new wells (ER-2-2, ER-3-3, and ER-4-1) were drilled near deeply buried, large-yield detonations (ER-2-2 and ER-4-1) or near faults (ER-2-2 and ER-3-3) to investigate the extent of contamination associated with tests near the LCA or faults. No new detections of elevated ^{3}H concentrations in the LCA were observed in the resampled existing wells or in samples collected while drilling the three new wells. This supports the observation that ^{3}H contamination of the LCA is of limited areal extent and that simulations documented in N-I (2013) adequately bound RN transport. Contamination in the AA/VA is generally limited to a few R_c around the working point (as observed during drilling of ER-2-2), except near WW-A, where 27 years of pumping for water supply induced migration toward the pumping well; in the LCA, no wells have ^{3}H concentration that exceed the MCL (20,000 pCi/L), except for the U-2ce (NASH) satellite well, which appears to be in an isolated thrust block of the lower carbonate aquifer thrust plate (LCA3). This supports the observation that ^{3}H contamination of the LCA is of limited areal extent and that simulations documented in N-I (2013) adequately bound RN transport.

Table ES-1
Responses to YF/CM PRC Comments
(Page 26 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
2.9.2 The Existing Observation Well Network Is Inadequate			
51	Conduct a comprehensive formal review of existing data quality, and maintain a groundwater monitoring program designed to evaluate model uncertainties and delineate contaminant boundaries.	This uncertainty addresses the well network necessary to determine the extent of contamination.	Continued execution of the UGTA strategy (FFACO, 1996 as amended) and implementation of the NNSS Integrated Sampling Plan (NNSA/NFO, 2014) will continue to address this comment. Sampling plan implementation will ensure samples are collected routinely and that the results are annually evaluated for quality and consistency with the conceptual models of flow and transport (N-I, 2013). ^{3}H concentration maps are presented in the Annual Site Environmental reports and will also be presented in UGTA Annual Sampling reports. A summary of RN detections in the SZ AA/VA and LCA domains spanning five decades in some cases was included in Tables 4-45 and 4-46 and as Appendix D in N-I (2013). In addition, numerous historical reports have been identified to help constrain permeability variations in the vicinity of underground nuclear tests, including those that involve post-shot holes. Selection and placement of monitoring wells is the focus of the final stage of the UGTA strategy (FFACO, 1996 as amended), the Closure Report (CR) stage, and not the CAI or CADD/CAP stages. No further actions are therefore necessary to address this recommendation.

Table ES-1
Responses to YF/CM PRC Comments
(Page 27 of 27)

#	Recommendation	Focus of the Concern	Summary of Response
52	General locations for new wells, aquifer tests, and sampling during the CADD/CAP stage, including samples from existing wells, are recommended in Section 5.9.2.	This uncertainty addresses the well network necessary to determine the extent of contamination.	Execution of the UGTA strategy (FFACO, 1996 as amended) and implementation of the NNSS Integrated Sampling Plan (NNSA/NFO, 2014) will continue to address this comment. Since the completion of N-I (2013), eight wells have been resampled (ER-2-1, ER-6-2, TW-B, UE-6d, UE-6e, UE-7nS, WW-2, and WW-3). Five of these wells (ER-2-1, ER-6-2, TW-B, UE-6d, and UE-6) were identified by the PRC as of special concern (N-I, 2015, Table 6-4) based on previous ^{3}H measurements. Additionally, three new wells (ER-2-2, ER-3-3, and ER-4-1) were drilled near deeply buried, large-yield detonations (ER-2-2 and ER-4-1) or near faults (ER-2-2 and ER-3-3) to investigate the extent of contamination associated with tests near the LCA or faults and to provide hydraulic data in the central parts of the basin that were not hydraulically stressed by the ER-6-1-2 MWAT in 2004. No new detections of elevated ^{3}H concentrations in the LCA were observed in the resampled existing wells or in samples collected during drilling the three new wells. This supports the observation that ^{3}H contamination of the LCA is of limited areal extent and that simulations documented in N-I (2013) adequately bound RN transport.

