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INFORMAL REPORT



# COMPUTER MODELS USED TO SUPPORT CLEANUP DECISION-MAKING AT HAZARDOUS AND RADIOACTIVE WASTE SITES

P.D. Moskowitz, R. Pardi, M.P. DePhillips and A.F. Meinhold

July, 1992

Prepared for:

Office of Radiation Programs
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Washington, DC 20460

Office of Environmental Restoration
U.S. Department of Energy
Washington, DC 20585

Office of Nuclear Material Safety and Safeguards
Nuclear Regulatory Commission
Washington, DC 20555

BIOMEDICAL AND ENVIRONMENTAL ASSESSMENT GROUP
ANALYTICAL SCIENCES DIVISION

## DISCLAIMER

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ANALYTICAL SCIENCES DIVISION
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

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# SURVEY QUESTIONNAIRE

*The following document is the result of a mail survey using a questionnaire similar to the one presented below. Without periodic update, due to new and expanding modeling efforts, this document may soon be obsolete. Therefore, in order to keep this living document a constant source of pertinent information it is important that we receive any additional information regarding models used in the field. Please advise us of any additional models, updated versions and/or novel applications. If you can furnish the authors with any of this information or have any comments regarding the accuracy of the information contained herein, please take the time to complete this survey.*

**RADIOLOGIC AND NONRADIOLOGIC ENVIRONMENTAL TRANSFER/PATHWAY**
**COMPUTER MODELING ACTIVITIES**

Name of Respondent: Title:

Organization:

Street

City: State: Zip Code:

Telephone (Commercial)

Site type (E.G., EPA Superfund, DOE Defense, NRC Commercial Nuclear Facilities):

Media impacted (i.e., groundwater, surface water, soils, or structures):

Name of Code (e.g., PRESTO) implemented and literature reference:

Code prepared by:

Code prepared for:

Status of modeling efforts (planned, ongoing, or completed):

Radioisotopes and nonradiologic contaminants evaluated:

End-points evaluated (e.g., environmental concentration, dose commitment):

Level-of-effort expended or planned (man-months):

Have you conducted any site-specific model calibration/validation efforts: If so please briefly describe the nature of these efforts:

Have the results of these modeling and calibration/validation efforts been published? If so where?

Other comments:

======================RETURN TO=====================

________________________

________________________

________________________

________________________

**Paul D. Moskowitz**
**Environmental Health Scientist**
**Biomedical and Environmental Assessment Group**
**Building 475**
**Brookhaven National Laboratory**
**Upton, New York 11973**

# ABSTRACT

Massive efforts are underway to cleanup hazardous and radioactive waste sites located throughout the U.S. To help determine cleanup priorities, computer models are being used to characterize the source, transport, fate and effects of hazardous chemicals and radioactive materials found at these sites. Although, the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), and the U.S. Nuclear Regulatory Commission (NRC) have provided preliminary guidance to promote the use of computer models for remediation purposes, no Agency has produced directed guidance on models that must be used in these efforts. As a result, model selection is currently done on an *ad hoc* basis. This is administratively ineffective and costly, and can also result in technically inconsistent decision-making. To identify what models are actually being used to support decision-making at hazardous and radioactive waste sites, a project jointly funded by EPA, DOE and NRC was initiated. The purpose of this project was to: 1) Identify models being used for hazardous and radioactive waste site assessment purposes; and 2) describe and classify these models. This report presents the results of this study. A mail survey was conducted to identify models in use. The survey was sent to ~550 persons engaged in the cleanup of hazardous and radioactive waste sites; 87 individuals responded. They represented organizations including Federal Agencies, national laboratories and contractor organizations. The respondents identified 127 computer models that were being used to help support cleanup decision-making. There were a few models that appeared to be used across a large number of sites (e.g., RESRAD). In contrast, the survey results also suggested that most sites were using models which were not reported in use elsewhere. Information is presented on the types of models being used and the characteristics of the models in use. Also shown is a list of models available, but not identified in the survey itself.

