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U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
OFFICE OF QUALITY ASSURANCE

AUDIT REPORT

OF

CIVILIAN RADIOACTIVE WASTE MANAGEMENT SYSTEM
MANAGEMENT AND OPERATING CONTRACTOR

LAS VEGAS, NEVADA
AND
ALBUQUERQUE, NEW MEXICO

AUDIT NUMBER SNL-ARP-97-08
JANUARY 30 THROUGH FEBRUARY 5, 1997

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Enclosure

1.0 EXECUTIVE SUMMARY

As a result of Performance Based Quality Assurance (QA) Audit SNL-ARP-97-08, the audit team determined that the Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) and Sandia National Laboratories (SNL) is satisfactorily implementing adequate and effective process controls for work performed under Work Breakdown Structure (WBS) 1.2.3.9.5, "Three-Dimensional Geologic Model." The CRWMS M&O and SNL process controls examined during this audit were in accordance with U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (CRWMS) Quality Assurance Requirements and Description document (QARD) DOE/RW-0333P, Revision 5. In addition, overall adequacy and compliance selected CRWMS M&O and SNL implementing procedures was found to be satisfactory.

The audit team identified three deficiencies during the course of the audit that were corrected prior to the postaudit meeting (see Section 5.5.4 of this report). One deficiency concerned inadequate entries to scientific notebooks being maintained by SNL. The second deficiency identified insufficient data traceability to SNL scientific notebooks. The third deficiency concerned missing training documentation for personnel performing modeling activities.

Additionally, there were seven recommendations for process improvements resulting from this audit which are listed in Section 6.0 of this report.

2.0 SCOPE

The performance based audit was conducted to evaluate the adequacy and effectiveness of CRWMS M&O and SNL process controls for performing activities that result in the development of the Geological Framework and Integrated Three-Dimensional Site Model. The audit was intended to determine the progress and development of the model and that the products are being developed in accordance with program requirements addressed by pertinent sections of the QARD.

PROCESS/ACTIVITY/OR END-PRODUCT

Activities involving development of the Geologic Framework and Integrated Three-Dimensional Site Model were selected for evaluation from Work Breakdown Structure (WBS) element 1.2.3.9.5, "Three-Dimensional Geologic Model."

The performance based evaluation of process effectiveness and product acceptability was based upon:

1. Satisfactory implementation of the critical process steps;
2. Use of trained and qualified personnel working effectively;
3. Documentation that substantiates the quality of the product;
4. Acceptable results and adequate end-product; and
5. Effectiveness of Corrective Action.

The CRWMS M&O critical process steps involved in the development of the audited deliverable were as follows:

- Data selection and input;
- Data transfer to the model;
- Data incorporation into the model (i.e., data reduction);
- Data output;
- Data output verification;
- Data update and changes;
- Review and acceptance.

TECHNICAL AREAS

The audit included a technical evaluation of the development process and adequacy of the Geological Framework and Integrated Three-Dimensional Site Model. Details of the technical evaluation are included in Section 5.4.

In addition, a sample of QA Program elements were evaluated only as they directly related to the technical areas. These program elements included:

1.0 Organization
2.0 QA Program (Qualification and Training of Personnel)
5.0 Implementing Documents
6.0 Document Control
16.0 Corrective Action
17.0 QA Records

Supplement I, Software
Supplement III, Scientific Investigation

3.0 AUDIT TEAM AND OBSERVERS

The following is a list of audit team members and their assigned areas of responsibility:

Name/Title/Organization	QA Program Elements/Requirements Processes Activities or End Products
Dennis C. Threatt, Audit Team Leader OQA	QA Program Elements directly related To support of the end product, QA Program Supplements I, III
Daniel A. Klimas, Auditor OQA	QA Program Elements directly related to support of end product, QA Elements 1.0, 2.0, 5.0, 6.0, 16.0, 17.0
Jefferson McCleary, Technical Specialist, CRWMS M&O	Supplement III, Process Steps for development of Geological Framework and Integrated 3-D Site Model

