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A COMPARISON OF CASUALTY ASSESSMENT RESULTS FROM THE TENDS AND CIVIC CODES

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27 June 1980

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Comparison of assessment results from the CIVIC and TENOS Population Casualty Assessment Codes was accomplished under selected input conditions and two U.S. population representations (data bases). Results indicate that for the large yield strike file employed, national results obtained from both codes did not differ significantly because of the significant overlapping of fallout fields. However, state-by-state results showed some significant

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variations due to the different fallout models employed (CIVIC, TENOS-WSEG-10) and the methodology for combining prompt and fallout effects. These variations, however, were not biased in any particular direction, i.e., in some cases TENOS results were higher while in others CIVIC results were higher.

PREFACE

The author wishes to express his appreciation for the invaluable support provided by LT COL's R. Edwards and D. Thomas, the DNA COR's for this work.

Dr. Dave Bensen and Mr. Jim Jacobs of the FEMA performed and provided the TENOS assessment. Their cooperation in providing the basic population data base, the strike file and the TENOS assessment results were instrumental to the project and their work is greatly appreciated.

Messrs. Ron Dietz and Mel Schoonover of SAI were instrumental in generating the required data bases for CIVIC use and performing the CIVIC assessment.

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SECTION 1

SUMMARY

1-1 GENERAL

A comparison of results from the civilian casualty assessment codes CIVIC and TENOS was accomplished with the intent of determining the influence of methodology differences employed by the two codes. The principal methodology differences examined were:

- fallout model - SEER versus WSEG-10,
- techniques for combining prompt and fallout effects,
- population representation (point versus area targets) and CEP considerations.

1-2 ASSESSMENT CONDITIONS

Three CIVIC and one TENOS assessment problems were executed with a population data base and weapon strike file provided by FEMA. Only one TENOS assessment was conducted by FEMA because of other high priority commitments. With the possible exception of variations in population posture (shelter conditions), this single assessment was representative of the normal operating capabilities of the code under the specified strike file. The population data base consisted of 98,606 records with a total population of 211,706,673 contained within the 48 contiguous states. The weapon strike file consisted of 1,459 weapons ranging in yield from 1-20 MT, with a total megatonnage of 6,607. Of the total number of weapons, 795 were fallout producers, with a total megatonnage of 4,375. The weapons inventory and strike file are considered reasonable and prudent. The weapon strike file produced significant overlapping of fallout areas over large areas of the United States.

1-3 CAVEATS

The observations noted below pertain only to the assessment conditions noted above. Based on this work and other code comparison work, it is clear that results obtained through the use of different assessment codes are heavily dependent on the size and nature of the data base and on size and yields employed in the weapon strike file. In general, the smaller and more dispersed the weapon laydown, the larger the differences between various assessment codes.

1-4 OBSERVATIONS

The results of the comparison show the following:

a. Comparison of CIVIC runs using the WSEG-10 option[(1)] and the improved SEER-II option (all other input conditions identical) showed that the WSEG-10 model produced nearly 11% more fallout-only fatalities than the improved SEER-II model.

The fallout-only fatality difference in this assessment is not as large as those that were produced in other assessment comparisons performed for DNA. This may be due to either a preponderance of very large weapons or the number of lesser yield weapons in the strike file. Either will subject a large part of the population data base to many overlapping fallout fields. Secondarily, at the larger yields, the differences in fallout contours produced by the two fallout models are not as pronounced as they are for the lower yield weapons. In addition, the GWC October winds used in this assessment has low wind shear characteristics. It was noted in previous studies that WSEG-10 compares well with other fallout models when the wind shear is low.

b. The comparison which was developed to show the influence of the prompt and fallout environment combining methodology in the two codes indicated that the CIVIC combining methodology produced about 11.2% greater fatalities than the methodology in TENOS. The combining methodology is independent of the fallout model employed.

c. TENOS does not use weapon CEP in casualty assessments and treats population areas as points, whereas most casualty assessment codes consider the CEP in prompt casualty calculations. To assess the impact of these conditions, two CIVIC calculations were made. In one, zero weapon CEP's and a point target representation of the population was employed. In the other, a normal CEP of 1500 feet and an area (P-95 circle) representation of the population was employed. Comparison of results from the two calculations showed that these two parameters, when employed in conjunction with

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[(1)] Two fallout models are contained in CIVIC—SEER and WSEG-10. The user can select at run-time, via an input flag, which model he desires to use for fallout assessments.

one another, had no influence on the outcome of the assessment for the weapon strike file employed.

d. The TENOS/CIVIC-1 comparison case in which CIVIC was[2] employed with zero weapon CEP and a point target representation of the population (to be consistent with TENOS methodology), showed national assessment results that were in reasonable agreement. The difference in prompt fatalities was about 4%, and almost all of this difference can be attributed to differences in the shelter damage functions and the prompt damage probability calculations because of the insignificant influence of CEP and target representation parameters noted in (a), above.

The combined environment fatality difference of 6.3% represents differences in three aspects of the assessment; the prompt environment calculations, the differences in the fallout models employed by the two codes, and the methodology for combining the prompt and fallout environments. From paragraphs (b) and (c) above, we note that the fallout model differences (TENOS/WSEG-10 results larger) and the combining methodology differences (CIVIC results larger) are sufficiently counterbalancing in this scenario that the differences between the CIVIC and TENOS assessment results can be considered negligible.

e. As might be expected, the results from the state-by-state summaries show the much wider variations that can be attributed in large part to the differences in fallout models and the extent of fallout area overlapping. The results for two states serve to illustrate this point. The combined fatality difference for the TENOS/CIVIC-1 comparison in the State of Alabama, for example, shows a 23.5% difference with the TENOS (WSEG-10) fatalities being higher. On the other hand, for the State of California the difference in combined fatalities is 9.7% with the CIVIC (SEER) fatalities being higher.

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[2] The notation CIVIC-1, CIVIC-2, CIVIC-3 is used only to describe the three CIVIC assessment cases (see Table 3) which involves only variation to the input run-stream. The differences in the methodology employed when these variations are employed are discussed in Appendix A.

For large weapon laydowns, particularly where large yield weapons are involved, one can conclude that differences in code methodology are washed out when looking at national results. However, where specific areas or location are of interest, particularly as regards constraints that may be employed with certain attack options, significant assessment differences may be observed when using the different methodologies/models employed in CIVIC and TENOS.

It should be noted that the assessments addressed in this study were based on the use of shelter distance-damage functions derived from FEMA data. AP-550 distance-damage functions for similar shelter categories are somewhat different because of the larger damage sigmas and could conceivably result in larger casualty estimates. However, this aspect of the damage methodology was not examined in this study.

SECTION 2

INTRODUCTION

This report documents the results of a code comparison program sponsored by DNA. The primary objective of the program was to evaluate the casualty differences that would be encountered when employing different population casualty assessment codes. This objective was to be satisfied by accomplishing the following:

- Exercise damage assessment models against a number of specific problem sets.
- Compare casualty output results.
- Identify where possible, the source of any significant differences in output results.

During the initial planning stages of the program, it was believed desirable to perform the comparative assessments using four computer programs:

- TENOS (employed by FEMA)
- READY (employed by FPA)
- SIDAC (employed by CCTC)
- CIVIC (development sponsored by DNA)

However, because of other high priority commitments, FPA and CCTC could not participate in the program and thus the only assessment codes that could be employed in the comparison were TENOS and CIVIC. Furthermore, the FEMA participation with TENOS was limited to a single assessment run.

SECTION 3

COMPARISON GROUND RULES AND ASSESSMENT CODE DIFFERENCES

3-1 GROUND RULES

In order that meaningful comparisons could be made, a number of ground rules or initial conditions were established by the program participants (FEMA, SAGA, DNA) at the outset of the work effort. These are shown in Table 1.

3-2 BASIC DIFFERENCES IN THE ASSESSMENT CODES

In order to establish some rationale or logic for the selection of assessment problems, it was useful to identify general methodology or data base factors that might contribute to differences in casualty results. Among those considered the most significant were:

- Population representation
- Population shelter distribution
- Prompt weapon effects damage methodology
- Fallout model employed
- Methodology for combining prompt and fallout effects
- Weapon associated parameters

With the establishment of these general factors, they were then specifically related to the capability of the codes that were to be employed in the comparative analysis. These are shown in Table 2.

The comparison ground rules and the methodology factors noted above were the basis for the specification of the assessment problems discussed in Section 4.

Table 1. Assessment stipulations.

- BASIC WEAPON LAYDOWN DATA PROVIDED BY FEMA
- CCTC WIND DATA BASE WAS TO BE EMPLOYED
    - OCTOBER "MOST-PROBABLE" WINDS
- POPULATION DATA BASE PROVIDED BY FEMA
    - "BEST SHELTERED" U.S. POPULATION DATA BASE (2X2 MINUTE GRID CELL DATA)
    - SHELTER DISTRIBUTION GIVEN FOR EACH CELL IN DATA BASE
- FALLOUT FATALITY/CASUALTY CALCULATIONS TO BE BASED ON MAXIMUM BIOLOGICAL DOSE
    - IRREPARABLE DOSE FRACTION = 0.1, REPAIR RATE = 2.5%/DAY
- SHELTER CHARACTERISTICS TO BE PROVIDED BY FEMA
    - DAMAGE PROBABILITY VERSUS OVERPRESSURE
    - FALLOUT PROTECTION FACTORS
- SAI WOULD TRANSFORM **FEMA** SHELTER CHARACTERISTICS INTO FORM SUITABLE FOR CIVIC

Table 2. TENOS and CIVIC assessment methodology differences.

