INTEGRATION PROJECT EXPERT PANEL

Closeout Report for Panel Meeting Held May 24 – 26, 2000

Prepared by the Integration Project Expert Panel

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1 Introduction

The May 2000 Integration Project Expert Panel (IPEP) meeting focused on two overarching issues and four technical focus areas. As was the case for the January 2000 IPEP meeting, a contact person for each focus area was assigned from both the IPEP and DOE prior to the meeting. The overarching issues considered at the meeting were:

- Hanford Site Outcomes and implementation
- Detailed Work Plan for FY01

The technical areas considered at the meeting were:

- Vadose Zone Monitoring
- Inventory
- Characterization
- Groundwater Remediation

The technical sessions were originally intended to be organized as if the topics were mutually independent; however, the contact persons from DOE did an excellent job of organizing the topics suggested by the IPEP into a well-coordinated series of sessions. Inventory and characterization had also been agenda items at the January 2000 IPEP meeting, but the time available at that meeting limited discussion of some topics. Therefore, several topics within these focus areas were addressed again at the May meeting, while other topics at the May meeting were new. Again, time limited our exploration of some topics at the May 2000 meeting, but the IPEP gained a clearer understanding of progress, not only toward integration, but also toward execution of some core projects and other tasks.

2 Hanford Site Outcomes and Implementation

2.1 Observations

The IPEP has expressed concern on numerous occasions that integration is not taking place at a sufficiently high level at Hanford. At the May 2000 IPEP meeting we were given a briefing on plans for integration at a site-wide level. Wade Ballard, who gave the briefing, heads an organization called *Planning and Integration* which he said had been in existence for about 6 months at the time of the May meeting. The efforts of this group are aimed at integrating activities at a site level in the timeframe of FY02 and beyond, although he said they will do what they can for FY00 and FY01. Mr. Ballard commented that the long lead-time is a result of the three-year budget process. While we would prefer more rapid action toward integration, we understand that site management operates under many restrictions. Our view remains that site-wide integration is badly needed, and we look forward to seeing this effort develop as quickly as feasible.

We have consistently encouraged the Integration Project (IP) to link project objectives to those activities that can contribute to Hanford Site cleanup decisions. Over the past eighteen months, it has become apparent that the decisions necessary for successful remediation of the Hanford Site have not been defined in such a way that they can be used by IP personnel for reliable long-term planning. To date, no generally accepted baseline is available at Hanford that defines cleanup decisions at a level of detail sufficient for effective IP planning, a fact that greatly complicates the IP's job. Thus, we were pleased to learn at the May 2000 IPEP meeting that there is now a significant management-level effort underway to define the Hanford Site decisions that must be supported by the IP.

At the January 2000 IPEP meeting, Hanford Site Manager Keith Klein indicated he would initiate an effort to define the Hanford Site clean-up decisions to which the IP should contribute. At the May 2000 meeting, we learned that this commitment has resulted in an effort by DOE and contractor personnel to develop a plan for achieving the Hanford Site Outcomes, which are currently defined as follows:

1. Restore the Columbia River Corridor for multiple uses.
2. Transition the Central Plateau for long-term waste management.
3. Put DOE's assets to work for the future.

IPEP members believe the detailed articulation of these Site Outcomes for Hanford is a significant step forward, integrating the concerns of many groups, providing a common framework for further discussion, and helping to build support.

Some years ago, the Hanford Site Uses Working Group developed three future use options for the Columbia River (HSUWG, 1992):

- Option 1: Wildlife and Recreation.
- Option 2: Recreational and Related Commercial, Scenic and Economic Uses.
- Option 3: Native American Uses.

Hanford Site Outcome #1 (Restore the Columbia River Corridor for multiple uses) appears to agree in principle with HSUWG Option #2, which is described in the HSUWG report as follows:

> *"Current recreational uses along the River, such as boating, hunting, fishing, bird watching and sightseeing would continue. In addition, existing private uses along the River, including withdrawal of water from and discharges to the River for irrigated agriculture, would also continue. The River would remain free-flowing, with no dams and no dredging. Native American archaeological sites along the River would be preserved.*
>
> *"This future use option would be compatible with Native American uses, except pasturing livestock."*

Hanford Site Outcome #2 (Transition the Central Plateau for long-term waste management), appears to agree in principle with the Findings and Recommendations for the Central Plateau in that same report (HSUWG, 1992):

> *"Some type of government presence or oversight of the area should be assumed for the foreseeable future due to the anticipated level of residual contamination in the 200 area.*
>
> *"Waste from throughout the Hanford site should be concentrated in the 200 area. Wastes and contaminants within the 200 area should be treated and managed to*

prevent migration from the 200 area or to other areas and/or off site. Waste streams resulting from treatment or other activities should not further contaminate or spread contaminants throughout and/or off the site.

"Based on the risk emanating from the contaminants in waste management activities in the central plateau, a "buffer" zone around the borders of these contaminants and waste management activities should be established to minimize exposure."

Defining how the Hanford Site Outcomes can be achieved presents a major challenge. However, we believe the personnel involved are proceeding appropriately by developing a set of questions designed to define more specifically how the Site Outcomes can be achieved, what decisions and actions are required, and who needs to take action. It is clear that the IP is one of several groups (both on- and off-site) that must provide input to key Hanford Site decisions leading to the desired outcomes.

In their discussion of the Hanford Site Outcomes at the May 2000 meeting, Tom Wintczak and Michael Hughes (Bechtel Hanford president) listed specific products and services needed from the IP to accomplish the Site Outcomes. For the River Corridor, the necessary IP contributions include verification of cleanup adequacy, monitoring of remaining wastes, technology development for groundwater remediation and, ultimately, a performance assessment tool to assess cumulative impacts. For the Central Plateau, the IP contributions include integrated characterization and monitoring, development of an integrated vadose zone and groundwater monitoring network, a performance tool to assess compliance for the next 50 years (and beyond), and a performance tool to meet composite analysis requirements.

