HOW TO DEAL WITH WASTE ACCEPTANCE UNCERTAINTY USING THE WASTE ACCEPTANCE CRITERIA FORECASTING AND ANALYSIS CAPABILITY SYSTEM (WACFACS)

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ABSTRACT

The Waste Acceptance Criteria Forecasting and Analysis Capability System (WACFACS) is used to plan for, evaluate, and control the supply of approximately 1.8 million yd^3 of low-level radioactive, TSCA, and RCRA hazardous wastes from over 60 environmental restoration projects between FY02 through FY10 to the Oak Ridge Environmental Management Waste Management Facility (EMWMF). WACFACS is a validated decision support tool that propagates uncertainties inherent in site-related contaminant characterization data, disposition volumes during EMWMF operations, and project schedules to quantitatively determine the confidence that risk-based performance standards are met. Trade-offs in schedule, volumes of waste lots, and allowable concentrations of contaminants are performed to optimize project waste disposition, regulatory compliance, and disposal cell management.

INTRODUCTION

The real world of remedial action (RA) project waste disposition deals with two key sources of uncertainties: (1) operational, namely the volume of waste to be dispositioned and the concentrations of the contaminants in the waste streams, and (2) programmatic, specifically project waste disposition cost and schedule.

RA projects claim to "have under control" the uncertainties in the volume of waste to be disposed at specific disposal sites or the probabilistic behavior of waste stream contaminants. There are, however, many horror stories of projects overrunning their budget or not meeting schedule because (1) estimates of the total volume of waste exceeded actual volumes disposed, or (2) waste disposal locations would not accept waste streams because concentrations exceeded waste acceptance criteria (WAC). Programmatic uncertainties are addressed by proven management techniques such as cost performance and control and resource scheduling/allocation. What is needed is a way to deal with waste stream volume and contaminate concentration uncertainties.

The Waste Acceptance Criteria Forecasting Analysis Capability System (WACFACS) is a decision support system that explicitly addresses operational uncertainties, namely uncertainties in waste volumes and waste stream concentrations. WACFACS is implemented and managed by Bechtel Jacobs Company LLC (BJC) -- specifically the EMWMF WAC Attainment Team (WAC AT)-- in conjunction with the US Department of Energy Oak Ridge Operations (DOE-ORO) to plan and control waste stream disposition at the Oak Ridge Environmental Management Waste Management Facility (EMWMF).

This paper discusses how WACFACS is used by the EMWMF WAC AT to approve project waste disposition at the EMWMF and the technical basis for WACFACS. It concludes with how WACFACS can be applied to meet the demands of other DOE-complex projects that require the use of on- or off-site disposition facilities.

WACFACS IS USED BY THE EMWMF WAC ATTAINMENT TEAM

WACFACS is used by the EMWMF WAC AT to decide what Oak Ridge RA projects or subprojects may initiate and complete waste disposition actions at the EMWMF during the period FY02 through FY11. The WAC Attainment Team has decision authority within BJC, and it reports decisions to DOE-ORO, US Environmental Protection Agency (EPA) Region IV, and the Tennessee Department of Environmental Conservation (TDEC). Details of the EMWMF and the WAC Attainment Team are discussed in [1]. Other WACFACS users include the RA projects themselves, EMWMF operational personnel, and waste management and strategic planners.

WACFACS outputs are generated for three time periods: (1) a project duration (for example, FY02 - FY05), (2) a 3-year planning window (e.g., FY02 - FY04) for WAC attainment calculations, and (3) the EMWMF life cycle baseline (LCB) planning cycle.

WACFACS is designed to address WAC attainment issues as discussed in the WAC attainment Data Quality Objectives (DQO) and in conjunction with internal prime contractor organization elements [1]. The issues addressed by these organizational elements when using WACFACS are as follows:

- Does a project meet the WAC attainment DQO?
- What planning needs to be accomplished for EMWMF utilization?
- Is the EMWMF operating efficiently?