Note: Cavity dimension based on maximum announced yield identified in NV-209-REV 16 (NNSA/NFO, 2015) and Equation 1 in UCRL-ID-136003 (Pawloski, 1999).

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November 7, 2016

From: Yucca Flat/Climax Mine (YF/CM) Preemptive Review Committee

To: Ed Kwicklis, Sharad Kelkar, Irene Farnham, Bill Wilborn

Subject: Close out of YF/CM PER memos dated May 29, 2015; July 20, 2015; and April 11, 2016

This memo formally closes out the three YF/CM preemptive reviews (PERs) documented in PER memos dated May 29 and July 20, 2015 and April 11, 2016. In these reviews, members of the YF/CM PER Committee reviewed the Modeling Team's approach and initial responses to External Peer Review comments. The Modeling Team's final responses to the Peer Review are provided in the report "*Response to External Peer Review Team Report for Corrective Action Unit 97: Yucca Flat/ Climax Mine, Nevada National Security Site, Nye County, Nevada*", dated October 2016.

The Modeling Team provided their responses to each of the PERs in three memos dated November 4, 2016. The PER Committee reviewed the responses and determined that the Modeling Team adequately addressed all PER concerns. Therefore, the PER Committee considers all PERs of the External Peer Review response document to be closed.

Sincerely,

/s/ Joseph Fenelon

Joseph Fenelon
YF/CM Preemptive Review Committee Chair
U.S. Geological Survey
Henderson, Nevada
Phone: 702 564-4605
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Preemptive Review Committee

Joe Fenelon, Chair, USGS
Nicole DeNovio, Golder contracted to Navarro
Karl Pohlmann, DRI
Andy Tompson, LLNL
Keith Halford, USGS
Jeff Wurtz, Navarro
Irene Farnham, Science Advisor, Navarro
Britt Jacobson, NDEP (ex officio member)

Attachment 3

Justification for Proceeding to Decision #4 of the UGTA Strategy for the Yucca Flat / Climax Mine Corrective Action Unit

An external peer review of the Yucca Flat / Climax Mine (YF/CM) flow and transport model and supporting data was performed during fiscal year (FY) 2014 and FY 2015. The outcome was reported in *External Peer Review Team Report for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada* (N-I, 2015). To support the review, clarification was provided by U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) to define the purpose and goal and the associated level of confidence required in the model and the model results necessary to advance from the Corrective Action Investigation (CAI) stage to the Corrective Action Decision Document/Corrective Action Plan (CADD/CAP) stage (Wilborn, 2014):

> *The model and supporting information should* be *sufficiently complete that the key uncertainties can be adequately identified such that they can be addressed by appropriate model evaluation studies. The model evaluation studies may include data collection and model refinements conducted during the CADD/CAP stage. One major input to identifying "key uncertainties" is the detailed peer review provided by independent qualified peers.*

While the External Peer Review committee (PRC) concluded that DOE was ready to transition to model evaluation studies in the CADD/CAP stage, they identified several model uncertainties and made recommendations for activities to address the uncertainties during the CADD/CAP stage. The uncertainties were associated with nine main areas related to the YF/CM flow and transport model documented in N-I (2013a): (1) model domain/boundary conditions, (2) model calibration, (3) hydraulic properties and pathways, (4) source term and mass flux, (5) transport, (6) simulating critical observations, (7) uncertainty assessment, (8) unforeseen uncertainties, and (9) location of RN plumes. There were several comments under each of these areas, and some of the comments contained sub-comments, thus leading to 52 total comments.

The YF/CM Modeling Team addressed the peer reviewer's concerns and recommendations in *Response to External Peer Review Team Report for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada* (Navarro, 2016). The YF/CM Pre-emptive review (PER) committee reviewed the YF/CM Modeling Team responses three times during different stages of their development and summarized their comments in a series of memorandums. On November 7, 2016, the PER committee formally closed out the three reviews stating that the Modeling Team adequately addressed their concerns described in the three memorandums.

The responses include the drilling of three new wells, additional data collection, reanalysis of existing data and models, and modeling studies. These supplemental analyses carefully address the uncertainties noted by the PRC, and demonstrate that the YF/CM flow and transport models documented in N-I (2013) are suitable representations of flow and transport behavior and appropriately bound the uncertainties in the contaminant boundary forecasts.