The IPEP applauds the effort on Site Outcomes, as well as the progress being made, especially with respect to the first Site Outcome, restoring the Columbia River Corridor, where a detailed analysis is well underway that links *end points* and *end states* with specific activities and, in some cases, cost estimates.[1] This information is summarized in a detailed table, color-keyed to the various sites in the 100 Area. This sort of rigorous planning is absolutely necessary for success to be achieved, and we are encouraged by these developments.

While significant progress is evident in development of the first Site Outcome, the second Site Outcome has proved more challenging, and the attempt to define the specific cleanup decisions to which the IP can contribute appears to have been more time consuming than originally anticipated. Still, the IPEP believes the overall effort is necessary and has had a good start. Although there is still a long way to go in this effort, we believe that the individuals and organizations involved will benefit greatly from the discussions leading to the definition of cleanup decisions, and that the role of the IP will be better defined as a result.

[1] At the May 2000 IPEP meeting several stakeholders remarked that planning and discussions have been greatly assisted by having defined the terms e*nd state* and *end point,* and we agree with that observation. *End state* is the completion of all active cleanup in a geographical area, including verification of cleanup effectiveness and completion of associated regulatory documentation. *End point* is the completion of a specific cleanup-related project in an area.

2.2 Concerns

The three Hanford Site Outcomes can be distinguished as either relating to different parts of the Site, or relating to different timeframes in the clean-up process. Thus, if the Site Outcomes are addressed individually, linkages among them may be missed. For example, focusing only on the river corridor and ignoring the potential for contaminants from the plateau to reach the river could result in a gap. The IP can provide several important services in this process -- looking at these issues from the standpoint of integration to ensure that the commitment to individual Site Outcomes does not overlook linkages among them, and ensuring that any gaps are addressed.

2.3 Conclusions

1. The Hanford Site Outcomes effort is off to a good start.
2. The products of the effort are likely to underscore the need for "integrated" thinking in resolving Site problems.
3. The IP can play a significant role in achieving desired Site Outcomes.

2.4 Recommendations

The Hanford Site Outcomes effort should be completed and documented; the results should be implemented on a DQO (Data Quality Objectives) basis so that planned projects can be explicitly linked to data and activity needs that contribute to defined clean-up goals and decisions.

3 Detailed Work Plan - FY01

3.1 Observations

At the May 2000 IPEP meeting, we noted that the Hanford Site budget for FY01 remains under severe pressure and that important decisions regarding resource allocation must be made. When a fiscal year is at hand and the budget has been defined, it is not so much a matter of "what would we like to do?" but rather "what are the best things to do given the resources available?" We believe that the strategy and budget allocations proposed by the IP for FY01 are reasonable within the constraints imposed externally. At the same time, Hanford management and DOE/HQ must continue to make the strongest possible case for the funding required for meeting agreed-upon objectives. As planning for remediation at Hanford matures and becomes more quantitative, and further progress is demonstrated, this should become easier and, we hope, more successful.

Revising the approach to SAC from multiple iterations over the next five years to a single update (and reducing the SAC budget for FY01) creates a challenge but appears to be a reasonable approach. In the closeout report for the January 2000 IPEP meeting we expressed skepticism that a useful SAC tool could be built and implemented by the initial (Rev. 0) deadline and suggested that it would likely take several annual iterations to become useful enough to affect decisions. The revised approach presented at the May meeting removes the annual schedule for revisions and calls for evolutionary updates to the initial Rev. 0 as test cases, data, and new software become available. We consider this to be a reasonable change of plan. It is still important that a timely first version be produced that convinces potential users that the effort can ultimately support regulatory decisions and composite analysis requirements.

Maintaining the overall budget level for Science and Technology (S&T) recognizes the importance of this effort to the IP, but it also highlights the fact that S&T projects *must* be relevant. Accelerating groundwater remediation activities is justified to align with the major Site Outcome relating to restoration of the River corridor. Reducing S&T that has longer-term applicability in favor of maintaining some characterization effort in the 200 Area is also justified as a way of balancing field data acquisition with other efforts in the overall program. An example of the potential synergy between characterization and S&T is the preliminary outcome of borehole 241-W23-19 (see Section 6.1 of this report) where the initial analytical data presented by Jeff Serne has already prompted discussion of future S&T efforts.

3.2 Conclusions

1. The budget decisions made by the IP for FY01 appear to be necessary because of the constraints imposed externally.
2. The IPEP concurs that the IP should proceed as planned for FY01.

4 Vadose Zone Monitoring

In the Vadose Zone Monitoring session, presentations were given on (1) characterization of groundwater recharge, (2) historical gross gamma logging, and (3) the Vadose Zone Transport Field Study planned for FY2000.

4.1 Characterization of groundwater recharge

4.1.1 Observations

An excellent summary of recharge studies conducted at Hanford over the past thirty years was presented by Glendon Gee. Many of these studies resulted in peer reviewed journal articles and reports, further bolstering their credibility. From this work it is clear that recharge rates vary widely across the Hanford site, from near zero in natural vegetated areas, to 100 mm/year or more (some 60 per cent of annual rainfall) at the gravel-covered areas around the tank farms. One very important observation that seems to be well established is the dramatic increase in recharge that tends to result from disruption of natural vegetative cover, further exacerbated by such procedures as installation of a gravel cover.

4.1.2 Conclusions

It appears that information is available on groundwater recharge rates that allows first-order estimates to be made. However, there is a need for more specific recharge data around tank farms, waste burial sites, cribs and other liquid discharge sites; this is especially true for specific gravel covered areas, for other areas with sparse vegetation, and for areas with run-on and intermittent flooding. Without such data, predictions of movement of contaminants remain highly uncertain. Downward-moving water is the main driving force for contaminant transport to the groundwater, and its magnitude needs to be well understood, especially within the tank farms.

4.1.3 Recommendations

The adverse effects of disrupting natural vegetative cover should be carefully considered in all relevant Hanford Site planning. Specifically, natural vegetative cover should be preserved where feasible and, similarly, the benefits of reestablishing natural vegetation on disturbed lands after cleanup or other disruptive activities should be carefully considered in planning.