4.0 AUDIT MEETINGS AND PERSONNEL CONTACTED

The preaudit meeting was held at the M&O offices in Las Vegas, Nevada, on January 30, 1997. A daily debriefing and coordination meeting was held with the CRWMS M&O and SNL management and staff, and daily audit team meetings were held to discuss issues and potential deficiencies. The audit was concluded with a postaudit meeting held at the CRWMS M&O offices in Las Vegas, Nevada, on February 5, 1997. Personnel contacted during the audit are listed in Attachment 1. The list includes those who attended the preaudit and postaudit meetings.

5.0 SUMMARY OF AUDIT RESULTS

5.1 Program Effectiveness

The audit team concluded that, in general, process controls are adequately and effectively being implemented by the CRWMS M&O and SNL for the areas identified in the scope of this audit. The process controls for performing activities involving development of the Geologic Framework and Integrated Three-Dimensional Site Model, under the management of the CRWMS M&O, were found to be effective. The model deliverable date is February 28, 1997. The audit team determined that the CRWMS M&O and SNL model developers are progressing well in producing a geologic model of the Yucca Mountain Site. The model is being adequately documented as to data sources and development process.

5.2 Stop Work or Immediate Corrective Actions Taken

There were no stop work order, immediate corrective actions or related additional items resulting from this audit.

5.3 QA Program Audit Activities

A summary table of audit results is provided in Attachment 2. The details of the audit evaluation, along with the objective evidence reviewed, are contained within the audit checklists. The checklists are kept and maintained as QA Records.

5.4 Technical Audit Activities

This performance-based audit was performed at two locations, SNL in Albuquerque, New Mexico, and the CRWMS M&O in Las Vegas, Nevada. The audit focused on those processes and activities associated with the development of the Integrated Site Model version 2.0 (ISM2.0) of the Yucca Mountain Site. This audit is in a sense a follow on to last years audit (YM-ARP-96-07) of the Three-Dimensional Geologic Model which was a major input to ISM1.0. The steps in development of the ISM2.0 are 1) data compilation, 2) data synthesis/issue resolution, 3) model construction, and 4) formal review. These are the same process steps as last year, but the level of complexity has increased significantly. Prior to evaluating these steps, it is important to note some of the increase in complexity and how it has impacted model development.

Fault geometries as measured or estimated in the field are modeled in the ISM2.0, rather than being represented as vertical faults as was done previously. While it is essential that the model represent the geometry of the site as accurately as possible it also introduces considerable complexity into the model. For example, in a fault block bounded by dipping faults, each progressively deeper rock layer will have a different areal extent within the block. In addition, more steeply dipping faults will be intersected and terminated by less steeply dipping faults as one goes down dip. Also, more faults have been added to the model (44 versus 26 previously). With more faults and dipping faults to keep track of computationally, computer run times have increased substantially, and the process of checking the output is also more time consuming because of the added detail. New and /or updated borehole lithostratigraphic contacts, and a new Paleozoic unconformity structure map have resulted in revised and refined isochore and structure contour maps throughout the model volume. The ISM2.0 also includes representations of mineral distribution and rock properties (porosity, density, thermal conductivity, etc.) as mapped onto lithostratigraphic units in 3D space. These additions are significant to process modelers and other downstream users of the model such as performance assessment. With this background in mind, the process steps are evaluated in the following paragraphs:

Data Compilation-The data that supports the geologic framework portion of the ISM2.0 comes from a wide variety of sources including borehole logs, downhole and surface geophysics, measured sections, and geologic maps. Some of this information is new, such as the new site geologic map and data from recently completed boreholes, and some is "revised from previous work" such as re-interpretations of older core logs. It appears that the model developers are adequately tracking the data as to source and status (Q and Non-Q), and seem to have located all of the data that is currently available. An inescapable observation is that the vast majority of the model volume is unconstrained by data. While the developers have done an admirable job of making maximum use of the available data, many aspects of the model remain interpretive. In addition to the data that support the geologic framework, other types of data support the rock properties portion of the ISM2.0, for example, laboratory determinations of porosity on core and data from the detailed analysis of borehole geophysical logs. Some of this data is input from other activities (ie. porosity from core) while other data such as the values derived from geophysical log analysis were essentially being developed contemporaneous with the audit and would provide input to the ISM2.0 and to a later report on rock properties modeling. This will be discussed again under the "review" process step. The ISM2.0 also incorporates mineralogic data developed by LANL but that was not part of this audit scope.

Data Synthesis/Issue Resolution-After the data have been compiled it must be synthesized, in concert with guiding geologic concepts, into a interpretation such as a fault network, or a structure contour map. During this process issues invariably arise as to how to best represent geologic relationships and interpretations in 3D space. These issues are resolved in a workshop format with participation by geologic mappers, geophysicists, and model developers. The results of these workshops are documented in scientific notebooks. The process just described is iterative, and it is apparent that good data integration is occurring. In fact, it could be argued that relative to the framework portion of the ISM2.0 the data refinement/synthesis/integration process went on too long. For a project like the YMP where new information will become available over an extended period, any model will be a frozen instant in time based on what was available as of a certain date. Allowing data input to continue until late in the process compresses the time available for model construction, report preparation, and review. The rock properties portion of the model does not face similar difficulties. Porosity data is really the only primary data source, all other rock properties are estimated based on their relationship to porosity, and their distribution in 3D space is simulated using geostatistical techniques. Only a few people are involved in this process and there is not a lot of "manual" interpretation. However, if there was "almost too much" interaction between the model developers and the project geologists and geophysicists, it could be argued that there was "perhaps too little" interaction between the ISM2.0 developers and the rock properties modelers and between the rock properties modelers and the mineral distribution modelers at LANL. For example, lithostratigraphic contacts in the ISM2.0 are based primarily

on core. Geophysical logging tools (from which some porosity measurements are derived) on the other hand "see" a larger volume of rock than the small diameter core, and in the same borehole contacts would be picked differently based on core vs geophysical logs. In terms of the model, this can result in some physical properties appearing to be stratigraphically out of place or anomalous, such as a high porosity zone in a geologically unlikely lithology like a vitrophyre. The affected zones are generally thin and are not anticipated to have much influence on process models, however, some of the rock properties simulations do appear anomalous and some discussion as to whether core picked contacts or geophysically picked contacts should be used in the model would be beneficial as the modeling effort continues to mature. The PI for the rock properties models indicated that he was unaware of how estimates of mineral distributions in the model space were being developed or how they would be displayed in the model. Again, it seems that some additional interactions in this area of sub-model development would be beneficial.

Model Construction-The ISM2.0 is constructed in Earthvision software which has been qualified in accordance with appropriate QA procedures. In general, thickness maps (isochores) of progressively deeper lithostratigraphic units are sequentially hung from a master structure contour map and resulting lower structure contour maps. The master structure contour map is for a unit high in the section for which there is a fairly complete data set. A few higher units are added to the master map or are hung from topography as needed. As would be expected with a model of this complexity, some "glitches" were encountered during model construction. It was interesting to see some of these problems identified and fixed in real time, during the audit. Some problems in the display of units near faults for example, were corrected by adjusting the grid cell size. Construction of a model of this size and complexity is a labor and computationally intensive activity and the model developers and the computer on which Earthvision runs were working 24 hours a day during the audit, again suggesting the need for an earlier data input cutoff. Some computer runs take as long as 36 hours. With the rock properties portion of the ISM2.0, it is somewhat difficult to tell where data synthesis ends and model construction begins, in part because of the geostatistical nature of the properties simulations. In addition the scientific notebook on the development of rock properties models was not always clear as to the sequence of steps followed or where information is located (considerable information is on computer stored spreadsheets for example). The hand drawn "flowchart" which was the key to the model development process was untitled, undated, and unsigned. These issues were discussed during the close out meeting at SNL and corrective actions taken. The completed rock properties simulations are transmitted to the ISM2.0 developers so they can be displayed in Earthvision as part of the ISM2.0, but no further data manipulation occurs in the ISM2.0.

