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A Comparison of Hazard Predication and Assessment Capability (HPAC) Software Dose-Rate Contour Plots to a Sample of Local Fallout Data from Test Detonations in the Continental United States, 1945-1962

Richard W. Chancellor

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THESIS

Richard W. Chancellor, Major, USAF

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DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GNE/ENP/05-02

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Richard W. Chancellor, BS

Major, USAF

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Richard W. Chancellor, BS

Major, USAF

Approved:

Charles J. Bridgman (Chairman)	March 9, 2005 date
Steven T. Fiorino (Member)	9 MAR 05 date
Vincent J. Jodoin (Member)	9 Mar 05 date

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Abstract

A comparison of Hazard Prediction and Assessment Capability (HPAC) software dose-rate contour plots to a sample of local nuclear fallout data from test detonations in the continental United States, 1945 - 1962, is performed. Fallout data from test detonations is obtained from "Compilation of Local Fallout Data from Test Detonations 1945-1962 Extracted from DASA 1251, Volume I - Continental U.S. Tests." This report contains fallout plots and radiation contours for each test in the atmospheric nuclear test program conducted by the United States prior to 1963. These plots are compared with the plots resulting from Defense Threat Reduction Agency's (DTRA) HPAC software using test day wind data and additional wind data for up to seven days following each test. The results from HPAC were extrapolated to H+1 hour using the $t^{-1.2}$ decay approximation. A visual comparison of the plots revealed mismatches between observed and predicted data. A numerical comparison using Warner, et al, Rowland and Thompson, dose-rate contour area comparisons and grounded unit time reference dose rate corroborated the results of the visual comparisons.

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Richard W. Chancellor

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I. Introduction

Motivation

In the event of a nuclear detonation today, especially a terrorist attack on the continental United States, officials and planners at all levels of government and non-governmental agencies need the ability to effectively predict fallout patterns and the ability to provide adequate warning or preparation to civilian populations or military forces.

The United States last conducted atmospheric nuclear tests in 1962. Data were collected and reported for each test including wind speed and direction as well as resulting fallout patterns and doses. Since then, predictions regarding atmospheric nuclear detonations have been limited to the results of computer modeling and simulation involving wind transport of radioactive particles and resulting fallout. One such computer model is Hazard Prediction and Assessment Capability (HPAC) from the Defense Threat Reduction Agency (DTRA). HPAC predicts hazards based on nuclear, biological, or chemical event effects. It includes the capability to model effects of nuclear weapon detonations including fallout and dose rates over geographical areas. DTRA, particularly the Fallout Working Group, and the Air Force Technical Applications Center are interested in the independent comparison of HPAC hazard predictions with the actual test data last obtained in 1962. Some visual comparisons have been done by McGahan [McGahan, 2004]; however, no numerical comparisons have been accomplished.

Background

Fallout data from test detonations are obtained from *"Compilation of Local Fallout Data from Test Detonations 1945-1962 Extracted from DASA 1251, Volume I - Continental U.S. Tests"* published in 1979 for the Defense Nuclear Agency (DNA), henceforth referred to as DASA-EX [DASA-EX, 1979:2]. This compilation was extracted from DASA 1251 *"Local fallout from Nuclear Test Detonations"* (U) Volume 2 *"Compilation of Fallout Patterns and Related Test Data"* (U) Parts 1 through 3. DASA-EX was prepared to serve as an unclassified source of information and data concerning the atmospheric nuclear test program conducted by the United States prior to 1963. Data from most U.S. detonations is presented in chronological order, including fallout patterns for each event. Over time, the Defense Atomic Support Agency (DASA) became DNA, which became DTRA.

Problem

The focus of this research is to compare the off-site dose-rate contour plots of select U.S. tests from the 1950s and 1960s produced by HPAC 4.03 and 4.04 with those found in DASA-EX using test day wind data and additional wind data for up to seven days following each test. The comparison will be accomplished visually and numerically. The visual comparison will focus on the magnitude and direction of the plots. The numerical comparison will use Warner and Platt [Warner, et al, 2001:1] to provide a Measure of Effectiveness (MOE), Rowland and Thompson [Rowland and Thompson, 1972:5] to provide a Figure of Merit (FM), dose-rate contour area comparisons and a step-function integration of the dose-rate plots to compare grounded unit time reference dose rates for each plot.

Scope

The goal is to conduct a comparison of HPAC 4.03 and 4.04 output to off-site dose-rate contour plots obtained from DASA-EX. A visual comparison of the magnitude and direction of the plots is conducted. A numerical comparison using Warner and Platt [Warner, et al, 2001:1], Rowland and Thompson [Rowland and Thompson, 1972:5], dose-rate contour area comparisons and grounded unit time reference dose rate is also conducted. The dose-rate contour plots obtained from DASA-EX serve as the only source of observed, or known, data for this thesis. The contour plots generated by HPAC 4.03 and 4.04 serve as the prediction.

Approach

DASA-EX was the source of the off-site dose-rate contour plots used to compare to the HPAC generated plots. Six tests were selected for comparison. Four came from a list identified by the Fallout Working Group [DTRA, July 2003:12] with the remaining two chosen by this author. Test day winds data used by the HPAC software were obtained from *"Nuclear Cloud Rise and Growth"* [Jodoin, 1994:35]. Additional wind data for up to seven days following each test were obtained from the Air Force Combat Climatology Center (AFCCC). Nuclear test information including date, time, yield, height of burst, latitude and longitude was obtained from DASA-EX. The dose-rate contour plots were generated by HPAC 4.03 and 4.04 and the results were extrapolated to H+1 hour using the $t^{-1.2}$ decay approximation [Bridgman, 2001:424][1].

HPAC version 4.03 uses the Defense Land Fallout Interpretive Code (DELFIC) distribution, a single lognormal distribution, to characterize the distribution of particle sizes in the fallout ranging from 1-1000 microns. HPAC version 4.04 uses the Heft distribution [McGahan, October, 2004:1]. It is comprised of a linear combination of three lognormal distributions, glass, crystalline and local, to characterize the distribution of particle sizes in the fallout [Heft, 1970:254]. The size of the aerial cloud particles, which are the glass and crystalline particles, ranges from a few tenths of a micron to one centimeter. The size of the local particles ranges from tens of microns to several centimeters [Heft, 1970:256]. Plots of these two distributions (DELFIC and Heft) can be found in Skaar [Skaar, 2005].

The resulting fallout plots provide a direct visual comparison, giving the reader a sense of the magnitude and direction of the HPAC predictive plots compared to the DASA-EX actual plots. The actual and predictive plots were then discretized to provide a point-wise numerical comparison of regions of overlap and exclusion between the two plots to provide a MOE and FM. The dose-rate contour areas were then compared. The plots were then evaluated using step-function integration to provide a comparison of unit time reference dose rates.

[1] The $t^{-1.2}$ law was used because this is the same adjustment used by DASA-EX to adjust later time measurements to an H+1 hour dose rate for the tests researched.

Sequence of Presentation

Chapter 2 presents the methodology of this research effort including discussions of the HPAC software, DASA-EX, selected U.S. atmospheric nuclear tests, procedure, MOE, FM, dose-rate contour area comparison and grounded unit time reference dose rate. Chapter 3 presents visual and numerical comparisons of HPAC predictions. The HPAC predictions used the data from DASA-EX, Jodoin, AFCCC and the actual dose-rate contour plots from DASA-EX. Chapter 4 presents a summary of the results and provides recommendations for future endeavors in this topic of research. Appendix A contains an example of the process. Appendix B contains a sample weather profile for a test.

II. Methodology

Chapter Overview

The purpose of this chapter is to present the methodology of this research effort including discussions of the selected U.S. atmospheric nuclear tests, procedure, HPAC software, DASA-EX, MOE, FM dose-rate contour area comparison and grounded unit time reference dose rate.

Selected Tests

Six tests were selected for this research effort. Two, George and Zucchini, were randomly selected by this author and four were selected from a list identified by the Fallout Working Group, chaired by DTRA [DTRA, July 2003:12]. The tests are identified in Table 1.

Table 1. Selected Tests

OPERATION	TEST	DATE/TIME (Z)	YIELD (kT)	HEIGHT OF BURST (ft)
TUMBLER-SNAPPER	George	1 Jun 52/1155Z	15	300
TEAPOT	Ess	23 Mar 55/2030Z	1	-67
TEAPOT	Zucchini	15 May 55/1200Z	28	500
PLUMBOB	Priscilla	24 Jun 57/1330Z	37	700
PLUMBOB	Smoky	31 Aug 57/1230Z	44	700
SUNBEAM	Johnie Boy	11 Jul 62/1645Z	0.5	-2

Each test was checked to ensure the detonation was below the fallout-free height of burst [Glasstone and Dolan, 1977:71]. A detonation below this height can be assumed to generate appreciable or significant fallout. A detonation above this height will still produce fallout, but local fallout will be negligible compared to a burst where the fireball touches the ground. The fallout free height of burst is found using Equation (1)

$$H \approx 180W^{0.4} \tag{1}$$

where H is the maximum height of burst for which there will be appreciable fallout and W is the actual yield in kilotons [Glasstone and Dolan, 1977:71].

Test information was input into both versions of HPAC to produce dose-rate contour plots for comparison with those found in DASA-EX. The HPAC plots were visually compared to those found in DASA-EX with emphasis on magnitude and direction of the plots. The plots were also compared numerically using two comparative methods. One method is the Measure of Effectiveness which involves point-to-point comparisons. This method is described by Warner, et al. The other method is the Figure of Merit which is an areal comparison developed by Rowland and Thompson. Additionally, an areal comparison of the individual dose-rate contours was performed. Finally, a step-function integration of each plot was performed to allow a comparison of total activity between the three plots. This integration is an approximation of the unit time reference dose rate which will be defined later in this chapter.

HPAC Overview

HPAC software is a counterproliferation and counterforce tool designed to predict the effects of chemical, biological, radiological and nuclear (CBRN) events including releases into the atmosphere and the corresponding effects on civilian and military populations. War fighters can use HPAC to weaponeer targets containing weapons of mass destruction (WMD) and to predict fallout patterns in response to hazardous material releases. HPAC uses incident, or integrated source term, models, high-resolution weather data and particulate transport algorithms to predict hazard areas and their effects in minutes. HPAC uses a graphical user interface (GUI), the Project Editor, for controlling the interactions between the other components [DTRA, 2003:1-3]. The Project Editor allows the user to interactively edit and view each project. It uses a mapping tool to allow the user to plot input and output on a map background [DTRA, 2003:5-1-1]. Figure 1 depicts the HPAC process.

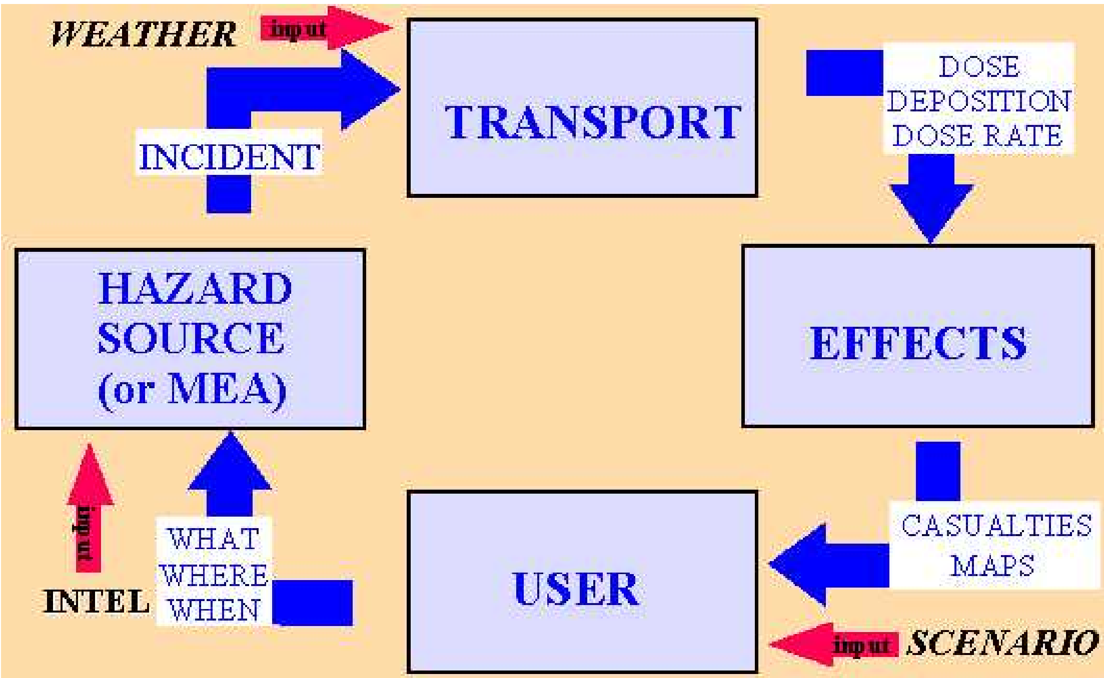


Figure 1. HPAC Process [DTRA, 2001:Ch. 10]

Two different versions of HPAC were used in this research, version 4.03 and version 4.04. A brief description of each version follows.

HPAC 4.03 and the DELFIC Particle Size Distribution

HPAC 4.03 uses one of seven integrated incident models, or source term models, to calculate the associated CBRN material release based on the user's input. The source term model used for this research effort was the Nuclear Weapon Explosion (NWPN) model [DTRA, 2003:1-3]. The NWPN model supports three types of nuclear weapons: surface or low-air burst (standard), buried and "special." The special weapon type is intended for low-yield weapons detonated within a structure and is not applicable to this research effort [DTRA, 2003:6-5-1]. NWPN defaults to U-238 as the fissionable material for all three weapon types. The NWPN model determines the amount and distribution of radioactive particles for HPAC to transport. It uses the DELFIC cloud rise model, using a weather profile provided by HPAC to generate the cloud rise in the spatial and temporal domains. When the cloud height stabilizes, DELFIC passes the activity distribution to HPAC for the transport process [DTRA, 2003:6-5-1].

The cloud activity distributions are based on the legacy fallout codes NewFall and K-Division Fallout Code, version 3 (KDFOC3) [DTRA, 2003:6-5-1]. These routines prescribe both activity and dust lofting by particle size group. NewFall uses the DELFIC distribution, a single lognormal distribution, to characterize the distribution of particle sizes in the fallout ranging from 1-1000 microns. NWPN uses KDFOC3 to prescribe both activity and dust lofting by particle size group for buried weapons [DTRA, 2003:6-5-1]. KDFOC3 breaks the nuclear detonation cloud in to three separate clouds: the mushroom, the stem and the base surge. KDFOC3 maintains two log-normal particle distributions for each cloud [DTRA, 2003:H-5].

HPAC 4.04 and the Heft Particle Size Distribution

HPAC 4.04 uses one of twelve integrated incident models, or source term models, to calculate the associated CBRN material release based on the user's input. The source term model used for this research effort was the Nuclear Weapon Special Edition (NWPNSE) model [DTRA, 2004:422]. The NWPNSE model supports three types of nuclear weapons: surface or low-air burst (standard), buried and contained. As with HPAC 4.03, the contained weapon type is not applicable to this research effort. Like the NWPN model in HPAC 4.03, NWPNSE defaults to U-238 as the fissionable material for all three weapon types. The NWPNSE model determines the amount and distribution of radioactive particles for HPAC to transport. It uses the DELFIC cloud rise model, using a weather profile provided by HPAC to generate the cloud rise in the spatial and temporal domains [DTRA, 2004:424]. However, cloud activity distributions are based on the Heft distribution. It is comprised of a linear combination of three lognormal distributions, glass, crystalline and local, to characterize the distribution of particle sizes in the fallout [Heft, 1970:254] [Skaar, 2005].

The crystalline particles are comprised of local soil material that was not melted due to entering the fireball at a late time [Heft, 1970:255]. The particle densities match those of the local soil. The glass particles are those particles that entered the fireball earlier and were therefore subjected to more heat. They are more abundant and typically have a larger particle diameter than the population of crystalline particles [Heft, 1970:255]. The glass particle densities are slightly less than or equal to the local soil. The diameter of the aerial cloud particles, comprised of the glass and crystalline particles, ranges from a few tenths of a micron to one centimeter [Heft, 1970:256]. The third component of the Heft distribution is the local distribution. These particles are a result of soil material interacting with the fireball at high temperature but separating from the fireball, before the temperature falls below the melting point of the soil. The local particle densities are usually very low compared to the local soil. The diameter of the local particles ranges from tens of microns to several centimeters [Heft, 1970:256].

HPAC Weather and Terrain

HPAC then uses its integrated databases that provide environmental data including weather and terrain and routines. These databases also interact with the user's weather data files that are downloaded from a Meteorological Data Server or other external data sources. The external data are more applicable to the user's particular incident of interest and therefore produce more tailored results. HPAC automatically invokes a mass-consistent wind field model called the Stationary WInd Fit and Turbulence (SWIFT) model when terrain elevation data are used [DTRA, 2003:1-3].

Weather is a key factor in predicting the downwind hazard associated with a particular release of weapons of mass destruction. Key variables include wind speed and direction, temperature, and humidity. These variables are critical in determining the direction and distribution of hazardous material. HPAC includes at least five different methods for getting weather data into the atmospheric transport model known as SCIPUFF. The methods are: fixed winds; historical weather data or climatology; surface observations and upper air profiles; mass consistent wind fields; and prognostic numerical weather prediction model output in either gridded or profile format [DTRA, 2003:4-9]. This author used upper air profiles to provide weather data. Detailed information on upper air profiles can be found in Appendix B: Weather Profiles.

The weather profiles used for this research effort are from two sources. Jodoin's dissertation [Jodoin, 1994:38] was the source of initial weather data, obtained as close to the detonation time and location as possible. Weather data for the seven days following the test were also obtained from the Air Force Combat Climatology Center (AFCCC). These data contained multiple updates for up to three different observation stations in the region of the test. In both cases, the weather data included wind direction, wind speed, pressure, temperature and humidity at different altitudes. Detailed information on these profiles is in Appendix B: Weather Profiles.

HPAC uses two types of terrain data. The default assumption is a flat Earth for the terrain, used to approximate small spatial domains. The second option uses a complex option. It uses 3-D terrain data representing topographic variations. However, use of the complex terrain option automatically invokes the mass-consistent wind field model, SWIFT [DTRA, 2003:4-10]. This research used the flat Earth assumption.