4.2 Historical gross gamma logging

4.2.1 Observations

The presentation on historical gross gamma logging by Russ Randall focused on changes in the character of gross gamma logs with time for specific boreholes. Of the 549 boreholes analyzed in these studies, 39 boreholes were found to have "unstable" zones, i.e., zones where the gross gamma readings changed significantly over time. These studies (e.g. Randall and Price, 1998; Randall et al., 1999) provide valuable qualitative identification of contaminant movement. In addition, in some boreholes changes in the gross gamma logs as a function of time were shown to correspond to the decay rates of certain nuclides, providing persuasive evidence of relatively short-lived nuclides decaying in place.

In the presentation and documents regarding historical gross gamma log analysis, the use of the term "clean" is misleading because the gross gamma data cannot distinguish reliably between truly clean zones and zones with significant contamination. The gross gamma logging instruments were intended for leak detection and were rather insensitive and, of course, incapable of distinguishing artificial gamma emitters from natural gamma emitters in most cases. The term "clean" should be replaced by a more accurate term such as *below detection threshold*.

4.2.2 Conclusions

The analysis of the historical gross gamma logs has been well conceived and executed, the results are informative and defensible, and technical reviews of the work (Stromswold, 1999; Wilson, 1999) have been appropriate and valuable.

4.2.3 Recommendations

1. We recommend that spectral gamma logging be continued at selected sites. The frequency of such logging should be appropriate for the location, with sites showing active migration or other changes in earlier logging studies being logged more frequently.
2. More quantitative information is needed on local recharge rates in key areas. The possibility of using borehole logging (and other measurements) for this purpose should be carefully considered.
3. In the gross gamma log analyses, the term "clean" should be replaced by a more accurate term such as *below detection threshold*.

4.3 Vadose Zone Transport Field Study

4.3.1 Observations

The presentation by Glendon Gee regarding the Vadose Zone Transport Field Study (Ward and Gee, 2000) was effective in linking that work with site needs and other projects, including EMSP development projects. The discussion in this session centered on the FY00 experiments underway (at the time of the May 2000 IPEP meeting) at the Sisson and Lu test facility.[2] The plan for this study combines well established methods for studying vadose zone flow and transport with newer technology, including a variety of geophysical methods. The results from the study should produce a much better understanding of flow and transport in the vadose zone which should be especially applicable to infiltration resulting from broken water lines, transfer pipes, and so forth. This well-designed study is being planned and conducted in cooperation with five national labs and three commercial companies; to date, this appears to be an excellent example of integration working in the S&T area.

The Field Study should be viewed as a series of experiments, not just the one described in the field study plan (Ward and Gee, 2000) and discussed at the January and May 2000 IPEP meetings. The first experiment in FY00 will evaluate geophysical methods and will estimate the distance of solute migration by coring at several locations in the experimental plot. This test is expected to provide insight into the physical system and estimate the travel time for first arrival of the injected solute, and also supply important data for an initial test of transport models. In the second experiment, porous cup lysimeters will be emplaced at many locations at the experiment site to collect pore water samples. The information on measured changes in water content and pore water concentration over space and time should provide data for testing and calibrating flow and multi-component reactive transport codes.

It is important that the vadose zone characterization program obtain physical and hydraulic properties that are sufficient to support chemical transport simulations. Data should be obtained from both shallow soil zones, appropriate for surface spills, and from deeper in the vadose zone to the saturated zone, applicable to trenches, cribs, and leaks from the base and sides of tanks. The data needed include properties such as hydraulic conductivity, porosity, permeability, bulk density, mineralogy, and sediment type, along with the spatial distribution of these properties.

To date, little quantitative information has been obtained regarding the lower vadose zone down to the water table, and many important questions about that region remain unanswered. For portions of the vadose zone more than a meter below land surface, most measurements of hydraulic properties have been made on core material. It is well known that core measurements may not be representative of *in situ* properties because the sample size is small relative to many geologic features, and because the samples may be highly disturbed by the coring process. The Vadose Zone Transport Field Study is of value here because, after the transport experiment, cores will be taken from intervals as deep as 18 meters, and this deeper section will also be evaluated with a variety of geophysical tools from commercial sources as well as national labs. It is hoped that the field experiments will provide data sufficient to evaluate how representative the core

[2] See, for example, Fayer et al (1993) for a description of this test site.

measurements are compared to measurements made with a variety of geophysical and monitoring tools. It should be remembered however, that the first transport experiment focuses on geophysical measurements and coring only, to determine the solute distribution, while subsequent tests will sample fluid.

4.3.2 Conclusions

The Vadose Zone Transport Field Study is a well-designed effort that is an excellent example of integration working in the S&T area.

4.3.3 Recommendations

As soon as possible after the first experiment, focus on executing the second experiment using lysimeters to collect pore water samples from the vadose zone at the experiment site, and using the data for model testing.

4.4 General Comments on Vadose Zone Monitoring

One of the potential end states of the Hanford site is long term storage of wastes on the central plateau, including leaving in place some of the wastes already in the vadose zone, leaving some fraction of the waste residues in the underground storage tanks, and storing wastes in engineered facilities in the 200 areas. Such long-term storage will require concomitant long-term monitoring of the vadose zone and of the engineered storage facilities in the central plateau area. Thus, vadose zone monitoring must be an integral part of the long term planning for the central plateau waste disposal and storage options.

Horton et al. (1999) provide a recent description of the Hanford Groundwater Project's vadose zone monitoring activities. They note that vadose zone monitoring has been limited to geophysical monitoring in drywells within single–shell tank farms and in drywells and groundwater wells at a few liquid effluent disposal facilities. Although an Environmental Monitoring Plan exists (DOE 1997), Horton et al. conclude that no strategy has been developed for site-wide and source-specific vadose zone monitoring.

We have not seen any detailed plans for monitoring the engineered storage facilities on the central plateau (e.g., ERDF, submarine reactor storage). Vadose zone monitoring must be carefully considered in the design of any long term storage facility to ensure adequate monitoring of potential leaks, and it is important to ensure the necessary technology is developed and demonstrated for vadose zone monitoring. It seems reasonable that the IP be closely involved in the development of plans and technology for long-term compliance monitoring of storage facilities on the central plateau.