A formal WAC attainment DQO process was performed in FY01 that led to the development of WACFACS. The stakeholders were DOE-ORO, US EPA Region IV, and TDEC. Key decisions were identified that related to EMWMF WAC attainment decisions and EMWMF operations:

- **DQO Decision 1**. Does the waste lot data meet the form and format required by the WAC Attainment Team?
- **DQO Decision 2**. Is the existing waste lot characterization data sufficient to assess the waste lot Sums of Fractions (SOFs)?
- **DQO Decision 3**. Using a graded approach for the effects of SOF uncertainties on the Volume Weighted Sums of Fractions (VWSFs), can the waste stream be disposed at the EMWMF?
- **EMWMF Operations Decision**. Is the EMWMF operating efficiently under current or projected demands?

The stakeholders agreed that key US EPA documents offered requisite and complete regulatory guidance for the technical basis of WACFACS [2, 3, 4, 5]. The success of WACFACS acceptance during its development is based upon frequent and open communication with all stakeholders.

THE TECHNICAL BASIS FOR WACFACS

The paradigm for WACFACS is illustrated in Figure 1. The paradigm is succinctly stated as:

> *Any RA project must meet one or more WAC in order to disposition the waste to one or more locations. Project cost and schedule requirements must be met. Waste volume and contaminant concentrations are intrinsically uncertain and must be managed.*

The operational employment of WACFACS (currently Version 1.0) is also illustrated in Figure 1. Version 1.0 is an effectiveness tool. Cost and schedule can be compared for various waste disposition alternatives using WACFACS outputs; and, this capability will be incorporated into WACFACS, Version 2.0.

WACFACS, Version 1.0, performs three primary functions to determine whether project waste may be dispositioned at the EMWMF.

- Data management. WACFACS requires that all waste lot Site Related Contaminant (SRC), volume, and schedule input data follow EPA DQO, usability, and DQA guidance. WACFACS identifies key drivers that influence SOF, the VWSF, and the Upper-90th Confidence Value for the VWSF, denoted as UCL_{90} (VWSF). The requirements guidance is placed at the project level; this ensures that WACFACS is used as a support for the project rather than vice-versa.

- Uncertainty management. WACFACS capitalizes on the variability and the uncertainties present in SRC and volume data to propagate these effects to compute the SOF and the UCL_{90} (VWSF). WACFACS quantifies the uncertainties in real time for the project SOF and UCL_{90} (VWSF) over fiscal years and quarters. Projects can make quantitative changes in uncertainties for all SRC concentrations, confidence in volume values (CIVV), and distributional assumptions. Using a Monte Carlo Analysis (MCA) approach, WACFACS employs the @Risk simulation software as described in [6]. A Bayesian updating approach is applied in estimation of the SOF and the VWSF, and the techniques identified in [7] and [8] are applicable.

- Sensitivity management**.** A WACFACS user can examine project, SRC, volume, and schedule drivers of the SOF, VWSF, and UCL_{90} (VWSF). Some results may indicate additional field sampling to mitigate UCL_{90} (VWSF) uncertainties. VWSF forecasting and analysis of uncertainties is accomplished to support short-term and strategic decisions and alternatives analyses.

WACFACS Architecture

As a modern waste management tool, WACFACS is designed to address specific key issues and decisions per the WAC attainment DQO requirements. A convenient graphical portrayal of the relation of the inputs, the outputs, the constraints, and the WACFACS process needed to meet the key decisions for WAC attainment is presented as a systems diagram in Figure 2. There are four components:

- Inputs represent the data required for the WACFACS to be executed. This includes volume and SRC values and their associated uncertainties. WACFACS inputs are obtained from extensive historical and current databases [e.g., Oak Ridge Environmental Information System (OREIS)] and the Waste Generation Forecast (WGF) project volume database.

- Constraints include the time frames of interest, the applicable regulatory guidance needed to implement WACFACS, and the values of the EMWMF analytic WAC.

- The WACFACS process represents the MCA engine used for data required for the WACFACS to be executed. WACFACS follows US EPA policy to use MCA probabilistic techniques with environmental data. The WACFACS MCA is illustrated in Figure 3. MCA is a random sampling technique that makes random draws from each of the probability functions.