	TENOS	CIVIC
Population Representation	Point	Option-Point or Area (P-95)
Shelter Distribution at Each Population Place	From Population Data Base	From Population Data Base or Assigned Through Code Algorithms
Weapon Impact Point Distribution Considerations	No	Yes
Probability of Weapon Arrival Considerations	No	Yes
Prompt Effects Damage Function	Blast Only (1 MT and Above)	Blast and Nuclear Radiation
Fallout Model	WSEG-10	Option-Improved SEER-II or WSEG-10
Combined Prompt and Fallout Effects	Independent Events Compounding	Procedure for Summing Radiation Components Plus Independent Events Compounding
Wind Data Base	5 Altitude Level GWC Grid Data	10 Levels for SEER; 5 Levels for WSEG-10
Biological Repair Function for Fallout Radiation	Yes	Option, Yes or No

SECTION 4

DEVELOPMENT OF ASSESSMENT PROBLEM SETS AND CIVIC MODIFICATIONS

4-1 DEVELOPMENT OF ASSESSMENT PROBLEMS

Based on the assessment code capabilities and program objectives, problem sets were developed which were designed to address the issues specified in the following subsections. It should be noted that in order to examine the impact of most methodology and/or input parameter differences between the two codes, it was estimated that about 22 CIVIC assessment cases would be required with various permutations in input parameters or damage methodology. Because the large strike file and data base implied long computer run times, this number of assessments could not be accommodated. Thus, a compromise of the three assess ment cases described below was instituted. The necessary limitation in assessment runs accommodated investigation of the most important methodology differences between the two codes under nominal input conditions. It did not, however, permit investigation of differences that might result due to variations in strike file (weapon yield), population shelter distribution, and wind data base.

4-1.1 Impact of Fallout Models Employed

With all input parameters identical, a direct comparison between TENOS (WSEG-10) and CIVIC (improved SEER-II) was desired. This baseline comparison coupled with two other comparisons was expected to provide some insight regarding the influence of other input parameters and code methodology.

4-1.2 Impact of Weapon CEP and Population Representation

Because TENOS does not employ CEP in its damage calculations, it was believed useful to compare output results with a CEP = 0 employed in both codes and then to employ CIVIC with a nominal weapon CEP of 1500 feet. TENOS also uses a point target representation of the population. To ascertain whether this parameter is important in casualty assessments CIVIC would be run with both point and area population representations. To accomplish this, each 2 x 2 minute cell location in the DCPA population data base was converted to an equal area circle with the center of the circle coincident with the DCPA cell center. The conversion was based on the algorithm

$$R(n.m) = \sqrt{\frac{4 \times \cos \text{(latitude of population place)}}{\pi}}$$

to estimate the radius of an equivalent P-95 radius.

4-1.3 Impact of Methodology for Combining Prompt and Fallout Environments

TENOS calculates damage to population points due to prompt and fallout environments independently and then compounds the two, under the independent events assumption, to specify total fatalities and casualties. CIVIC on the other hand strives to account for the additive nature of the radiation environments (prompt and fallout) in ascertaining total fatality and casualty results. It appeared useful, therefore, to establish whether this refinement in methodology makes any impact on casualty and fatality results. To ascertain this impact, a direct comparison of the output results of the TENOS and CIVIC codes (using the WSEG-10 option in CIVIC) was desired.

4-1.4 Summary of CIVIC and TENOS Problem Sets

Table 3 summarizes the conditions of the CIVIC and TENOS comparison problems. Table 4 summarizes the characteristics of the weapon strike file provided by FEMA.

4-2 CIVIC MODIFICATIONS

The ground rules and problem sets established above required that some non-inconsequential modifications be made to the CIVIC code in order to perform the desired assessments. The major modifications are shown in Table 5.

4-3 DCPA POPULATION DATA BASE CHARACTERISTICS

The DCPA "best sheltered" U. S. population data base for the contiguous 48 states contains 98,606 population records with a total population of 211,766,673. For each record in the data base, a distribution of the population into one or more of six structure/shelter types is given based on data from the National Shelter Survey. This distribution was employed in both the TENOS and CIVIC assessment runs. Definitions of the various structure types contained in the National Shelter Survey are given in Table 6.

Table 3. Assessment problems.

Problem Number	Population Representation	CEP (feet)	Fallout Model
TENOS[1]	Point	0	TENOS/WSEG-10
CIVIC-I[1]	Point	0	CIVIC/SEER
CIVIC-II[3]	Area[2]	1500	CIVIC/SEER
CIVIC-III[4]	Point	0	CIVIC/WSEG-10

(1) To provide direct comparison with TENOS results.

(2) 2X2 minute cell converted to equal area circle

$$\text{P-95(nm)} = \sqrt{\frac{4 \times \cos\ (\text{lat. of population place})}{\pi}}$$

(3) To determine influence of CEP and point versus area target representation

(4) To determine influence of CIVIC prompt and fallout combining techniques.

Table 4. Weapon laydown characteristics.

YIELD	TOTAL NUMBER	HOB'S (FT)	NUMBER SURFACE BURST
1 MT	847	0/9400	429
2 MT	190	0/9323	93
3 MT	180	0/10673	100
20 MT	242	0/20087	173
	1459		795
	6607 MT		4375 MT

All weapons presumed to arrive, i.e., PA = 1.0

Table 5. CIVIC modifications.

- MODIFICATION TO ACCESS AND EMPLOY A U.S. POPULATION DATA BASE
  - ORIGINAL CODE WAS CONSTRAINED TO EURASIAN CONTINENT
- MODIFICATION TO ACCESS AND EMPLOY SHELTER DISTRIBUTION BY POPULATION PLACE DIRECTLY FROM DATA BASE
- MODIFICATION TO OPERATE ON AND PROVIDE OUTPUT FOR SIX SHELTER CATEGORIES INSTEAD OF FOUR
- MODIFICATION TO ACCESS AND EMPLOY A WIND DATA BASE APPLICABLE TO WESTERN HEMISPHERE
  - ORIGINAL CODE WAS CONSTRAINED TO EURASIAN CONTINENT
- CONVERSION OF CCTC WIND DATA BASE INTO CIVIC COMPATIBLE FORMAT
- INSTALL WSEG-10 FALLOUT MODEL AS OPTION TO SEER
  - TEST TO DETERMINE SIGNIFICANCE OF CIVIC PROMPT + FALLOUT COMPOUNDING METHODOLOGY
- CONVERT CIVIC TO CDC 7600 COMPUTER
  - LARGE LAYDOWN AND DATA BASE - EXCESSIVE RUN TIME ON SLOWER MACHINE
- MODIFICATION TO MAKE ASSESSMENTS ON EITHER POINT OR AREA TARGETS

Table 6. NSS structure types.

MLOP/ MCOP (PF)		Shelter Type	Description
35/25 (5000)	-	A	Subway stations, tunnels, mines, and caves with large volume relative to entrances.
10/7 (500)	*	B	Basements and sub-basements of massive (monumental) masonry buildings.
		C	Basements and sub-basements of large, fully engineered structures having any floor system over the basement other than wood, concrete flat plate, or band beam support.
10/4 (25)	-	D	Basements of wood frame and brick veneer structures including residences.
8/2 (55)	*	E	First three stories of buildings with "strong" walls, less than ten aboveground stories, and less than 50% apertures.
		F	Fourth through ninth stories of buildings with "strong" walls, less than ten aboveground stories, and less than 50% apertures.
5/2 (70)	*	G	Basements and sub-basements of buildings with a flat plate or band beam supported floor system over the basement.
		H	First three stories of buildings with "strong" walls, less than ten aboveground stories, and greater than 50% apertures; or, first three stories of buildings with "weak" and less than ten aboveground stories.
		I	All aboveground stories of buildings having ten or more stories. Fourth through ninth stories of buildings having "weak" walls.
5/2 (5)		R	Classified as "Residual" on FEMA Population File, i.e., not belonging specifically to any of above structural types. Given vulnerability of shelter type G/H/I by SAI.

Note: For the above description, load bearing walls are considered as "weak" walls.

*Grouped together because of similar vulnerability characteristics.

