Appendix A

Consequence Assessment Models

General Characteristics		
1	**Abstract of Model Capabilities**	The Air Force Dispersion Assessment Model (ADAM) was developed so that the U.S. Air Force could calculate the source emissions rate and transport and dispersion of accidental releases of eight specific chemicals: Chlorine, fluorine, nitrogen tetroxide, hydrogen sulfide, hydrogen fluoride, sulfur dioxide, phosgene, and ammonia. Release scenarios include continuous and instantaneous, area and point, pressurized and unpressurized, and liquid/vapor/two-phase options. Dispersion is calculated for ground-based jets or for ground-level area sources for neutrally buoyant and negatively buoyant clouds. The model accounts for chemical reactions and phase changes.
2	**Sponsor and/or Developing Organization**	AL/EQS, Tyndall AFB, FL TMS, Burlington, MA
3	**Last Custodian/ Point of Contact**	Sponsor AL/EQS 139 Barnes Drive Tyndall AFB, FL 32403-5319 (904) 283-6002 Developer Dr. Phani Raj, TMS, Inc., 99 South Bedford St., Suite 211 Burlington, MA 01803-5128 (617) 272-3033 The source code and executable programs for ADAM can be accessed on EPA's SCRAM Web Site at http://www.epa.gov/scram0001/. (executable file is adam.zip, 277Kb, zipped).
4	**Life-Cycle**	ADAM was first developed for the USAF by TMS in the mid-1980s. In the late 1980s, the model was expanded so that it would better handle HF and fluorine. In 1991–1992, the USAF technical project monitor, Bruce Kunkel, debugged the code and modified some sections so that it would be more robust, and carried out many sensitivity studies.
5	**Model Description Summary**	ADAM is the most comprehensive of the publicly available models, in the sense that it treats a wide spectrum of source emission conditions (e.g., pressurized tank ruptures, liquid spills, liquid/vapor/two-phase) and also treats a variety of dispersion conditions (e.g., ground-based jets or ground-level area sources, all types of relative cloud densities, chemical reactions and phase changes, dense gas slumping). The code is restricted to eight chemicals of interest to the USAF. The formulas have been designed so that ADAM reduces to AFTOX for neutrally dense (i.e., passive) clouds.
6	**Application Limitation**	ADAM is limited to eight chemicals (see number 1) and cannot be used for other chemicals without modifying the source code. For a horizontal jet release, the model always assumes that the jet is ground-based, even though the user needs to provide the jet elevation information. ADAM does not treat the vertical component of the jet trajectory.
7	**Strengths/ Limitations**	**Strengths:** ADAM treats a wide variety of source conditions and accounts for the effects of dense gases, chemical reactions, and latent heat exchanges. It reduces to AFTOX for non-buoyant clouds. **Limitations:** ADAM can be applied to only eight chemicals. The 1990 version had many bugs, although Kunkel (1992) has corrected the bugs as part of his evaluations and sensitivity studies.
8	**Model References**	! Raj, P.K. and J.A. Morris, 1987: Source Characterization and Heavy Gas Dispersion Models for Reactive Chemicals. AFGL-TR-88-0003(I), AFGL/AFSC, USAF, Hanscom AFB, MA 01731-5000. ! Raj, P. K., 1990: Hydrogen Fluoride and Fluorine Dispersion Models Integration into ADAM. GL-TR-90-0321(I), GL/AFSC, USAF, Hanscom AFB, MA 01731-5000. ! Mullett, C. and P.K. Raj, 1990: A User's Manual for ADAM. GL-TR-90-0321(II). GL/AFSC, USAF, Hanscom AFB, MA 01731-5000. ! Kunkel, B.A., 1992: A Review and Evaluation of the ADAM 2.1 Dispersion Model. PL-TR-92-2245. PL/DG/AFMC, USAF, Hanscom AFB, MA 01731-5000.