In instances where the modeling team believed that the concerns of the PRC could be efficiently investigated with existing models or with simple new models, the team ran these simulations to explore the impact of the suggested parameter changes or conceptual models recommended by the PRC. Flow models designed to explore the alternate conceptual models and bounding scenarios were calibrated and particle tracking calculations were performed. Transport modeling was done on a subset of cases to assess the 95th percentile contaminant boundary. In most cases the models that could achieve acceptable calibrations led to particle breakthroughs and transport forecasts that were equivalent to or less extensive than the base case. Because transport pathways and the extent of contamination in these alternative models are similar to those models already documented in N-I (2013), it is unnecessary to test these alternative models further in CADD/CAP.

In some cases, uncertainties that should be further evaluated were identified. For instance, Navarro (2016) noted that in the base-case model of (N-I, 2013), MCL exceedance at the southern boundary occurred in about 10 percent of the realizations. However, recent reanalysis of the water balance for Yucca Flat by Fenelon et al. (2016) supports that the base case flow model overestimated the water flux through Yucca Flat. Flux estimates resulting from a reanalysis of the data from the ER-6-1-2 multiple well aquifer test (MWAT) led to boundary flux values (19 kg/s) that are nearly an order of magnitude smaller than those from the base case (189.6 kg/s). Preliminary simulations using the 19-kg/s flux values led to 95 percentile contaminant boundary forecasts that were well north of the southern boundary of the model. While this supports the present model boundaries as sufficiently large to include all expected contaminant boundary locations, these models will be explored more fully during the model evaluation phase of the CADD/CAP stage. Given the impact of the basin groundwater flux on the contaminant boundary extent, formal documentation of the reanalysis of ER-6-1-2 MWAT (Halford, 2009, 2012, and 2016) is being planned as a specific uncertainty reduction activity during the CADD/CAP stage.

In addition, three models with alternative fault conceptualizations recommended by the PRC led to greater particle breakthrough at 1,000 years compared to the base case: (1) models containing faults without low permeability cores, (2) models containing only faults with trace lengths greater than 3km, and (3) models with only the largest basin-forming faults. During the CADD/CAP stage, these alternate models will be explored further using the more realistic basin groundwater flux constraints described above.

The PER committee requested that specific criteria be developed to distinguish between plausible and implausible models, and that a more realistic model than the present Base Case model be developed. This process is appropriate for the CADD/CAP stage and will therefore be described in the Model Evaluation Plan. As a result of responding to the PRC comments, new data have been collected and older data sets re-analyzed, so that the modeling team is now in a position to evaluate model plausibility and further test only models that already agree with important existing data and observations.

In summary, the external peer review was performed and the YF/CM Modeling Team formally addressed all comments resulting from the review. The PER committee has reviewed the YF/CM Modeling Team responses to PER memorandums and determined that they adequately addressed all PER concerns. The evaluations described in Navarro (2016) performed as a result of PRC comments allows the YF/CM Modeling Team to focus on remaining *key uncertainties to be addressed during model evaluation as* described in the Wilborn (2014) clarification. Therefore, the PRC process has met its objective and the YF/CM CAU can advance to the next stage of the FFACO strategy, Decision #4.

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Christine Andres, Chief
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REQUEST TO PROCEED TO DECISION #4 OF THE FEDERAL FACILIYTY AGREEMENT AND CONSENT ORDER (FFACO) UNDERGROUND TEST AREA (UGTA) STRATEGY FOR CORRECTIVE ACTION UNIT (CAU) 97: YUCCA FLAT/CLIMAX MINE

Following the FFACO process, an external peer review of the Yucca Flat/Climax Mine (YF/CM) flow and transport model and supporting data has been completed and the YF/CM Modeling Team addressed the peer reviewer's concerns and recommendations. The Executive Summary of the Navarro response to the peer review document summarizing the peer reviewer's concerns and recommendations and the YF/CM Modeling Team's responses, is presented as Attachment 1 to this letter.