HPAC Transport

HPAC then uses its particulate transport algorithms called the Second-order Closure Integrated PUFF (SCIPUFF) model. SCIPUFF is a Lagrangian model that calculates material dispersion in the environment, taking into account diffusion and turbulence caused by weather, terrain and other factors [Sykes, 1998:1]. Two noteworthy aspects of the SCIPUFF model are the numerical technique used to solve the dispersion model and the parameter used for turbulent diffusion. Gaussian puff methodology is used to numerically solve the dispersion model equations. In this method, a collection of arbitrarily oriented three-dimensional puffs is used to represent a time-dependent concentration field, which is also arbitrary. Second order closure theory is used to parameterize the turbulent diffusion, linking the atmospheric wind velocity statistics and predicted dispersion rates of lofted materials [Sykes, 1998:1].

DASA-EX Test Data

DASA-EX was prepared by General Electric in 1979 for DNA to serve as an unclassified source of information and data regarding the atmospheric nuclear tests conducted by the U.S. prior to 1963. Data from most U.S. detonations are presented in chronological order, including fallout patterns for each event [DASA-EX:2].

DASA-EX includes basic data for each test such as date, time, latitude, longitude, height of burst in feet and yield in kilotons. Wind speed and direction as a function of altitude are included for each test. The data are for times as close to the test time as possible. The wind direction is given in degrees from where the wind is blowing, measured clockwise from the north. Wind velocities listed are in statute miles per hour.

On-site and off-site fallout patterns with dose-rate contours are included for most tests. The dose-rate contours were drawn to show gamma dose rate in roentgens per hour, three feet above the ground at one hour past detonation reference time. When no actual decay information was available, the $t^{-1.2}$ decay approximation was used to extrapolate the data to H+1 hour [DASA-EX:2].

Measure of Effectiveness, Warner, et al

This numerical comparison looks at areas of dose-rate contours for each type of plot and compares them on a point by point basis. In this case, the plots from DASA-EX are compared with the plots from HPAC versions 4.03 and 4.04. The dose-rate contour plots from DASA-EX are defined as the areas of observation. The dose-rate contour plots from both versions of HPAC are defined as the areas of prediction. Areas where DASA-EX and each version of HPAC agree are defined as areas of overlap. Areas attributed solely to DASA-EX with no overlap from HPAC are defined as areas of false negative. That is to say, there are observed data from DASA-EX, but no prediction from HPAC to match the data. Areas attributed solely to HPAC with no overlap from DASA-EX are defined as areas of false positive. In this case, there are no observed data from DASA-EX, yet HPAC predicted the area [Warner, et al, 2001:1]. Figure 2 illustrates the different types of area definitions.

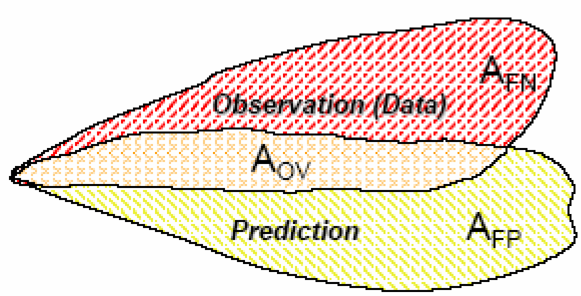


Figure 2. Conceptual View of 3 Comparative Dimensions [Warner, et al, 2001:1]

This Measure of Effectiveness (MOE) is a two-dimensional comparison. The x-axis of the comparison is composed of the ratio of overlap to the observed area. The y-axis of the comparison is composed of the ratio of overlap to the predicted area

[Warner, et al, 2001:1]. Equation (2) shows how the MOE is obtained using the area definitions

$$MOE = (1 - \frac{A_{FN}}{A_{OB}}, 1 - \frac{A_{FP}}{A_{PR}}) \quad (2)$$

where

A_{FN} = Area of False Negative (Underprediction)
A_{OB} = Area of Observed Data (DASA 1251-1-EX)
A_{FP} = Area of False Positive (Overprediction)
A_{PR} = Area of Predicted Data (HPAC)
A_{OV} = Area of Overlap
$A_{OB} = A_{OV} + A_{FN}$
$A_{PR} = A_{OV} + A_{FP}$

Because this model is a point-by-point direct comparison between plots, the direction of each plume matters. Even though both plumes may have the same area, the fact that they might be oriented in different directions changes their MOE score. Figure 3 depicts an example MOE. The diagonal line indicates the break between the region of decreasing over-prediction and the region of decreasing under-prediction. As a MOE moves up on the chart, it indicates less over-prediction (or false positive) by the model, in this case HPAC. As a MOE moves to the right on the chart, it indicates less under-prediction (or false negative) by the model.

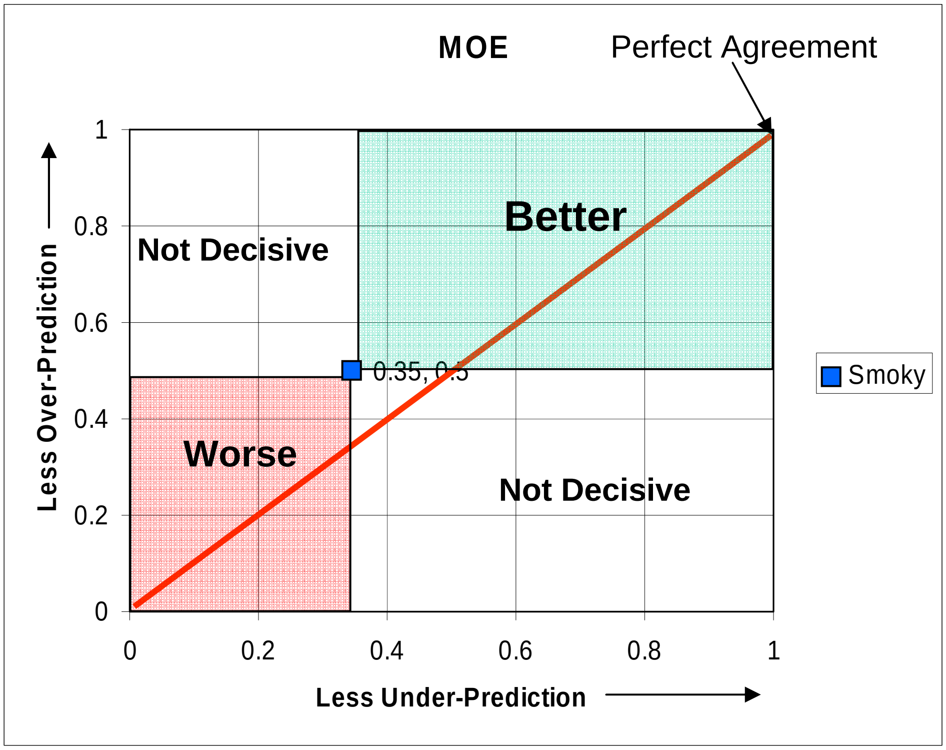


Figure 3. Example MOE [Warner, et al, 2002:4]

The MOE does not present a single numerical representation for all of the dose-rate contours in aggregate. Instead it represents a comparison of each individual dose-rate contour for each test [Warner, 2005]. Therefore, if a test reflects six different dose-rate levels, there will be six independent MOEs conducted for that test.

Figure of Merit, Rowland and Thompson

Rowland and Thompson devised their method for comparing fallout patterns in 1972 to address the Fallout community's need to consistently compare different plots as there was no procedure for producing standardized comparison, even between two examiners. At the time, the community relied on: qualitative visual comparisons based on juxtaposition of contour plots reduced to similar scales; hotline comparisons involving greatest radial extent of a particular dose rate and widths of contours at certain distances; areal measurements of specific contours and cumulative doses compared to radial distances; and exact measurements involving point-to-point comparisons within the contour plots [Rowland and Thompson, 1972:3].

The visual comparisons were sensitive to observer bias while the hotline comparisons had multiple trade-offs at each area of comparison such as deciding the merit of shorter or longer radial distances compared to wider or narrower contours. Areal comparisons by separate contour did not produce an integrated measure. At the time, exact, point-to-point comparisons were not a viable option [Rowland and Thompson, 1972:4].

Their method is based on the areal method and derives a single Figure of Merit (FM) to numerically quantify the goodness of fit between two fallout patterns. Their FM accounts for the areal distribution of the contour plots, the dose-rate of each contour and direction of each contour plot. The area of each similar contour pattern being compared is calculated and the area which does not overlap for the same two contour plots is also calculated. The measure of agreement is given by a non-linear FM ranging from 0, no common area, to 1, two identical patterns [Rowland and Thompson, 1972:5]. Equation (3) shows how the FM is obtained.

$$FM = \frac{\sum_{i=1}^{N} \frac{(V_i + V_{i-1})}{2} (A_i - A_{i-1})}{\sum_{i=1}^{N} \frac{(V_i + V_{i-1})}{2} (A_i - A_{i-1})} \frac{(Common\ Area)}{(Largest\ Area)} \qquad (3)$$

where

N = number of contours which have the same value
V_i = unit value of the i^{th} contour ($V_i < V_{i-1}$)
A_i = area enclosed by the i^{th} contour

and

A_0 = taken to be zero
V_0 = taken as $10V_i$

The method has several advantages over the old comparison methods previously mentioned. One advantage is that observer bias is eliminated because different examiners should produce the same FM. Another is that the FM accounts for a number of pattern variables, such as differing hotline directions and contour widths, with a single number. Finally, higher dose-rate contours are weighted within the formula [Rowland and Thompson, 1972:5].

Dose-Rate Contour Area Comparison

A third way of comparing the dose-rate contour plots is an areal comparison of the dose-rate contours. This comparison is reflected in square miles because the DASA-EX and HPAC plots are shown using miles.

Grounded Unit Time Reference Dose Rate

The final method of numerically comparing the dose-rate contour plots is the unit time reference dose rate (at one hour) for each plot. The unit time reference dose rate represents the dose rate if a volumetric integration of the activity remaining in the air and deposited on the ground were performed at one hour [Bridgman, 2001:425]. Normally, the unit time reference dose rate would be derived using continuous dose rates radiating out from ground zero. However, the dose-rate contour plots from DASA-EX represent only the grounded activity in a step-wise fashion. For this reason, the dose-rate contour plots from both versions of HPAC were also evaluated in a step-wise fashion. The step-function integration was performed taking each dose rate value at one hour on a fine grid, multiplying them by the area that each point represents and summing them all. The sum was divided by the yield, which then represents the dose rate at one hour per kiloton for one square kilometer. This sum is a stepwise approximation to the grounded portion of the unit time reference dose rate, henceforth referred to as Grounded UTRDR. Its value will always be less than the true unit time reference dose rate.

If all of the activity for one kiloton of fission indicated by the volumetric integration mentioned above were spread uniformly over one square kilometer at one hour, the total activity would be called the source normalization constant, as derived by Bridgman [Bridgman, 2001:425]. Expected values for the source normalization constant, *k*, range between 2590 to over 7500 $\frac{R-km^2}{hr-kT}$ [Bridgman, 2001:436]. This value is based on 75% of the total gamma activity attributed by Glasstone and Dolan to the fission products produced by one kiloton of fission, 530 gamma-megacuries at one hour after detonation [Glasstone and Dolan, 1977:453]. The fraction 75 percent is based in part on Baker's bimodal distribution which assumes 75 percent of the activity is contained in the particles which contribute to local fallout [Bridgman, 2001:425]. Hereafter, this value of the source normalization constant is referred to as the "theoretical value" and is provided for comparative purposes only.

III. Results and Comparisons

Chapter Overview

The purpose of this chapter is to present visual and numerical comparisons of HPAC predictions using the data from DASA-EX, Jodoin and AFCCC, and the actual dose-rate contour plots from DASA-EX. The tests are presented in chronological order, earliest to latest. Dose-rate contour plots for each test are depicted in four ways in this chapter. The plot is presented in its original format from DASA-EX and then in the gray-scale format which is a product of Canvas software [Canvas 2004]. The Canvas software was used to import the line drawings from DASA-EX and HPAC and turn them into a gray scale picture by tracing the drawings and establishing contour plots for each dose rate within the test.

Dose-rate contour plots from HPAC 4.03 and 4.04 are also presented in gray scale format. Extra effort was taken to present the plots so that all are on the same scale. This should give the reader a visual appreciation of the differences in magnitude and direction.

Operation TUMBLER-SNAPPER George

The George test shot took place June 1, 1952 at 1155 Greenwich Mean Time (GMT) or Zulu (Z). It was a tower burst, detonated 300 feet above the ground, yielding 15 kilotons. The off-site fallout pattern at Figure 4 was drawn from readings obtained by ground mobile monitors from the Radiological Safety organization on detonation day (D-Day). Off-site refers to the area exceeding 4000 yards from ground zero [DASA-EX, 1979:93]. The dose-rates were extrapolated to H+1 hour using the $t^{-1.2}$ decay approximation [DASA-EX, 1979:93]. The dose-rate contours were plotted on a grid with units of 20 statute miles, oriented to the North. Figure 5 is a gray-scale version of Figure 4.

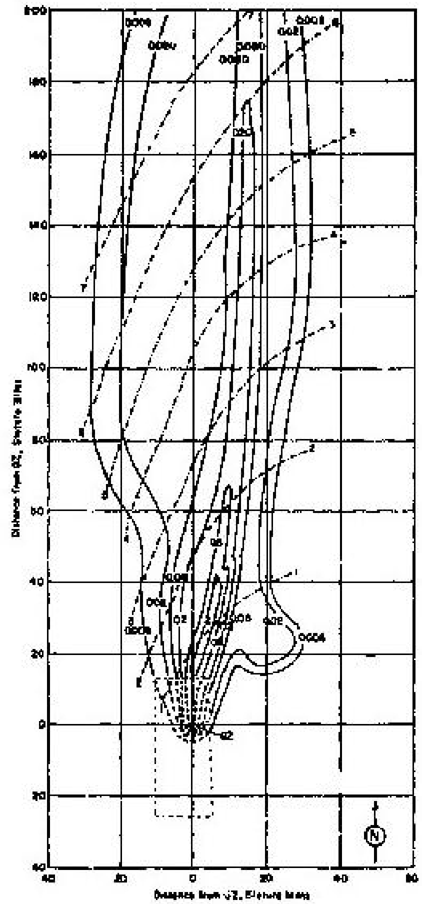


Figure 4. Operation TUMBLER-SNAPPER, George [DASA-EX, 1979:95]

The original chart from DASA-EX was imported into Canvas where it was electronically traced to produce a gray-scale image. This image is shown compared to the HPAC 4.03 and 4.04 output of the same test. The available winds data from Jodoin and AFCCC were input into HPAC 4.03 and 4.04 yielding the dose-rate contour plots at Figure 6 and Figure 7. The dose rate contour values in this plot are shown in the legend next to Figure 7.

Visual Comparison - George

A visual comparison of Figure 5, Figure 6 and Figure 7 indicates all three plots are oriented in the same northerly direction. The rough magnitudes of all three plots are the same; all extend at least 200 miles. The DASA-EX plot and the HPAC 4.03 plots are at least 60 miles wide, while the HPAC 4.04 plot is narrower, measuring approximately 40 miles wide. The DASA-EX plot shows some unique features in the 0.008 r/hr and 0.02 r/hr dose-rate contour plots at the lower southeast corner and along the lower western side. The spur in the southeast corner and the exaggerated bulge in the lower western side are not modeled in either of the HPAC plots, although there is a slight curve to the west in the HPAC plots for the corresponding dose-rate contour plots at the location of the exaggerated bulge in the DASA-EX plot. These unique features could be due to terrain features not adequately modeled in either version of HPAC or limitations in the sampling techniques at the time of the test. The dose-rate contour plots for 0.08 r/hr and higher are significantly narrower in the DASA-EX plot as compared to both of the HPAC plots. Again, this could be terrain dependent, sampling technique or an artifact of the modeling techniques reflected in HPAC.

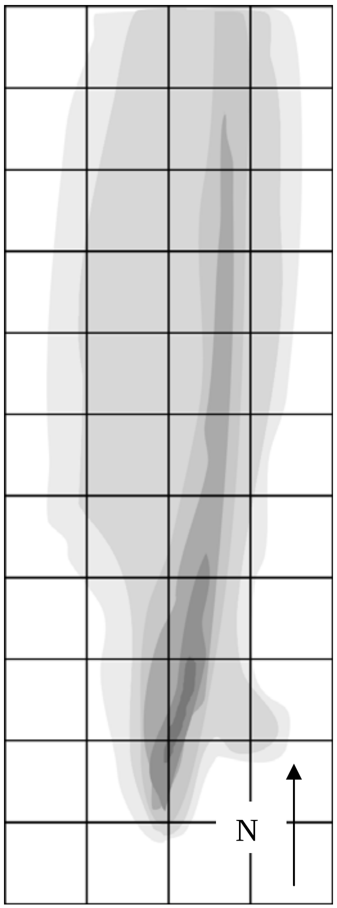


Figure 5. George, DASA-EX

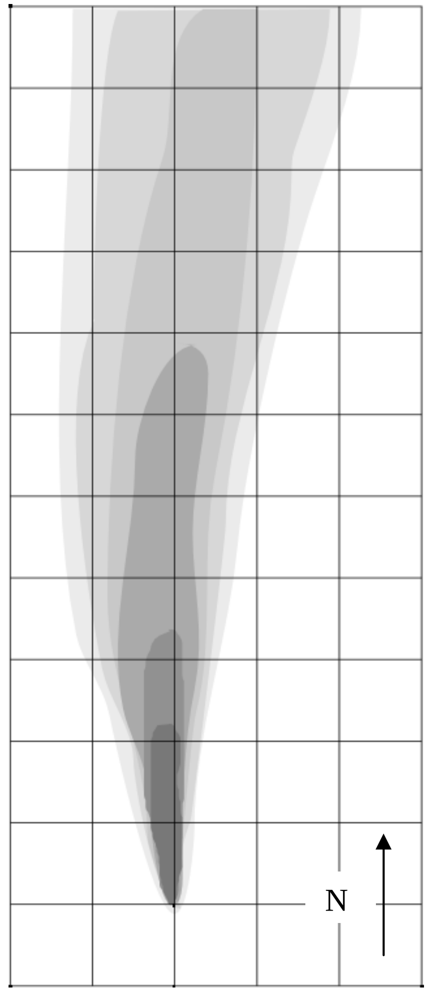


Figure 6. George, HPAC 4.03

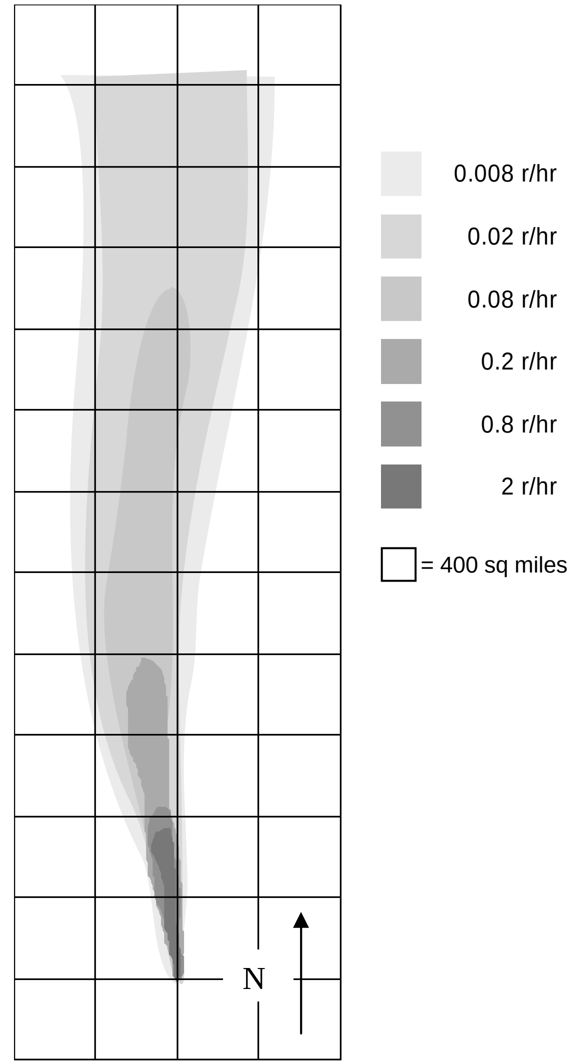


Figure 7. George, HPAC 4.04

MOE - George

A comparison of DASA-EX dose-rate contour plots to HPAC 4.03 dose-rate contour plots was performed for each individual dose-rate level. The comparison was also conducted for DASA-EX versus HPAC 4.04 dose-rate contour plots at each individual level.