- Outputs represent the calculations using the input data and the comparisons to the constraints. WACFACS outputs include the sum of fractions (SOF) and volume-weighted sum of fractions

(VWSF) at the EMWMF. In order to manage uncertainty, WACFACS combines the inputs and their uncertainties to propagate the uncertainties through the SOF and VWSF calculation. The outputs are the SOF, the VWSF, the UCL_{90} (VWSF), and the soil-to-debris ratio. The decision is based on whether the outputs meet, or do not meet, the constraints.

WACFACS Inputs

There are three types of data required as input to WACFACS: (1) project information, (2) volume information and uncertainties, and (3) SRC information and uncertainties. The purpose of the input data is to combine volume and SRC averages and their uncertainties to calculate SOFs and the UCL_{90} (VWSF) over a time horizon to determine if WAC attainment DQOs are met or not met. Table 1 provides details of the input requirements.

WACFACS Data Input Worksheets are used by the project to provide the following:

- General project information to include the project name and the WACFACS point of contact.
- Project or subproject schedule information to include waste disposition time periods.
- SRC input data to include identification of SRCs and usability and DQA based estimates for the mean, the variance, the coefficient of variation, the minimum and maximum values, and the probability functions each SRC follows.
- Volume input data to include identification of total volume, waste material volumes, confidence in volume estimates, and waste lot disposition information.

Volume input data are supplied from the LCB WGF. WGF data inputs are deterministic values for total volume, soil volume, and debris and other waste form volumes. WACFACS requires up-to-date WGF information with a quarterly time domain for WGF data management configuration control (i.e., for WACFACS purposes, downloaded WGF data will be under configuration control at the start of each fiscal year first quarter, second quarter, third quarter, and fourth quarter). Projects use WACFACS to assign confidence estimates for the projected disposition volumes.

SRC input data are supplied by each project, and the data are obtained from the OREIS database and from RI/FS data, pre-design data, remedial action plan data, and process knowledge data sources. SRC input data uncertainties are computed using DQA techniques based upon data usability and applicable DQO.

Table I. Input Data Requirements and Data Sources

Data requirement	Data source	Comment
SRC input data (pCi/g or mg/kg)	Project or subproject databases and data sources: OREIS, RI/FS, Pre-design data, Remedial action plan data, or Process Knowledge	• Data usability is performed on all SRC input data • DQO-like processes to guide subsequent sampling and analysis may be applicable
SRC input data uncertainties	DQA performed on SRC input data	SRC concentration uncertainties expressed as probability function (Normal, Lognormal, or PERT Beta)
Volume input data (CY or yd^3)	Project or subproject LCB WGF volumes for future wastes and waste lot volume estimates for lots under consideration updated quarterly	Inputs are deterministic values for: • Total volume • Soil volume • Debris and other waste form volume

Data requirement	Data source	Comment
Volume input data confidence (-/+ %)	Project or subproject remedial action plan	Confidence values for volumes (-/+ % of volume) are Low, Medium, or High; Uncertainties are expressed as the estimates representing a Very Low Value or a Very High Value
Time Frame	Time frames of interest: • Project waste lot disposition time frame • 3-year window • EMWMF life cycle	The 3-year window VWSFs will be used to assess whether waste lots can be approved for disposal

Notes: OREIS = Oak Ridge Environmental Information System

WACFACS Outputs

This section discusses the WACFACS output measures used to address the WAC attainment DQO. The following outputs are provided by WACFACS: (1) SOF, (2) VWSF and UCL_{90} (VWSF), and (3) the soil-to-debris ratio.

Since the inputs to WACFACS are probability density functions for the volume and for each SRC concentration, the resultant outputs are probability density functions. The following formula is used to compute the (output) probability density function for the SOF for a Project P.

$$f_P(SOF) = \sum_i \frac{g_j(C_{iP})}{WAC_i} \qquad \text{(Eq. 1)}$$

where $g_j(C_{iP})$ represents a probability density function for the distribution of the average concentration of SRC i, (j = 1 (Normal), 2 (Lognormal), and 3 (PERT Beta)) for Project P. WAC_i is the analytic WAC value for SRC i. During the course of WACFACS execution, $UCL\text{-}95(C_i)$ (the upper 95% confidence value for the average concentration of SRC i) is also computed for all SRC in the WAC for Project P.