ACKNOWLEDGMENT

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EPA Office of Radiation Programs (ORP)
EPA Office of Solid Waste and Emergency Response (OSWER)
DOE Office of Environmental Restoration and Waste management (EM)
NRC Office of Nuclear Material Safety and Safeguards (ONMSS)

The project Steering Committee for this effort includes:

EPA

Beverly Garcia Frias, EPA/ORP Work Assignment Manager
Lynn Deering, EPA/OSWER
Kung-Wei Yeh, EPA/ORP

DOE

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Paul Beam, DOE/EM

NRC

John Austin, NRC/ONMSS
Harvey Spiro, NRC/ONMSS
Michael Weber, NRC/ONMSS

Consultants and Contractors

Paul D. Moskowitz and Richard R. Pardi, Brookhaven National Laboratory
John Mauro, S. Cohen & Associates, Inc.
Jim Rumbaugh, III, Geraghty & Miller, Inc.
David Back, Hyrogeologic, Inc.

We acknowledge the technical support provided by these organization and individuals. We also thank all survey respondents who helped make this report possible.

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TABLES



FIGURES

# 1. INTRODUCTION

Massive efforts are underway to cleanup hazardous and radioactive wastes found at contaminated sites throughout the U.S. [e.g., U.S. Environmental Protection Agency (EPA) Superfund Sites and the Nuclear Regulatory Commission (NRC) decommissioning sites.] The nature and extent of cleanup to be accomplished at many of these sites will be based on initial studies [e.g., Remedial Investigation/Feasibility Studies (RI/FS)] resulting from formally or informally negotiated agreements between the site and the governing Agency. In these evaluations, models (e.g., computerized environmental pathway or engineering) are often used to characterize the source, transport, fate and effects of hazardous chemicals and radioactive materials identified at the sites. The models may also be used to characterize benefits of alternative remediation options.

The EPA (e.g., USEPA, 1988, 1989a, 1989b), the U.S. Department of Energy (DOE) (e.g., Case et.al., 1989) and NRC (e.g., Kozak, 1989, 1990a, 1990b) have begun preliminary efforts to promote the consistent use of models for site evaluation purposes at Superfund hazardous waste sites and low-level radioactive waste repository sites, respectively. No Agency, however, has published specific, standard protocols to be used as guidance for the selection of models to be used at these or NRC decommissioning sites. Further, no Agency has produced lists of "certified" models for selected applications (e.g., uranium in ground water). As a result, model selection by site Remedial Project Managers (RPMs), their equivalent, is done on an *ad hoc* basis. Because of this, RI/FS-type efforts with similar problems can be based on different models with different outcomes. Some of the selected models are well known and have been subjected to wide-spread critical review. Others have been developed for site-specific applications and have not received outside evaluation. Consequently, Agency review of model choice and validity of the results must be done on a site-by-site basis. This is administratively ineffective and costly, and can result in inconsistent decision-making.

To assist EPA, DOE, NRC and site-level personnel (e.g., On-Scene Coordinators or RPMs) select appropriate models for RI/FS-type studies and administrators to review these submissions, this report: Identifies, through the use of a mail survey and a literature review, models being used for hazardous and radioactive waste assessment purposes at EPA Superfund, DOE, NRC and other hazardous and radioactive waste sites; and, describes and classifies these models according to their basic characteristics.

## 2. THE SURVEY

A mail survey was conducted to identify radiologic and nonradiologic environmental transfer or pathway computer models which have been used or are being used to support the cleanup of hazardous and radioactive waste sites. The intent of the survey was to gather basic administrative and technical information on the extent and type of modeling efforts being conducted at EPA, DOE, NRC and other hazardous and radioactive waste sites, and to identify a point of contact for further follow-up. The survey questionnaire is shown in Table 1.

The survey was conducted in two phases: The first in the Spring of 1990; and, the second in the Summer of 1991. Mailing lists were developed by compiling names and addresses provided by EPA, DOE and NRC staff, and selecting names from various technical reports. The lists included representatives from the three sponsoring Agencies, national laboratories, universities and consulting engineering firms. The first questionnaire was mailed to ~350 persons; the second questionnaire was sent to an additional ~200 persons.