MOE DASA-EX versus HPAC 4.03 - George[2]

At the 0.008 r/hr dose-rate, HPAC 4.03, the predicted area, is longer and wider than DASA-EX, the observed area. However, both extend in the same general direction. This leads to a MOE of (0.79, 0.80), which reflects a very good overall agreement between observed predicted data. At the 0.02 r/hr dose-rate, the same holds true, leading to a MOE of (0.77, 0.76), and again reflects a very good overall agreement between observed and predicted data. At the 0.08 r/hr dose-rate, the DASA-EX plot is significantly thinner than the HPAC 4.03 plot. It is also oriented towards north-northeast, while the HPAC 4.03 plot is oriented to the north. This very thin plot combined with the slight change in direction does not give much opportunity for significant overlap. As such, the MOE is (0.54, 0.28). The low value for the Y-coordinate of the MOE reflects under prediction for the reasons just discussed. The same holds true for the 0.2 r/hr, 0.8 r/hr and 2 r/hr dose rates. Therefore, they yield MOEs of (0.30, 0.18), (0.33, 0.18) and (0.23, 0.05) respectively as shown by Table 2. Figure 8 shows this information in graphical form.

[2] The 0.008 r/hr, 0.02 r/hr and 0.08 r/hr dose rate contours are truncated in the DASA-EX and HPAC 4.03 plots. Therefore, the MOE calculations for those dose rates are not represented as entirely complete.

MOE DASA-EX versus HPAC 4.04 - George[3]

At the 0.008 r/hr dose-rate, HPAC 4.04, the predicted area, is the same length, but much thinner than DASA-EX, the observed area, for the first 120 miles of the contour plot. However, both extend in the same general direction. This leads to a MOE of (0.57, 0.80), which reflects some overall agreement between observed predicted data. However, the low X-value corroborates the thin width of the HPAC 4.04 plume. At the 0.02 r/hr dose-rate, the same holds true, leading to a MOE of (0.52, 0.72), and again reflects some overall agreement between observed and predicted data. At the 0.08 r/hr dose-rate, the DASA-EX plot is significantly thinner than the HPAC 4.03 plot. It is also oriented towards north-northeast, while the HPAC 4.03 plot is oriented to the north-northwest. This very thin plot combined with the slight change in direction does not give much opportunity for any overlap. As such, the MOE is (0.11, 0.14). The low value for both coordinates of the MOE reflects under prediction for the reasons just discussed for HPAC 4.04. The same holds true for the 0.2 r/hr and 0.8 r/hr dose rates. Therefore, they yield MOEs of (0.16, 0.32), (0.20, 0.31) respectively. The 2 r/hr dose rate plots have hardly any overlap between the two plots, as both point in different directions. This yields a MOE of (0.01, 0.00) as shown by Table 3. Figure 9 shows this information in graphical form.

[3] The 0.008 r/hr, 0.02 r/hr and 0.08 r/hr dose rate contours are truncated in the DASA-EX and HPAC 4.04 plots. Therefore, the MOE calculations for those dose rates are not represented as entirely complete.

Table 2. MOE Values - George, DASA-EX vs. HPAC 4.03

George		
X	Y	Dose-Rate
0.23	0.05	2
0.33	0.18	0.8
0.30	0.18	0.2
0.54	0.28	0.08
0.77	0.76	0.02
0.79	0.80	0.008

Table 3. MOE Values - George, DASA-EX vs. HPAC 4.04

George		
X	Y	Dose-Rate
0.01	0.00	2
0.20	0.31	0.8
0.16	0.32	0.2
0.11	0.14	0.08
0.52	0.72	0.02
0.57	0.80	0.008

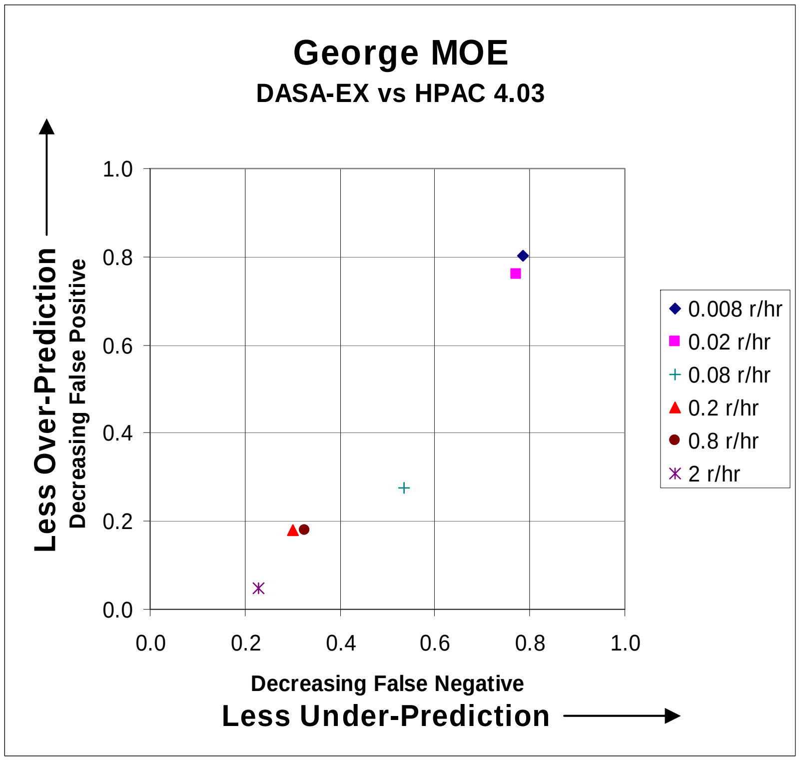


Figure 8. MOE - George, DASA-EX vs. HPAC 4.03

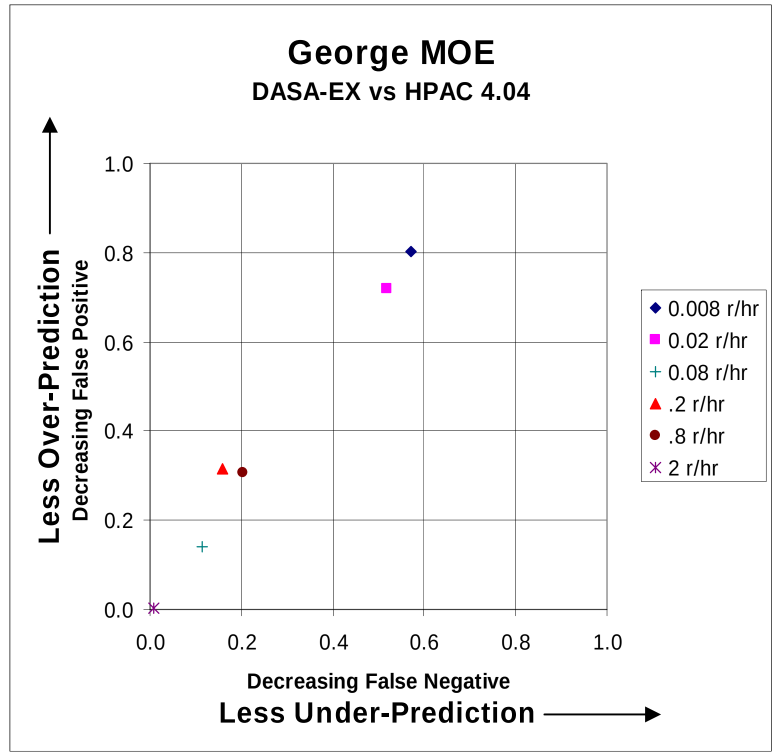


Figure 9. MOE - George, DASA-EX vs. HPAC 4.04

FM - George

The non-linear FM for comparing the DASA-EX dose-rate contour plots to those of HPAC 4.03 is 0.17. The value for the comparison between DASA-EX and HPAC 4.04 is 0.08. These values are weighted based on the values of the dose-rates. Therefore, the fact that both of the HPAC plots and the DASA-EX plots diverge at the higher dose-rates means the FM is low even though the overall magnitude and direction of the plots are similar as discussed in the visual comparison portion above.

Dose-Rate Contour Area - George

The dose-rate contour areal comparison is summarized in Table 4. The data agree with the visual comparison previously discussed. HPAC 4.03 predicts larger dose-rate contour areas with the exception of the 0.02 r/hr dose-rate.

Grounded UTRDR - George

The Grounded UTRDR is summarized in Table 4 in $\left[\dfrac{R-km^2}{hr-kT}\right]$. HPAC 4.03 predicts more grounded activity than DASA-EX or HPAC 4.04.

Table 4. George - Contour Area and Grounded UTRDR

George			
	Contour Area (sq miles)		
Dose Rate (r/hr)	DASA-EX	HPAC 4.03	HPAC 4.04
2	62.6	266.3	120.2
0.8	246.7	256.5	74.4
0.2	810.8	1317.2	353.1
0.08	1278.6	2681.7	1269.5
0.02	5122.2	2995.7	3497.5
0.008	2369.4	2030.6	1546.8
	Grounded UTRDR		
	DASA-EX	HPAC 4.03	HPAC 4.04
	122.3	223.0	95.7

Operation TEAPOT Ess

The Ess test shot took place March 23, 1955 at 2030 Greenwich Mean Time (GMT) or Zulu (Z). It was a sub-surface burst, detonated 67 feet below the ground, yielding 1 kiloton. The off-site fallout pattern at Figure 10 was drawn from ground survey readings taken by the off-site Radiological Safety organization on detonation day (D-Day). Off-site refers to the area exceeding 7000 yards from ground zero [DASA-EX, 1979:201]. The dose-rates were extrapolated to H+1 hour using the $t^{-1.2}$ decay approximation. The dose-rate contours were plotted on a grid with units of 20 statute miles, oriented to the North. The dose rate contour values in this plot are shown in the legend next to Figure 11 which is a gray-scale version of Figure 10.

Again, the original chart from DASA-EX was imported into Canvas where it was electronically traced to produce a gray-scale image. This image is shown compared to the HPAC 4.03 and 4.04 output of the same test. As before, the available winds data from Jodoin and AFCCC were input into HPAC 4.03 and 4.04 yielding the dose-rate contour plots at Figure 12 and Figure 13.

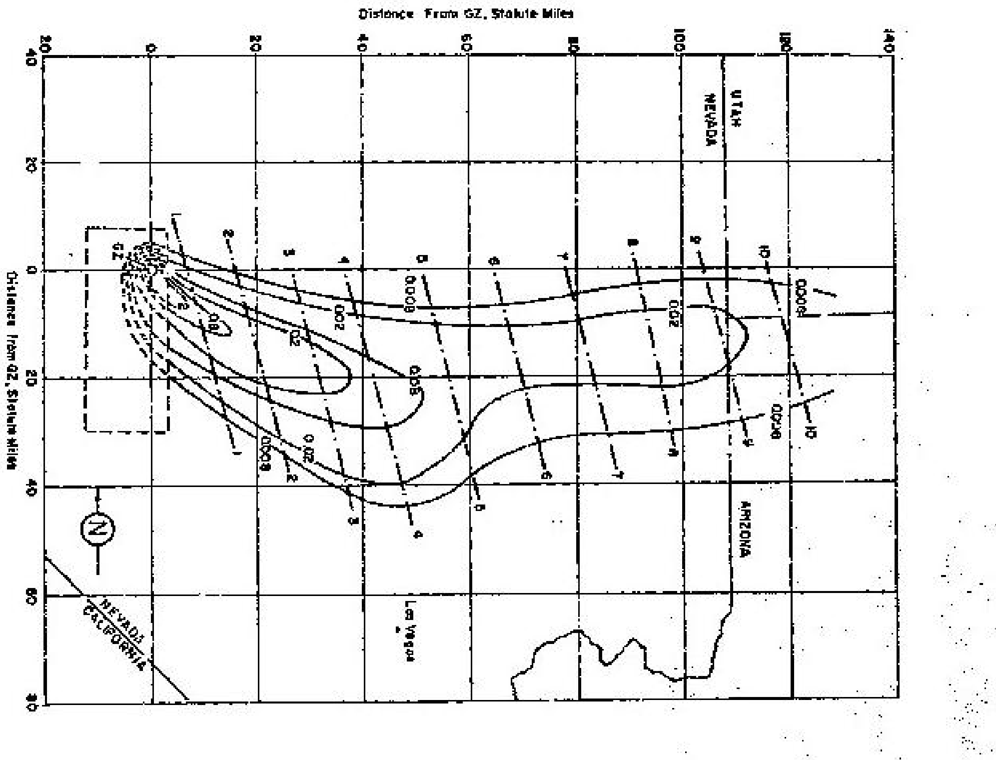


Figure 10. Operation TEAPOT, Ess [DASA-EX, 1979:204]

Visual Comparison - Ess

A visual comparison of Figure 11, Figure 12 and Figure 13 indicates all three plots are initially oriented in the same southeasterly direction. However, the DASA-EX plot swings east after approximately 60 miles, while the HPAC plots continue in their original direction. The rough magnitudes of all three plots are the same; all extend at least 120 miles and are at least 40 miles wide. The difference between the HPAC plots and the DASA-EX plot appears to be attributable to the weather files used by HPAC.

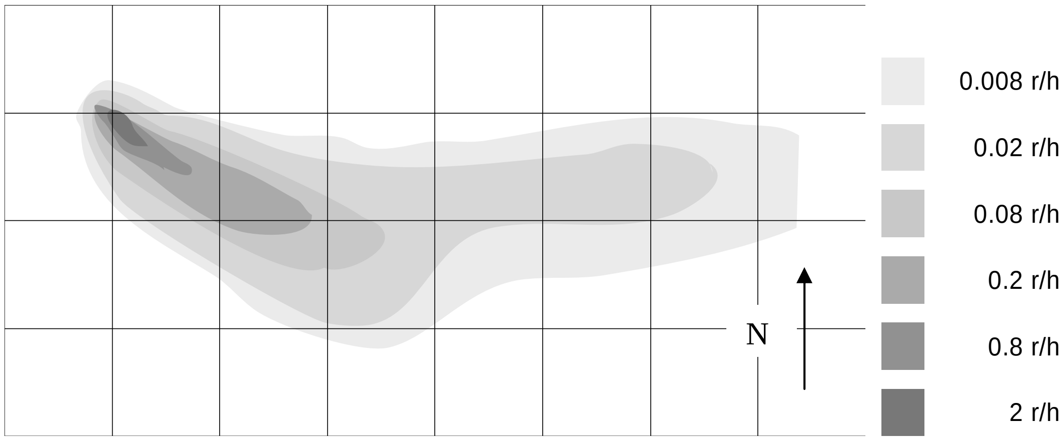


Figure 11. Ess, DASA-EX

□ = 400 sq miles

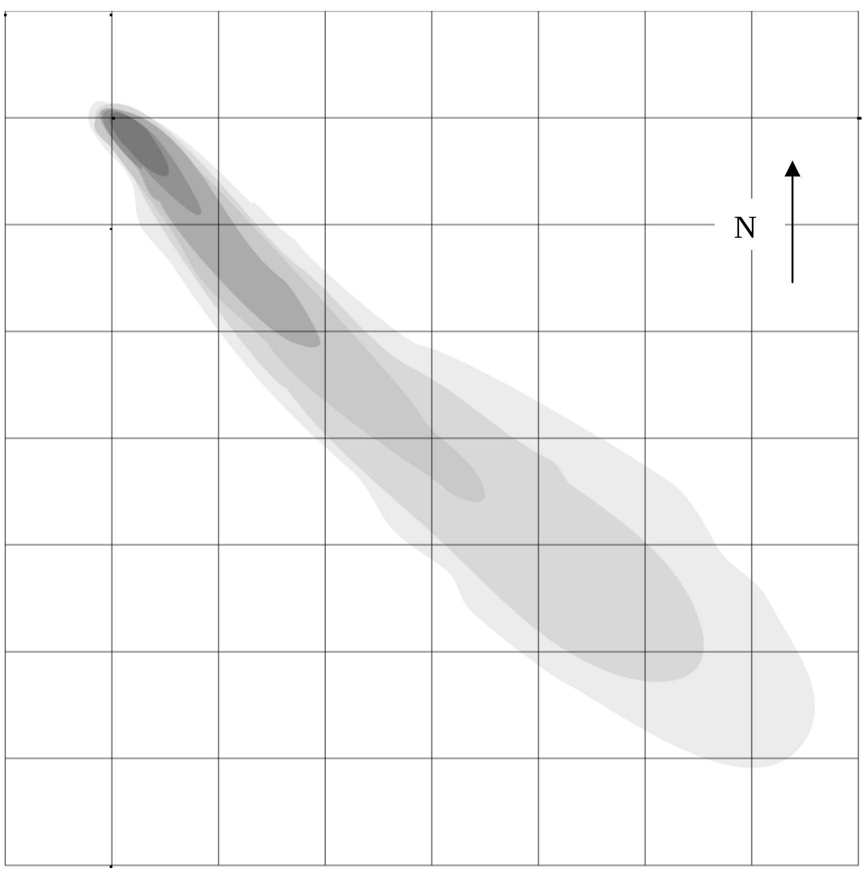


Figure 12. Ess, HPAC 4.03

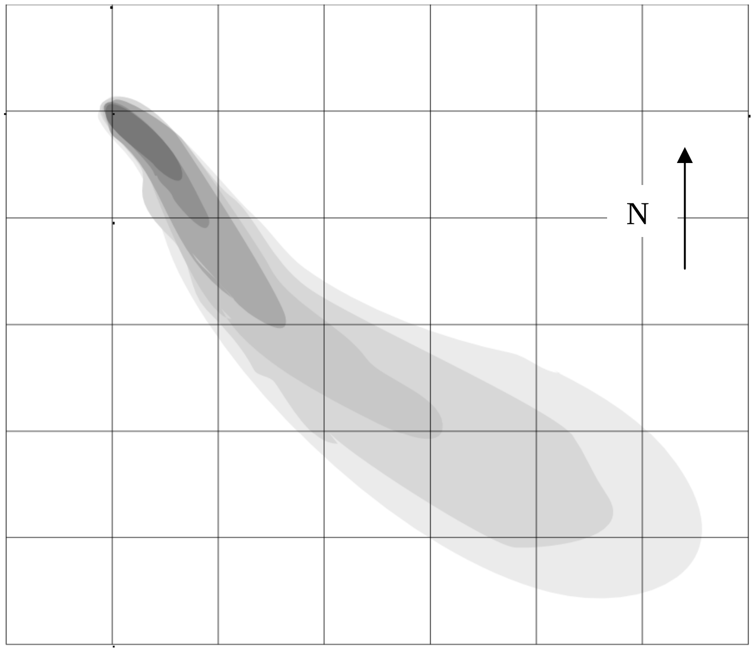


Figure 13. Ess, HPAC 4.04

MOE - Ess

As before, a comparison of DASA-EX dose-rate contour plots to HPAC 4.03 dose-rate contour plots was performed for each individual dose-rate level. The comparison was also conducted for DASA-EX versus HPAC 4.04 dose-rate contour plots at each individual level.