The following formula is used to compute the probability density function for the VWSF for Project P.

$$h_P(VWSF) = \frac{1}{g(V_{tot,T})} \sum_j f_P(SOF_j)\, g(V_{jP}) \qquad \text{(Eq. 2)}$$

where $f_P(SOF_j)$ is the probability density function for the SOF for waste lot j, $g(V_{jP})$ is the probability density function for the volume of waste lot j for Project P, and $g(V_{tot,T})$ is the probability density function for the total of in-cell volumes for T = 3-year projection from the WGF of volumes to be placed in the EMWMF; (note that T may be other time frames can be used for planning purposes).

The UCL_{90} *(VWSF)* is computed as:

$$UCL_{90}(VWSF) = \int_{-\infty}^{VWSF(90)} h(VWSF)\,dh(VWSF) \qquad \text{(Eq. 3)}$$

The value VWSF(90) is that value of VWSF such that Eq. 3 holds. Time-based UCL_{90} *(VWSF)* are usually desired so that the integration includes the discrete time periods of interest. Furthermore, the UCL_{90} *(VWSF)* is computed for the EMWMF hazard index (HI) and a carcinogenic WAC measure.

The VWSF at any time T is computed as the sum of the VWSF for each project that occurs in time T.

$$h_T(VWSF) = \sum_{All\ P\ in\ T} h_P(VWSF) \qquad \text{(Eq. 4)}$$

The Final VWSF at the terminus time T* for the EMWMF is computed as the sum of the VWSF for all time T.

The probability density function for the soil-to-debris ratio for waste lot j is computed as:

$$g(SD_j) = \frac{g_S(S_j)}{g_D(D_j)} \qquad \text{(Eq. 5)}$$

Interpretation of WACFACS Output

The clearest benefit of WACFACS is that it allows users to efficiently examine the VWSF for many projects over proposed project waste disposition schedules. The following significant operational questions may be answered:

- For all projects, when does the UCL_{90} (VWSF) exceed 1?
- Which key projects influence the VWSF behavior?
- During what fiscal years does such an influence to occur?
- For specific projects, what SRC exert the most significant influence on the VWSF?
- What project volumes -- and when -- cause the most significant influence on the VWSF?

As discussed earlier, WACAFCS output is both easily and rapidly used to determine if a single project meets the DQO based on the project UCL_{90} (VWSF). But, as the questions above illustrate, the power of WACFACS is much greater. Figure 4 illustrates answers to all the above questions using <u>hypothetical data</u>.

- Several RA projects perform during the illustrative three-year window. Some projects start and finish in the time frame, while others overlap with the start or the end year of the window. The top portion of Figure 4 identifies that at the end of FY05, the UCL_{90} (VWSF) > 1 for the RA projects planned during the three-year window. What could have caused this to occur?

- Examining the lower portion of Figure 4, the key drivers for the UCL_{90} (VWSF) > 1 at the end of FY05 are (1) the U-238 concentrations in the Y-12 Soils project, (2) the U-238 and U-234 concentrations in the BYBY project. While such other, and (3) the volume that is dispositioned from the Y-12 Soils project in FY05. (The interpretation of the diagram, called a Tornado Diagram of the regression coefficients, is that (1) a one standard deviation increase in the SOF for U-238 in Y-12 Soils will increase the VWSF by 0.78 standard deviations, (2) a one standard deviation increase in the U-238 and U-234 concentrations in the BYBY project will collectively increase the VWSF by 0.41+0.21 = 0.62 standard deviations, and (3) a one standard deviation increase in the volume that is dispositioned from the Y-12 Soils project in FY05 will increase the VWSF by 0.16 standard deviations.)