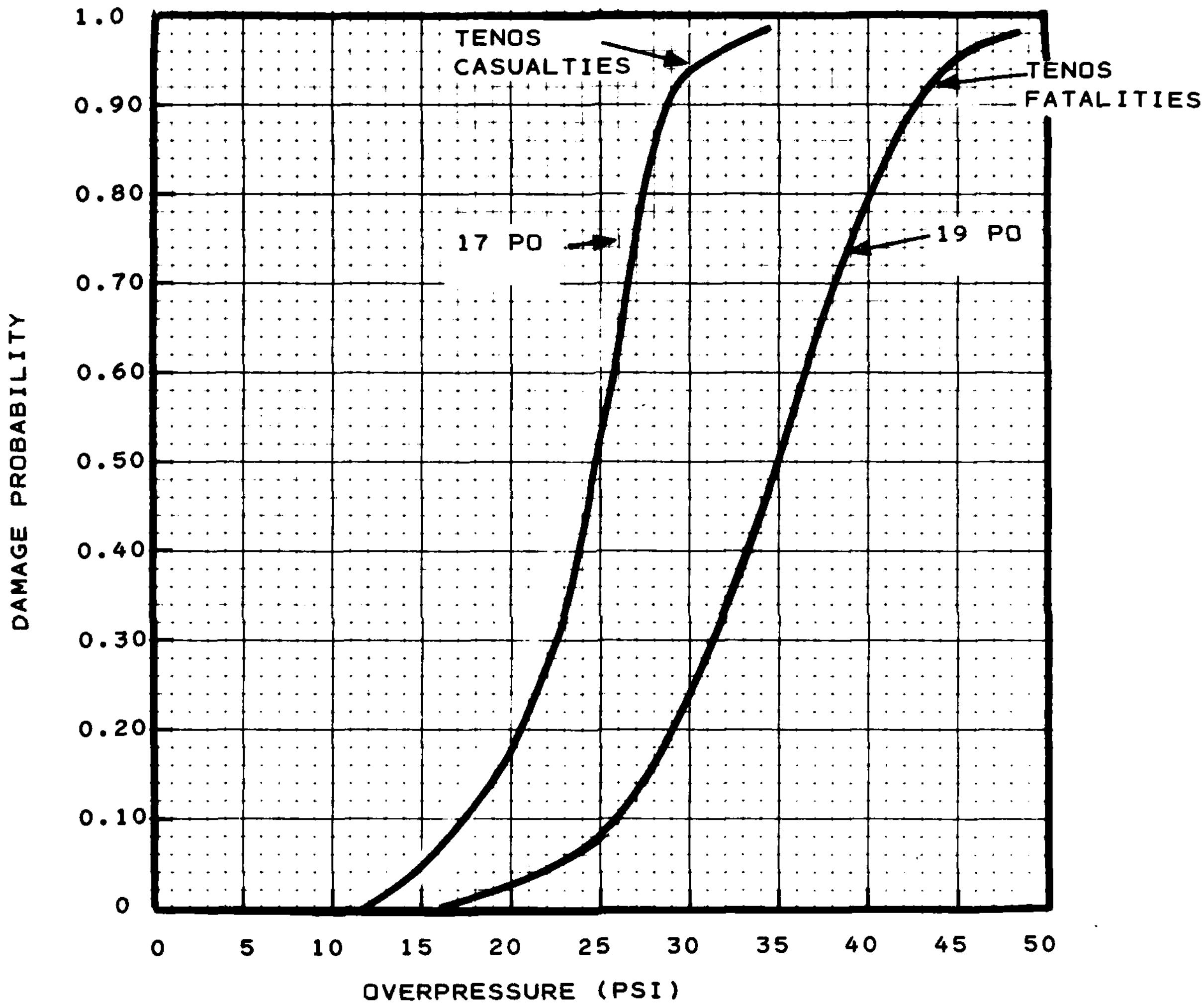
SECTION 5

SPECIFICATION OF PROMPT DAMAGE FUNCTIONS

One of the fundamental inputs required for the calculation of prompt casualties is the information necessary for specifying casualty criteria for each of the shelter categories considered. Under the ground rules established for the program, the shelters to be employed were those specified by FEMA. If meaningful comparisons were to be made between code output, it was necessary that in the base case assessment problems, similar damage functions be employed in both codes to remove this factor as a potential source of difference in assessment results.

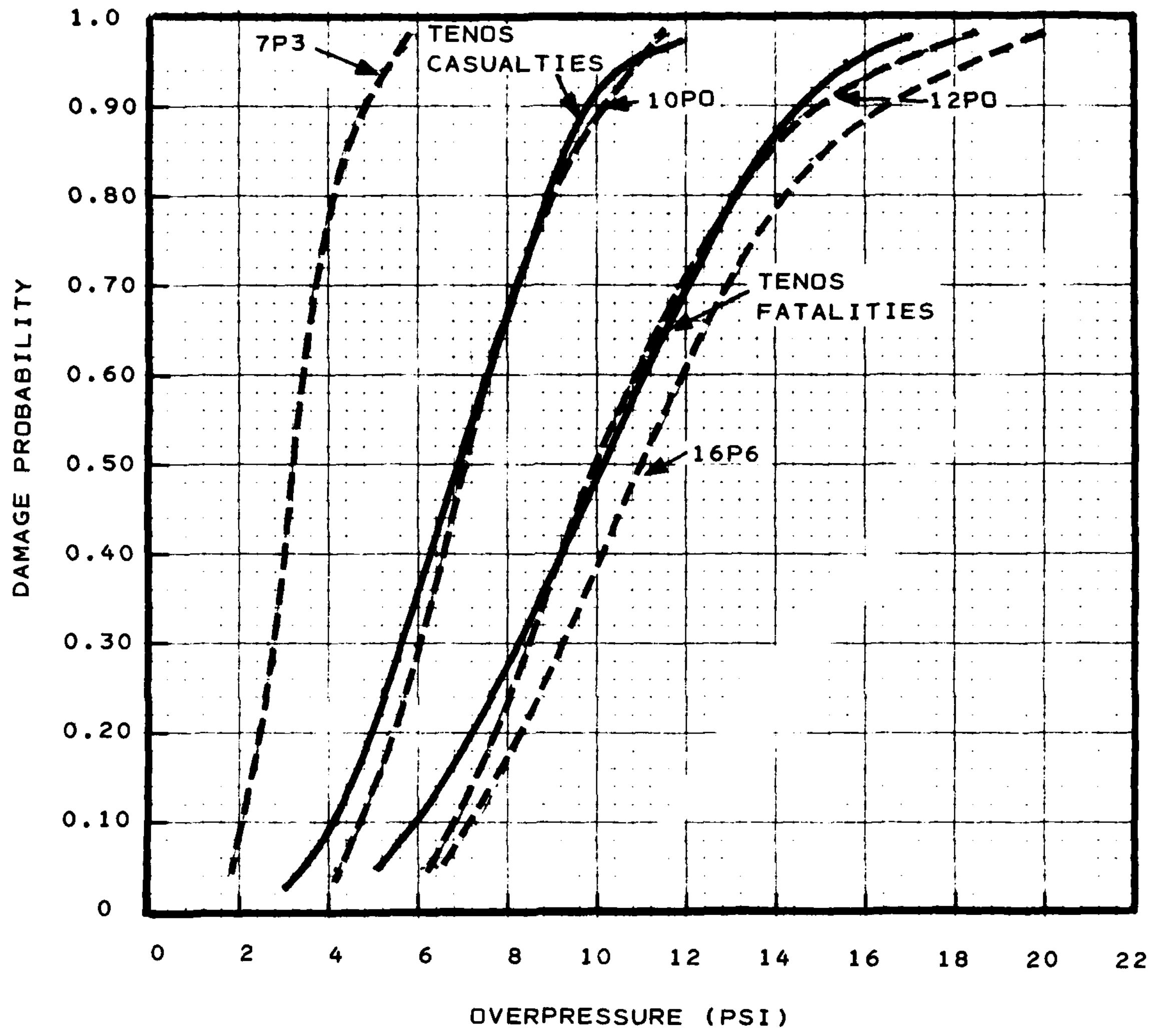
As a starting point in the analysis, the National Shelter Survey damage functions employed by TENOS were examined to determine their characteristics in terms compatible with the CIVIC code. Six shelter damage functions associated with a "best" sheltered posture were examined. It should be noted that these damage functions pertain only to the blast environment because the yields employed in most FEMA assessment analyses are large and, therefore, blast is the predominant damage mechanism. However, because CIVIC calculates the weapon radius contributions from the blast and radiation environments, those input parameters necessary for the radiation calculations were assigned by SAI.

For each shelter category (for fatalities and casualties) a VNTK assignment was made to specify the blast vulnerability along with a damage sigma that was appropriate to each TENOS shelter damage function. Plots of the probability of fatality (and injury) as a function of peak overpressure are shown in Figures 1-6 for six shelter categories. Figure 7 is a similar plot for fallout radiation. Included in Figures 1-6 (where appropriate) are references to the AP-550 personnel vulnerability VNTK values associated with the corresponding structure categories given in AP-550. These references are shown because AP-550 provides for only five structure types for civilian casualty assessments, i.e., single story structures, multi-story structures basements, hasty shelters and deep underground shelters. Table 6 summarizes the assignments made for each of the necessary CIVIC input parameters. The damage sigma values shown for the blast environment (and used in CIVIC) were obtained by folding the basic damage probability as a



AP-550 VNTK'S BASED ON YIELD
OF 1 MT

Figure 1. Shelter 35/25-mines, caves and tunnels (Type A).