MOE DASA-EX versus HPAC 4.03 - Ess[4]

At the 0.008 r/hr and 0.02 r/hr dose-rates, DASA-EX changes direction as previously discussed, while the HPAC plot does not. This leads to MOEs of (0.25, 0.19) and (0.28, 0.21) respectively. While the plots have similar magnitudes, the change in direction by the DASA-EX causes the HPAC model to severely under predict. At the 0.08 r/hr, 0.2 r/hr, 0.8 r/hr and 2 r/hr dose rates, both plots have similar shapes and

[4] The 0.008 r/hr dose rate contour is truncated in the DASA-EX plot. Therefore, the MOE calculation for that dose rate is not represented as entirely complete.

magnitudes. The DASA-EX plot tends a few degrees to the north of the HPAC plot. This yields MOEs of (0.46, 0.30), (0.51, 0.38), (0.85, 0.51) and (0.75, 0.25) respectively as shown in Table 5. In these cases, the higher value for the X-coordinate indicates the HPAC model is under predicting some while over predicting quite a bit. Figure 14 shows this information in graphical form.

MOE DASA-EX versus HPAC 4.04 - Ess[5]

At the 0.008 r/hr and 0.02 r/hr dose-rates, DASA-EX changes direction as previously discussed, while the HPAC plot does so only slightly. This leads to MOEs of (0.21, 0.22) and (0.24, 0.24) respectively. While the plots have similar magnitudes, the sharper change in direction by the DASA-EX causes the HPAC model to severely under predict. At the 0.08 r/hr, 0.2 r/hr, 0.8 r/hr and 2 r/hr dose rates, both plots have similar shapes and magnitudes. The DASA-EX plot tends a few degrees to the north of the HPAC plot. This yields MOEs of (0.36, 0.28), (0.48, 0.39), (0.76, 0.41) and (0.91, 0.24) respectively as shown in Table 6. In these cases, the higher value for the X-coordinate indicates the HPAC model is under predicting some while over predicting quite a bit. Figure 15 shows this information in graphical form.

5 The 0.008 r/hr dose rate contour is truncated in the DASA-EX plot. Therefore, the MOE calculation for that dose rate is not represented as entirely complete.

Table 5. MOE Values - Ess, DASA-EX vs. HPAC 4.03

	Ess	
X	Y	Dose-Rate
0.75	0.25	2
0.85	0.51	0.8
0.51	0.38	0.2
0.46	0.30	0.08
0.28	0.21	0.02
0.25	0.19	0.008

Table 6. MOE Values - Ess, DASA-EX vs. HPAC 4.04

	Ess	
X	Y	Dose-Rate
0.91	0.24	2
0.76	0.41	0.8
0.48	0.39	0.2
0.36	0.28	0.08
0.24	0.24	0.02
0.21	0.22	0.008

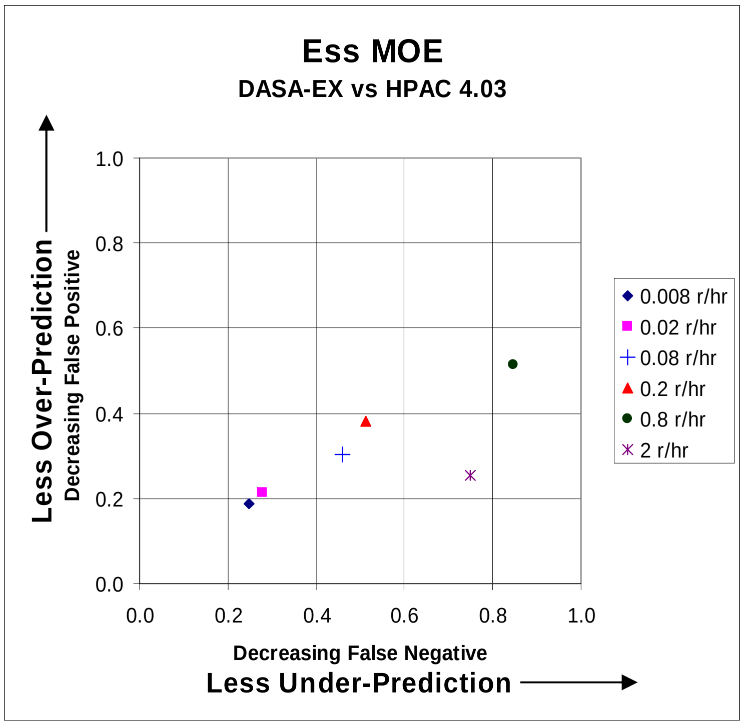


Figure 14. MOE - Ess, DASA-EX vs. HPAC 4.03

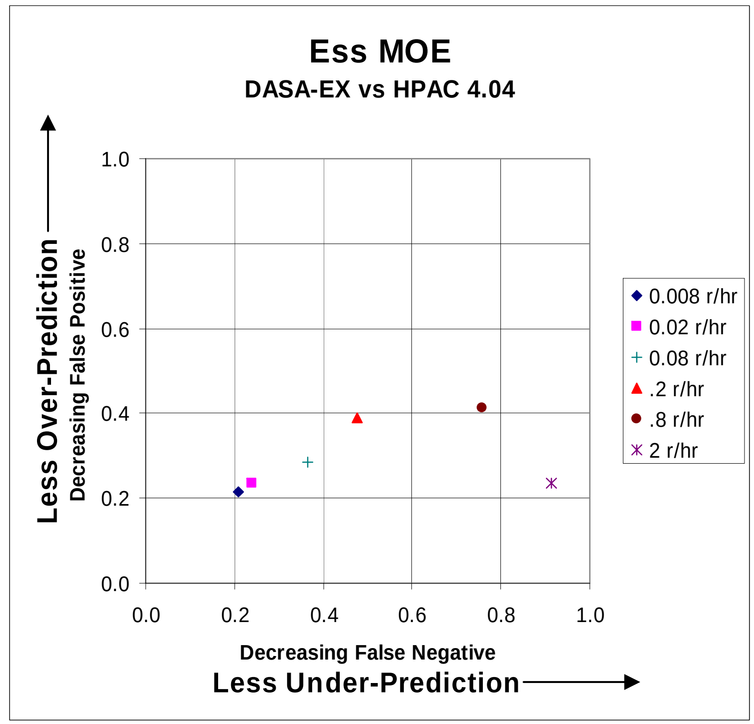


Figure 15. MOE - Ess, DASA-EX vs. HPAC 4.04

FM - Ess

The non-linear FM for comparing the DASA-EX dose-rate contour plots to those of HPAC 4.03 is 0.29. The value for the comparison between DASA-EX and HPAC 4.04 is 0.57. The fact that both of the HPAC plots and the DASA-EX plots diverge at the lower dose-rates means the FM is somewhat improved because of the similarities shared at the higher dose rates.

Dose-Rate Contour Area - Ess

The dose-rate contour areal comparison is summarized in Table 7. The data agree with the visual comparison previously discussed. HPAC 4.03 predicts larger dose-rate contour areas than DASA-EX at all dose rates. HPAC 4.04 predicts larger dose-rate contour areas than DASA-EX with the exception of the 0.8 r/hr, 0.02 r/hr and 0.008 r/hr dose rates.

Grounded UTRDR - Ess

The Grounded UTRDR is summarized in Table 7 in $\left[\frac{R-km^2}{hr-kT}\right]$. HPAC 4.03 and HPAC 4.04 predict more grounded activity than DASA-EX.

Table 7. Ess - Contour Area and Grounded UTRDR

Ess			
	Contour Area (sq miles)		
Dose Rate	DASA-EX	HPAC 4.03	HPAC 4.04
2	22.2	58.4	76.5
0.8	52.9	58.2	48.7
0.2	276.5	346.5	303.2
0.08	382.8	606.6	485.3
0.02	1548.7	1794.7	1341.5
0.008	1557.6	2038.5	1335.5
	Grounded UTRDR		
	DASA-EX	HPAC 4.03	HPAC 4.04
	559.4	862.9	851.7

Operation TEAPOT Zucchini

The Zucchini test shot took place May 15, 1955 at 1200 Greenwich Mean Time (GMT) or Zulu (Z). It was a tower burst, detonated 500 feet above the ground, yielding 28 kilotons. The off-site fallout pattern at Figure 16 was drawn from ground survey readings taken by the off-site Radiological Safety organization on detonation day (D-Day). Off-site refers to the area exceeding 4000 yards from ground zero [DASA-EX, 1979:240]. The dose-rates were extrapolated to H+1 hour using the $t^{-1.2}$ decay approximation. The dose-rate contours were plotted on a grid with units of 20 statute miles, oriented to the North. The dose rate contour values in this plot are shown in the legend next to Figure 17 which is a gray scale version of Figure 16.

As with the previous tests, the original chart from DASA-EX was imported into Canvas where it was electronically traced to produce a gray-scale image. This image is shown compared to the HPAC 4.03 and 4.04 output of the same test. Again, the available winds data from Jodoin and AFCCC were input into HPAC 4.03 and 4.04 yielding the dose-rate contour plots at Figure 18 and Figure 19.

Visual Comparison - Zucchini

A visual comparison of Figure 17, Figure 18 and Figure 19 indicates the HPAC plots are initially oriented in an easterly direction before swinging to the south east after approximately 80 miles and then returning to the east after an additional 80 miles. However, the DASA-EX plot is initially oriented to the southeast before making a hard swing to the northeast after approximately 60 miles. The magnitudes of the HPAC plots are much greater than the DASA-EX plot, although the HPAC 4.04 plot is approximately one third thinner than the HPAC 4.03 plot. The difference between the HPAC plots and the DASA-EX plot appears to be attributable to the weather files used by HPAC. Additionally, the DASA-EX plot has a unique indentation on its northwestern edge, approximately 130 miles from ground zero. It also has at least two pronounced scallops in its southeastern side starting approximately 100 miles from ground zero. These features are readily apparent in the HPAC plots and could be due to terrain features not adequately modeled in either version of HPAC or limitations in the sampling techniques at the time of the test.

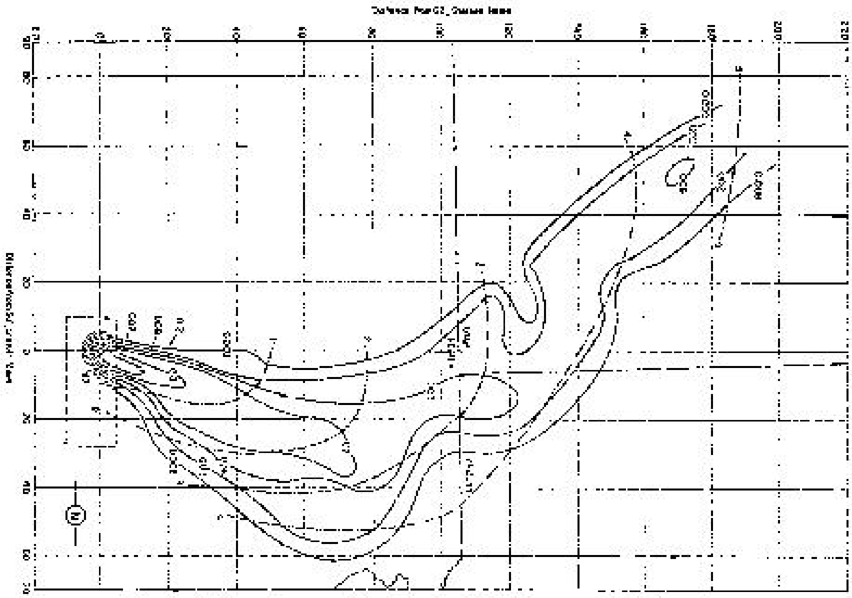


Figure 16. Operation TEAPOT, Zucchini [DASA-EX, 1979:240]

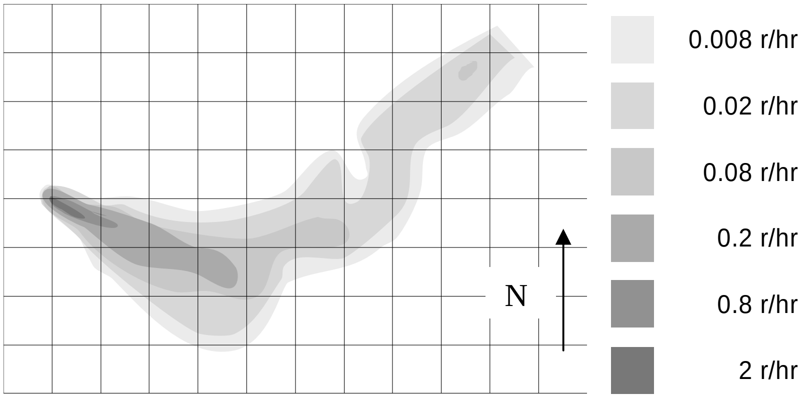


Figure 17. Zucchini, DASA-EX

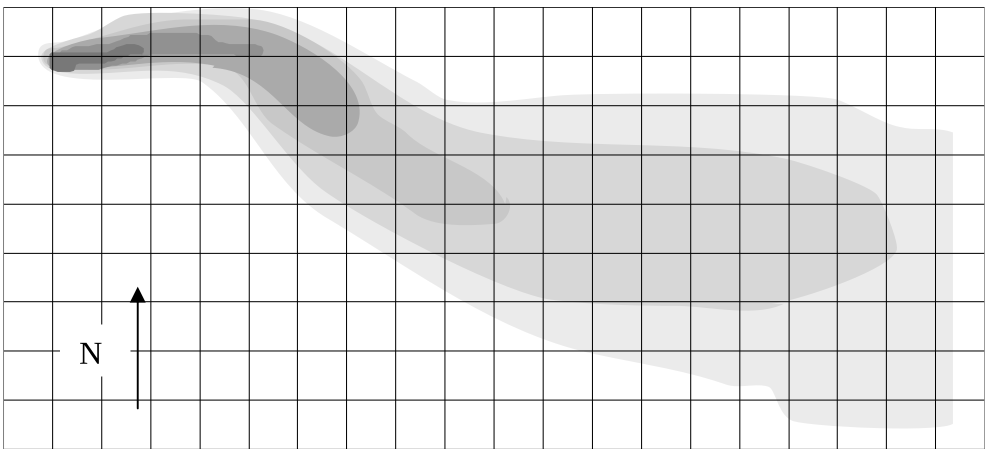


Figure 18. Zucchini, HPAC 4.03

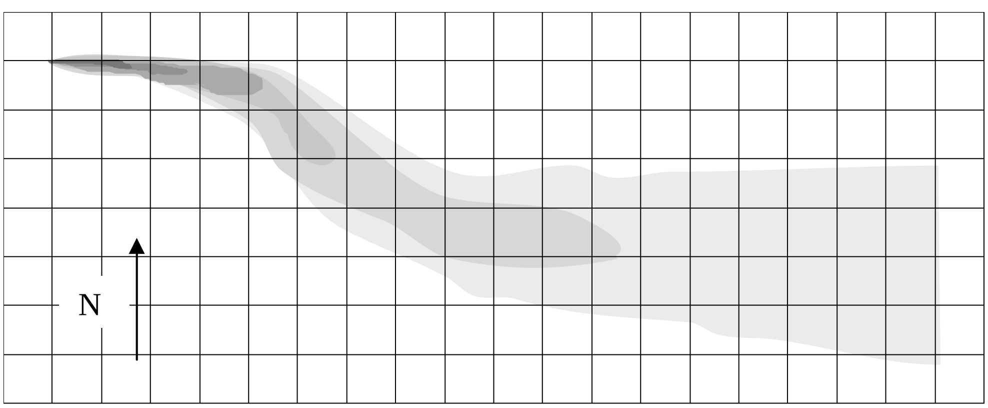


Figure 19. Zucchini, HPAC 4.04

= 400 square miles

MOE - Zucchini

Like the previous tests, a comparison of DASA-EX dose-rate contour plots to HPAC 4.03 dose-rate contour plots was performed for each individual dose-rate level. The comparison was also conducted for DASA-EX versus HPAC 4.04 dose-rate contour plots at each individual level.