- Such results indicate, for example, that efforts should be undertaken to better understand the variability of U-234 and U-238 in the Y-12 Soils and the BYBY projects, and to obtain refined volume estimates or initiate volume reduction approaches in the FY05 Y-12 Soils project. This information could certainly not be readily ascertained by a simple examination of the concentrations or the volumes from the multiple projects, nor could it be gleaned by a time-forecast of RA project waste disposition. If a set of trade-offs is to be identified, the sensitivity approach quantifies the relative merits of, say, changing the schedule (and, subsequently the volume) of the Y-12 Soils project to disposition to the EMWMF. In a similar sense, perhaps the waste streams from the Y-12 Soils project and the BYBY project should be split into smaller waste lots to accommodate the influence of the U-234 and U-238 in the planned waste disposition plans.

CONCLUSION - APPLICATIONS OF WACFACS TO THE DOE COMPLEX

From a DOE-complex wide perspective, 1.8 million yd^3 of wastes dispositioned to the Oak Ridge EMWMF between FY02 through FY10 represent an incremental portion of all DOE waste. From an Oak Ridge perspective, however, this volume fills the design capacity of the EMWMF in support of meeting the Oak Ridge clean-up mission.

Dealing with the uncertainties associated with the disposition challenge at the EMWMF is identical to other DOE-sites. As DOE policy shifts from destruction and permanent isolation to a containment remedy, the wealth of ten years of remedial investigation data at all DOE sites can be capitalized upon to effectively identify which remediation projects can truly disposition their waste to a containment facility. The uncertainties endemic in all remediation and disposition decisions cannot be ignored or wished away; instead, they can be used as a valuable piece of information in a waste management tool such as WACFACS.

REFERENCES

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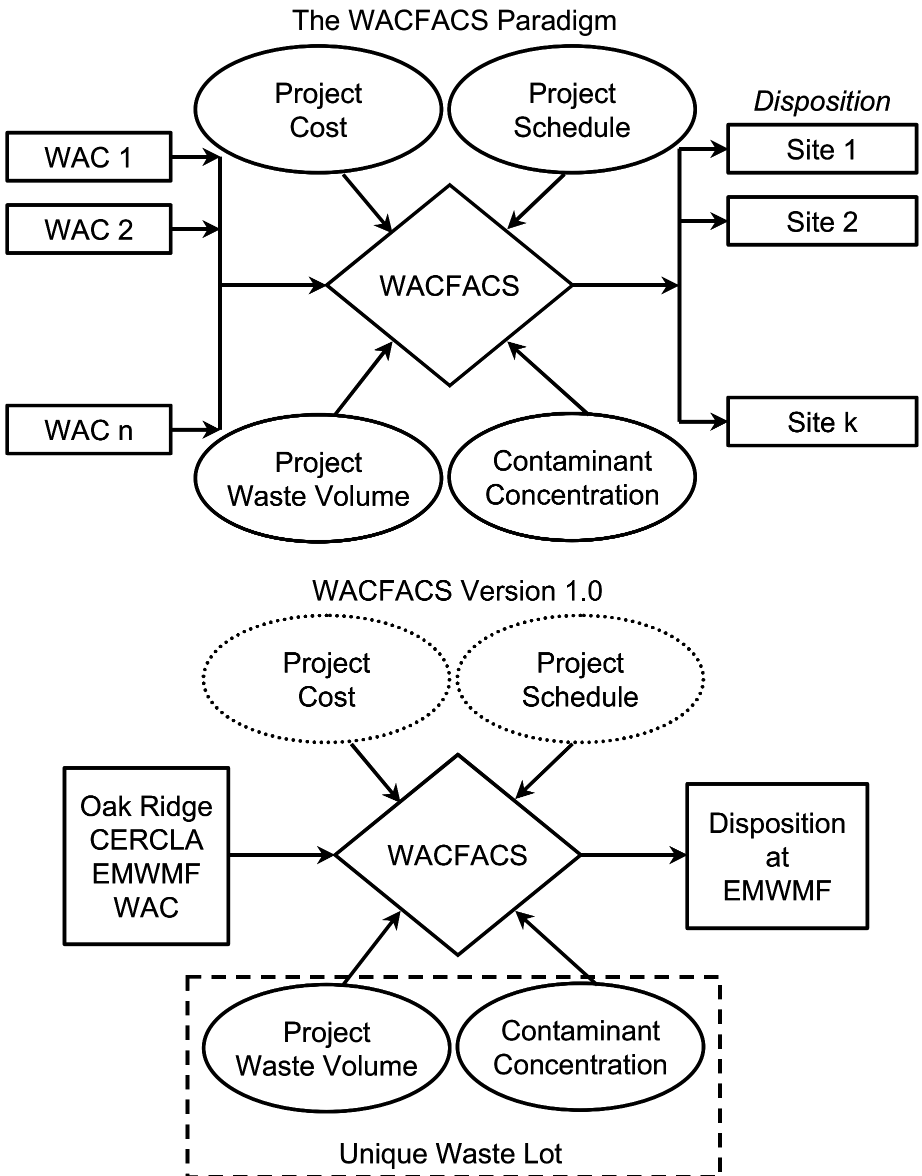