The issue of future vadose zone monitoring is very broad and potentially rather open-ended, but also very important. Rather than proceed on an ad-hoc basis, it seems that a site-wide vadose zone monitoring plan is needed that defines a suite of activities that are both necessary and sufficient to meet the various evolving needs at the Hanford site. Because of the scope and complexity of potential vadose zone monitoring activities, a methodical approach will be needed. For example, a reasonable first step is to develop a methodology for prioritizing vadose zone monitoring activities along with a decision framework for management actions.

4.5 Recommendations

We recommend that a draft site-wide vadose zone monitoring plan be developed and published for comment. The plan should include such factors as a list of *potential* vadose zone monitoring needs, the types of monitoring activities that could be used to fulfill each need, a methodology for prioritizing the monitoring activities, and a plan and approximate schedule for developing a viable monitoring program.

5 Inventory

5.1 Observations

In the Inventory session, presentations ranged from the general (e.g., types of wastes and their locations; the SAC inventory model) to the specific (e.g., estimating tank-leak volumes and concentrations to establish soil inventories in the tank farms). The Inventory session was developed around the framework of a summary table that addresses nine parameters necessary for generating "inventory" estimates for use in a risk assessment model:

- location of wastes
- what wastes are present
- interim decisions
- final disposition decisions
- relative uncertainty
- which project is working on estimate
- source for SAC Rev 0
- constraints/assumptions
- key issues.

5.1.1 SAC Requirements

Charles Kincaid described the work that has gone into developing the summary table and the concept of incorporating the efforts of several Hanford projects into the SAC model. Three specific examples were provided of technical and scientific efforts to resolve the more than 200 parameters that develop from this matrix. The discussion closed with a presentation of how the three examples would be used in the SAC inventory model to develop "realizations of inventory". An unweighted inventory scheme will be used for the first estimates. An interface to vadose zone transport is not currently under development. This effort shows great promise and we look forward to the development of more quantitative data along these lines.

5.1.2 S-SX Tank Farms Leak Estimates

Among the quantitative developments presented at the session were two presentations by Tom Jones. In the first presentation, Mr. Jones described efforts to develop inventory estimates of single-shell tank leaks in the S and SX tank farms, efforts which include searching historical records, some only recently declassified, and adding new field characterization data. This work appears to be moving toward resolving concerns raised by the IPEP and its predecessor, the Vadose Zone Expert Panel (VZEP), regarding a reduction in the uncertainty associated with volume, chemical composition, and curie content of single-shell tank leaks. Topics discussed included:

- waste composition at time of leak(s)
- leak volume
- leak inventory
- speciation
- uncertainties.

The data are used as input to models developed previously, and may also provide the rationale for modification of the models to reduce the magnitude of uncertainty associated with past estimates and help resolve discrepancies among estimates.

The Hanford Defined Waste (HDW) model (Agnew, 1995) developed by Steve Agnew of LANL (Los Alamos National Laboratory) is being used to estimate leak volumes and tank inventories for comparison with results from other models developed at Hanford. A colleague of Agnew, on temporary assignment from LANL, is working with Hanford personnel in this effort.

The leak data for tanks SX-104, SX-113 and SX-115 appear reasonable, but data are poor for the remaining SX tanks. The Spectral Gamma Logging System (SGLS) data obtained for the SX farm appear to provide the best current indicator of leak volume. If successful, the approach being used at S and SX farms may be valid for other tank farms, with appropriate adjustments to make the model more specific to each tank farm. Mr. Jones and staff appear to be successfully incorporating a wide range of data bases, historical and new, along with several leak-estimate models, and applying good scientific principles to the program.

Tom Jones presented a preliminary set of data indicating that Tc solid phases and aqueous complexes in the tanks could affect the amount of Tc actually released in a leak. An important consideration in estimating leak composition is the careful modeling of supernatant and precipitant concentration. Because the liquids have sometimes been at elevated temperature and high ionic strength, the classical solution chemistry models do not compute ionic activities correctly. Computations such as this may be quite important, and can be cited as an example of how using more sophisticated chemical physics in the computations will provide theoretical support to the inventory and transport estimates. It is important to ensure that the best algorithms have been made available, such as the ion interaction approach with corrections for temperature.

The migration of contaminants other than gamma-emitters is difficult to characterize with geophysical tools; the kinds of calculations discussed here can help with the estimation of source terms and give us an estimate of what to look for and what is co-migrating through the vadose zone. It is important to pursue rigorous chemical modeling of in-tank waste to better characterize leak compositions, which can be compared to actual subsurface samples obtained during future vadose zone characterization.

5.1.3 Kriging of gamma data at SX Farm

The second presentation by Mr. Jones described the work of a researcher at Montana State University (MSU) attempting to develop estimates of leak volumes using a statistical method (kriging) based largely on spectral and gross gamma-ray logs in boreholes and laterals at SX farm (Goodman, 2000). IPEP members are concerned about various technical aspects of this work, and we are not persuaded that the work is justified from a cost-benefit standpoint. It is not the kriging itself that is at issue but rather the quality of the data and the assumptions upon which the kriging was based.

Technical concerns about the kriging study include the following:

- The approach used by Goodman is based largely on statistics and does not delve into the nature of the data adequately, leading to results that cannot be considered reliable without more validation, if at all. For example, it appears that ^{137}Cs contamination is being underestimated in the hottest zones as a result of deadtime in the gross count logging instrument (Stromswold, 1999; Wilson, 1999). In particular, there is evidence that countrates have dropped to zero in some zones of high radiation intensity due to detector paralysis (Wilson, 1999). Ignoring the deadtime effect is likely to result in underestimation of contamination, quite possibly by a large amount.

- In places where data were available from laterals beneath the tanks, we were told that roughly half of the inventory of ^{137}Cs was found along the laterals. Nonetheless, in places where no laterals were present, the assumption was made that no contamination was present. While this optimistic assumption may be unavoidable for the kriging calculations themselves, it appears likely to result in an underestimate of contamination that is difficult to defend, a problem that should have been corrected in the data interpretation phase of the study unless a convincing counter-argument can be made.