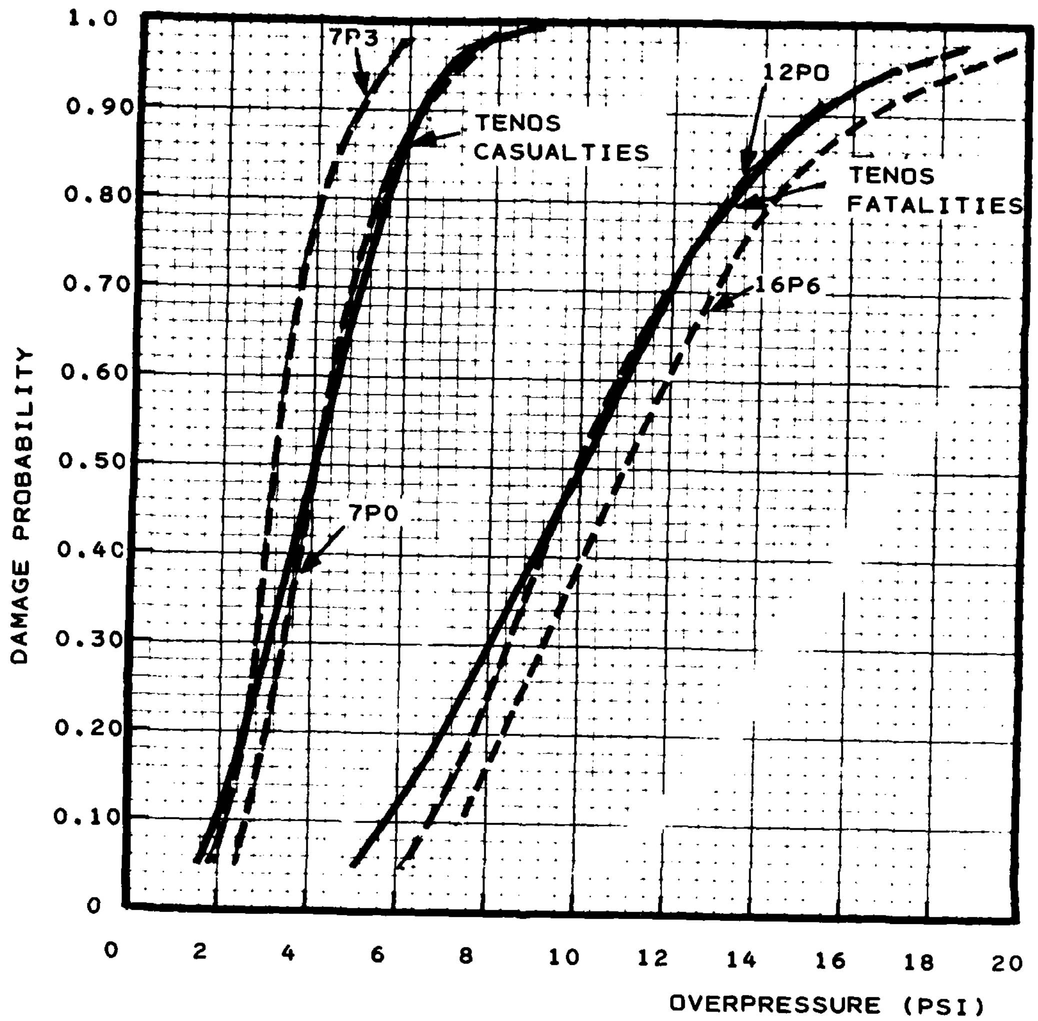


AP-550 REFERENCES

16P6 = FATALITIES - BASEMENTS
7P3 = CASUALTIES - BASEMENTS

ALL AP-550 VNTK'S BASED
ON YIELD OF 1 MT

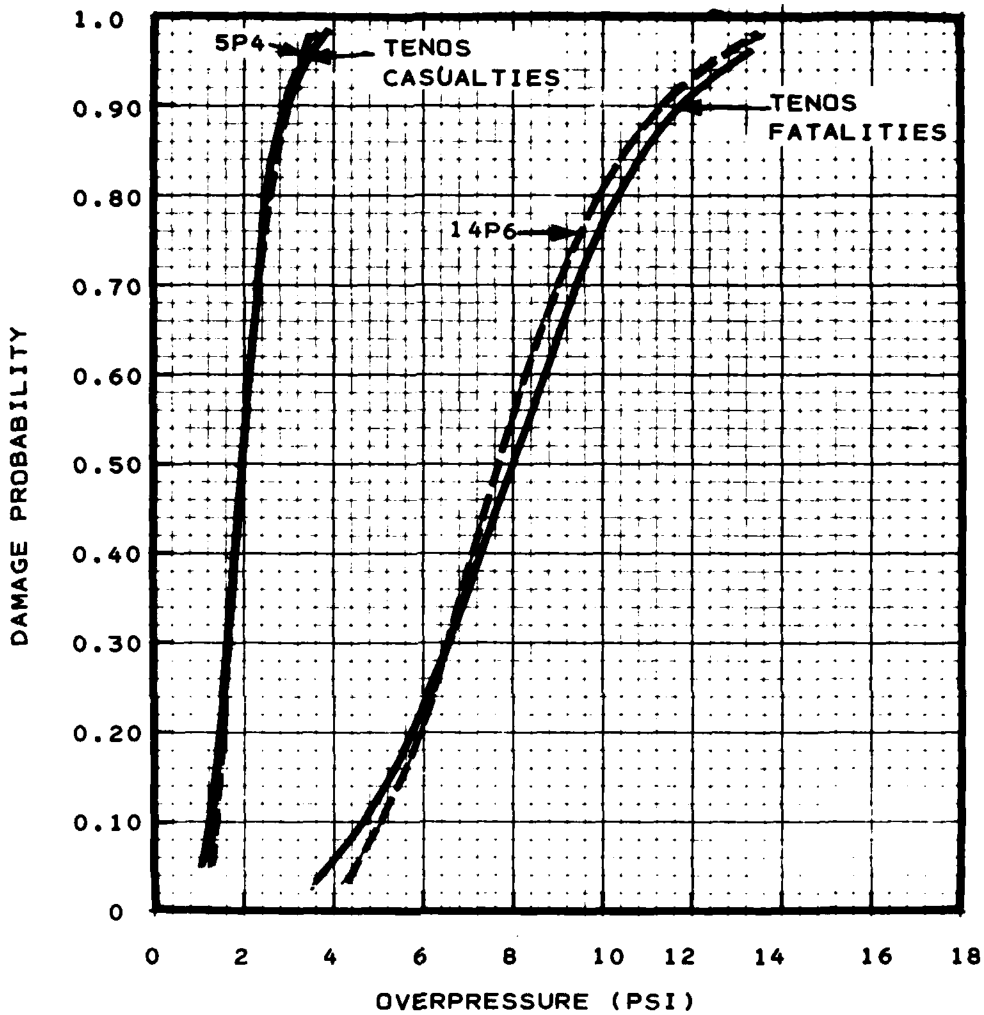
Figure 2. Shelter 10/7-best basements (Type B/C).



AP-550 REFERENCES
7P3 CASUALTIES - BASEMENTS
16P6 FATALITIES - BASEMENTS

ALL AP-550 VNTK'S BASED
ON YIELD OF 1 MT

Figure 3. Shelter 10/4-basements of wood frame structures (Type D)

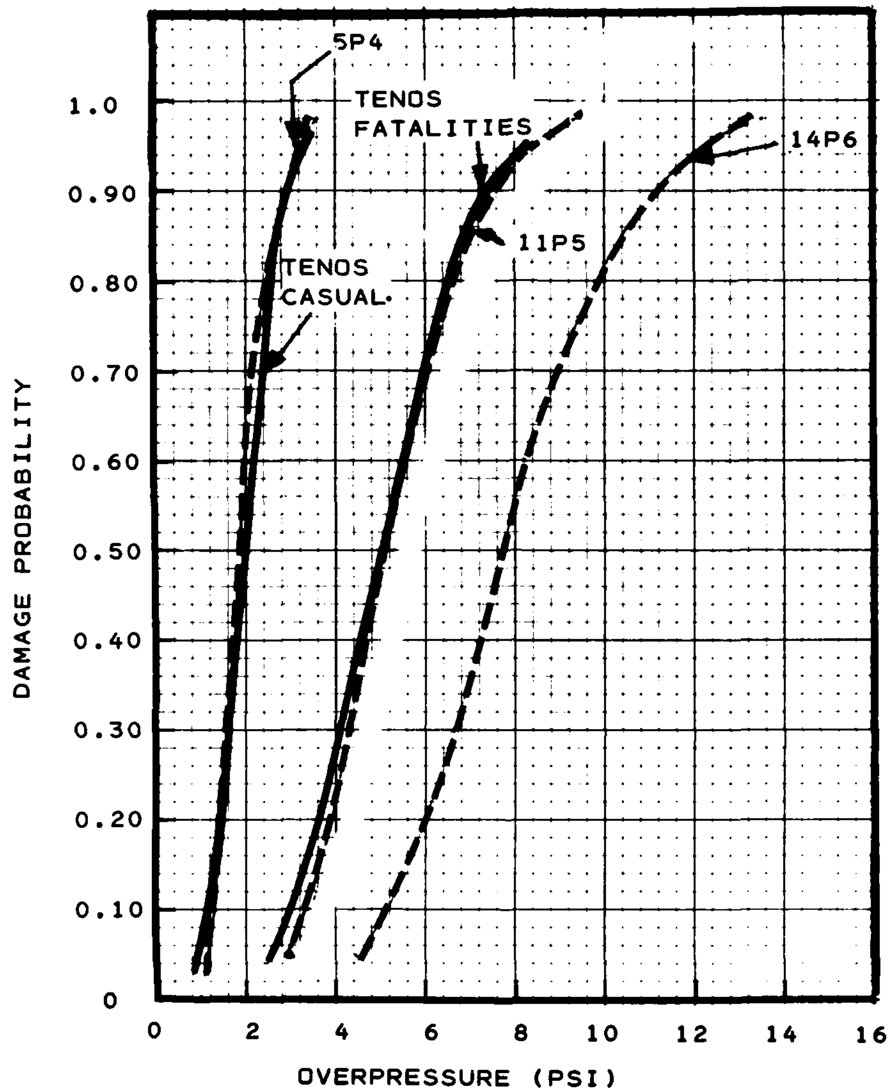


AP-550 REFERENCES

5P4 - CASUALTIES } MULTI-STORY
14P6 - FATALITIES } BUILDINGS

AP-550 VNTK'S BASED ON
YIELD OF 1 MT

Figure 4. Shelter 8/2-upper stories (<10) of strong walled buildings (Type E/F).