Although the questionnaire received widespread distribution, we know that some important organizations (e.g., U.S Geological Survey) or personnel engaged in modeling at hazardous and radioactive waste sites were not contacted. Also, because respondents were asked to participate in this effort on a voluntary basis, it possible that other ongoing modeling efforts were not reported. The survey, however, attempted to develop a "snapshot"

Table 1. Mail Survey Questionnaire

## RADIOLOGIC AND NONRADIOLOGIC ENVIRONMENTAL TRANSFER/PATHWAY COMPUTER MODELING ACTIVITIES AT EPA/DOE/NRC SITES

Prepared for

Office of Radiation Programs
U.S. Environmental Protection Agency

Office of Environmental Restoration and Waste Management
U. S. Department of Energy

Office of Nuclear Material Safety and Safeguards
U. S. Nuclear Regulatory Commission

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Name of Respondent: Title:

Organization:

Street:

City: State: Zip Code:

Telephone (Commercial):

Site type (e.g., EPA SUPERFUND, DOE Defense, NRC Commercial Nuclear Facilities):

Media impacted (i.e., groundwater, surface water, soils, or structures):

Name of code (e.g., PRESTO) implemented:

Code prepared by:

Code prepared for:

Status of modeling efforts (planned, ongoing, or completed):

Radioisotopes and nonradiologic contaminants evaluated:

End-points evaluated (e.g., environmental concentration, dose commitment):

Level-of-effort expended or planned (man-months):

Have you conducted any site-specific model calibration/validation efforts: If so, please briefly describe the nature of these efforts:

Have the results of these modeling and calibration/validation efforts been published? If so, where:

Other comments:

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PLEASE RETURN COMPLETED QUESTIONNAIRE TO:


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Upton, New York 11973
(516 282-2017) (FTS 666-2017)

perspective of a dynamic, rapidly changing community of sites, models, and responsible parties (e.g., modelers and RPMs). In this context, we believe the list of respondents and models identified should be illustrative of those involved in the cleanup of hazardous and radioactive waste sites.

## 3. MODEL CLASSIFICATION SCHEME

While the survey was being conducted, we concluded early-on that a classification scheme would be needed to organize the discussions on modeling capabilities due to their wide range of focus. One way to classify models is according to their major purpose (e.g., environmental transport, accidents etc.). Another common way to classify models is by the environmental media they simulate (e.g., air, soil, surface water or ground water). Models could also be broken down into those groups which simulate only the physical transport of a contaminant through air, soil or water; and those which follow the contaminant through the food chain to man, producing estimates of dose or risk. A classification scheme based on a combination of these categories is used here.

The major categories used in this report are:

1. Multi-Media;
2. Air;
3. Surface Water;
4. Ground Water;
5. Aqueous Geochemistry;
6. Engineering/Performance/Accident;
7. Radiation Dose;
8. Utilities (Model Support Software).

The first four classes of models are concerned with the transport and fate of hazardous and radioactive materials in the environment. In the first class, Multi-Media models, some attempt is made to integrate several possible media (e.g., air, ground water, food chain, etc.) into one simulation. Subclasses within the first group include Hazard Ranking, Radioactive Fate and Transport, General Purpose and Food Chain. Hazard Ranking models rank waste sites based on the risks they may present to the public; the numbers produced by these models are used relative to each other, and are not used to estimate risk at individual facilities. In contrast, Radioactive Materials Fate and Transport, and General Purpose models provide an estimate of the environmental transport, exposure and risk presented by releases of radioactive materials or other types of pollutants, respectively.

Transport models predict the physical movement of contaminants through one media (e.g., air, surface water and ground water). Air models sometimes include consideration of other pathways (e.g., soil deposition and agricultural uptake). Similarly, many surface water models evaluate unsaturated-zone transport of water. This report, however, groups models as air, surface or ground water on the basis of their primary focus, rather than their potential applications or ancillary use.

The other four classes of models are used for more-specific purposes. Aqueous Geochemical and Hydrogeochemical models attempt to establish the relative abundance or concentration of various contaminant species. Geochemical models are often used to predict whether a given dissolved pollutant will be precipitated during transport in a stream or ground water; or conversely, whether a solid pollutant might be dissolved under certain aqueous conditions.