The YF/CM Modeling Team responses were reviewed at varying stages by the YF/CM Pre-emptive review (PER) committee. Through an iterative process of receiving comments, revising the document, and performing additional analyses, the PER committee determined that the YF/CM Modeling Team adequately addressed their concerns and the PER process was closed out (Attachment 2 to this letter).

With the completion of the external peer review and the UGTA modeling team responses to the peer reviewer's recommendations, the National Nuclear Security Administration Nevada Field Office (NNSA/NFO) requests approval to proceed to Decision #4 of the FFACO UGTA Strategy. Attachment 3 to this letter provides further justification for proceeding to Decision #4 and also identifies activities to be addressed as Model Evaluation studies.

Please direct comments and questions to Bill Wilborn, of my staff, at (702) 295-3188.

Original Signed by:
Rob Boehlecke

Robert F. Boehlecke, Manager
Environmental Management Operations

EMO:12130.CD

Enclosures:
As stated

Appendix D

DOE and NDEP Correspondence Regarding Advancement to CADD/CAP Stage of the UGTA Strategy

R.F. Boehlecke (NNSA/NFO) to C. Andres (NDEP)

(7 Pages)

C. Andres (NDEP) to R.F. Boehlecke (NNSA/NFO)

(2 Pages)

Department of Energy
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JAN 1 8 2017

Christine Andres, Chief
Bureau of Federal Facilities
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REQUEST TO RESCIND JANUARY 11, 2017 LETTER AND TO REISSUE REQUEST FOR ACCEPTANCE OF THE FLOW AND TRANSPORT MODEL FOR CORRECTIVE ACTION UNIT (CAU) 97: YUCCA FLAT/CLIMAX MINE CORRECTIVE ACTION DECISION DOCUMENT/CORRECTIVE ACTION PLAN (CADD/CAP) STUDIES

The National Nuclear Security Administration Nevada Field Office (NNSA/NFO) would like to rescind the subject letter and asks that the Nevada Division of Environmental Protection (NDEP) accept this letter and enclosure as the official request for acceptance of the Yucca Flat/Climax Mine Flow and Transport Model for the CADD/CAP studies.

With the successful progression to Decision 4 in the Underground Test Area (UGTA) Strategy, your acceptance of the Yucca Flat/Climax Mine Flow and Transport Model for the CADD/CAP studies is requested. The NDEP's acceptance of this Model is the final decision in the corrective action investigation stage and is required prior to moving forward to the CADD/CAP stage. Justification for Model acceptance is attached.

The NNSA/NFO requests that you provide a response with your acceptance of the Flow and Transport Model within 30 days of the date of this letter.

Please direct comments and questions to Bill Wilborn, of my staff at (702) 295-3188.

/s/ Robert F. Boehlecke

Robert F. Boehlecke, Manager
Environmental Management Operations

EMO:12182.CD

Enclosures:
As stated

JAN 1 8 2017

cc w/encl. via e-mail:
Mark McLane, NDEP
J. T. Fraher, DTRA/CXTS
Navarro Central Files
NSTec Correspondence Management
W. R. Wilborn, NFO
FFACO Group, NFO
NFO Read File

Justification for Acceptance of the Yucca Flat / Climax Mine Flow and Transport Model for Corrective Action Decision Document / Corrective Action Plan Studies

Background

The *Federal Facility Agreement and Consent Order* (FFACO) (1996, as amended) corrective action process for the Yucca Flat/Climax Mine corrective action unit (CAU) was initiated with the *Corrective Action Investigation Plan (CAIP) for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nevada* (DOE/NV, 2000). The CAIP identified a model development process to evaluate the impact of underground nuclear testing on the Yucca Flat/Climax Mine CAU groundwater flow system.