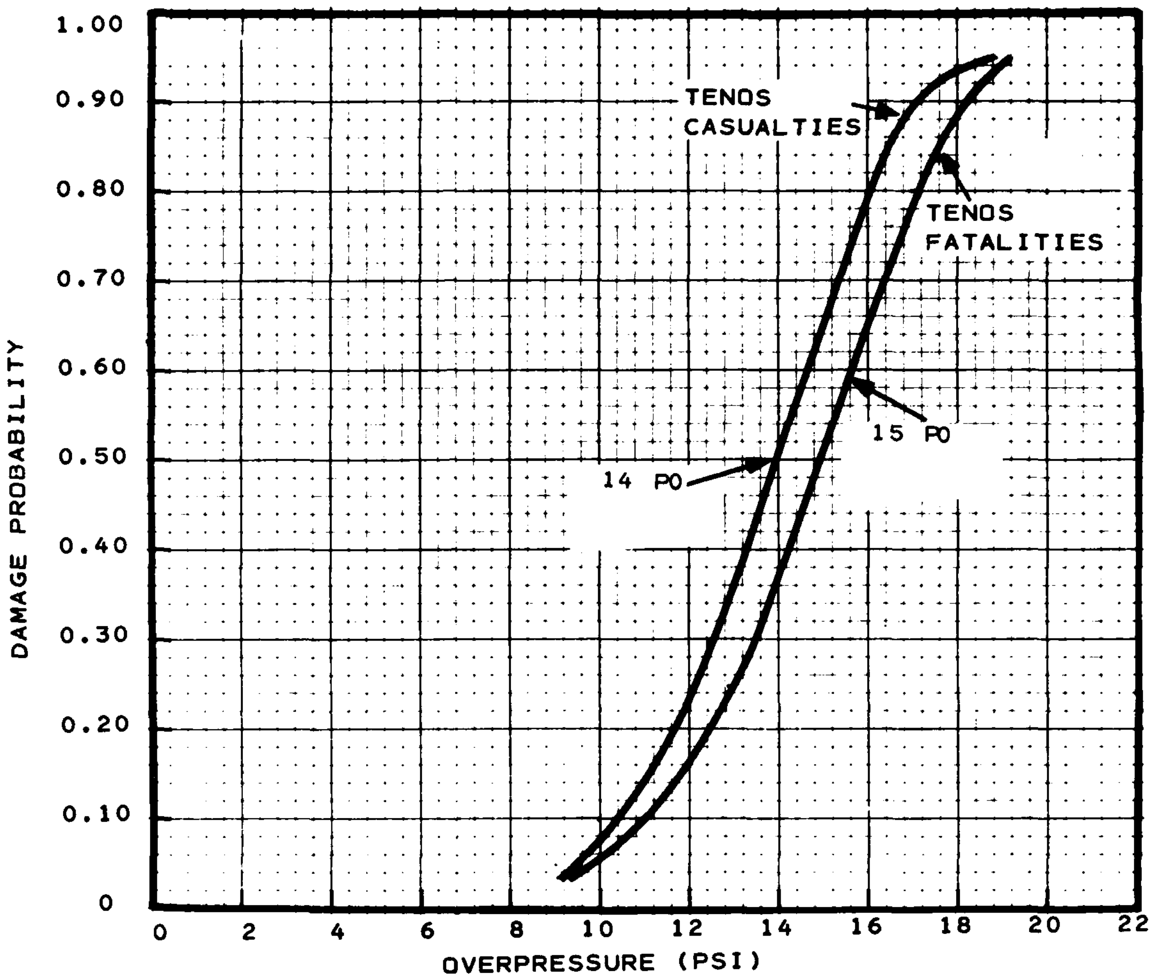


AP-550 REFERENCES

5P4 = CASUALTIES - MULTI-STORY BLDGS.
14P6 = FATALITIES - MULTI-STORY BLDG.S

AP-550 VNTK'S BASED ON YIELD OF 1 MT

Figure 5. Shelter 5/2-tall (>10 stories) weak walled upper story space and weak basements (Type G/H/I).



AP-550 VNTK'S BASED ON
YIELD OF 1 MT

Figure 6. 15 psi upgraded blast shelter.

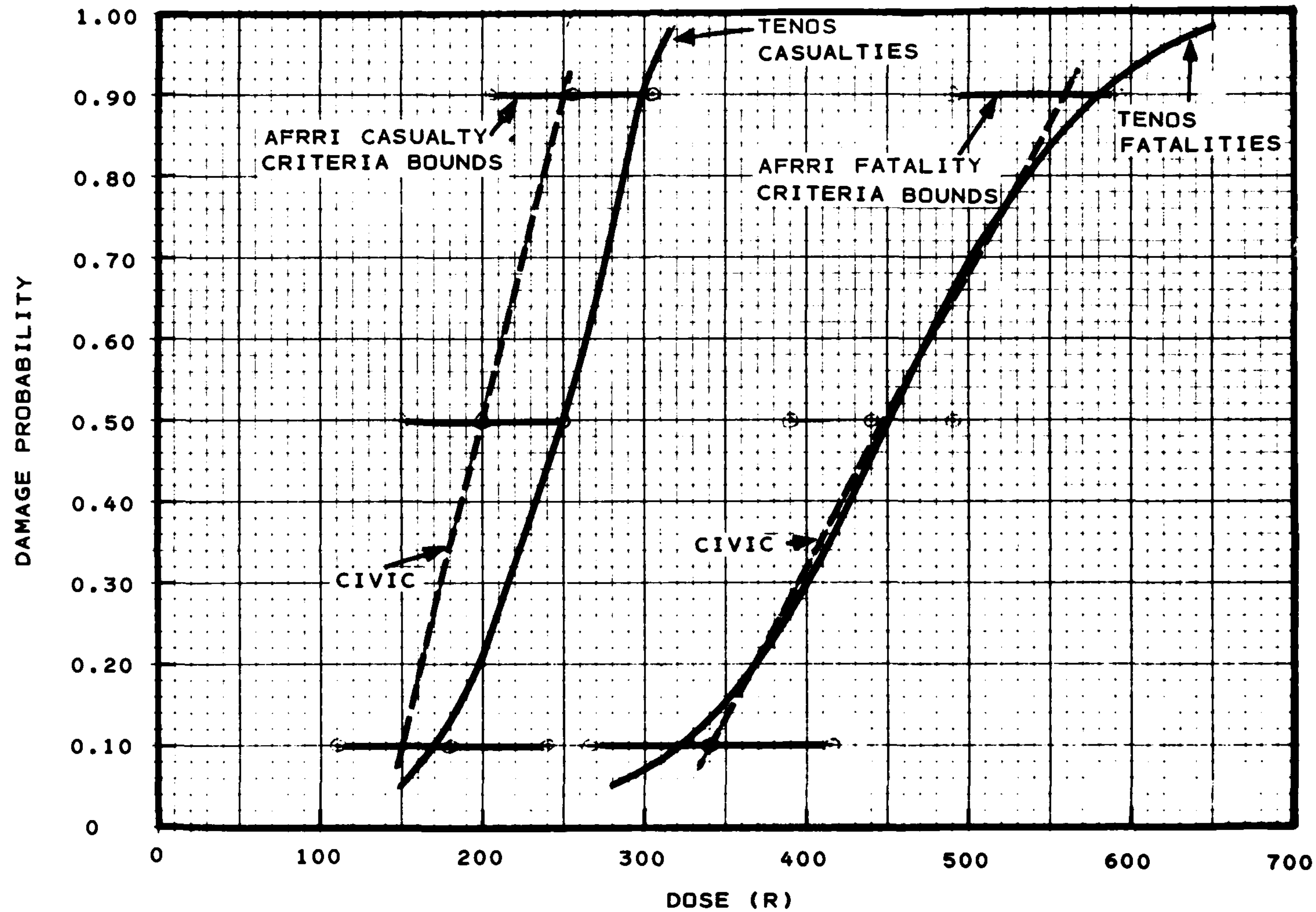


Figure 7. TENOS fallout radiation damage functions (warned) (fallout only).

Table 7. Summary - shelter characteristics.