- Potential sources of uncertainty are not adequately examined in the report (Goodman, 2000), including the great uncertainty in developing correlation coefficients between various gross gamma detectors and the high-resolution spectral gamma detectors (Goodman, 2000, Figure 3, pp 1-5). This is considered in more detail in Appendix A.

In the closeout remarks presented at the end of the May 2000 IPEP meeting, we recommended that kriging be discontinued. This recommendation was based on our view that the validity of developing inventory estimates by kriging, under Hanford Site conditions, has not been demonstrated, and that the inventory data being developed for ^{137}Cs do not seem to be valuable enough to justify the cost. On reflection, our recommendation may have been stated too inflexibly and might be misinterpreted. We do not intend that kriging be dropped completely from future consideration for estimates of in-ground inventory. Rather, the quality of the existing gross gamma log data base, which is quite adequate for other uses to which the data have been put, does not appear to be adequate to support the quantitative results of the Goodman study.

The use of a statistical approach for estimating inventory can only be valid to the extent that the data are valid and relevant. Goodman's kriging study for estimating ^{137}Cs inventory includes data that are largely unrelated to ^{137}Cs concentrations or otherwise invalid (see Appendix A). While the SGLS spectral log measurements may be the best available data set for developing estimates of leak volumes, the existing data have not been shown to be adequate to support a geostatistical (e.g., kriging) calculation for estimating leak volume. In any event, it is essential that the underlying physics be considered in any application of such data.

Kriging studies of tank farms spectral gamma log data have also been performed by the DOE Grand Junction Projects Office (e.g., GJPO, 2000, Appendix E) to produce three dimensional "visualizations" of contamination and "lower bound" estimates of contaminant volume and curie content. While the spectral gamma data are much more defensible than the historical gross gamma logs, there are still questions including the effect of borehole contamination on the spectral gamma logs (as well as on the gross gamma data). Spectral shape factor analysis (Wilson, 1998) was developed to distinguish borehole contamination from formation contamination; that technique is now in routine use for the GJPO work, but the development was halted prematurely and the technique does not seem to have been adequately validated (e.g., VZEP, 1999). No information is available on the question of borehole contamination in the highest concentration zones because shape factor analysis has not been extended to the high rate detector.

It is entirely possible that shape factor analysis can be improved and/or validated and used to produce spectral gamma logging data sets of sufficient quality to support kriging. Another option is to ignore the possibility of borehole contamination entirely and assume that all the concentration estimates based on spectral gamma logs are due to formation contamination, resulting in an upper bound estimate for the regions investigated that, with some validation, can probably be considered defensible. This approach is reasonable because no theory or experimental evidence known to us suggests that the most highly contaminated zones indicated by spectral gamma logging are actually borehole contamination.

Stan Sobczek, scientific advisor to the Nez Perce Nation, contributed to the follow-on discussion by presenting his independent estimates of the amount of contaminated soil in the SX tank farm. The presentations in the Inventory session provided a good illustration of the scope and complexity of inventory issues. This session generated a great deal of interest and discussion, in part from its importance and in part from the quality of the work and the enthusiasm of the presenters.

5.1.4 Conclusions

1. The inventory estimates of leaks in the S and SX tank farms is resolving concerns that have been raised by the IPEP and the VZEP.
2. The quality of the existing gross gamma log data base does not appear to be adequate to support the quantitative results of the Goodman study.
3. It is essential that the underlying physics be considered when using data such as gamma-ray logging data.

5.1.5 Recommendations

1. Continue progress toward developing a quantitative inventory data base for SAC.
2. Continue progress in the development of leak-estimate models and data bases, using S and SX tank farms as prototypes, but extending to other tank farms as soon as possible.
3. Improve the capability for spectral gamma logging in "hot zones", including improvements in shape factor analysis if borehole contamination is thought to be an important factor in estimating in-ground inventory.

4. Continue geophysical logging, including spectral gamma, where other information lends support for identifying contamination as formation related (e.g., unstable zones in gross gamma logs).
5. If adequate data are available and the need is clear, we recommend that any future kriging or similar statistical analysis be carefully peer reviewed for feasibility before funding and the results peer reviewed again for validity.

6 Characterization

6.1 Observations

In July 1998, TWRS (Tank Waste Remediation System) put forward a plan for tank farm characterization proposing that three boreholes be installed each year beginning in FY1999, with the ultimate goal of installing 24 new characterization boreholes in the tank farms. In the closeout report for the January 2000 IPEP meeting, we expressed concern about an apparent reduction in the characterization effort from the 1998 plan (IPEP, 2000). During the first two years of the program plan, one new borehole was installed during FY1999 with another planned for summer 2000. We requested that a five-year plan of action toward characterization be presented at the May 2000 IPEP meeting.

In a presentation by Tony Knepp, the RPP (River Protection Project, successor to TWRS) indicated that, although there has been some reallocation of funding due to general budget reductions at Hanford, there has not been a retreat from the overall program outlined in 1998. Instead, the drilling schedule has been delayed to allow for the evaluation of new data from the extension of drywell 41-09-39 and the subsequent studies during its closure, the evolving results from the new (1999) RCRA monitoring well 241-W23-19, and the development of new drilling capability for characterization, particularly for the slant hole beneath tank SX-108. The long-term schedule calls for a total number of characterization wells approximating that of the 1998 Work Plan, but the reduction in drilling planned for the immediate five-year effort reflects the delay.

Prior to Mr. Knepp's description of a five-year plan for vadose zone characterization by the RPP, he and contractor personnel presented an update on recent work by the project, mostly concerning results since the January 2000 IPEP meeting. We were told that a report describing the results of the 1999 decommissioning of drywell 41-09-39 is nearing completion.

Jeff Serne provided a summary of some of the results from his laboratory analyses of the core samples collected during drilling of RCRA well 241-W23-19, an integrated effort where installation of a TPA-mandated groundwater-monitoring well provided an avenue for collecting and analyzing soil samples near the leak from tank SX-115. The IPEP observed that the data from 241-W23-19 have promise for many applications, including S&T. We look forward to the report on 241-W23-19.