The process included data analysis to compile and evaluate existing and new data for use in the Yucca Flat / Climax Mine Flow and Transport model. These data analysis activities are documented in a series of reports:

- *Phase I Hydrologic Data for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nye County, Nevada* (SNJV, 2006a)
- *Phase I Contaminant Transport Parameters for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nye County, Nevada* (SNJV, 2007)
- *A Hydrostratigraphic Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat-Climax Mine, Lincoln and Nye Counties, Nevada* (BN, 2006)
- *Geochemical and Isotopic Evaluation of Groundwater Movement in Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nevada (SNJV, 2006b)*
- *Evaluation of Hydrologic Source Term Processes for Underground Nuclear Tests in Yucca Flat, Nevada Test Site: Introduction and Executive Summary* (Pawloski et al., 2008)

Following data analysis, groundwater flow and contaminant transport models were developed. The scope of the modeling effort included use of the transport model to forecast the extent of the contaminant transport within 1,000 years as required in the FFACO (1996, as amended). As identified in the FFACO, these forecasts provide planning tools to facilitate regulatory decisions designed to protect the health and safety of the public. The groundwater flow and contaminant transport model for CAU 97 is described in the Yucca Flat/Climax Mine *Phase I Flow and Transport Model Document for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada* (N-I, 2013).

As required in the FFACO (1996, as amended), an external peer review of this document and supporting data was then performed. The external peer committee (PRC) concluded that the Yucca Flat/Climax Mine is ready to transition to the CADD/CAP stage subject to the caveat that uncertainties and associated recommendations that the PRC identified are carefully addressed during the CADD/CAP stage (N-I, 2015). Extensive studies were then conducted in response to the PRC recommendations. These studies, including drilling three new wells, additional data collection, reanalysis of existing data and models, and modeling studies, are documented in *Response to External Peer Review Team Report for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada* (Navarro, 2016).

Following publication of the Yucca Flat/Climax Mine Modeling Team's responses (Navarro, 2016), NNSA/NFO requested and was given approval to advance to Decision 4 in the FFACO (1996, as amended). Decision 4, a *Nevada Division of Environmental Protection (NDEP) Decision, asks* if the CAU Model is Acceptable for CADD/CAP studies.

Justification

The justification for recommending NDEP acceptance of the Yucca Flat / Climax Mine flow and transport model for CADD/CAP studies include the following:

1. The flow and transport document (N-I, 2013) addressed the FFACO requirements including development of ensembles of contaminant boundary forecasts that incorporate multiple alternatives models of boundary conditions, recharge, hydrostratigraphic framework models, alternative sets of calibrated flow models, and Monte Carlo simulations of radionuclide transport.
2. NDEP identified no deficiencies in the data or model results and agreed to proceed to External Peer review (Murphy, 2014).
3. The PRC (N-I, 2015) recommended that the Yucca Flat / Climax Mine CAU is ready to transition to model evaluation studies in the CADD/CAP stage.
4. Supplemental analyses (Navarro, 2016) addressed the uncertainties noted by the PRC, and demonstrated that the Yucca Flat / Climax Mine flow and transport models documented in N-I (2013) are suitable representations of flow and transport behavior and appropriately bound the uncertainties in the contaminant boundary ensemble forecasts.
5. Recommendations made by the PRC regarding parameter adjustments and conceptual models did not result in the development of credible models that produced significantly different transport pathways or contamination extents.
6. Long-standing conceptual models of the general hydrogeology of Yucca Flat have been upheld by UGTA work:
    1. Limited inflow into Yucca Flat due to low-permeability rock northwest, north and northeast of the basin
    2. Low or zero long-term net infiltration through alluvium, and small recharge in surrounding hills
    3. Groundwater ^{14}C ages and $^{36}Cl/Cl$ ratios are indicative of late ice-age recharge in both the shallow alluvial/volcanic aquifers and in the lower carbonate aquifer (supports near-absence of modern recharge)
    4. Hydraulic head differences of 6 to 20 m between shallow alluvial/volcanic flow system and LCA due to slow drainage of paleo-recharge across the relatively impermeable TCU
7. The evaluations described in Navarro (2016) performed as a result of PRC comments allows the Yucca Flat / Climax Mine Modeling Team to focus on remaining key uncertainties to be addressed during model evaluation. CADD/CAP activities identified during the Peer Review process include: ER-6-1-2 multiple well aquifer test reanalysis and alternative fault conceptualization evaluations. As recommended by the pre-emptive review committee, a more realistic model than the present Base Case model will also be developed during the CADD/CAP stage.