MOE DASA-EX versus HPAC 4.03 - Zucchini[6]

In all dose-rate levels except the 2 r/hr, HPAC 4.03 grossly under predicted compared to the DASA-EX data. This appears to be directly attributable to the dramatic changes in the contour plots directions typically caused by poor, or incomplete, weather data. HPAC 4.03 produces dramatically larger plots than DASA-EX; however, they are oriented in completely different directions. At the 2 r/hr dose rate, there is enough overlap between the two plots to produce a MOE (0.68, 0.12). The value of the X-coordinate shows HPAC did not under predict as badly as the remainder of the dose rates. The MOEs for the lower dose rates are shown in Table 8. Figure 20 shows this information in graphical form.

[6] The 0.008 r/hr and 0.02 r/hr dose rate contours are truncated in the DASA-EX plot and the 0.008 r/hr dose rate contour is truncated in the HPAC 4.03 plot. Therefore, the MOE calculations for those dose rates are not represented as entirely complete.

MOE DASA-EX versus HPAC 4.04 - Zucchini[7]

Just like the HPAC 4.03 plots, in all dose-rate levels, HPAC 4.04 grossly under predicted compared to the DASA-EX data. This appears to be directly attributable to the dramatic changes in the contour plots directions typically caused by poor, or incomplete, weather data. HPAC 4.04 produces dramatically larger plots than DASA-EX; however, they are oriented in completely different directions. The MOEs for all dose rates are shown in Table 9. Figure 21 shows this information in graphical form.

[7] The 0.008 r/hr and 0.02 r/hr dose rate contours are truncated in the DASA-EX plot and the 0.008 r/hr dose rate contour is truncated in the HPAC 4.04 plot. Therefore, the MOE calculations for those dose rates are not represented as entirely complete.

Table 8. MOE Values - Zucchini, DASA-EX vs. HPAC 4.03

Zucchini		
X	Y	Dose-Rate
0.68	0.12	2
0.48	0.08	0.8
0.11	0.05	0.2
0.23	0.11	0.08
0.26	0.09	0.02
0.35	0.09	0.008

Table 9. MOE Values - Zucchini, DASA-EX vs. HPAC 4.04

Zucchini		
X	Y	Dose-Rate
0.10	0.07	2
0.10	0.08	0.8
0.04	0.08	0.2
0.07	0.15	0.08
0.16	0.20	0.02
0.22	0.10	0.008

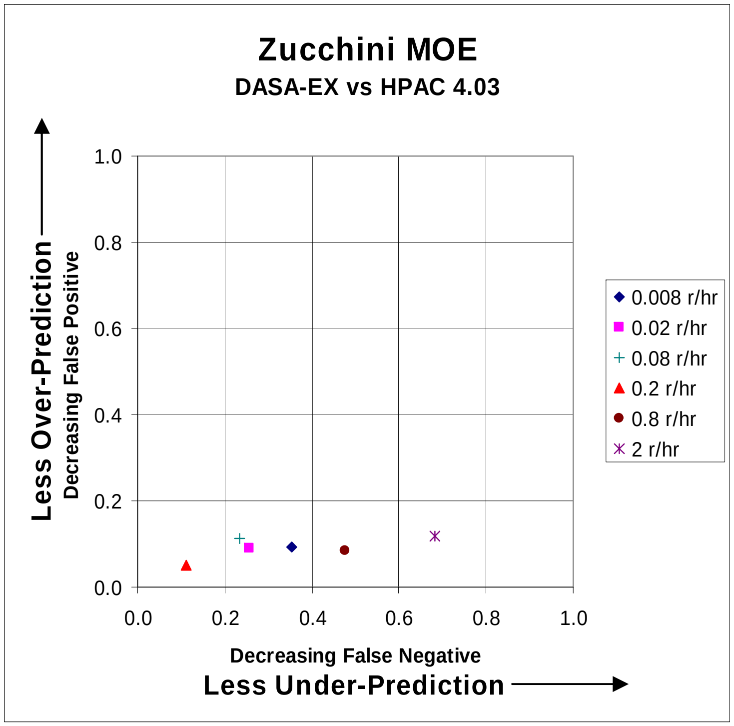


Figure 20. MOE - Zucchini, DASA-EX vs. HPAC 4.03

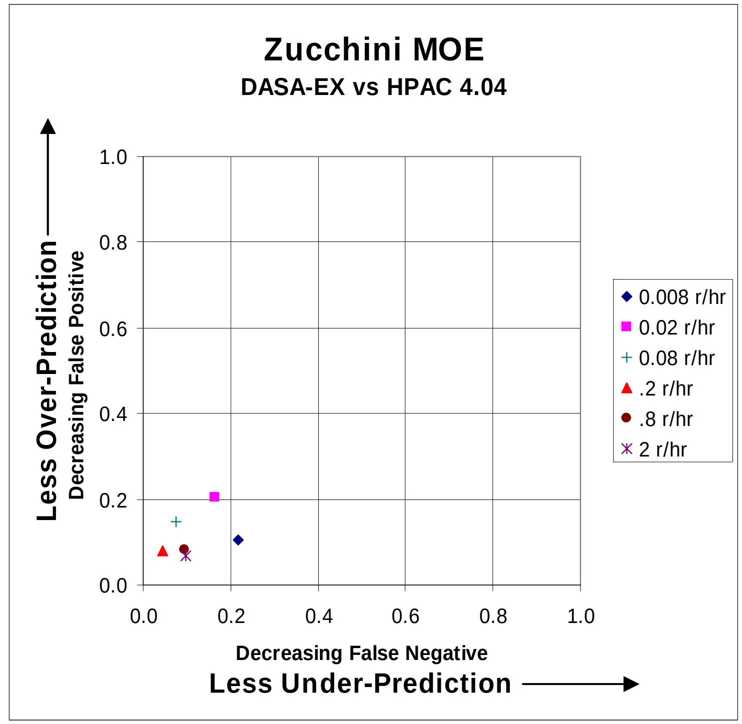


Figure 21. MOE - Zucchini, DASA-EX vs. HPAC 4.04

FM - Zucchini

The non-linear FM for comparing the DASA-EX dose-rate contour plots to those of HPAC 4.03 is 0.05. The value for the comparison between DASA-EX and HPAC 4.04 is 0.02. The fact that both of the HPAC plots and the DASA-EX plots diverge at all of the dose-rates means the FM indicates a nearly complete mismatch.

Dose-Rate Contour Area - Zucchini

The dose-rate contour areal comparison is summarized in Table 10. The data agree with the visual comparison previously discussed. HPAC 4.03 predicts larger dose-rate contour areas at all dose rates.

Grounded UTRDR - Zucchini

The Grounded UTRDR is summarized in Table 10 in $\left[\frac{R-km^2}{hr-kT}\right]$. HPAC 4.03 predicts more grounded activity than DASA-EX or HPAC 4.04.

Table 10. Zucchini - Contour Area and Grounded UTRDR

Zucchini			
	Contour Area (sq miles)		
Dose Rate	DASA-EX	HPAC 4.03	HPAC 4.04
2	38.3	203.3	58.0
0.8	88.5	493.7	66.2
0.2	925.5	1572.7	469.2
0.08	1284.0	2483.9	559.6
0.02	3667.7	12022.9	3627.1
0.008	2342.5	14416.9	12535.8
	Grounded UTRDR		
	DASA-EX	HPAC 4.03	HPAC 4.04
	48.8	154.5	44.4

Operation PLUMBOB Priscilla

The Priscilla test shot took place June 24, 1957 at 1330 Greenwich Mean Time (GMT) or Zulu (Z). It was a balloon burst, detonated 700 feet above the ground, yielding 37 kilotons. The off-site fallout pattern at Figure 22 was drawn from ground and aerial survey readings. Off-site refers to the area exceeding 4000 yards from ground zero [DASA-EX, 1979:274]. The dose-rates were extrapolated to H+1 hour using the $t^{-1.2}$ decay approximation. The dose-rate contours were plotted on a grid with units of 20 statute miles, oriented to the North. The dose rate contour values in this plot are shown in the legend below Figure 23 which is a gray scale version of Figure 22.

As before, the original chart from DASA-EX was imported into Canvas where it was electronically traced to produce a gray-scale image. This image is shown compared to the HPAC 4.03 and 4.04 output of the same test. The available winds data from Jodoin and AFCCC were input into HPAC 4.03 and 4.04 yielding the dose-rate contour plots at Figure 24 and Figure 25.

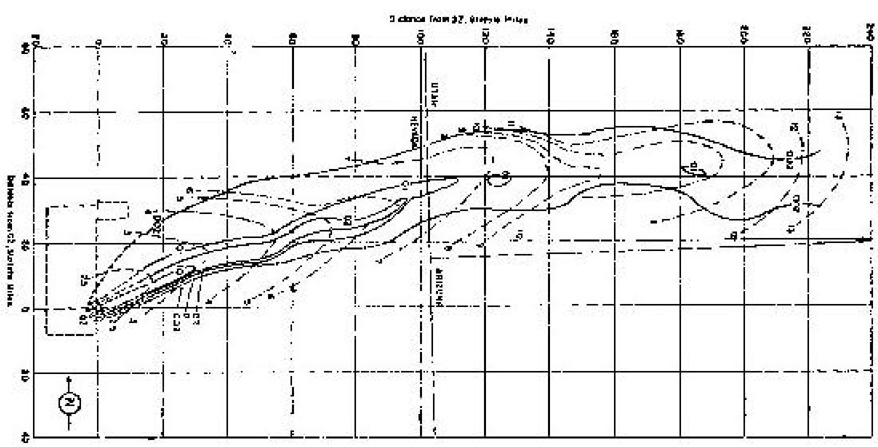


Figure 22. Operation PLUMBOB, Priscilla [DASA-EX, 1979:276]

Visual Comparison - Priscilla

A visual comparison of Figure 23, Figure 24 and Figure 25 indicates the HPAC plots are oriented in a northeasterly direction. However, the DASA-EX plot swings to the east after approximately 100 miles. The magnitudes of all three of the plots are different. The DASA-EX plot is nearly three times longer than the HPAC 4.03 plot and four times longer than the HPAC 4.04 plot. The HPAC 4.04 plot is half as wide as both the DASA-EX plot and the HPAC 4.03 plot. The DASA-EX dose-rate contour plot for 0.2 r/hr is significantly thinner than the corresponding dose rate in the HPAC 4.03 plot. One difference between the HPAC plots and the DASA-EX plot appears to be attributable to the weather files used by HPAC. However, that does not seem to account for the significantly smaller size of the HPAC 4.04 plot. It appears to generate and distribute much less activity than either of the other plots. The increased activity depicted in the DASA-EX plot could be attributed to the mass of the cab holding the suspended nuclear device. As previously mentioned, this test took place at 700 feet and the device was suspended from a balloon. The materials holding the nuclear device would then contribute to the particles in the fallout pattern. Additionally, because this test took place at 700 feet, the fireball barely touched the ground. This is reflected in the fact that both versions of HPAC show much less activity deposited ion the ground than the DASA-EX plot.

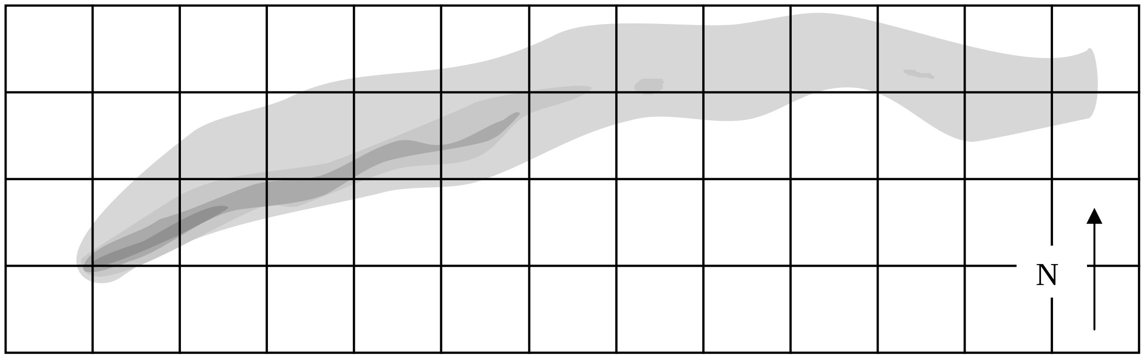


Figure 23. Priscilla, DASA-EX

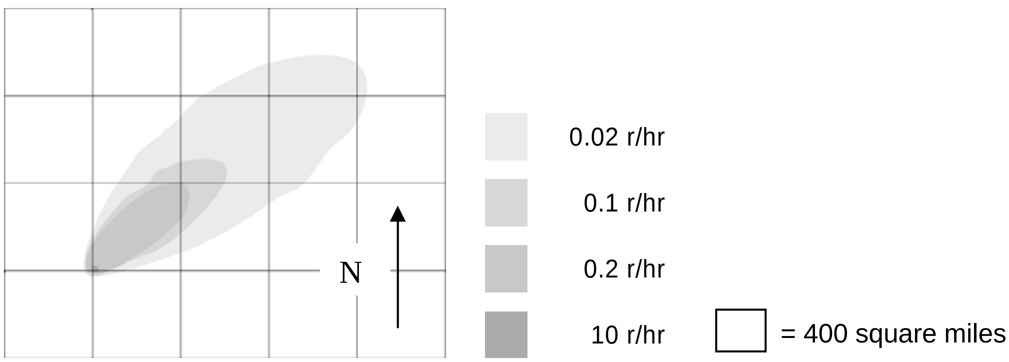


Figure 24. Priscilla, HPAC 4.03

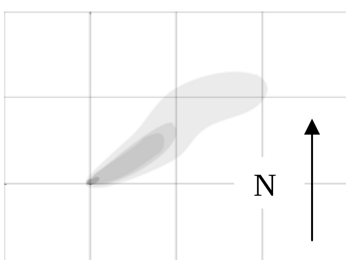


Figure 25. Priscilla, HPAC 4.04

MOE - Priscilla

Again, a comparison of DASA-EX dose-rate contour plots to HPAC 4.03 dose-rate contour plots was performed for each individual dose-rate level. The comparison was also conducted for DASA-EX versus HPAC 4.04 dose-rate contour plots at each individual level.

MOE DASA-EX versus HPAC 4.03 - Priscilla[8]

In all dose-rate levels, HPAC 4.03 significantly under predicted compared to the DASA-EX data. The elongated, curving plots from DASA-EX give the appearance that weather data could be one of the reasons HPAC under predicted. HPAC 4.03 produced dramatically smaller plots than DASA-EX; however, they are oriented in the same direction. The 0.1 r/hr and 10 r/hr dose rate contours produced MOEs of (0.09, 1.00) and (0.00, 1.00) respectively. The Y-coordinate for both of these initially looks like a good number. However, when visually comparing the plots, it becomes apparent that the number shows a perfect match because HPAC 4.03 produced such a small amount of activity at both of these levels that there was no chance of having a false positive, or over prediction. The MOEs for these dose rates are shown in Table 11. Figure 26 shows this information in graphical form.

MOE DASA-EX versus HPAC 4.04 - Priscilla[9]

As with HPAC 4.03, HPAC 4.04 significantly under predicted in all dose-rate levels when compared to the DASA-EX data. Again, weather data could be one of the reasons HPAC under predicted. HPAC 4.04 produced dramatically smaller plots than DASA-EX; however, they are oriented in the same direction. Each of the dose-rate MOEs has a Y-coordinate equal to 1.00. Again, just like HPAC 4.03, when visually comparing the plots, it becomes apparent that the number shows a perfect match because

[8] The 0.02 r/hr dose rate contour is truncated in the DASA-EX plot. Therefore, the MOE calculation for that dose rate is not represented as entirely complete.

[9] The 0.02 r/hr dose rate contour is truncated in the DASA-EX plot. Therefore, the MOE calculation for that dose rate is not represented as entirely complete.

HPAC 4.04 produced such a small amount of activity at each of these levels that there was no chance of having a false positive, or over prediction. The MOEs for these dose rates are shown in Table 12. Figure 27 shows this information in graphical form.