The FY2000 field program was well under way at the time of the May IPEP meeting, with the successful completion of testing of the safety and efficacy of angle (slant hole) drilling outside the SX tank farm, including a suite of new sampling tools, and the beginning of drilling beneath tank SX-108 on May 22, 2000. With a variety of safety issues precluding relogging the laterals installed beneath the tanks, at least for the present, angle drilling appears to offer the best capability for estimating the concentration and volume of leaked contaminants, and investigating geologic properties, beneath the tanks. Newly designed drilling and coring systems are intended to reduce dragdown, with a corresponding reduction in the uncertainty in contaminant concentration and volume estimates.

Development by Hanford contractors of a drilling rig that incorporates improved sample shielding with less worker radiation dose is an excellent example of "putting more technology" into the programs. The IPEP agrees that development of a new drill rig and new sampling systems is a warranted adjustment of funds to deliver long-term gain. It is money well spent to increase safety for field and lab personnel while also improving sample quality and decreasing sample-handling costs, if all goes as planned. The IPEP applauds the angle-drilling effort; we consider this to be a significant new tool for future drilling activities.

On a somewhat smaller scale, RPP demonstrated the value and usefulness of direct push technology (cone penetrometer) for shallow soil investigations. A test case is underway at a site in the northern portion of the S farm, where an unplanned release occurred.

The technical portion of the session concluded with Kevin Lindsey's presentation of geologic findings from the data developed during installation of RCRA wells 241-W22-50, 241-W23-19 and 299-W22-48 and a presentation by the Nez Perce Tribe technical staff member, Stan Sobczek, of his independent interpretation of the geologic and geophysical data for the SX tank farm. A lively debate developed between Sobczek and Lindsey over the former's stratigraphic correlations based on gamma logs in the SX tank farm. Stan's work seems to have been hampered by a very limited set of logging data from each borehole. The addition of other logs would allow much more robust interpretations regarding stratigraphy to be made; the combination of calibrated neutron logs and scintillator-based spectral gamma logs (KUT logs) should be especially helpful.

A brief description was provided of the RPP vadose zone characterization plans for FY2001. Tony Knepp pointed out that the few months following the May 2000 IPEP meeting would be the time for the IPEP to provide any input into development of those plans. There was a general feeling among IPEP members that the plan for the FY2001 field program in tank farms B-BX-BY was an excellent one, with a strong case having been made for a vertical borehole in this instance. Shortage of time prevented discussion of several other items planned for FY2001.

As before, we commend the RPP vadose zone program managers for their efforts to integrate the program's specialized needs into the site-wide integration effort. Examples of cooperative integration, in addition to those noted above, include: integration with the S&T program, development of what appears to be a smoother working relationship with Ecology (for which we also commend Ecology), working with the Nez Perce Tribe's technical staff, and coordination with the RCRA program.

A summary of subsurface physical conditions for B-BX-BY WMA (including the current state of knowledge regarding the location and extent of contaminant plumes in the B-BX-BY tank farm) was presented by Marc Wood, along with a discussion of planned characterization efforts (Wood et al, 2000). This project should be valuable in planning field work for detailed subsurface sampling. The details of whether the plumes are the result of surface spills or tank side or bottom leaks were investigated using historical anecdotal information as well as technical information. This detailed preliminary analysis will guide characterization protocols such as whether shallow direct push methods of sampling will be sufficient or whether deep boreholes will be needed to characterize the leaks, and where to locate the penetrometer pushes or boreholes. This work should also be useful in designing borehole sampling for gamma emitters and, perhaps more importantly, it identifies where to begin looking for co-migrating but non-gamma-emitting radionuclides which can only be identified with certainty in the vadose zone by core analysis.

6.2 Conclusions

1. The data from well 241-W23-19 look very promising.
2. The angle-drilling effort is a major step forward and should provide an important new tool for future drilling activities.
3. The drilling plan for B-BX-BY tank farms appears to be excellent.
4. The efforts to understand subsurface physical conditions should be valuable in planning field work for detailed subsurface sampling.

6.3 Recommendations

Keep on track with field characterization, especially in concert with the long range effort outlined at the meeting. Do not retreat from the five-year plan for subsurface characterization.

7 Groundwater Remediation

7.1 Background

Prior to the May meeting, we provided a list of questions to the IP regarding groundwater remediation activities under their management. These questions included the following:

- What is the current performance status of each of the groundwater remediation systems?
- What are the long term plans for groundwater remediation at Hanford?
- What are the major technical needs for achieving groundwater cleanup goals?
- Are the S&T projects directed towards meeting those needs?
- Provide a case study to illustrate these questions for one of the contaminant plumes.

7.2 Current Status of Subsurface Remediation at Hanford

Groundwater and soil remedial actions at Hanford represent an important part of the overall site cleanup. In FY 2000, the expected level of expenditures for remedial actions in the 100 and 200 areas are $5.35M and $1.5M, respectively, with the costs for the 100 area projected to increase to $7.2 M in FY 2001. Total projected life cycle cost estimates for groundwater cleanup have not been completed pending decisions on final remedies for the various operable units. The current goal, based on tri-party agreements, is to complete groundwater cleanup by 2018.

Currently, groundwater cleanup is underway at five operable units[3] using pump-and-treat technology with re-injection of the treated water in most areas. Soil remediation at OU 200-ZP-2 for removal of carbon tetrachloride has been in operation since 1993. All remedies are considered interim at this time, with final RODs scheduled for each OU over the next several years.

According to documents provided to the IPEP, the remedial action systems are meeting the performance goals for plume capture at some of the areas with less success in others. Soil remediation has removed large amounts of carbon tetrachloride from the vadose zone but available evidence suggests that more than half of the mass of the carbon tetrachloride discharged to cribs still resides in the vadose zone, probably as pure phase.