8. NDEP agreed that the Peer Review process has been completed and that the Yucca Flat / Climax Mine CAU can advance to Decision 4 of the FFACO strategy (Andres, 2016).

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ERD.170123.0006

National Nuclear Security Administration

Department of Energy
National Nuclear Security Administration
Nevada Field Office
P.O. Box 98518
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Christine Andres, Chief
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REQUEST TO RESCIND JANUARY 11, 2017 LETTER AND TO REISSUE REQUEST FOR ACCEPTANCE OF THE FLOW AND TRANSPORT MODEL FOR CORRECTIVE ACTION UNIT (CAU) 97: YUCCA FLAT/CLIMAX MINE CORRECTIVE ACTION DECISION DOCUMENT/CORRECTIVE ACTION PLAN (CADD/CAP) STUDIES

The National Nuclear Security Administration Nevada Field Office (NNSA/NFO) would like to rescind the subject letter and asks that the Nevada Division of Environmental Protection (NDEP) accept this letter and enclosure as the official request for acceptance of the Yucca Flat/Climax Mine Flow and Transport Model for the CADD/CAP studies.

With the successful progression to Decision 4 in the Underground Test Area (UGTA) Strategy, your acceptance of the Yucca Flat/Climax Mine Flow and Transport Model for the CADD/CAP studies is requested. The NDEP's acceptance of this Model is the final decision in the corrective action investigation stage and is required prior to moving forward to the CADD/CAP stage. Justification for Model acceptance is attached.

The NNSA/NFO requests that you provide a response with your acceptance of the Flow and Transport Model within 30 days of the date of this letter.

Please direct comments and questions to Bill Wilborn, of my staff at (702) 295-3188.

Original Signed by:
Rob Boehlecke

Robert F. Boehlecke, Manager
Environmental Management Operations

EMO:12182.CD

Enclosures:
As stated

NEVADA DIVISION OF
ENVIRONMENTAL PROTECTION

STATE OF NEVADA
Department of Conservation & Natural Resources
Brian Sandoval, Governor
Bradley Crowell, Director
David Emme, Administrator

ERD.170124.0001

January 23, 2017

Mr. Robert F. Boehlecke, Manager
Environmental Management Operations
National Nuclear Security Administration
Nevada Field Office
P.O. Box 98518
Las Vegas, Nevada 89193-8518

RE: ACCEPTANCE OF THE FLOW AND TRANSPORT MODEL FOR CORRECTIVE ACTION UNIT (CAU) 97: YUCCA FLAT/CLIMAX MINE CORRECTIVE ACTION DECISION DOCUMENT/CORRECTIVE ACTION PLAN (CADD/CAP) STUDIES
Federal Facility Agreement and Consent Order (FFACO)

Dear Mr. Boehlecke:

The Nevada Division of Environmental Protection, Bureau of Federal Facilities staff (NDEP) has received and reviewed the National Nuclear Security Administration/Nevada Field Office's (NNSA/NFO) January 18, 2017 letter requesting acceptance of the Yucca Flat/Climax Mine Flow and Transport Model for CADD/CAP Studies. While the NDEP does not agree with all of the Peer Review's comments and recommendations to the NNSA/NFO about the Yucca Flat/Climax Mine Flow and Transport Model, the NDEP does find that all of our Agency's comments and recommendations in regards to the model have been adequately addressed by the NNSA/NFO's studies and responses to the Peer Review.

Therefore, pursuant to Section 3.0 of Appendix VI of the FFACO, the NDEP accepts the Yucca Flat/Climax Mine Flow and Transport Model for CADD/CAP Studies and approves proceeding to the CADD/CAP stage for Yucca Flat/Climax Mine CAU 97. This approval is given with the conditions that all planned actions in Justification #7 of the above-referenced letter be identified in the Yucca Flat/Climax Mine CADD/CAP. The results of all of these actions must be documented and presented to the NDEP via interim documents, letters or presentations during the CADD/CAP stage.

If you have questions regarding this matter, please contact me at (702) 486-2850 ext. 232 or Mark McLane at ext. 226.