Table 11. MOE Values - Priscilla, DASA-EX vs. HPAC 4.03

Priscilla		
X	Y	Dose-Rate
0.00	1.00	10
0.13	0.48	0.2
0.09	1.00	0.1
0.24	0.70	0.02

Table 12. MOE Values - Priscilla, DASA-EX vs. HPAC 4.04

Priscilla		
X	Y	Dose-Rate
0.01	1.00	10
0.08	1.00	0.2
0.02	1.00	0.1
0.09	1.00	0.02

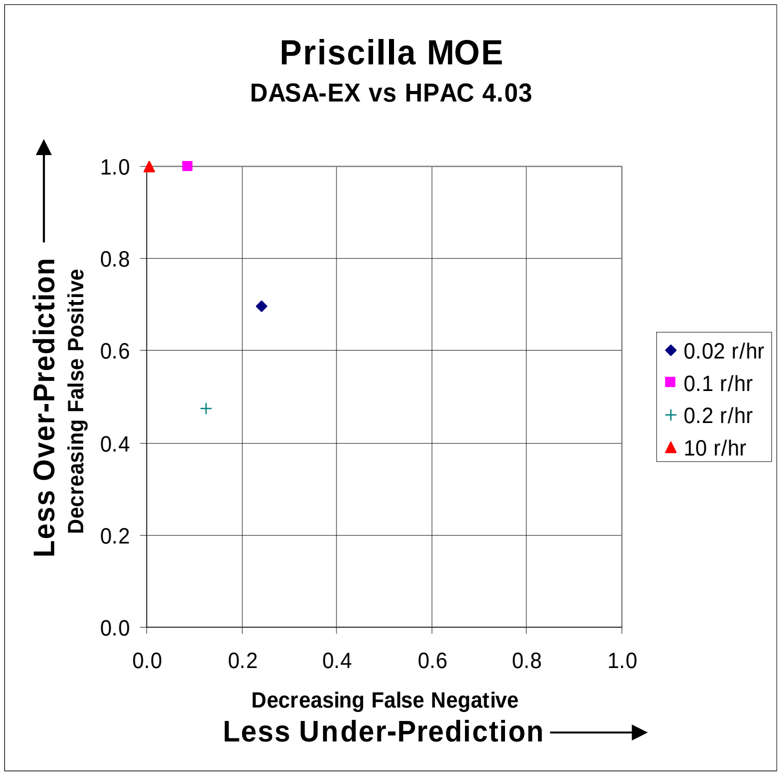


Figure 26. MOE - Priscilla, DASA-EX vs. HPAC 4.03

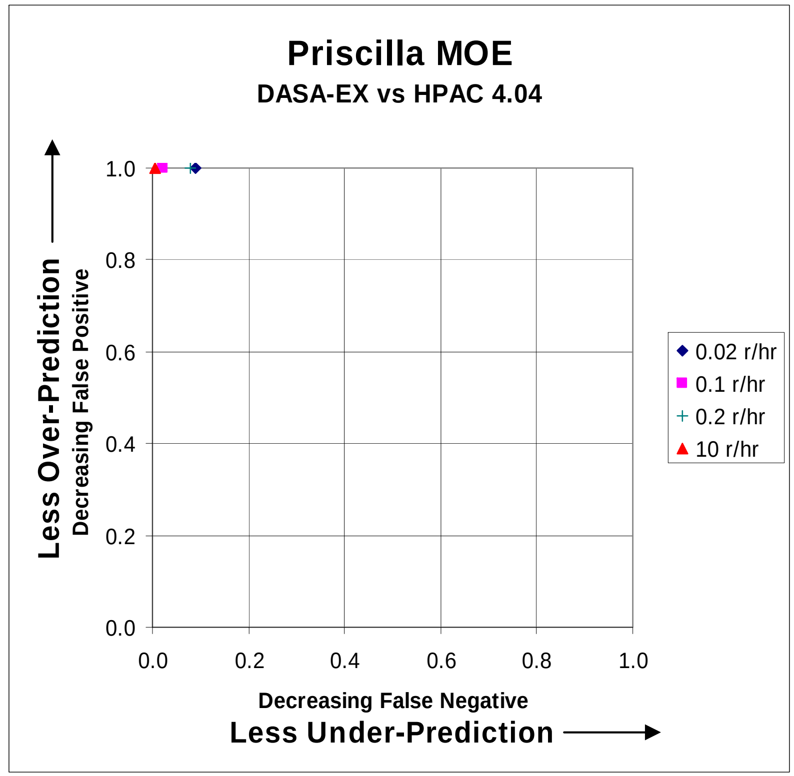


Figure 27. MOE - Priscilla, DASA-EX vs. HPAC 4.04

FM - Priscilla

The non-linear FM for comparing the DASA-EX dose-rate contour plots to those of HPAC 4.03 is 0.02. The value for the comparison between DASA-EX and HPAC 4.04 is 0.02. The fact that both of the HPAC plots are so much smaller than the DASA-EX plots at all of the dose-rates means the FM indicates a nearly complete mismatch.

Dose-Rate Contour Area - Priscilla

The dose-rate contour areal comparison is summarized in Table 13. The data agree with the visual comparison previously discussed. HPAC 4.03 predicts larger dose-rate contour areas than HAPC 4.04 at all dose rates. However both versions of HPAC under predict DASA-EX at all dose rates.

Grounded UTRDR - Priscilla

The Grounded UTRDR is summarized in Table 13 in $\left[\frac{R-km^2}{hr-kT}\right]$. DASA-EX depicts more grounded activity than both versions of HPAC.

Table 13. Priscilla - Contour Area and Grounded UTRDR

Priscilla			
	Contour Area (sq miles)		
Dose Rate	DASA-EX	HPAC 4.03	HPAC 4.04
10	76.1	2.2	3.6
0.2	346.8	243.1	74.0
0.1	587.0	178.9	35.1
0.02	4210.4	1261.4	331.9
	Grounded UTRDR		
	DASA-EX	HPAC 4.03	HPAC 4.04
	168.1	19.6	10.5

Operation PLUMBOB Smoky

The Smoky test shot took place August 31, 1957 at 1230 Greenwich Mean Time (GMT) or Zulu (Z). It was a tower burst, detonated 700 feet above the ground, yielding 44 kilotons. The off-site fallout pattern at Figure 28 was drawn from ground and aerial survey readings. Off-site refers to the area exceeding 8000 yards from ground zero [DASA-EX, 1979:326]. The dose-rates were extrapolated to H+1 hour using the $t^{-1.2}$ decay approximation. The dose-rate contours were plotted on a grid with units of 20 statute miles, oriented to the North. The dose rate contour values in this plot are shown in the legend below Figure 29 which is a gray scale version of Figure 28.

As with all other tests in this document, the original chart from DASA-EX was imported into Canvas where it was electronically traced to produce a gray-scale image. This image is shown compared to the HPAC 4.03 and 4.04 output of the same test. The available winds data from Jodoin and AFCCC were input into HPAC 4.03 and 4.04 yielding the dose-rate contour plots at Figure 30 and Figure 31.

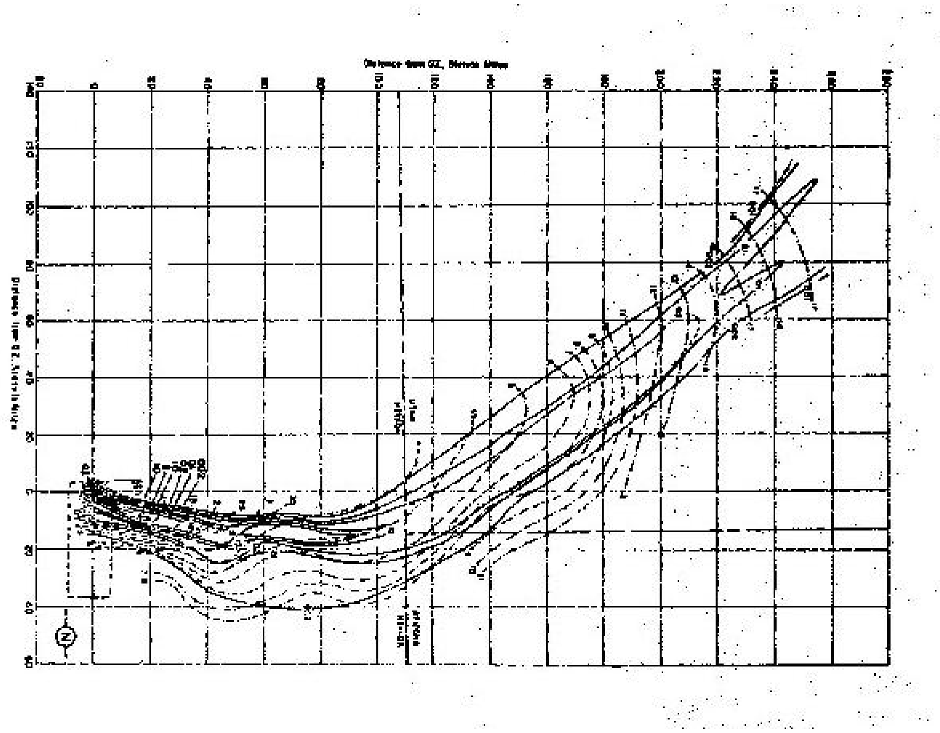


Figure 28. Operation PLUMBOB, Smoky [DASA-EX, 1979:328]

Visual Comparison - Smoky

A visual comparison of Figure 29, Figure 30 and Figure 31 indicates the three plots are initially oriented in the east-southeast direction. However, the DASA-EX plot swings to the northeast after approximately 100 miles. The magnitudes of all three of the plots are different. The DASA-EX plot is nearly two times longer than the HPAC 4.03 plot and three times longer than the HPAC 4.04 plot. The HPAC 4.03 plot is nearly twice as wide as both the DASA-EX plot and the HPAC 4.04 plot. As with previous tests, one difference between the HPAC plots and the DASA-EX plot appears to be attributable to the weather files used by HPAC. The long, dramatically curving shape of the DASA-EX plot seems to indicate the weather file used by both versions of HPAC could benefit from additional fidelity. However, that does not seem to completely account for the significantly smaller size of both of the HPAC plots. The HPAC 4.04 plot appears to generate and distribute much less activity than the HPAC 4.03 plot. The increased activity depicted in the DASA-EX plot could be attributed to the mass of the cab holding the suspended nuclear device. As previously mentioned, this test took place at 700 feet and the device was suspended from a balloon. The materials holding the nuclear device would then contribute to the particles in the fallout pattern. Additionally, because this test took place at 700 feet, the fireball barely touched the ground. This is reflected in the fact that both versions of HPAC show much less activity deposited ion the ground than the DASA-EX plot.

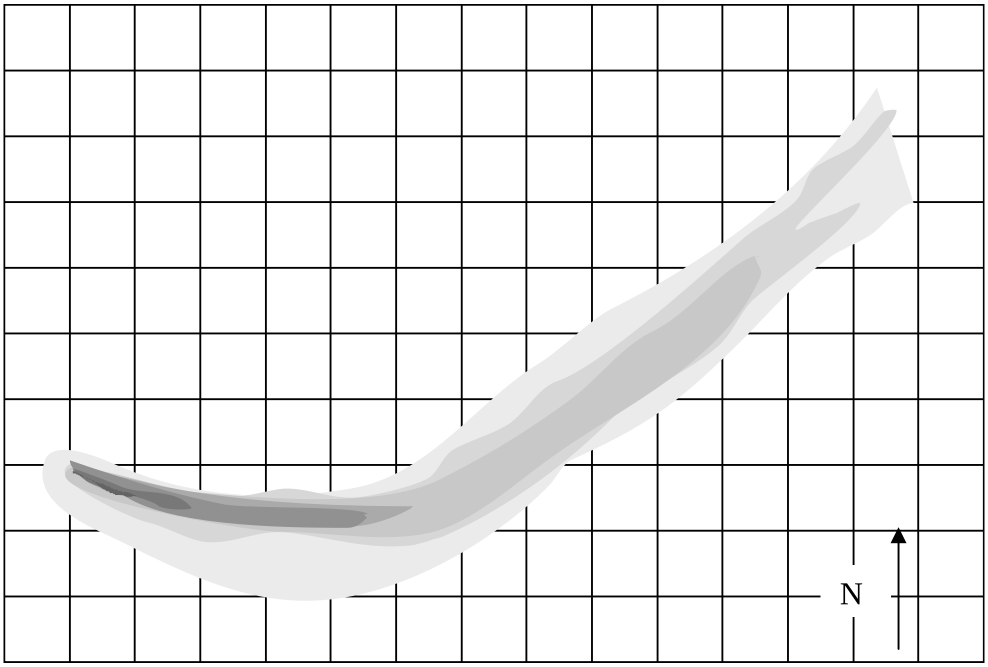


Figure 29. Smoky, DASA-EX

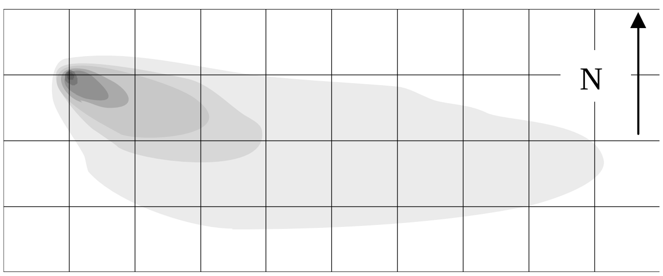


Figure 30. Smoky, HPAC 4.03

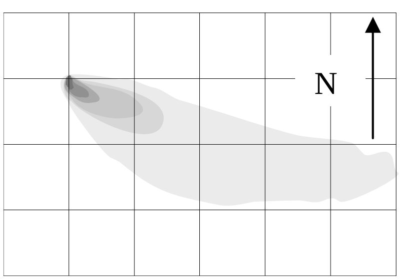
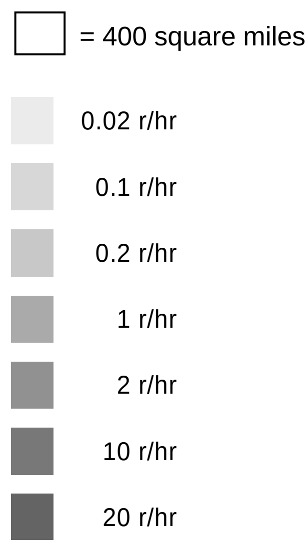


Figure 31. Smoky, HPAC 4.04



MOE - Smoky

Again, a comparison of DASA-EX dose-rate contour plots to HPAC 4.03 dose-rate contour plots was performed for each individual dose-rate level. The comparison was also conducted for DASA-EX versus HPAC 4.04 dose-rate contour plots at each individual level.

MOE DASA-EX versus HPAC 4.03 - Smoky[10]

Similar to the Priscilla test, HPAC 4.03 significantly under predicted compared to the DASA-EX data in all dose-rate levels. While the HPAC 4.03 plot is twice as wide as the DASA-EX plot, it is only half as long. The 0.02 r/hr dose rate is the only contour plot to generate a reasonable MOE (0.41, 0.57) in both the X and Y directions. This is due to the sheer size of that dose-rate contour plot. It still is a significant under prediction compared to the DASA-EX plot. The MOEs for all of the dose rates are shown in Table 14. Figure 32 shows this information in graphical form.

MOE DASA-EX versus HPAC 4.04 - Smoky[11]

HPAC 4.04 significantly under predicted compared to the DASA-EX data in all dose-rate levels. The dose-rate contour plot for 20 r/hr was so insignificant it produced a MOE 0f (0.00, 0.00). The MOEs for all of the dose rates are shown in Table 15. Figure 33 shows this information in graphical form.

[10] The 0.02 r/hr dose rate contour is truncated in the DASA-EX plot. Therefore, the MOE calculation for that dose rate is not represented as entirely complete.

[11] The 0.02 r/hr dose rate contour is truncated in the DASA-EX plot. Therefore, the MOE calculation for that dose rate is not represented as entirely complete.

Table 14. MOE Values - Smoky, DASA-EX vs. HPAC 4.03

Smoky		
X	Y	Dose-Rate
0.00	0.00	20
0.01	0.05	10
0.07	0.47	2
0.12	0.51	1
0.13	0.51	0.2
0.15	0.54	0.1
0.41	0.57	0.02

Table 15. MOE Values - Smoky, DASA-EX vs. HPAC 4.04

Smoky		
X	Y	Dose-Rate
0.00	0.00	20
0.00	0.00	10
0.00	0.10	2
0.02	0.29	1
0.05	0.77	0.2
0.06	0.85	0.1
0.24	0.92	0.02

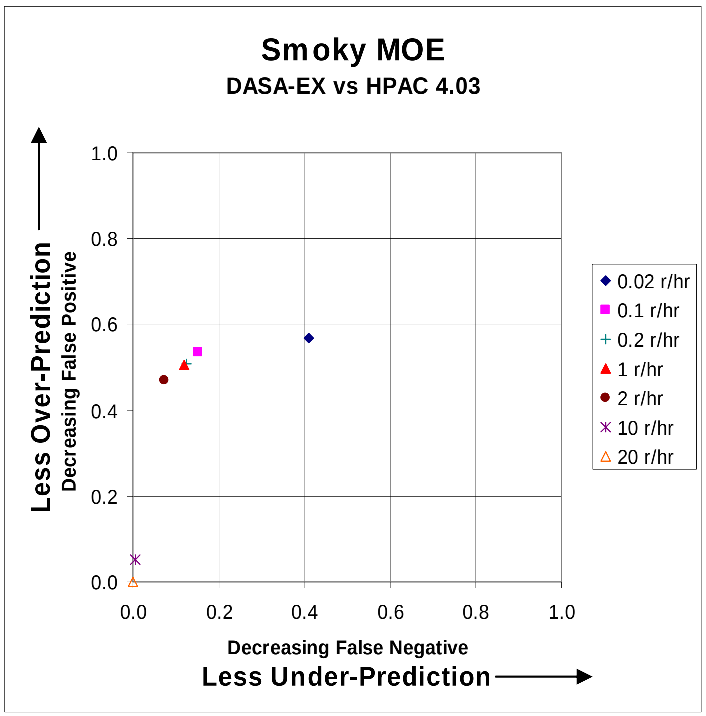


Figure 32. MOE - Smoky, DASA-EX vs. HPAC 4.03

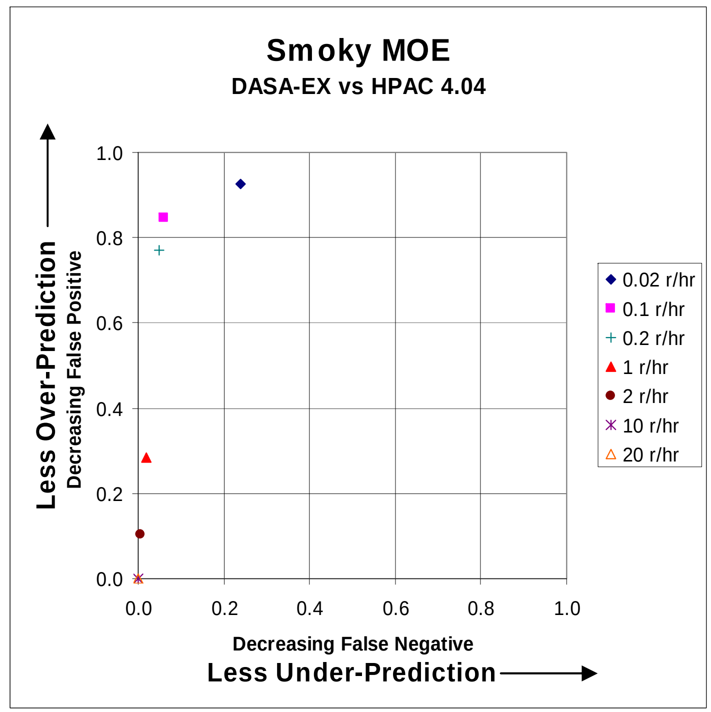


Figure 33. MOE - Smoky, DASA-EX vs. HPAC 4.04

FM - Smoky

The non-linear FM for comparing the DASA-EX dose-rate contour plots to those of HPAC 4.03 is 0.09. The value for the comparison between DASA-EX and HPAC 4.04 is 0.03. Again, the fact that both of the HPAC plots are so much smaller than the DASA-EX plots at all of the dose-rates means the FM indicates a nearly complete mismatch.

Dose-Rate Contour Area - Smoky

The dose-rate contour areal comparison is summarized in Table 13. The data agree with the visual comparison previously discussed. HPAC 4.03 predicts larger dose-rate contour areas than HAPC 4.04 at all dose rates except the 20 r/hr. However both versions of HPAC under predict DASA-EX at all dose rates except 2 r/hr and 0.02 r/hr.