Shelter Category	TENOS Overpressure(1) Fatal. (psi)	TENOS Overpressure(1) Casual. (psi)	VNTK CIVIC Approximation(2) Fatal.	VNTK CIVIC Approximation(2) Casual.	CIVIC Prompt Radiation Transmission Factors: Neutron Trans. Factor	CIVIC Prompt Radiation Transmission Factors: Second. Gamma Trans. Factor	CIVIC Prompt Radiation Transmission Factors: Fission Product Gamma Trans. Factor	TENOS and CIVIC Fallout Protection Factor
A	35	25	19PO	17PO	0.01	0.01	0.005	5000
B/C	10	7	12PO	10PO	0.45	0.35	0.075	500
D	10	4	12PO	7PO	0.45	0.35	0.075	30
E/F	8	2	14P6	5P4	0.95	0.60	0.1	55
G/H/I	5	2	11P5	5P4	0.95	0.60	0.1	70
Resid.	5	2	11P5	5P4	0.95	0.60	0.1	5

(1) Overpressure for 50 percent damage probability.

(2) For yields of 1 MT or greater.

function of overpressure data with overpressure as a function of range data for a scaled HOB of 650 feet/KT$^{1/3}$ to obtain distance-damage functions. From these distance-damage functions, values for σ_D were calculated via the approximate relationship

$$\frac{\sigma_D}{1-\sigma_D^2} = \frac{R_{.31}-R_{.69}}{R_{.5}}$$

where the subscripts to the range (R) values indicate the damage probabilities at which the range values are taken.

For all the shelters specified, the damage sigmas resulting from the above expression were equal to or less than .2. Thus, for the purposes of the CIVIC calculations the damage sigmas employed were as shown below.

CIVIC Damage Sigmas

Shelter Category	Blast	Radiation
A - Fatalities	0.1	0.5
- Casualties	0.1	0.5
B/C - Fatalities	0.2	0.5
- Casualties	0.2	0.5
D - Fatalities	0.2	0.5
- Casualties	0.2	0.5
E/F - Fatalities	0.2	0.3
- Casualties	0.2	0.3
G/H/I - Fatalities	0.2	0.2
- Casualties	0.2	0.3
Resid - Fatalities	0.1	0.2
- Casualties	0.1	0.2

SECTION 6

RESULTS AND OBSERVATIONS

The results of four assessment cases are shown in Table 8 for the national summaries and in Tables 9-12 for the state-by-state summaries. Table 13 shows the percent differences between those national assessment cases that contain the methodology differences which were the objective of the study.

Based on the data contained in these tables, the following observations can be made.

a. Comparison of results from the cases CIVIC-1 and CIVIC-2 where in CIVIC-2 a zero CEP was replaced with a nominal CEP of 1500 feet and an area (P-95 circle) rather than point target representation of the population was employed, shows that these two parameters, when employed in conjunction with one another, had no influence on the outcome of the assessment for the weapon laydown employed.

b. Comparison of results from cases CIVIC-1 and CIVIC-3 in which the only differences in CIVIC operation was the use of different fallout models (SEER and WSEG-10), showed a fallout-only fatality difference of nearly 11% with the WSEG-10 model producing the larger fatalities. The combined environment fatality difference was about 9%, which reflects the phenomena that some of the excess WSEG-10 fallout-only fatalities were also prompt fatalities and thus were not counted in the combined calculation.

The fallout fatality difference in this assessment is not as large as those that were produced in other assessment comparisons performed for DNA.[(1)] This is due primarily to the preponderance of very large weapons in the strike file which affected a large part of the population data base to many overlapping fallout fields. This is the typical case for strategic assessments.

[(1)] Swick, E. J., "A Comparison of COBRA, SIDAC, and CIVIC Population Damage Assessment Results", DNA5220F, Science Applications, Inc., Dec. 1979.

Secondarily, at the larger yields, the differences in fallout contours produced by the two fallout models are not as pronounced as they are for the lower yield weapons. In addition, the GWC October wind used in the assessment has the low wind shear characteristics most suited to favorable WSEG-10 comparisons with other models.

c. Comparison of results from cases CIVIC-3 and TENOS basically reflect the influence of the prompt and fallout environment combining methodology in the two codes. As a first approximation, if one adds the difference between the TENOS and CIVIC-3 prompt fatalities to the TENOS combined fatalities, one finds the difference between the TENOS and CIVIC-3 results to be about 11.2% with the CIVIC code giving higher fatalities.

d. The TENOS/CIVIC-1 comparison case in which CIVIC was employed with zero weapon CEP and a point target representation of the population (to be consistent with TENOS methodology), showed national assessment results that were in reasonable agreement. The difference in prompt fatalities was about 4%, and almost all of this difference can be attributed to differences in the shelter damage functions and the prompt damage probability calculations because of the insignificant influence of CEP and target representation parameters noted in (a) above.

The combined environment fatality difference of 6.3% represents differences in three aspects of the assessment; the prompt environment calculations, the differences in the fallout models employed by the two codes, and the methodology for combining the prompt and fallout environments. From paragraphs (b) and (c) above, we note that the fallout model differences (TENOS/WSEG-10 results larger) and the combining methodology differences (CIVIC results larger) are sufficiently counterbalancing in this scenario that the differences between the CIVIC and TENOS assessment results can be considered negligible.

e. As might be expected, the results from the state-by-state summaries show the much wider variations that can be attributed in large part to the differences in fallout models and the extent of fallout area overlapping. The results from two states serve to illustrate this point. The combined fatality difference for the TENOS/CIVIC-1 comparison in the state of Alabama for example, shows a 23.5% difference with the TENOS (WSEG-10) fatalities being higher. On the other hand, for the state of California the difference in combined fatalities is 9.7% with the CIVIC (SEER) fatalities being higher.

For large weapon laydowns, particularly where large yield weapons are involved, one can conclude that differences in code methodology are washed out when looking at national results. However, where specific areas or locations are of interest, particularly as regards constraints that may be employed with certain attack options, significant assessment differences may be observed when using the different methodologies/models employed in CIVIC and TENOS.

Table 8. National total comparisons.

	PROMPT ONLY		FALLOUT ONLY		COMBINED	
	FATALITIES	CASUALTIES	FATALITIES	CASUALTIES	FATALITIES	CASUALTIES
TENOS	74,210,098	-	19,718,868*	-	93,928,966	126,070,390
CIVIC-1	77,209,418	103,697,559	54,126,875	78,826,226	100,275,337	130,169,115
CIVIC-2	77,151,184	103,687,632	54,077,218	78,811,457	100,272,959	130,254,254
CIVIC-3	77,209,18	103,697,559	59,987,640	87,226,995	109,171,111	138,911,476

*Figure reflects fallout fatalities of that population surviving prompt effects, i.e., it is not an independent accounting as are the CIVIC figures.

Table 9. TENOS results.

	PROMPT ONLY		FALLOUT ONLY		COMBINED	
	FATALITIES	CASUALTIES	FATALITIES	CASUALTIES	FATALITIES	CASUALTIES
ALABAMA	820,032	-	1,797,880	-	2,617,912	3,085,395
ARIZONA	355,819	-	418,362	-	774,181	1,128,018
ARKANSAS	266,649	-	1,112,799	-	1,379,448	1,800,436
CALIFORNIA	11,645,653	-	2,918,168	-	14,563,821	16,792,677
COLORADO	629,736	-	128,876	-	758,612	1,190,277
CONNECTICUT	1,348,490	-	450,892	-	1,799,382	2,391,770
DELAWARE	226,973	-	21,866	-	248,839	341,042
WASH. D.C.	650,664	-	442	-	651,106	677,993
FLORIDA	2,922,917	-	170,819	-	3,093,736	4,688,467
GEORGIA	1,234,683	-	1,620,057	-	2,490,740	3,680,936
IDAHO	46,236	-	1,004	-	47,240	88,559
ILLINOIS	5,138,054	-	101,378	-	5,239,432	6,685,963
INDIANA	1,638,872	-	347,274	-	1,986,146	2,832,742
IOWA	548,030	-	108,231	-	656,261	968,944
KANSAS	398,629	-	272,533	-	671,162	1,108,843
KENTUCKY	791,216	-	40,892	-	832,108	1,245,757
LOUISIANA	1,322,490	-	247,719	-	1,570,209	2,278,041
MAINE	133,178	-	103,702	-	236,880	408,253
MARYLAND	2,109,752	-	167,602	-	2,277,354	2,831,801
MASSACHUSETTS	2,613,097	-	497,620	-	3,110,717	4,376,461
MICHIGAN	3,531,020	-	189,219	-	3,720,239	5,061,645
MINNESOTA	1,096,269	-	50,673	-	1,146,942	1,567,982
MISSISSIPPI	283,032	-	1,059,606	-	1,342,638	1,847,676
MISSOURI	1,460,900	-	447,059	-	1,907,959	2,801,916
MONTANA	193,704	-	80,313	-	274,017	331,652
NEBRASKA	189,938	-	95,964	-	285,902	544,076
NEVADA	192,982	-	45,183	-	238,165	382,563
NEW HAMPSHIRE	166,791	-	77,065	-	243,856	390,241
NEW JERSEY	3,557,915	-	688,485	-	4,246,400	5,599,874
NEW MEXICO	218,107	-	96,916	-	315,023	474,319
NEW YORK	7,816,936	-	1,036,054	-	8,852,990	11,289,068
NORTH CAROLINA	929,401	-	322,710	-	1,252,111	2,116,774
NORTH DAKOTA	44,216	-	91,631	-	135,847	201,489
OHIO	3,922,124	-	371,046	-	4,293,170	5,997,226
OKLAHOMA	548,207	-	1,129,705	-	1,677,912	2,078,535
OREGON	645,951	-	16,802	-	662,753	911,889
PENNSYLVANIA	3,324,362	-	1,069,875	-	4,394,237	6,895,693
RHODE ISLAND	554,789	-	113,970	-	668,759	766,995
SOUTH CAROLINA	558,826	-	197,539	-	756,365	1,147,903
SOUTH DAKOTA	39,648	-	111,257	-	147,905	258,564
TENNESSEE	820,838	-	454,980	-	1,275,818	1,923,042
TEXAS	4,695,773	-	534,414	-	5,230,187	7,262,345
UTAH	413,399	-	194,723	-	608,122	704,738
VERMONT	14,833	-	20,942	-	35,775	73,128
VIRGINIA	1,101,275	-	169,543	-	1,270,818	2,258,831
WASHINGTON	1,255,718	-	392,346	-	1,648,064	2,026,494
WEST VIRGINIA	240,630	-	86,185	-	326,815	521,429
WISCONSIN	1,500,278	-	20,797	-	1,521,075	1,930,090
WYOMING	51,068	-	25,750	-	76,381	101,838