Formal Review-Since the audit occurred during the model development process this step has not yet occurred. However, because of the schedule for submittal of

the ISM2.0, there are some issues which need discussed. Some inputs to the ISM2.0 such as the models of mineral distributions provided by LANL have already received reviews as part of the development process. Reviewers had already been selected for the ISM2.0 and an individual had been selected who could adequately review the geologic framework aspects of the model. The rock properties portion of the ISM2.0, however, has not been reviewed at SNL as it is to be part of a report on rock properties scheduled for submittal in the April/May time frame. Therefore, as originally planned, the rock properties portion of the ISM2.0 would not have received any technical review. This has been compensated for by adding a reviewer to the planned QAP-3-1 review who can technically evaluate the rock properties portion of the ISM2.0. It should be noted however, that should the review of the rock properties report in April uncover any problems, a subsequent revision of the ISM2.0 may be necessary. This is not viewed as a major problem as new data will require that the model be updated anyway at some point.

Conclusions-The model developers at CRWMS M&O/SNL are progressing well in producing an integrated site model (the ISM2.0) which will be useful in supporting process models and later performance assessment and licensing activities. The model is being adequately documented as to data sources and the development process. The addition of dipping faults and the resulting need to have a consistent three dimensional representation of the fault network has added significant rigor to the geologic interpretation of the site. The algorithms that create surfaces and resulting volumes in the modeling software are being adequately constrained by data (where available) and by professional geologic interpretation such that the model will be technically defensible. The inclusion of rock properties and mineralogic distribution representations in the ISM2.0 will allow process modelers to run their models (unsaturated zone flow for example) on the anticipated geometry and properties of the site. This is an important advance for the project.

5.5 Summary of Deficiencies

The audit team identified three deficiencies during the audit that were corrected prior to the postaudit meeting. Synopses of the deficiencies corrected during the audit are detailed below.

5.5.1 Corrective Action Requests (CAR)

None

5.5.2 Deficiency Reports (DR)

None

5.5.3 Performance Reports (PR)

None

5.5.4 Deficiencies Corrected During the Audit

Deficiencies which are considered isolated in nature and only requiring remedial action can be corrected during the audit. The following deficiencies were identified and corrected during the audit:

1. The SNL procedure on Scientific Notebooks requires that notebook entries be signed or initialed and dated. The QARD also requires this (section III.2.2.B.4.). Contrary to this requirement, the SNL notebooks for the rock properties modeling activity contained a number of entries that were not signed or dated. Also, some corrections had not been appropriately initialed and dated and one notebook was missing the introduction required by procedure since the notebook was considered a continuation of a previous notebook by the PI. These problems were corrected prior to the postaudit meeting by providing an introduction, and by signing or initialing and dating entries and corrections as required.

2. In addition, there is a QARD requirement (III.2.2.C) that scientific notebooks be reviewed to verify that there is sufficient detail to retrace or repeat the investigation without recourse to the original investigator. The SNL scientific notebooks had not yet been reviewed as the work was still in process. However, examination of the notebooks during the audit indicated that there was not always enough information to allow the investigation to be retraced. For example, the results of geophysical borehole log analysis are on spreadsheets which are computer stored, and there are no "pointers" in the notebook directing a later user or reviewer to where that information is located. These issues were discussed at the exit meeting at SNL (early in the audit) and corrections were made prior to audit completion

3. During review of training records for those individuals associated with the modeling activities, it was determined that two individuals had not completed their reading assignments for procedures that had been assigned to them. This was corrected by obtaining training assignment forms showing completion of the assigned training.