Sincerely

/s/ Christine D. Andres

Christine D. Andres
Chief
Bureau of Federal Facilities

CDA/MM

ec: EM Records, NNSA/NFO
W. R. Wilborn, NNSA/NFO
NSTEC Correspondence Management
Navarro Central Files

cc: EM Records, NNSA/NFO
FFACO Group, NNSA/NFO
J. T. Fraher, DTRA/CXTS
W. R. Wilborn, NNSA/NFO

Appendix E

Nevada Division of Environmental Protection Comments

(4 Pages)

NEVADA ENVIRONMENTAL MANAGEMENT OPERATIONS ACTIVITY
DOCUMENT REVIEW SHEET

1. Document Title/Number: **CAU 97: Yucca Flat/Climax Mine Draft CADD/CAP**	2. Document Date: **May 2017**
3. Revision Number: **0**	4. Originator/Organization: **Navarro**
5. Responsible EM Nevada Program Activity Lead: **Bill Wilborn**	6. Date Comments Due: **June 22, 2017**
7. Review Criteria:	
8. Reviewer/Organization Phone No.: **Nevada Division of Environmental Protection**	9. Reviewer's Signature:

10. Comment Number/Location		11. Type[a]	12. Comment	13. Comment Response
1.	Page ES-1, Last Paragraph and Page 9, Section 2.1, First Paragraph		A reference to Appendix B should be added to the sentence before the bullets to refer to the reader to the tables of information presented in Appendix B that explain these bullets. The tables clarify why Rainier Mesa studies are presented in a Yucca Flat document.	Reference to Appendix B was added as requested.
2.	2. Page 12, Figure 2-1		It is not clear what this figure actually adds to the document. At a minimum, a legend needs to be added to the figure and the text related to this figure needs to be enhanced to describe all the items actually shown on the figure. The figure may also be removed and only the text enhanced to explain the concepts being portrayed. Should the figure be retained, the six bullets below provide examples of needed changes to the figure: a. The first "Model Inputs" box should be Flow Model Inputs; the second "Model Inputs" box should be Transport Model Inputs. This clarification needs to be included to be consistent with the text on Page 11. b. The second orange arrow going from the "Flow Model Inputs" box to the “Calibrations to Targets" box is not clear in what additional model uncertainty is included in the calibration to targets that is not included in the flow model. Please clarify in the text. c. The "HST" box should be HST Model to be consistent with the text on Page 11. d. The "HFM Geology" box should be HFM Geology Models to be consistent with the text on Pages 11 and 15. e. Are the solid orange arrows related to the uncertainty portion of each box? It would be clearer if they were red as the word "Uncertainty" in the boxes is red. Please indicate the meaning of the black and orange arrows on the figure and in the text.	The figure was removed and text revised in Section 2.2.1 to improve the concept of uncertainty represented by the contaminant boundary versus the uncertainty represented by the contaminant boundary ensemble.

[a]Comment Types: M = Mandatory, S = Suggested.
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3.	Global		Work that has already been completed, such as the Hydrostratigraphic Framework Models described in Section 2.2.1.2, should be written in the past tense. Using the present tense, such as what is done for the sentence at the end of the first paragraph on Page 16, indicates that all five of this models are still considered valid. Is this the case? Somehow the text in Section 2 should indicate past tense for completed CAIP work and work that will be addressed during the CADD/CAP Stage should be written in future tense.	The text throughout Section 2 was revised to indicate past tense for completed CAIP work, and work that will be addressed during the CADD/CAP stage was written in future tense. Present tense was used when work being presented is still current.
4.	Page 23, Partial Paragraph at top of page, Last Sentence		Either a reference should be made to Appendix C, Table ES-1, Section 2.3.2 or a statement added to this paragraph to explain why there are no large masses of RN transported to the LCA.	The following text was added to the end of this paragraph: "However, these models calibrated poorly compared to other models (Navarro, 2016; Appendix A, Figure A-1c), and were shown to be unlikely because contamination in the LCA has not been observed near large-yield, deeply buried tests located either close to the LCA or near faults (U-3cn-5, UE-7nS, ER-2-2, ER-3-3, ER-4-1, and ER-7-1) (see Appendix C, Table ES-1, Section 2.3.2)."
5.	Page 38, Section 3.2, Third Paragraph, Second Sentence		"A monitoring network will be installed ... " should be reworded to indicate "A monitoring plan will be developed ... "	Text was revised to state "A monitoring plan will be developed..."