9	**Input Data/Parameter Requirements**	In order to make a model run, the user must specify chemical information, release information, ground conditions, atmospheric conditions, release site and time information, and output options. ADAM treats only eight chemicals, namely ammonia, chlorine, fluorine, hydrogen sulfide, hydrogen fluoride, nitrogen tetroxide, phosgene, and sulfur dioxide. Properties of those chemicals are stored in a database and therefore need not be provided by the user. The user can either directly specify the source strength, or instruct ADAM to calculate the source strength based on information such as pipe diameter, pipe length, and storage pressure. By default, ADAM determines atmospheric stability using Golder's nomogram, based on the surface roughness specified by the user and the Monin-Obukhov length internally calculated by the model. If the standard deviation of wind direction is known and is provided as an input, ADAM will use it to determine atmospheric stability. The user has the option of providing an additional data file containing wind direction (but not wind speed) as a function of time in order to simulate the effects of variable wind direction. Up to 100 data points for wind direction can be entered. ADAM does not impose any limit on the time resolution for these time-varying wind direction data. However, it is recommended that the time interval between successive wind directions should be around 10 minutes or longer, since the effect of varying wind directions over a shorter time period has been parameterized through the lateral dispersion coefficient, s_y.
10	**Output Summary**	In addition to displaying a contour plot of the results for a default concentration value assumed by the model on the computer screen (but which can be changed by the user if necessary), ADAM also creates a summary output file which includes downwind distributions of the maximum predicted concentration, the cloud width, the cloud travel time, and the cloud advective speed. The information used to create contour plots on the screen is also saved in a separate output file, so that the plots can be regenerated at a later time.
11	**Applications**	See the references under number 8 for examples of applications and evaluations with field data. Also see Hanna et al. (1991), for evaluations of ADAM and 13 other models with the Goldfish hydrogen fluoride field tests and the Desert Tortoise ammonia field tests.
12	**User-Friendliness**	The ADAM model has a graphical user interface (GUI). The user moves through a series of menus or panels to define the scenario. After calculations are completed, the model then displays a contour plot on the computer screen. The plot shows the area where predicted concentrations exceed a toxic limit.
13	**Hardware-Software Interface Constraints/ Requirements**	**Computer operating system:** The model runs in the MS-DOS environment, PC (486 or better). **Computer platform:** **Disk space requirements:** It requires at least 2.5 megabytes of disk space. **Run execution time** (for a typical problem)**:** **Programming language:** The computational part of the ADAM model is written in standard FORTRAN. The graphical user interface is written in FORTRAN, but with calls to the proprietary HISCREEN graphics library routines, which are specific to the FORTRAN compiler and computer hardware. **Other computer peripheral information:**
14	**Operational Parameters**	**Identify whether the code has any error diagnostic messages to assist the user in troubleshooting operational problems:** The ADAM model validates the input parameters that the user specifies through the GUI. A value that is out of range will be flagged and the user is requested to enter that value again. The model has limited run-time error diagnostics. **Set up time for:** Requires only minimal set-up time. After the model files are copied onto a computer's hard disk, the user needs to specify the type of display monitor and printer. Batch mode Capability (several cases at once). Due to its graphical user interface (GUI), the ADAM model cannot be run in batch mode, at least not in straightforward manner.
15	**Surety Considerations**	**All quality assurance documentation:** The ADAM model has been reviewed by the U.S. Air Force (Kunkel 1992). The model is known to converge to the U.S. Air Force's AFTOX model for passive releases. **Benchmark runs:** See Kunkel (1992) for comparisons with AFTOX, and Hanna et al. (1991) for comparisons with 13 other models. **Validation calculations:** **Verification with field experiments that has been performed with respect to this code:** The original references include many examples of comparisons with field experiments (see number 8 above). The paper by Hanna et al. (1991) evaluates ADAM with the Desert Tortoise ammonia and the Goldfish hydrogen fluoride field experiments. Performance is reasonably good in all case, showing agreement with data as good as the best of the available models.
16	**Runtime Characteristics**	Run execution time for typical problem (CPU or Real Time) – The model takes only a few seconds to run on a Pentium PC for a typical scenario.