Fig. 1. The Paradigm and the Operational Employment of WACFACS at the EMWMF

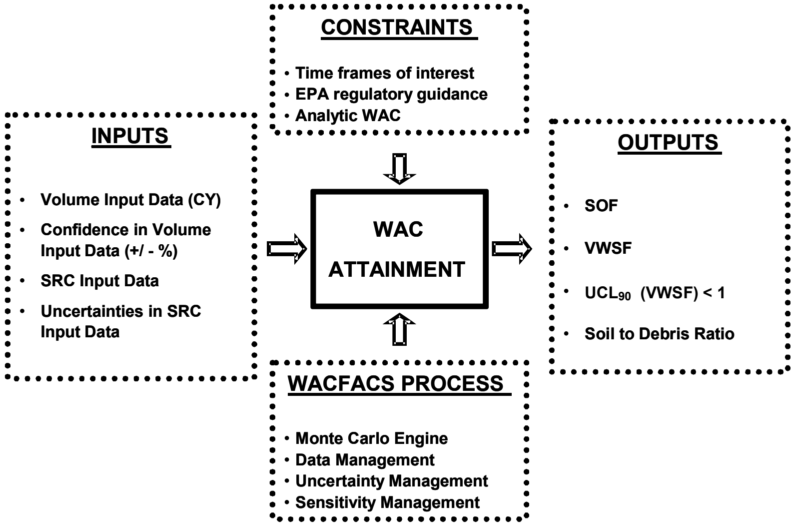

Fig. 2. WACFACS Systems Diagram.

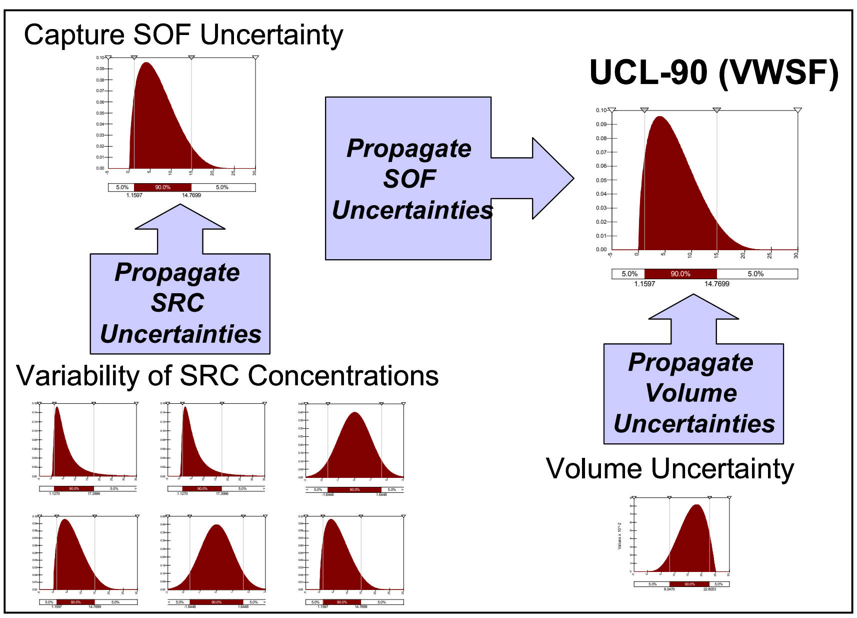

Fig. 3. WACFACS MCA Probabilistic Technique.