The GWVZ project is also pursuing alternative technologies to accelerate groundwater cleanup, improve mass removal efficiencies, and reduce costs. The In-Situ Redox Manipulation (ISRM) technology for in-situ immobilization of hexavalent chromium (Cr^{+6}) in a permeable barrier was developed at Hanford and we were told that a substantial portion of the chromium plume in Operable Unit (OU) 100-HR-3 will soon be addressed by this technology. Still, uncertainties remain regarding the long-term efficacy of this technology. One of the outcomes described at the meeting is to have the Columbia River corridor in an *end state* condition, which we take to mean that no further action will be required in the future. Yet, a Battelle "accomplishments" flyer received after the meeting describes the PNNL-developed chemical barrier for Cr^{+6} retention as having only a 30-year lifetime. This does not appear to fit the DOE/RL definition of *end state* given above unless it is anticipated that a 30 year lifetime is adequate to achieve the desired end state.

7.2.1 Observations and Conclusions

1. The groundwater remediation program at Hanford is well established and has generally been successful in meeting interim remedial action objectives.
2. The pump-and-treat systems are operating at extraction rates that are designed to minimize plume migration but the rates are not sufficient to achieve restoration. DOE contractors estimate that plume capture ranges from 70 to 94 percent of the estimated aerial extent of the plumes. Reduction in flux rates was not presented.
3. The average total flow rate from all groundwater systems is about 2,200 L/min, or about 1.16 million cubic meters per year (m^3/yr) (307 million gallons per year [mgd/yr]). Unit costs for these remedial systems thus amount to about $\$6/m^3$ ($22.8/1000 gallons). This unit cost is consistent with median costs for pump-and-treat systems elsewhere as presented by EPA in a recent review of 28 pump-and-treat systems nationwide (EPA, 1999).

[3] Currently, groundwater cleanup is underway at operable units 100-KR-4, 100-NR-2, 100-HR-3, 200-UP-1, and 200-ZP-1.

4. The innovative technology ISRM has been deployed at Hanford for control of the Cr^{+6} plume at OU 100-HR-3 and OU 100-KR-4. Success of this technology could reduce life-cycle costs for these Ous, but uncertainties remain on the long-term efficacy of this technology.
5. The long-term strategy for determining final remedies for groundwater remediation depends upon negotiations with regulators in parallel with development of alternative technologies for characterization and remediation. For each of the operable units, regulatory and stakeholder goals conflict with technical limitations to reaching restoration goals. Resolution of these conflicts will be difficult, and a plan to achieve consensus has not been developed, to our knowledge.
6. The vertical and aerial extent of the carbon tetrachloride plume is still uncertain, particularly in the northern direction. The lack of data on the distribution of CCl_4 (carbon tetrachloride) in the region surrounding the Plutonium Finishing Plant (the North Zone) is a major impediment to characterization and remediation of that contaminant plume. Available evidence suggests that more than half of the mass of the carbon tetrachloride discharged to cribs still resides in the vadose zone, probably as pure phase. Locating and remediating this huge mass of solvent in the vadose zone, if possible, should greatly reduce future problems that would result from discharge of this solvent into the groundwater.
7. Cleanup of the carbon tetrachloride plume in OU 200-ZP-1 represents a number of major technical challenges. The proposed strategy has merit but because of the limited feasibility of DNAPL remediation in the saturated zone, this strategy should also incorporate contingency planning if new technologies fail to show the capability to achieve restoration.

7.3 Recommendations

1. Complete the characterization of the source area for carbon tetrachloride and define the extent of the plume in the North Zone. It is vital that the principal source be located even if it is on restricted sites and we urge Hanford Site management to address this issue as soon as possible.
2. Conduct an outside independent peer review of the proposed PITT test in the unsaturated or saturated zones in the carbon tetrachloride plume.
3. Continue to quantify the efficiency of plume control for all groundwater contaminated sites and provide easy access to this information for the stakeholders.
4. Develop plans or expand existing plans for coordination of technology development and negotiations with regulators to ensure that current schedules can be met.
5. Use scenario testing to determine remediation technology needs for different end-states for the groundwater in both the 100 and 200 areas.
6. Develop contingency plans for groundwater remediation if technology development is not successful in meeting cleanup objectives.

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Appendix A:
Additional comments on kriging study

John Matuszek, John G. Conaway, James R. Karr, and Ralph O. Patt

The discussion in this appendix supplements the discussion in Section 4.1.3 of this report regarding limitations of the gross-, total- and spectral-gamma data available for geostatistical analysis (e.g., kriging), and some specific concerns with the procedures used in the recent kriging study (Goodman, 2000). It is not the kriging itself that is at issue but rather the quality of the data and the assumptions upon which the kriging was based. This appendix is not a peer review of Goodman's kriging study but, rather, discusses several technical concerns noted by some panel members when they read the kriging report. Goodman was not able to attend the May IPEP meeting so he has not yet had the opportunity to respond to these concerns, although he is welcome to do so. If the inventory estimates developed in the kriging study are to be used, a complete technical peer review should be performed.

This appendix refers to four figures in Goodman's kriging report as presented to IPEP for the May meeting; please refer to Figures 3, 5, 14, and 15 in Goodman's report.

Figures 3 and 5 (pages 1-5 and 1-10)

The correlation curve shown in Figure 3 does not inspire confidence because it shows a straight line drawn through a cloud of data with very large variance and no apparent trend. Aside from the great variance across the entire collection of data sets in Figure 3, some specific departures from purely statistical scatter appear to contribute additional uncertainty to the calibration effort. Goodman points out two anomalies in Figure 3 – the assigned values of 25 cps (counts per second) for "background" in type 2 detectors (abscissa at 3.2) and the apparent saturation of type 4 detectors (abscissa at approximately 9).[4] He does not appear to have considered in his line fitting either the effects of including the anomalous data sets or of the results of detector and system performance at high countrates. The analysis represented by Figure 5 has similar deficiencies.

Since Goodman uses only data transposed to equivalent type 4 detector countrates, the overall effect is one of biasing the results toward low concentration values at high countrates. Thus, it appears likely that the total amount of ^{137}Cs in the soil, and the volume of tank liquor leaked, are underestimated.

Figures 14 and 15 (pages 1-18 and 1-19)

Figures 14 and 15 prompt somewhat different concerns from those above. For these figures, a single detector is involved – the high resolution SGLS system. In principle, if **only** ^{137}Cs were measured and detectors and systems responded perfectly at all countrates, the resulting plot should be a straight line with a slope of +1. However, none of the preceding apply.