Specific Characteristics		
Part A: Source Term Submodel Type		
A1	**Source Term Algorithm?**	_✔_YES __NO
A2	**For Chemical Consequence Assessment Models**	**Liquid spill: _✔_ pool evaporation __ particulate resuspension** The Ille and Springer evaporation model is used. The area equals the diked area or the equilibrium area calculated by a pool-spreading formulation.
A2	**For Chemical Consequence Assessment Models (Cont.)**	**Pressurized releases:_✔_ two-phase jets_✔_ flashing_✔_ entrainment_✔_ aerosol formation** The thermodynamics of two-phase jets is accounted for. All unflashed liquid is assumed to remain in the cloud as an aerosol (i.e., no rain-out). Entrainment factor for a turbulent jet = 0.065. The fraction of aerosol is calculated in the flashing module. No rain-out occurs. **Solid spills: __ resuspension __ sublimation**
Part B: Dispersion Submodel Type		
B1	**Gaussian**	**_✔_Straight-line plume __Segmented plume __ Statistical plume __ Statistical puff**
B2	**Similarity**	**__ Plume _✔_ Puff**
Part C: Transport Submodel Type		
C2	**Deterministic**	ADAM is a deterministic model.
C4	**Frame of Reference**	**_✔_ Eulerian __ Lagrangian __ Hybrid __ Eulerian-Lagrangian**
Part D: Fire Submodel Type (Not Applicable)		
Part E: Energetic Events Submodel Type (Not Applicable)		
Part F: Health Consequence Submodel Type		
F1	**For Chemical Consequence Assessment Models**	**Health effects: __ fatalities __ cancers __ latent cancers __ symptom onset** **Health criteria** **__ IDLH __ STEL __ TLV __ TWA** **__ ERPG __ TEEL __ AEGL __ WHO** **Zones with flammable limits: _✔_ UFL _✔_ LFL** **Blast overpressure regions:** **Fire radiant energy zones:** **Risk qualification:** **Concentration: _✔_ single value __ time-history __ integrated dose** **Probits:** Probits are used to compute the probability of a particular health consequence (e.g., fatality). Expressed as chemical specific probability units computed with a logarithmic probit equation.
Part G: Effects and Countermeasures Submodel Type (No Information Provided.)		
Part H: Physical Features of Model		
H2	**Release Elevation**	**_✔_ ground _✔_ roof**
H4	**Horizontal Plume Meander**	Yes
H5	**Horizontal/Vertical Wind Shear:**	Yes
H7	**Cloud Buoyancy**	**_✔_ neutral [passive] _✔_ dense [negative] _✔_ plume rise [positive]**
H8	**Cloud Liquid Droplet Formation/ Aerosolization**	Yes
H9	**(Radio)chemical Transformation and In-Cloud Conversion Processes**	Yes

Part I: Model Input Requirements		
I1	**Radio(chemical) and Weapon Release Parameters**	**Release rate: _✔_ Continuous _✔_ Time dependent_✔ Instantaneous** **Release container characteristics: _✔_ vapor temperature** **_✔_ tank diameter** **_✔_ tank height _✔_ tank temperature _✔_ tank pressure_✔ nozzle diameter** **_✔_ pipe length** **Jet release: _✔_ initial size __ shape** **__ concentration profile at end of jet affected zone** **Release dimensions: _✔_ point __ line _✔_ area** **Release elevation: _✔_ ground _ roof _ stack**
I2	**Meteorological Parameters**	**Wind speed and wind direction: _✔single point __ single tower/multiple point __ multiple towers** **Temperature: _✔_ single point __ single tower/multiple point _✔_ multiple towers** See above. **Dew point temperature: _✔_ single point __ single tower/multiple point _✔_ multiple towers** **Precipitation: _✔_ single point __ single tower/multiple point __ multiple towers** **Turbulence typing parameters: __ temperature difference _✔_ sigma theta** **__ sigma phi __ Monin-Obukhov length __ roughness length** **__ cloud cover __ incoming solar radiation _✔_ user-specified** **Four dimensional meteorological fields from prognostic model:** See above.
Part J: Model Output Capabilities		
J1	**Hazard Zone**	Concentrations are output as a function of downwind distance in a table. The area of a hazard zone is also calculated and displayed on the computer screen. Does not explicitly give concentrations at off-ceterline receptors. Computes the exposure area of the hazard zone from the specified toxic endpoint concentration value.
J2	**Graphic Contours and Resolution**	Yes
J4	**Tabular at Fixed Downwind Locations**	Yes
Part K: Model Usage Considerations (No Information Provided.)		