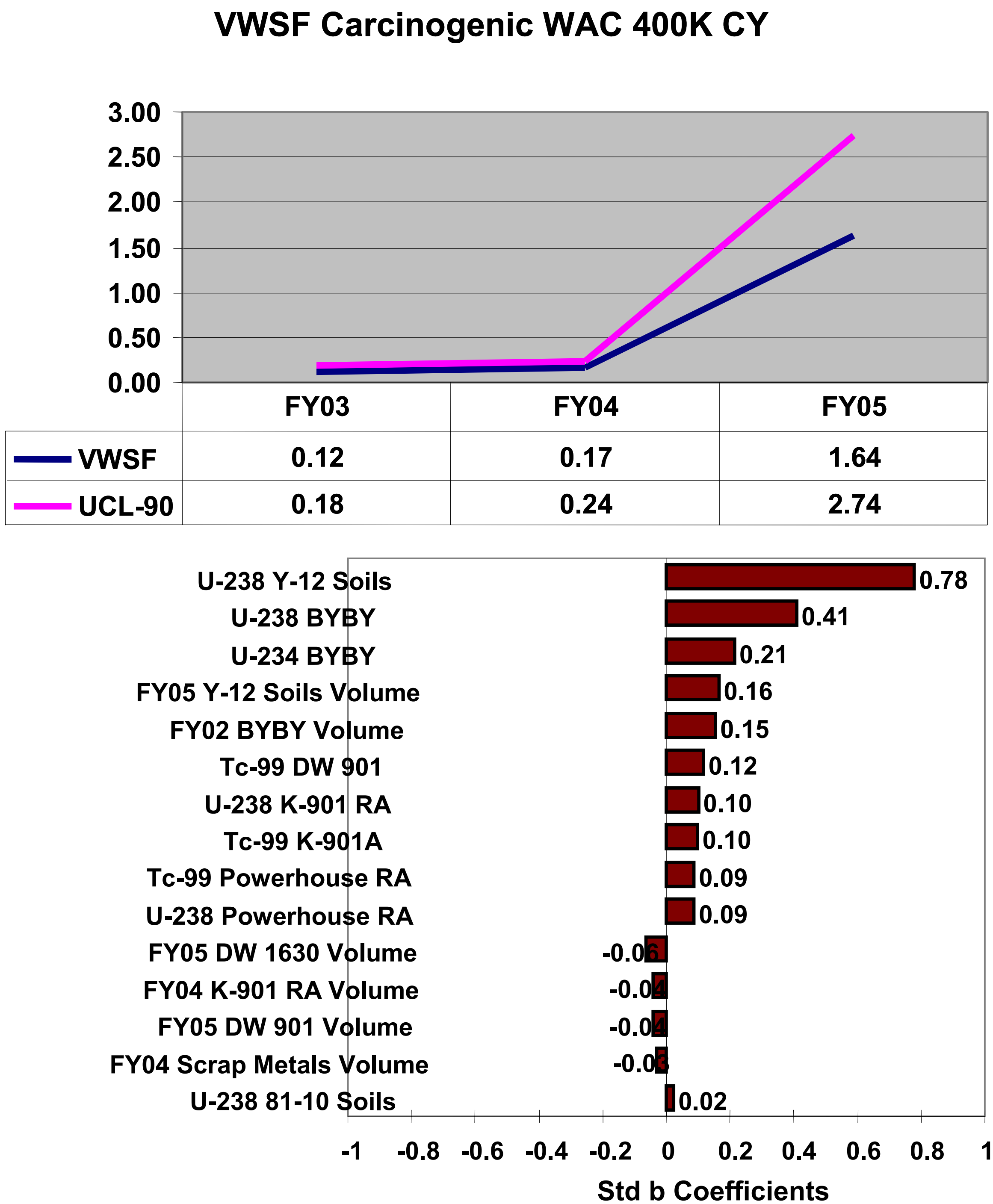

Fig. 4. WACFACS VWSF Three-Year Window and VWSF Sensitivity (**Hypothetical Data**).