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6.	Page 39, Section 3.2, First Paragraph, Second Sentence:		Has an official decision been made that long-term monitoring will become the responsibility of the landlord and not DOE's Office of Legacy Management?	The text was modified to read: **"**The current assumption, as stated in the Nevada Test Site Environmental Management End State Vision (DOE, 2006), is that once the UGTA Activity CAUs are ready for closure (currently planned for fiscal year 2030), responsibilities for long-term stewardship (long-term monitoring and management activities) will be turned over to the landlords, currently NNSA/NFO. Although the responsible organization may be reassigned by 2030, planning and mitigation strategies are in process and will continue to be implemented to ensure proper stewardship of the contaminated sites to protect workers, the public, and the environment, now and for future generations."
7.	Page 45, Section 4.2, CAU Regulatory Objectives, Second paragraph, First sentence:		The regulatory boundary objective uses the term "Yucca Flat basin." It appears that the term "Yucca Flat hydrographic area" is being used in place of Yucca Flat basin. If so, please state this.	The following statement was added to the text: "The hydrographic area will represent the Yucca Flat basin, with respect to the regulatory boundary objective."
8.	Page 48, Section 4.4, Model Evaluation Approach, First and Second full sentences on top of page:		NDEP would like to discuss the first sentence for clarity, as the target could still be met if some of the data-collection activities are conclusive and others are inconclusive. Additionally, the second sentence mentions overall goals. Only one overarching goal is discussed in the first paragraph, first sentence of Section 4.4 on Page 47. The second sentence on Page 47 lists ways to meet this goal. Are there other goals included in this "overall goals"? If so, where are they presented? Please clarify.	Text was revised to include statements directly from the FFACO. The purpose of model evaluation was described as increasing confidence in the reliability of model results. Discussion was added from the FFACO regarding model acceptance by NDEP. Rather than stating that the "overall goals" can be achieved (if a data-collection activity is deemed inconclusive and the affected target is included as an alternative model in the ensemble), it was stated that "model acceptability" can be achieved.
9.	Page 49, Section 4.4, First paragraph, Fifth bullet:		The terms "the CAU" should be inserted between "to move" and "to CR" Please correct.	Text was revised to include "the CAU."

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10.	Page 51, Section 4.4.4, Assess Impact of New Data and Refine Model as Necessary (Step 4), Paragraph after bullets, Fourth sentence		"Criteria based on the model-evaluation targets" Please indicate that these criteria are shown in Section 4.5.3.	Reference to Section 4.5.3 was added.
11.	Page 54, Section 4.5, Data-Collection Activities, Second full paragraph, Fourth sentence		"Criteria based on model-evaluation targets ... " Please indicate that these criteria are shown in Section 4.5.3.	The last sentence was modified to state that the criteria are presented along with the approach to model refinement in Section 4.5.3.
12.	Page 58, Section 4.5.2, First Partial Paragraph, Second Full Sentence:		Please replace the word "thought" with "anticipated" in this sentence.	The word "anticipated" replaced the word "thought" in this sentence.
13.	Page 58, Section 4.5.2, Data Collection and Analysis, Paragraph following the bullets, Third sentence:		" ... individual uncertainty reduction targets." Please reference Table 4-1 in this sentence.	Reference to Table 4-1 was added.
14.	Page 59, Section 4.5.2.2		The title of this subsection should be " . MWAT Reanalysis" to be consistent with Table 4-1 on Page 55.	Heading was changed to "Formalizing ER-6-1-2 MWAT Reanalysis."
15.	Page 62, Section 4.5.3, Second Sentence:		Will there be other criteria/data considered?	Criteria will include those listed but may also be expanded. This will be described in the model evaluation report.

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