Table 10. CIVIC-1 results.

	PROMPT ONLY		FALLOUT ONLY		COMBINED
	FATALITIES	CASUALTIES	FATALITIES	CASUALTIES	FATALITIES
ALABAMA	795,897	1,319,621	1,763,580	2,134,294	2,120,348
ARIZONA	329,903	846,021	600,878	698,307	794,747
ARKANSAS	253,946	485,820	1,134,325	1,376,200	1,228,113
CALIFORNIA	11,996,043	15,065,052	12,875,340	14,278,192	16,121,041
COLORADO	684,671	1,090,937	351,156	605,114	898,841
CONNECTICUT	1,422,515	1,962,246	1,679,484	1,989,259	2,339,518
DELAWARE	237,635	317,196	132,154	256,154	274,074
WASH. D.C.	656,820	676,957	79,273	111,630	659,106
FLORIDA	2,927,842	4,438,752	854,136	1,598,721	3,209,780
GEORGIA	1,254,841	1,861,385	1,607,834	2,443,109	2,490,329
IDAHO	44,086	82,984	20,787	42,126	59,419
ILLINOIS	5,426,443	6,518,194	960,540	2,427,352	5,594,186
INDIANA	1,686,678	2,256,634	845,796	1,459,952	2,211,415
IOWA	567,476	726,885	118,473	338,410	635,866
KANSAS	412,666	667,908	347,054	609,433	657,389
KENTUCKY	811,556	1,082,775	133,528	428,552	888,772
LOUISIANA	1,319,681	1,735,602	787,021	1,290,758	1,390,102
MAINE	143,015	218,843	136,976	302,616	260,291
MARYLAND	2,213,930	2,731,594	1,351,726	1,875,837	2,456,669
MASSACHUSETTS	2,773,730	3,626,664	2,018,802	3,237,913	3,745,852
MICHIGAN	3,744,678	4,841,919	1,438,794	2,525,896	4,155,819
MINNESOTA	1,195,667	1,158,470	426,898	736,213	1,255,260
MISSISSIPPI	277,783	445,463	825,537	1,045,998	991,138
MISSOURI	1,561,775	2,189,924	996,862	1,758,881	2,076,399
MONTANA	201,662	263,501	178,163	220,787	293,728
NEBRASKA	211,577	409,489	137,277	320,734	327,377
NEVADA	184,560	338,353	36,494	75,435	207,243
NEW HAMPSHIRE	171,682	219,689	134,947	296,317	262,512
NEW JERSEY	3,785,351	4,857,820	2,918,010	3,903,742	4,771,905
NEW MEXICO	208,904	371,838	135,042	229,147	267,323
NEW YORK	8,315,513	10,388,945	5,860,325	6,965,505	10,183,501
NORTH CAROLINA	902,555	1,430,717	800,833	1,497,131	1,433,557
NORTH DAKOTA	45,862	81,582	132,031	209,740	159,727
OHIO	4,110,123	5,459,655	1,552,826	2,880,049	4,643,565
OKLAHOMA	548,145	909,338	1,071,856	1,634,335	1,447,511
OREGON	717,956	948,823	247,239	388,065	748,283
PENNSYLVANIA	3,604,941	5,199,745	2,349,138	4,673,506	4,715,979
RHODE ISLAND	579,028	713,411	138,502	376,675	631,648
SOUTH CAROLINA	550,151	801,392	446,938	1,561,869	820,873
SOUTH DAKOTA	43,224	80,719	172,199	332,397	203,119
TENNESSEE	815,347	1,210,333	1,156,365	1,509,121	1,517,422
TEXAS	4,652,127	6,564,203	2,607,532	4,169,953	5,294,592
UTAH	433,797	608,089	487,469	557,084	637,670
VERMONT	18,799	37,357	37,220	81,053	53,640
VIRGINIA	1,134,721	1,912,535	286,116	873,116	1,270,818
WASHINGTON	1,347,267	1,666,937	1,449,400	1,773,060	1,916,113
WEST VIRGINIA	251,223	351,744	92,416	185,971	295,644
WISCONSIN	1,582,357	1,894,339	1,357,789	394,574	1,618,479
WYOMING	53,269	69,159	75,794	118,381	99,468

C-1 results.

...LTIES	COMBINED FATALITIES	COMBINED CASUALTIES
134,294	2,120,348	2,640,293
698,307	794,747	1,129,789
376,200	1,228,113	1,508,493
278,192	16,121,041	17,763,226
605,114	898,841	1,368,908
089,259	2,339,518	2,592,649
56,154	274,074	378,734
11,630	659,106	676,967
98,721	3,209,780	4,903,934
443,109	2,490,329	3,392,458
42,126	59,419	118,918
427,352	5,594,186	6,917,169
459,952	2,211,415	3,043,938
338,410	635,866	890,513
609,433	657,389	1,026,847
428,552	888,772	1,344,555
290,758	1,390,102	1,934,433
02,616	260,291	476,322
75,837	2,456,669	2,983,321
37,913	3,745,852	4,589,517
25,896	4,155,819	5,419,640
36,213	1,255,260	1,660,442
5,998	991,138	1,314,004
8,881	2,076,399	2,938,686
0,787	293,728	352,853
0,724	327,377	631,542
75,435	207,243	396,389
6,317	262,512	402,761
3,742	4,771,905	5,616,921
9,147	267,323	452,502
5,505	10,183,501	12,076,310
7,131	1,433,557	2,354,590
9,740	159,727	240,162
0,049	4,643,565	6,244,564
4,335	1,447,511	2,000,638
8,065	748,283	965,632
73,506	4,715,979	7,059,155
76,675	631,648	754,770
1,869	820,873	1,845,928
2,397	203,119	354,091
9,121	1,517,422	2,081,766
9,953	5,294,592	7,496,987
7,084	637,670	719,061
1,053	53,640	113,290
3,116	1,270,816	2,152,461
3,060	1,916,113	2,251,605
8,971	295,644	426,225
3,574	1,618,479	2,021,818
3,381	99,468	141,316

Table 11. CIVIC-2 results.