A simplified sketch of Goodman's Figure 14 is shown as Figure A1, below. The data structure in Figure 14 appears to result from at least four distinct phenomena plus a lot of

[4] Note that Goodman's log scales on the graphs are natural logarithms (base e).

scatter. Figure A1 is divided into four regions, designated by the letters A – D, based on the phenomena involved; Goodman's best-fit line is represented by the dotted line in Figure A1.

Region A is a low countrate region where gamma rays from natural gamma emitters (and possibly instrumental noise) affect the total counts without adding to the ^{137}Cs concentration estimate. At very low countrates, the natural signal dominates completely.

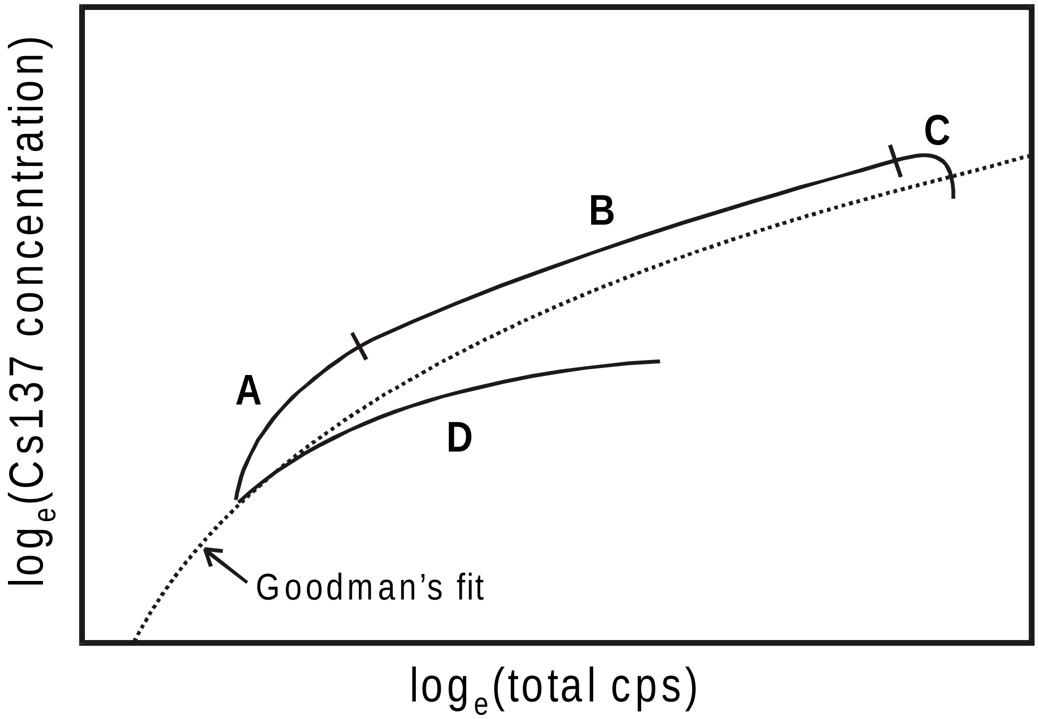

Figure A1 - Simplifed sketch of Goodman's Figure 14.

Region B is an essentially linear region where estimated ^{137}Cs concentrations are proportional to total counts with a slope of approximately +1, as expected.

Region C is a high countrate region where deadtime and detector paralysis are evident. At very high ^{137}Cs concentrations (large dead time), the spectral peak representing ^{137}Cs is gradually subsumed into the broad baseline region developed from incomplete charge collection in the detector, incomplete conversion of the analog signal and by excessive summing. At very high countrates the spectral peak completely disappears (see discussion of these observations in VZEP, 1997, section 6.7). The convex curvature and sudden drop in the abscissa values evident in region C (Figure A1) are a result of these instrument effects.

In region D a separate, distinct line is visible, possibly the result of some sort of borehole or detector effect. Fainter "lines" similar to the one designated as region D also appear to be present in Figure 14.

The power curve fitted in Goodman's Figure 14 ignores the data structure, includes data that clearly should not have been included, and misses entirely the linear region of proportionality between estimated ^{137}Cs concentrations and total counts (region B). Of the four regions shown in Figure A1, only data from region B should have been included in the calibration of ^{137}Cs concentration versus total counts. In other words, only values that were initially reported as ^{137}Cs concentrations should have been used in the kriging calculations for estimating ^{137}Cs inventory. DOE/GJPO personnel used carefully validated, best available methodology for converting the spectral log results to ^{137}Cs concentration estimates. The inclusion of other data in an attempt to make the kriging more robust in fact had the opposite effect.

Goodman's Figure 15 represents an attempt to show how well the calibration of Figure 14 can predict actual ^{137}Cs concentrations, using for validation the measured concentrations of core samples converted to equivalent cps values. The straight line Goodman extends through the so-called "scatter plot" of Figure 15 is not justified by theory and does not predict well the values obtained in the analysis of the soil samples. Moreover, this straight line is drawn through essentially the same data that a power curve was drawn through in Figure 14.

Only 21 of 96 ^{137}Cs pseudo-concentration values (based on core samples) shown in Figure 15 fall within the measurement range of the spectral gamma logging system. The remainder of the data are created by converting measured soil concentration to spectral gamma countrate, even when no data exist at those countrates to accomplish such a conversion. In other words, this exercise is an attempt to match one set of extrapolated values against another set of extrapolations. Since the few points where SGLS data can be coupled with core sample results have discrepancies of up to 3 magnitudes, it is not surprising that extrapolations might differ by up to 7 magnitudes.

The use of a statistical approach for estimating inventory can only be valid to the extent that the data are valid and relevant. Goodman's kriging study for estimating ^{137}Cs inventory includes data that are largely unrelated to ^{137}Cs concentrations or otherwise invalid. While the SGLS spectral log measurements may be the best available data set for developing estimates of leak volumes, the existing data have not been shown to be adequate to support a geostatistical (e.g., kriging) calculation for estimating leak volume. In any event, it is essential that the underlying physics be considered in any application of such data.

References for Appendix A

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