5.5.5 Follow-up of Previously Identified CARs and DRs

There were no previously issued deficiencies that were determined to be applicable to the scope of this audit.

6.0 RECOMMENDATIONS

The following recommendations resulted from the audit and are presented for consideration by the CRWMS M&O and SNL's management.

1. For future versions of the ISM , a fixed data cutoff date should be established to allow adequate time for model construction and review. The model will probably become more complex with time as more data is generated from the ESF and other project activities, and more rock properties and mineral distribution simulations are developed. With this complexity will come longer computer run times and more detailed output to check. Proper planning for these activities will eliminate the need for the 24 hour work days that were observed during this audit.

2. As the ISM evolves, more data and more data types will become incorporated. It will therefore be necessary to expand the review to include all of the technical disciplines that the model covers. For the ISM2.0, no formal review had yet occurred but planning for the review was well underway and no technical reviewer for the rock properties portion of the model had been identified. A technical reviewer was added so the planned review will now comply with QAP-3-1. Given that planning for the review of complex technical documents that have licensing implications is not a trivial task, adequate attention needs to be devoted to planning and conducting reviews.

3. While the level of interaction between the ISM2.0 developers and project geologists and geophysisicts was high, and if anything went on too long, the same can not be said for the level of interaction with rock properties modelers. The PI for rock properties modeling at SNL indicated that he was unaware that he was listed as an author of the report on the ISM2.0 and was also unaware of how the mineral distribution simulations were developed at LANL or how they would be incorporated into the ISM2.0. It seems that more interaction between sub-model developers, and between sub-model and integrated model developers would be beneficial to the overall effort.

4. It would be a good practice to keep scientific notebooks as current as possible and include "pointers" to where information is located that can't be included in the notebook such as computer spreadsheets. Had the rock properties model developer become unavailable to the project for some reason, it would have been possible but difficult for another trained individual to find all the necessary information and continue the investigation. This is a potential problem for any scientific investigation activity that includes significant utilization of computers, or where data, information, or samples are located in different areas and cannot be included directly in the notebook.

5. Although the SNL procedure for scientific notebooks, QAIP 20-2, revision 1, contained sufficient criteria to meet QARD requirements, it was noted that some

requirements were ambiguous and some statements regarding entries to scientific notebooks were in the attached guidelines. It is recommended that the procedure be consolidated and streamlined such that the requirements are clearly stated and statements regarding entries to scientific notebooks be included in the context of the process so that the procedure is easily followed and appropriate entries are made. This will ensure that the notebooks are continuously updated properly to allow scientific investigations to progress unencumbered.

6. The SNL procedure for scientific notebooks also contained a requirement that the period for technical review of the notebook be identified in the introduction of the notebook. While the lack of entry for the introduction was noted and corrected during the audit, the requirement for specifying the review period is somewhat obscure in the procedure and can easily be overlooked. It is recommended that the procedure be revised to more clearly state the review requirements and not leave it to the discretion of the PI to specify the review period in the scientific notebook. This would provide more consistency in accomplishing the required technical reviews.

7. The M&O procedure for Computer Software Qualification, QAP-SI-0, revision 1, contained criteria for review of software documentation that did not match the criteria for content; i.e., the Checklist for Software Qualification Report (SQR) for Developed Software contains the criteria to include a "Reference list of all documentation relevant to the qualification." The procedure requires that records include those identified in the SQR as lifetime or nonpermanent. There was no criteria in the checklist requiring the identification of additional records and the criteria for the list of documentation could be interpreted ambiguously since the review documentation which is developed after the SQR could be considered relevant to the software qualification. It is recommended that the procedure be revised to clarify these issues.