PROMPT ONLY		FALLOUT ONLY		COMBINED	
FATALITIES	CASUALTIES	FATALITIES	CASUALTIES	FATALITIES	CASUALTIES
793,597	1,319,860	1,763,580	2,134,294	2,134,294	2,640,367
326,290	845,848	594,638	695,733	788,725	1,129,721
255,633	485,687	1,376,593	1,376,593	1,228,222	1,598,864
11,992,580	15,064,311	12,824,184	14,196,504	16,112,994	17,762,357
684,741	1,090,901	330,687	584,149	897,037	1,367,633
1,419,795	1,960,549	1,679,484	1,989,259	2,337,411	2,591,839
237,646	317,580	132,154	256,814	274,345	379,000
655,589	676,576	79,273	111,630	657,853	676,587
2,922,860	4,438,524	854,136	1,598,721	3,205,009	4,903,787
1,254,667	1,859,348	1,607,834	2,443,109	2,490,311	3,340,695
44,103	82,908	20,778	42,126	59,518	118,844
5,426,334	6,518,462	960,540	2,427,352	5,594,541	6,917,516
1,684,425	2,256,333	845,796	1,459,952	2,209,581	3,043,617
565,121	725,966	118,473	338,410	633,900	889,794
412,866	667,891	358,924	613,005	668,448	1,029,677
813,020	1,082,505	133,528	428,552	890,363	1,344,247
1,317,942	1,735,598	787,021	1,290,758	1,390,243	1,934,245
142,939	218,770	191,709	414,631	308,291	560,831
2,214,345	2,731,771	1,351,726	1,875,837	2,457,031	2,983,413
2,772,640	3,633,322	2,018,802	3,237,913	3,744,039	4,594,896
3,739,713	4,829,629	1,438,794	2,525,896	4,151,691	5,416,856
1,197,117	1,518,872	426,898	736,213	1,256,732	1,660,770
276,764	445,150	825,537	1,045,998	990,197	1,313,702
1,561,896	2,190,212	996,862	1,758,881	2,076,745	2,939,116
200,338	262,737	172,878	218,104	292,105	352,075
212,068	409,493	139,926	320,560	330,721	631,833
182,367	338,255	35,200	73,028	205,195	396,281
170,804	219,567	134,947	296,317	261,676	402,525
3,784,759	4,859,054	2,918,010	3,903,742	4,770,827	5,617,008
209,488	371,723	128,537	217,040	266,713	452,387
8,309,876	10,391,288	5,860,325	6,965,505	10,177,307	12,078,231
898,198	1,428,682	800,833	1,497,131	1,430,011	2,353,106
45,786	81,568	131,559	209,471	159,488	240,114
4,105,583	5,458,490	1,552,826	2,880,049	4,639,928	6,243,592
546,514	908,834	1,075,661	1,644,906	1,450,211	2,010,175
719,750	948,687	247,133	388,032	749,997	965,484
3,062,592	5,197,608	2,349,138	4,673,506	4,712,878	7,056,347
577,606	713,091	138,502	376,675	630,276	754,445
548,717	801,105	446,938	1,561,869	819,721	1,845,892
42,734	80,631	171,404	332,107	201,966	354,293
814,896	1,209,317	1,156,365	1,509,121	1,515,807	2,080,921
4,653,103	6,562,382	2,588,718	4,168,286	5,292,955	7,497,012
433,331	608,412	483,329	551,617	636,673	719,586
18,586	37,205	37,220	81,053	53,470	113,151
1,133,594	1,911,784	286,116	873,018	1,208,943	2,151,767
1,348,063	1,865,858	1,444,139	1,762,292	1,915,539	2,250,136
250,748	351,354	92,416	185,971	295,147	425,892
1,576,002	1,894,847	135,789	394,574	1,612,375	2,022,357
53,058	69,087	73,626	118,153	98,651	141,270

Table 12. CIVIC-3 results.

PROMPT ONLY		FALLOUT ONLY		COMBINED	
FATALITIES	CASUALTIES	FATALITIES	CASUALTIES	FATALITIES	CASUALTIES
795,897	1,319,621	1,983,986	2,400,955	2,402,997	2,878,498
329,903	846,021	599,457	737,597	786,425	1,133,202
253,946	485,820	1,150,389	1,299,600	1,275,615	1,521,635
11,996,043	15,065,052	11,754,942	13,123,299	15,311,897	16,974,529
684,671	1,090,937	337,937	532,231	933,145	1,356,137
1,422,515	1,962,246	1,848,876	2,071,323	2,456,162	2,657,689
237,635	317,196	196,791	259,770	323,711	384,523
656,820	676,957	4,936	77,852	656,838	676,958
2,927,842	4,438,752	3,381,242	6,081,504	5,029,977	7,410,704
1,254,841	1,861,385	1,339,620	1,913,467	2,266,755	3,106,721
44,086	82,984	21,389	42,468	60,507	119,260
5,426,443	6,518,194	736,882	2,485,112	5,651,543	6,966,590
1,686,678	2,256,634	1,150,696	1,919,828	2,473,951	3,337,109
567,476	726,885	159,697	380,802	670,192	939,141
412,666	667,908	537,309	891,837	876,710	1,334,596
811,556	1,082,775	405,118	799,473	1,090,608	1,585,102
1,319,681	1,735,602	2,114,879	2,809,161	2,601,666	3,200,554
143,015	218,843	251,235	507,840	376,030	667,573
2,213,930	2,731,594	911,916	1,445,206	2,496,816	2,988,863
2,773,730	3,626,664	3,003,504	3,586,855	4,324,267	4,785,663
3,744,678	4,841,919	973,431	2,002,690	4,126,364	5,338,026
1,195,667	1,518,470	245,149	489,505	1,303,779	1,660,692
277,783	445,463	1,171,684	1,452,903	1,293,345	1,621,137
1,561,775	2,189,924	819,108	1,441,808	2,156,451	2,921,560
201,662	263,501	174,240	196,496	294,855	340,704
211,577	409,489	512,010	746,680	649,721	919,953
184,560	338,353	147,877	168,729	259,129	431,637
171,682	219,689	203,990	337,572	344,822	465,863
3,785,351	4,857,820	2,534,057	4,018,287	4,982,175	5,864,067
208,904	371,838	240,409	306,307	362,656	496,432
8,315,513	10,388,945	5,734,655	7,707,094	10,808,697	12,949,890
902,555	1,430,717	792,627	1,538,120	1,494,180	2,440,204
45,862	81,582	130,073	202,505	164,080	240,507
4,110,123	5,459,655	1,718,236	3,217,700	4,830,205	6,579,404
548,145	909,338	1,312,404	1,620,050	1,700,017	2,132,748
717,956	948,823	218,971	358,889	772,239	976,957
3,604,941	5,199,745	2,241,187	4,605,991	4,974,245	7,421,376
579,028	713,411	359,179	471,860	719,831	748,099
550,151	801,392	142,767	485,762	632,804	1,093,860
43,224	80,719	287,309	366,933	306,511	384,409
815,347	1,210,333	869,280	1,421,652	1,297,165	1,922,808
4,652,127	6,564,203	4,704,302	6,451,038	7,529,974	9,573,293
433,797	608,089	489,055	556,513	650,094	725,175
18,799	37,357	52,460	111,823	69,977	142,249
1,134,721	1,912,535	363,742	1,002,437	1,313,534	2,457,001
1,347,267	1,866,937	1,258,124	1,633,554	1,879,608	2,200,706
251,223	351,744	184,808	434,301	378,131	643,898
1,582,357	1,894,339	95,107	390,747	1,636,873	2,013,673
53,269	69,159	94,006	122,869	118,669	143,896

Table 13. % differences in assessment cases.

Comparison	Prompt Only		Fallout Only		Combined	
	Fatalities	Casualties	Fatalities	Casualties	Fatalities	Casualties
CIVIC-1/CIVIC-2 (1) (CIVIC-2 Reference)	+.08%	+.01%	+.09%	+.02%	~0%	-.07%
CIVIC-1/CIVIC-3 (2) (CIVIC-1 Reference)	0%	0%	+10.8%	+10.7%	+8.9%	+6.7%
CIVIC-3/TENOS (3) (CIVIC-3 Reference)	-3.9%	-	-	-	-14%	-9.2%
CIVIC-1/TENOS (CIVIC-1 Reference)	-3.9%	-	-	-	-6.3%	-3.1%

(1) Influence of CEP and point or area population representation

(2) Influence of fallout models only

(3) Influence of methodology for combining prompt and fallout effects

SECTION 7

GLOSSARY

AFRRI - Armed Forces Radiological Research Institute.

CCTC - Command and Control Technical Center.

CIVIC - A computer code that estimates civilian fatalities and casualties due to the employment of nuclear weapons. Both prompt and fallout effects can be taken into account in the estimates. Development sponsored by the Defense Nuclear Agency (DNA).

FEMA - Federal Emergency Management Agency.

FPA - Federal Protection Agency.

GWC - Global Weather Center.

MCOP - Mean Casualty blast Overpressure Vulnerability expressed in pounds per square inch.

MLOP - Mean Lethal blast Overpressure Vulnerability expressed in pounds per square inch.

PF - Protection Factor. A factor which accounts for the fallout radiation protection afforded by various structure types. When the free-field fallout radiation dose is divided by this factor, the resulting dose is the dose to which people within the structure may be subjected.

TENOS - A computer code developed by the Federal Emergency Management Agency (FEMA) to estimate fatalities and casualties due to the employment of nuclear weapons. Both prompt and fallout effects can be taken into account in the estimates.

WSEG-10 - A fallout model developed by the Institute for Defense Analysis for the Weapon Systems Evaluation Group.

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APPENDIX A

CIVIC INPUT OPTIONS

For the calculation of prompt effects damage probabilities, three distributions are normally employed; the damage function distribution (normally a log-normal distribution), the weapon impact point distribution (circular normal), and the population distribution within a circle of specified radius (circular normal). The last two distributions are combined into one for the purposes of the damage calculation and are represented by an "Adjusted Circular Error Probable" (CEP_A). Mathematically, CEP_A is represented by

$$CEP_A = \left[CEP^2 + \frac{\ell n\ 2}{\ell n\ 20} (\text{Target Radius} * 6076.1155)^2\right]^{1/2}$$

$$= \left[CEP^2 + 8{,}542{,}294 * TR^2\right]^{1/2}$$

The "$\ell n\ 2/\ell n\ 20$" term converts the 95th percentile of the target distribution to the 50th percentile used for CEP. The factor "6076.1155" converts nautical miles (units normally used for target radius) to feet.

In CIVIC, input run-stream option flags are available to permit the calculation of CEP_A with either CEP = 0, target radius = 0, or both.

The reason for these options is to be able to vary the damage calculations without having to modify either the weapon strike file which contains the CEP as a unique entity, or the population data base which contains the target radius as a unique entity.

For the purposes of fallout calculations, CIVIC contains two fallout models; SEER and WSEG-10. Either of these options can be selected at the discretion of the user simply by setting the appropriate flag in the input run-stream.

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