Grounded UTRDR - Smoky

The Grounded UTRDR is summarized in Table 16 in $\left[\frac{R-km^2}{hr-kT}\right]$. DASA-EX depicts more grounded activity than both versions of HPAC.

Table 16. Smoky - Contour Area and Grounded UTRDR

Smoky			
	Contour Area (sq miles)		
Dose Rate	DASA-EX	HPAC 4.03	HPAC 4.04
20	18.5	4.3	4.8
10	77.0	8.8	2.2
2	419.9	65.2	15.7
1	79.9	85.3	25.9
0.2	2199.5	504.0	127.4
0.1	1831.2	592.3	137.6
0.02	4383.4	4966.6	1905.3
	Grounded UTRDR		
	DASA-EX	HPAC 4.03	HPAC 4.04
	163.1	38.2	14.8

Operation SUNBEAM Johnie Boy

The Johnie Boy test shot took place July 11, 1962 at 1645 Greenwich Mean Time (GMT) or Zulu (Z). It was a shallow underground burst, detonated 23 inches below the ground, yielding 0.5 kilotons. The off-site fallout pattern at Figure 34 was drawn from readings taken by the REECO Radiation Safety Group and the Public Health Service. Off-site refers to the area exceeding 5333 yards from ground zero [DASA-EX, 1979:563]. The dose-rates were extrapolated to H+1 hour using the $t^{-1.2}$ decay approximation. The dose-rate contours were plotted on a grid with units of 20 statute miles, oriented to the North. The dose rate contour values in this plot are shown in the legend next to Figure 35 which is a gray scale version of Figure 34.

As with all other tests in this document, the original chart from DASA-EX was imported into Canvas where it was electronically traced to produce a gray-scale image.

This image is shown compared to the HPAC 4.03 and 4.04 output of the same test. The available winds data from Jodoin and AFCCC were input into HPAC 4.03 and 4.04 yielding the dose-rate contour plots at Figure 36 and Figure 37.

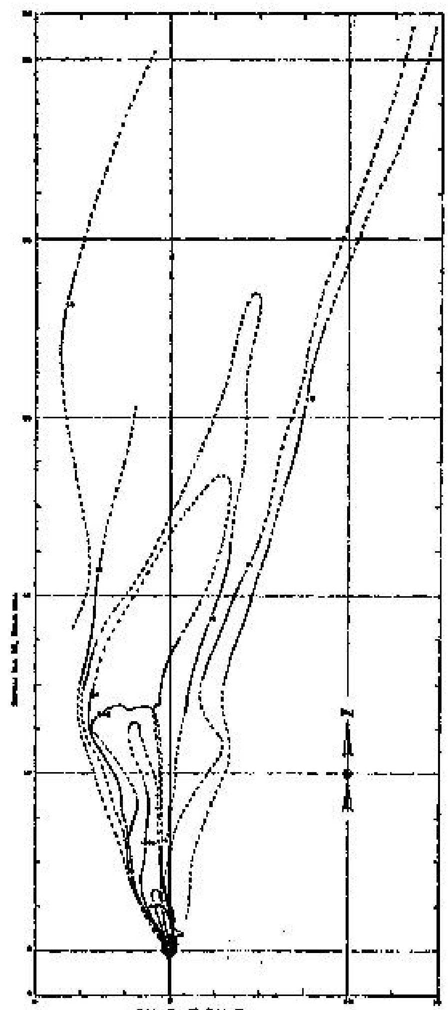
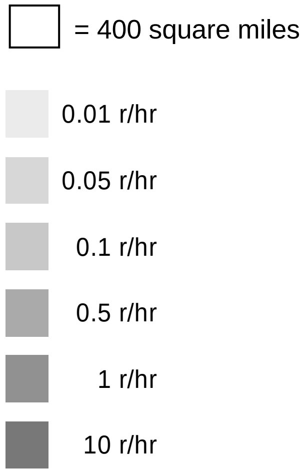


Figure 34. Operation SUNBEAM, Johnie Boy [DASA-EX, 1979:565]

Visual Comparison - Johnie Boy

A visual comparison of Figure 35, Figure 36 and Figure 37 indicates the three plots are oriented in a northeastern direction. The DASA-EX plot is half the size of both of the HPAC plots. One reason for this is the level of uncertainty in producing the plot at the time right after the test [DASA-EX, 1979:563] which limited the ability to plot the dose-rate contours any further distance from ground zero.



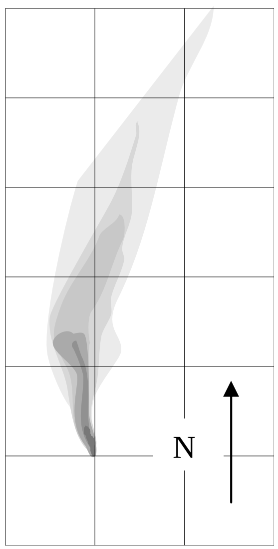


Figure 35. Johnie Boy, DASA-EX

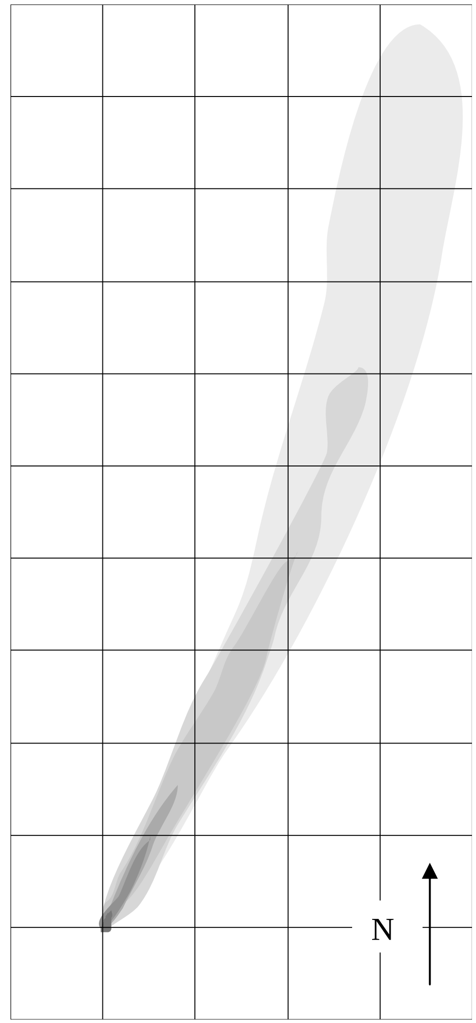


Figure 36. Johnie Boy, HPAC 4.03

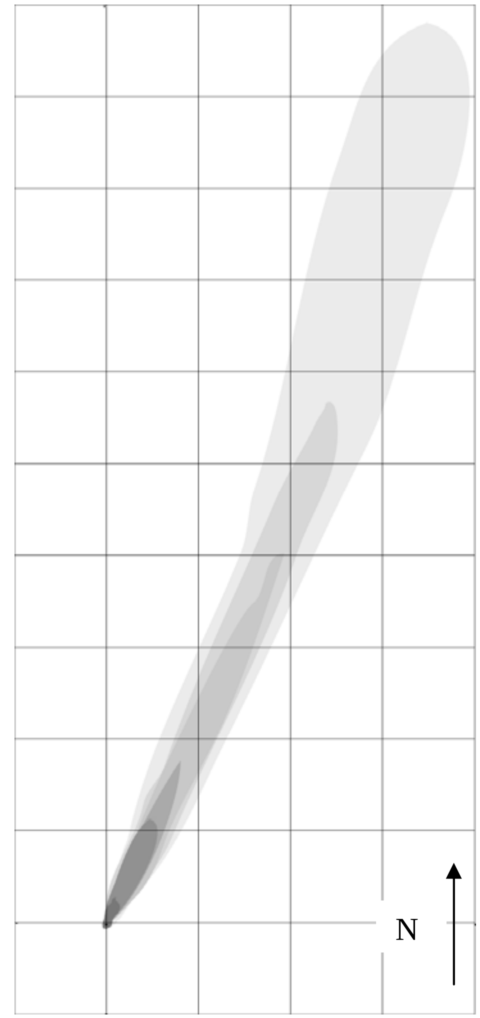


Figure 37. Johnie Boy, HPAC 4.04

MOE - Johnie Boy

Again, a comparison of DASA-EX dose-rate contour plots to HPAC 4.03 dose-rate contour plots was performed for each individual dose-rate level. The comparison was also conducted for DASA-EX versus HPAC 4.04 dose-rate contour plots at each individual level.

MOE DASA-EX versus HPAC 4.03 - Johnie Boy[12]

The DASA-EX plot is oriented to the north for approximately 40 miles before shifting slightly to the north-northeast. Both of the HPAC plots are immediately oriented to the northeast. All three of the plots are approximately 20 miles wide. Both of the HPAC plots are very similar in magnitude and direction. Even though the DASA-EX plot and the HPAC 4.03 plot are both oriented in similar directions, the slight difference in initial directions yields MOEs that reflect no agreement, as indicated by Table 17. Both the X and Y coordinates for all of the dose-rate levels are essentially zero. Figure 38 shows this information in graphical form

MOE DASA-EX versus HPAC 4.04 - Johnie Boy[13]

This comparison is essentially the same as the previous case involving HPAC 4.03. Even though the DASA-EX plot and the HPAC 4.04 plot are both oriented in similar directions, the slight difference in initial directions yields MOEs that reflect no

[12] The 0.01 r/hr dose rate contour is truncated in the DASA-EX plot. Therefore, the MOE calculation for that dose rate is not represented as entirely complete.

[13] The 0.01 r/hr dose rate contour is truncated in the DASA-EX plot. Therefore, the MOE calculation for that dose rate is not represented as entirely complete.

agreement, as indicated by Table 18. Both the X and Y coordinates for all of the dose-rate levels are essentially zero. Figure 39 shows this information in graphical form.

Table 17. MOE Values - Johnie Boy, DASA-EX vs. HPAC 4.03

Johnie Boy		
X	Y	Dose-Rate
0.00	0.00	10
0.03	0.02	1
0.02	0.02	0.5
0.01	0.00	0.1
0.01	0.00	0.05
0.00	0.00	0.01

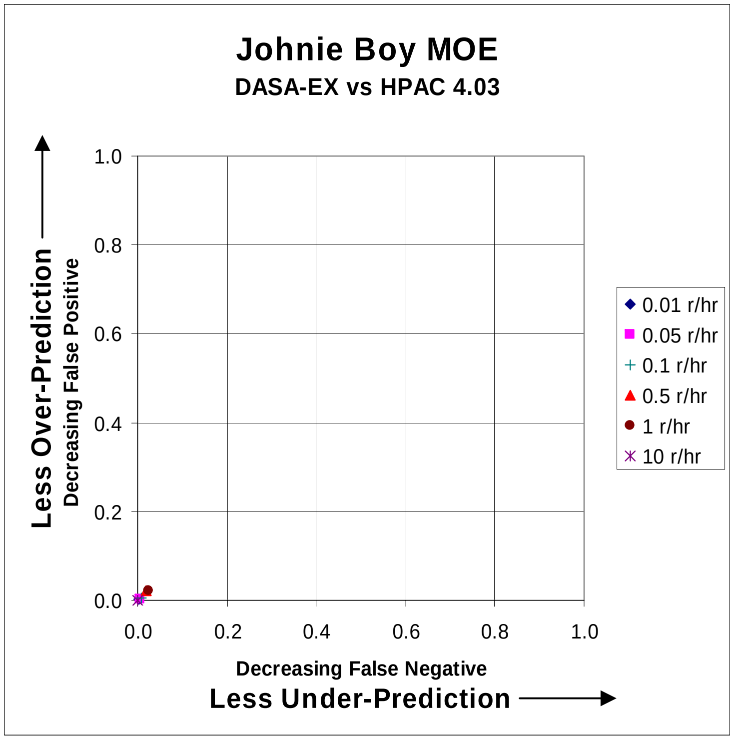


Figure 38. MOE - Johnie Boy, DASA-EX vs. HPAC 4.03

Table 18. MOE Values - Johnie Boy, DASA-EX vs. HPAC 4.04

Johnie Boy		
X	Y	Dose-Rate
0.02	0.01	10
0.05	0.01	1
0.02	0.02	0.5
0.01	0.01	0.1
0.01	0.00	0.05
0.00	0.00	0.01

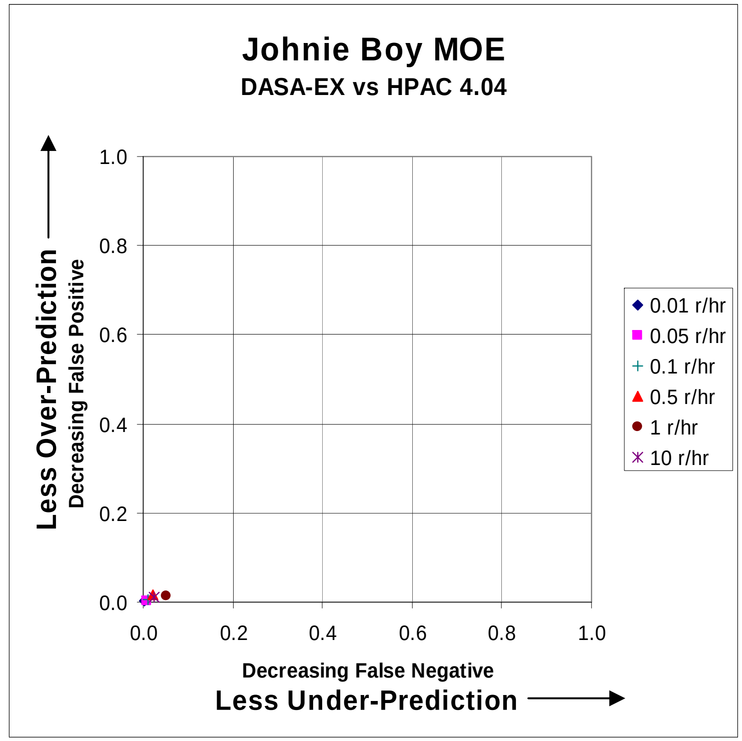


Figure 39. MOE - Johnie Boy, DASA-EX vs. HPAC 4.04

FM - Johnie Boy

The non-linear FM for comparing the DASA-EX dose-rate contour plots to those of HPAC 4.03 is 0.02. The value for the comparison between DASA-EX and HPAC 4.04 is 0.01. Again, the fact that both of the HPAC plots do not overlap the DASA-EX plots at each of the dose-rates means the FM indicates a complete mismatch.

Dose-Rate Contour Area – Johnie Boy

The dose-rate contour areal comparison is summarized in Table 19. The data agree with the visual comparison previously discussed. HPAC 4.04 predicts larger dose-rate contour areas than DASA-EX and HAPC 4.03 at all dose rates except the 0.01 r/hr.

Grounded UTRDR - Johnie Boy

The Grounded UTRDR is summarized in Table 19 in $\left[\frac{R-km^2}{hr-kT}\right]$. Both versions of HPAC predict more grounded activity than DASA-EX.

Table 19. Johnie Boy - Contour Area and Grounded UTRDR

Johnie Boy			
	Contour Area (sq miles)		
Dose Rate	DASA-EX	HPAC 4.03	HPAC 4.04
10	7.4	7.1	13.3
1	25.9	29.8	84.6
0.5	72.7	50.1	47.1
0.1	175.2	432.9	341.9
0.05	208.0	463.4	500.7
0.01	641.6	2482.7	2671.3
	Grounded UTRDR		
	DASA-EX	HPAC 4.03	HPAC 4.04
	884.3	1121.7	1696.2

IV. Summary and Conclusions

Chapter Overview

The purpose of this chapter is to present a summary of the results of the visual and numerical comparisons of the different tests and provide recommendations for future endeavors in this topic of research.

Results

The results of this research effort show definite trends regarding the dose-rate contour plots of HPAC 4.03 and 4.04 when compared to the original data in DASA-EX. Further, the use of visual comparisons and numerical analyses combined into one document provides a capability previously unrealized. Although each of the techniques used is not new, the combination provides future researchers a suite of tools to perform multiple, independent analyses of the same data.

Visual Comparisons

In general, it can be seen that the HPAC 4.03 plots compare more favorably with the DASA-EX plot than do the HPAC 4.04 plots. For the six tests evaluated, both HPAC plots matched the general direction at the outset of each plot; although Ess, Priscilla and Smoky had shifts in the DASA-EX plots that were not matched by HPAC. These shifts appear to be caused by wind direction changes. Increased fidelity in the weather data used by HPAC might alleviate the resulting mismatch farther into the contour plots. DASA-EX showed unique spurs and eddies that were not apparent in either version of HPAC. These could be traced to terrain subtleties not modeled in HPAC. They could also be traced to data gathering techniques post-test.

It is interesting to note that Priscilla and Smoky have very thin, elongated contour plots in DASA-EX while both versions of HPAC produce more rounded contours. The increased activity depicted in both DASA-EX plots could be attributed to the mass of the cab holding the suspended nuclear device. As previously mentioned, both tests took place at 700 feet and the device was suspended from a balloon. The materials holding the nuclear device would then contribute to the particles in the fallout pattern. Additionally, because these tests took place at 700 feet, the fireball barely touched the ground. This is reflected in the fact that both versions of HPAC show much less activity deposited ion the ground than the DASA-EX plots. Another possible explanation is the fidelity of the weather data used by HPAC as well as the way HPAC models transverse wind shear. Finally, the visual comparisons clearly showed that HPAC 4.04 typically deposits less activity than HPAC 4.03. This could be attributable to the use of the Heft distribution in HPAC 4.04. It is possible that this distribution has such a large percentage of fallout mass suspended as very fine particles that they do not deposit within the ranges covered by DASA-EX or HPAC 4.04, if ever. Further information on this can be found with Skaar [Skaar, 2005].

An additional consideration for the differences between the DASA-EX and HPAC plots could be HPAC computed stabilized cloud height compared to those recorded in DASA-EX. However, this was not evaluated in this research effort.

Numerical Comparisons

The numerical comparisons used in this research effort complemented the visual comparisons with few unexpected results. The MOE used for each dose-rate contour comparison between DASA-EX and each version of HPAC numerically reinforced what was seen in the visual comparisons. For example, while HPAC might predict dose-rate contours that appear to be the same magnitude and direction as those in DASA-EX, the fact that the plots were not covering the exact same plot of ground meant they were mismatches. The same held true for the FM method as well. In the case of the MOE method, some dose rates were matched more closely than others; however, this does not appear to be a function of increased modeling accuracy for that dose-rate.