7.0 LIST OF ATTACHMENTS

Attachment 1: Personnel Contacted During the Audit
Attachment 2: Summary Table of Audit Results

ATTACHMENT 1

Personnel Contacted During the Audit

Name	Organization/Title	Preaudit Meeting	Contacted During Audit	Postaudit Meeting
Quittmeyer, R.	CRWMS M&O/Senior Staff			X
Hoxie, D	USGS/SPO Manager	X	X	X
Clayton, R.	CRWMS M&O/Model Lead	X	X	X
Rautman, C.	SNL/PI		X	
Zelinski, W.	SNL/Spectra/Modeler	X	X	
Porter, D.	SAIC/M&O/QA Support	X	X	
Pelletier, J.	SNL/KTech/QA Support	X	X	
Schelling, J.	SNL/Lab QA Manager		X	

Legend

PI	Principal Investigator
SAIC	Scientific Applications International Corporation
SPO	Scientific Program Operations
USGS	United States Geological Survey

ATTACHMENT 2
Summary Table of Audit Results
For Procedural Compliance Evaluations

ELEMENT	IMPLEMENTING DOCUMENTS	DETAILS (Checklist)	DEFICIENCIES	RECOMMEND-ATIONS	PROGRAM ADEQUACY	PROCEDURE COMPLIANCE	OVERALL
1	QAIP 1-2, R11	pg. 1			SAT	SAT	SAT
	QAP-1-0, R4	pg. 1			SAT	SAT	
2	QAIP 2-5, R4	pgs. 1-4	CDA # 3		SAT	SAT	SAT
	QAIP 2-1, R5	pgs. 1-4			SAT	SAT	
5	QAIP 5-1, R6	pgs. 5, 6			SAT	SAT	SAT
	QAIP-5-1, R5	pgs. 5, 6			SAT	SAT	
6	QAP-3-1, R6	pg. 7			SAT	SAT	SAT
	QAIP 6-1, R3	pgs. 8, 9			SAT	SAT	
	QAIP 6-3, R4	pgs. 9-10			SAT	SAT	
16	AP-16.1Q, R1	pgs. 10,11			SAT	SAT	SAT
	AP-16.2Q, R1	pgs. 10,11			SAT	SAT	
17	AP-17.1Q, R0	pg. 12			SAT	SAT	SAT
SI	QAIP 19-1, R2	pg. 13			SAT	SAT	SAT
	QAP-SI-0, R1	pgs. 13		REC # 7	SAT	SAT	
SIII	QAIP 20-1, R4	pgs. 15-16			SAT	SAT	SAT
	QAIP 20-2, R1	pgs. 14-16	CDA # 1	REC # 5, 6	SAT	SAT	
	QAP-SIII-0, R0	pgs. 15-16			SAT	SAT	

ATTACHMENT 2
Summary Table of Audit Results For Process/Product Evaluations

ACTIVITY	PROCESS STEPS	DETAILS (Checklist)	DEFICIENCIES	RECOMMEND-ATIONS	PROCESS EFF.	PRODUCT ADEQUACY	OVERALL
Three-Dimensional Geologic Model	Data Selection and Input	pgs. 1-3	CDA # 2	REC # 1, 4	SAT	SAT	SAT
	Data Transfer	pgs. 2, 3			SAT	SAT	
	Data Reduction	pgs. 4, 5, 8, 12		REC # 3	SAT	SAT	
	Data Output	pg. 5, 10-12			SAT	SAT	
	Data Output Verification	pgs. 6-8			SAT	SAT	
	Data Update and Changes	pgs. 4, 9, 10			SAT	SAT	
	Review and Acceptance	pg. 13		REC # 2	SAT	SAT	

TOTAL	Pages - Program: 16 Process: 13	3	7	*SATISFACTORY*

"DOCUMENTS REVIEWED" includes the referenced procedure or process step and the associated records/objective evidence

CARs . . . . . Corrective Action Requests
DRs . . . . . Deficiency Reports
PRs . . . . . Performance Reports
CDA . . . . . Corrected During Audit
REC . . . . . Recommendation

ADEQUACY . . Meets Requirements or Expectations
COMPLIANCE . Procedures Implemented
EFF. . . . . Effectiveness - Satisfies Measurement Criteria
OVERALL . . . . Summary of Element or Process