The dose-rate areal comparisons corroborated the visual comparisons. HPAC 4.03 typically predicted larger dose-rate contour areas than HPAC 4.04 in all cases except Johnie Boy.

The Grounded UTRDR comparison revealed that HPAC 4.03 predicts more activity than DASA-EX in four of the cases. The other two favored DASA-EX. HPAC 4.04 predicted greater activity than DASA-EX in two of the cases (Ess and Johnie Boy). It is noted that in all cases the Grounded UTRDR was considerably less than theoretical values of the source normalization constant cited earlier. This is unquestionably due to the step function integration that had to be used.

Recommendations for Future Research

In the future, research in this topic could include weather data with increased fidelity. This would likely require the use of reanalysis data to show improved weather trends over the areas in question. The effort could also benefit from high fidelity terrain models to possibly capture some of the nuances shown in the DASA-EX plots. The Grounded UTRDR could also be dramatically improved by converting the step-wise plots in DASA-EX into continuous curves. Although the curves would not be actual data from DASA-EX, they would allow for a reasoned approach to obtaining a more realistic Grounded UTRDR value for each plot. Both versions of HPAC allow for near-continuous data for the plots produced. The effort would be to perform the metamorphosis of the DASA-EX data. A comparison of stabilized cloud heights between HPAC and DASA-EX could also be performed.

Appendix A: Example of Process

Six tests were selected for this research effort; four were selected based on input from the minutes of the Fallout Working Group and two were randomly selected by this author. Each test was evaluated to ensure it was lower than the fallout free height of burst. Following selection of a particular test, the dose-rate contour plot was extracted from the DASA 1251-EX electronic PDF file and imported into Canvas software. The image was traced over each dose-rate contour line using Canvas software. This was done in successive steps until the entire set of dose-rate contour lines was traced. Each dose-rate contour line was then filled in using successively darker gray-scale colors for each increase in dose rate. A grid was then inserted over the document based on the scale contained in DASA-EX. The scale is 20 miles by 20 miles for each grid square. Dots were then marked on key intersections of the grid to provide data interpretation at later steps. The image was then saved as a gray-scale TIF file on a scale designed to produce three pixels for statute mile within the picture; therefore, each square mile is represented by nine pixels. For example, if the original DASA-EX diagram was 120 miles wide by 240 miles long, the resulting TIF file was saved to a resolution of 361 pixels wide by 721 pixels long. This represents three pixels per linear mile plus one pixel for the edge of the grid.

The TIF file was imported in to MATLAB as a gray-scale image. MATLAB imports this image in a pixel-by-pixel fashion and assigns gray-scale values ranging from 255 (white space) to 0 (black space) to each pixel. The black dots previously inserted were located as zeros within the MATLAB image array. From there the exact pixel representing ground zero was determined and the contour values for the image were then interpreted from there. This yields a gridded image from DASA-EX that can be compared to the HPAC output.

The HPAC output was obtained by entering the details of the test event into each version of HPAC. Dose rate contour plots were obtained by selecting the custom output option and entering dose rates of interest. The dose rates of interest were obtained by observing the HPAC run time for each event and then using the $t^{-1.2}$ decay rate approximation to determine the dose rate at H+1 hour. This method was used because HPAC does not plot H+1 hour dose rates as a function of final dose rate. However, DASA-EX is plotted in H=1 hour dose rates. The custom plot was then saved as a JPEG file and imported into Canvas. From there, the picture was processed like the DASA-EX pictures were processed as mentioned earlier. The document was set to scale using the option available in Canvas and the ruler embedded in the HPAC plot picture. A 20 mile by 20 mile grid was then inserted on top of the picture to facilitate visual comparisons between both versions of HPAC as well as the DASA-EX plots. The image was saved in gray-scale format and imported in to MATLAB. This yields a gridded image that can be compared point to point with the Canvas image using the gray scale values which now represent dose-rates.

Appendix B: Weather Profiles

HPAC uses several types of weather data. They are focused in two main areas: real-time/forecasts and past. Because this research effort involved events that already occurred, the option involving real-time and forecast data are not addressed. For events that have already occurred, HPAC offers the option of using historical data or specific data for specific events. The historical data option makes use of upper air climatology data for two days of each month from 1990. According to the literature, this year was chosen arbitrarily. The two days are the 15th and 16th of each month. HPAC chooses which day to use based on the start date of the particular project [DTRA, 2003:A-2]. In this case, actual data were available; therefore, the historical option was not used.

This research effort involved six nuclear tests that took place between 1952 and 1962. Weather data were available for these tests; however, it was not readily available. Some weather observation data were available in Jodoin for each of the events. These data were derived from DASA-EX and other unclassified sources. The data were in the form of a *profile* observation. However, this single observation did not add much fidelity to either of the HPAC models. The lack of weather updates caused the models to predict fallout contour plots that were oriented in one direction following the bomb detonation. To improve upon this, additional weather observations were obtained through the Air Force Combat Climatology Center (AFCCC). This author requested weather data for each of the tests for a period beginning at test time through seven days after the test. These data were received from AFCCC as Rawinsonde Observations (RAOBS) in a format that was not immediately useable by either version of HPAC. However, after a few modifications to the files, they were in the correct format. These modifications included changing the order of some of the columns of data, combining some of the columns, correcting negative altitude values in a few places and filling in missing data field entries with “-9999”. These changes rendered the files useable and they were then used to run both versions of HPAC.

Profile files typically contain more than one observation at a station and typically contain vertical profiles of wind, temperature and humidity [DTRA, 2003:C-7]. The data columns within the files contain multi-level upper air observations [DTRA, 2003:C-5]. The data within the file are grouped according to the station where they originated, then by date and time. They are then arranged in ascending order according to that date and time. When multiple stations are used, the data are organized in the same fashion. Each file contains observations at a given altitude for wind direction in degrees, wind speed in meters per second, pressure in millibars, temperature in degrees Celsius and percent humidity. Figure 40 is a small part of the *Profile* file used for the Ess test. It shows three stations 72386 (Las Vegas NV), 72387 (Mercury/Desert Rock NV) and 72486 (Ely NV), which were provided by AFCCC. It also shows data from LASL, which are the test day data obtained from Jodoin.

```
# CREATOR:       Weather File Editor Version 1.17 (The-
Computer/192.168.0.1)
# DATE:          2005-02-04 04:49
# SOURCE:        OBS
# EDITED:        YES
# REFERENCE:     AGL
# TYPE:          OBSERVATION
# TIMEREFERENCE: UTC
# MODE:          OBS ALL
PROFILE
6  6
ID      YYYYMMDDHOUR    LAT     LON     ELEV
                HOURS   N       E       M
Z       WDIR    WSPD    P       T       H
M       DEG     M/S     MB      C       %
-9999
```

ID: 723860 19550323 3.0   36.08   -115.16 660

0	250	2.0	938	13.3	17
90	-9999	-9999	930	17.2	18
352	225	6.0	900	15.8	20
834	250	6.0	850	12.2	22
1338	270	5.0	800	8.4	24
1870	290	10.0	750	4.2	28
2424	315	14.0	700	-0.8	36
3000	315	16.0	650	-6.0	40
3632	315	18.0	600	-9.8	15
4300	340	17.0	550	-15.0	16
5010	315	15.0	500	-21.1	38
5770	315	20.0	450	-27.2	56
6130	-9999	-9999	428	-30.0	64
6616	315	20.0	400	-33.1	60
7541	315	21.0	350	-40.7	-9999
8572	315	23.0	300	-48.0	-9999
9748	315	19.0	250	-56.9	-9999
9840	-9999	-9999	246	-57.7	-9999
11136	315	21.0	200	-64.2	-9999
11380	-9999	-9999	192	-65.5	-9999
11955	270	23.0	175	-61.5	-9999
12740	-9999	-9999	154	-58.7	-9999
12916	270	24.0	150	-58.7	-9999
14060	270	26.0	125	-58.7	-9999
15455	270	18.0	100	-62.0	-9999
16834	295	12.0	80	-61.0	-9999
17152	-9999	-9999	76	-60.5	-9999

ID: 723870 19550323 3.0   36.95   -116.08 1196

0	225	7.0	880	12.5	22
290	250	10.0	850	11.7	23
793	295	8.0	800	7.9	26
1324	315	9.0	750	3.6	30
1875	315	9.0	700	-1.3	35
2484	315	14.0	650	-6.2	37
3082	315	25.0	600	-11.2	30
3754	340	30.0	550	-15.5	16
4455	340	32.0	500	-20.6	18
5226	-9999	-9999	450	-25.7	37
5254	315	27.0	450	-9999	-9999
6066	315	24.0	400	-32.5	20
6990	315	26.0	350	-39.7	-9999
8023	295	33.0	300	-47.4	-9999
9201	305	34.0	250	-57.0	-9999
10581	295	31.0	200	-65.9	-9999
11395	295	29.0	175	-61.2	-9999
12355	270	30.0	150	-62.1	-9999
13485	270	37.0	125	-60.3	-9999
14872	-9999	-9999	100	-60.3	-9999
16249	-9999	-9999	80	-64.5	-9999
17064	-9999	-9999	70	-64.4	-9999
18005	270	26.0	60	-64.3	-9999
19124	270	19.0	50	-60.6	-9999
20529	265	14.0	40	-60.2	-9999
22342	270	9.0	30	-55.2	-9999

23513	-9999	-9999	25	-55.7	-9999
24942	270	9.0	20	-56.3	-9999

ID: 724860 19550323 3.0 39.28 -114.85 1913

0	155	3.0	807	1.0	52
66	205	4.0	800	3.0	47
167	-9999	-9999	792	5.5	35
587	295	9.0	750	2.0	38
1144	295	12.0	700	-2.4	43
1727	295	15.0	650	-7.5	51
2344	295	17.0	600	-13.0	63
3007	315	22.0	550	-18.8	74
3327	-9999	-9999	527	-20.9	71
3705	295	23.0	500	-21.6	47
4487	295	35.0	450	-26.2	49
5320	-9999	-9999	400	-31.2	35
6248	-9999	-9999	350	-39.5	22
7280	-9999	-9999	300	-48.2	-9999
8027	-9999	-9999	268	-54.2	-9999
8452	-9999	-9999	250	-56.6	-9999
9841	-9999	-9999	200	-63.4	-9999
10007	-9999	-9999	195	-64.2	-9999
10655	-9999	-9999	175	-65.0	-9999
11605	-9999	-9999	150	-59.3	-9999
12743	-9999	-9999	125	-59.2	-9999
14146	-9999	-9999	100	-55.9	-9999
14387	-9999	-9999	96	-55.0	-9999
15548	-9999	-9999	80	-61.2	-9999
16387	-9999	-9999	70	-60.6	-9999
17358	-9999	-9999	60	-60.0	-9999
18506	-9999	-9999	50	-57.9	-9999
19904	-9999	-9999	40	-58.0	-9999
21716	-9999	-9999	30	-56.2	-9999
22155	-9999	-9999	28	-55.8	-9999

ID: 723870 19550323 9.0 36.95 -116.08 1196

0	45	0.0	882	12.0	39
305	270	3.0	850	9.4	29
803	295	5.0	800	5.8	27
1324	315	7.0	750	2.1	25
1881	295	13.0	700	-1.3	14
2464	295	16.0	650	-5.3	15
3090	315	18.0	600	-10.2	37
3754	315	21.0	550	-14.5	41
4472	315	20.0	500	-18.3	17
5224	315	18.0	450	-25.1	32
6066	-9999	-9999	400	-32.8	20
6094	315	23.0	400	-9999	-9999
6992	-9999	-9999	350	-40.0	-9999
7019	315	24.0	350	-9999	-9999
8025	-9999	-9999	300	-48.5	-9999
8051	315	23.0	300	-9999	-9999
9222	315	31.0	250	-58.0	-9999
10595	295	28.0	200	-66.4	-9999
11397	295	31.0	175	-68.2	-9999
12354	295	23.0	150	-58.0	-9999

13491	270	22.0	125	-61.8	-9999
14873	-9999	-9999	100	-59.6	-9999

ID: 723860 19550323 15.0 36.08 -115.16 660

0	295	4.0	939	16.8	37
90	-9999	-9999	929	13.2	27
170	-9999	-9999	920	13.5	23
355	315	7.0	900	12.6	23
831	315	8.0	850	10.4	23
850	-9999	-9999	847	10.2	23
1332	315	10.0	800	6.5	23
1850	315	14.0	750	3.4	23
2414	295	7.0	700	-0.5	26
2990	290	10.0	650	-5.3	30
3624	315	18.0	600	-9.9	36
4280	315	18.0	550	-13.4	34
4810	-9999	-9999	513	-16.2	27
5013	315	19.0	500	-17.9	17
5780	315	24.0	450	-24.7	18
6636	315	23.0	400	-32.0	20
7562	315	23.0	350	-40.1	-9999
8593	315	25.0	300	-48.8	-9999
9765	315	29.0	250	-58.2	-9999
10500	-9999	-9999	223	-63.3	-9999
10970	-9999	-9999	206	-63.3	-9999
11145	295	32.0	200	-63.9	-9999
11710	-9999	-9999	182	-66.1	-9999
11960	295	26.0	175	-63.0	-9999
12915	270	26.0	150	-60.0	-9999
13340	-9999	-9999	140	-58.2	-9999
14060	270	27.0	125	-58.2	-9999
15457	270	25.0	100	-60.7	-9999
16847	270	23.0	80	-59.2	-9999
17680	-9999	-9999	70	-60.4	-9999
18636	295	19.0	60	-61.8	-9999
19765	270	12.0	50	-61.5	-9999
20290	-9999	-9999	46	-59.6	-9999
21176	295	5.0	40	-57.0	-9999
23008	270	9.0	30	-53.9	-9999
23690	-9999	-9999	27	-51.4	-9999

ID: 724860 19550323 16.0 39.28 -114.85 1913

0	-9999	-9999	808	3.4	49
76	-9999	-9999	800	2.7	50
587	315	7.0	750	-2.9	60
1135	315	14.0	700	-8.4	72
1717	315	19.0	650	-11.7	69
1897	-9999	-9999	635	-12.5	68
2321	315	24.0	600	-10.6	29
2407	-9999	-9999	594	-10.6	25
2987	315	28.0	550	-15.8	16
3699	315	30.0	500	-20.3	17
4487	315	44.0	450	-25.9	28
5318	-9999	-9999	400	-32.0	30
6243	-9999	-9999	350	-40.3	-9999
7271	-9999	-9999	300	-50.0	-9999

```
8337    -9999   -9999   254     -58.5   -9999
8436    -9999   -9999   250     -58.8   -9999
9814    -9999   -9999   200     -65.3   -9999
10625   -9999   -9999   175     -65.4   -9999
11587   -9999   -9999   150     -58.9   -9999
12737   -9999   -9999   125     -55.1   -9999
14145   -9999   -9999   100     -59.0   -9999
15530   -9999   -9999   80      -61.0   -9999
16037   -9999   -9999   74      -61.1   -9999
16364   -9999   -9999   70      -58.4   -9999
17340   -9999   -9999   60      -55.3   -9999
18500   -9999   -9999   50      -55.9   -9999
19917   -9999   -9999   40      -56.0   -9999

ID: LASL    19550323 20.3   37.1    -116.02 1307
1219    -9999   -9999   878     17.9    21
1307    310     5.364   -9999   -9999   -9999
1509    -9999   -9999   850     14.0    23
1524    -9999   -9999   848     13.8    23
1829    -9999   -9999   820     10.2    28
2134    -9999   -9999   790     6.7     29
2400    -9999   -9999   765     3.4     31
2438    -9999   -9999   759     3.0     32
2743    -9999   -9999   732     0.8     36
2810    -9999   -9999   726     0.4     36
2990    -9999   -9999   709     0.3     28
3048    -9999   -9999   704     0.1     29
3093    -9999   -9999   700     0.0     28
3190    -9999   -9999   691     -0.5    29
3353    -9999   -9999   675     -1.7    29
3540    -9999   -9999   662     -2.7    26
3658    -9999   -9999   653     -3.6    28
3962    -9999   -9999   628     -6.2    31
4267    -9999   -9999   604     -9.0    38
4572    -9999   -9999   581     -11.9   40
4877    -9999   -9999   559     -14.4   46
5182    -9999   -9999   536     -16.3   40
5486    -9999   -9999   514     -18.1   38
5686    -9999   -9999   500     -19.5   37
5791    -9999   -9999   492     -20.2   38
6096    290     19.22   -9999   -9999   -9999
6401    290     19.22   -9999   -9999   -9999
6706    290     20.56   -9999   -9999   -9999
7010    290     22.35   -9999   -9999   -9999
7315    290     24.59   -9999   -9999   -9999
7620    290     24.14   -9999   -9999   -9999
9144    290     29.5    -9999   -9999   -9999
10668   300     26.38   -9999   -9999   -9999
```

Figure 40. Example of a Complete Profile File

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Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/EN)
2950 Hobson Way
WPAFB OH 45433-7765

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ATTN: TDOC
8725 John J. Kingman Rd, MS 6201 MAJ Robert Sobeski
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14. ABSTRACT
A comparison of Hazard Prediction and Assessment Capability (HPAC) software dose-rate contour plots to a sample of local nuclear fallout data from test detonations in the continental United States, 1945 - 1962, is performed. Fallout data from test detonations is obtained from "Compilation of Local Fallout Data from Test Detonations 1945-1962 Extracted from DASA 1251, Volume I - Continental U.S. Tests." This report contains fallout plots and radiation contours for each test in the atmospheric nuclear test program conducted by the United States prior to 1963. These plots are compared with the plots resulting from Defense Threat Reduction Agency's (DTRA) HPAC software using test day wind data and additional wind data for up to seven days following each test. The results from HPAC were extrapolated to H+1 hour using the $t^{-1.2}$ decay approximation. A visual comparison of the plots revealed mismatches between observed and predicted data. A numerical comparison using Warner, et al, Rowland and Thompson, dose-rate contour area comparisons and grounded unit time reference dose rate corroborated the results of the visual comparisons.

15. SUBJECT TERMS
Fallout, Radioactive Fallout, Mathematical Analysis, Numerical Analysis, HPAC, Nuclear Test Detonations, Detonations

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U	U	U	UU	91	**19b. TELEPHONE NUMBER** *(Include area code)* (937) 255-3636, ext 4675 (charles.bridgman@afit.edu)