The group of models classified as Engineering/Performance/Accident models evaluate safety and the potential for contaminant transport based on an analysis of human-engineered structures. Engineering models calculate volumes, slopes or stresses of engineered or natural structures. Accident models estimate the transport and ultimate effects of radionuclides released during an accident in a nuclear reactor. Performance models assess the capability of engineered structures meant to isolate waste from the environment; models designed to assess the risk associated with releases from landfills and other engineered facilities; and models used to estimate the levels of contaminants that can remain after cleanup based on environmental transport and risk information.

Radiation dose models determine the amount of shielding needed in a radiation area, or calculate radiation dose from radioactive substances transported through the environment as established by the use of other transport models. The last category, Utilities, includes software which supports or enhances the use of the aforementioned classes of models.

## 4. SURVEY RESULTS

### 4.1 Responses

A total of 87 individuals responded; 61 in Phase 1, and 28 in Phase 2 (two individuals responded to both surveys). The persons and organizations responding to the survey are listed in Table 2, along with the models identified by each respondent. Model application responses were received from individuals, both modelers and division heads supervising a group of modelers, representing 38 different companies, facilities or Agency Offices. In total, these respondents identified 127 different models.

Some of the organizations responding to the survey are DOE National Laboratories with strong research and development programs; and, a few of the models identified were developed by the respondents and applied at other sites. To the extent allowed by the information provided in the questionnaire, these development responses are not included in the analysis of the survey responses. The information provided, however, has been used in preparing Appendix A which gives a brief description of each of the models identified in the survey, including the sponsoring agency, a description of the model, and relevant references.

TABLE 2 – Administrative Data and Models Used

| Count | Name | Organization | Street Address | City | State | Zip | Telephone | Models Used |
|---|---|---|---|---|---|---|---|---|
| 1 | David Abbot | EG&G Mound Applied Tech. | P.O. Box 3000 | Miamisburg | OH | 45343 | 513–865–3936 | NUREG–0707 |
| 2 | Peter F. Anderson | GeoTrans, Inc | 46050 Manekin Plaza | Sterling | VA | 22170 | | FTWORK |
| 3 | Richard W. Arnseth | Science Applications Inte | 301 Laboratory Rd. | Oak Ridge | TN | 37830 | | MODFLOW/MOC |
| 4 | Burton R. Baldwin | EG&G Idaho | P.O. Box 1625 | Idaho Falls | ID | 83415 | 208–526–4231 | RSAC |
| 5 | Marcel P. Bergeron | Pacific Northwest Lab | P.O. Box 999, MS K6–77 | Richland | WA | 99352 | 509–376–8410 | CFEST |
| 6 | B.G. Blaylock | Oak Ridge National Lab | P.O. Box 2008 | Oak Ridge | TN | 37831 | 615–576–2118 | AIRDOS–EPA |
| 7 | William C. Borden | Bechtel National, Inc. | P.O. Box 350 | Oak Ridge | TN | 37831 | 615–482–0347 | RESRAD |
| 8 | L.S. Cahn | UNC Geotech | P.O. Box 14000 | Grand Junction | CO | 81502 | 303–248–6563 | GW Flow Model RESRAD |
| 9 | Daniel G. Carfagno | EG&G/mound applied Techno | P.O. Box 3000 | Miamisburg | OH | 45343 | | RESRAD |
| 10 | Dennis J. Carr | Feed Materials Prod Ctr | P.O. Box 398704 | Cincinnati | OH | 45239 | 513–738–6200 | SWIFT III |
| 11 | Young–Soo Chang | Argonne National Lab | 9700 S. Cass Avenue | Argonne | IL | 60439 | 708–972–4076 | ISCST/ISCLT |
| 12 | David A. Charlton | CHEM–NUCLEAR ENV. Svcs. | 2309 Renard Place, Suite 300 | Albuquerque | NM | | 505–766–3061 | RAECOM |
| 13 | Charles L. Cheever | Argonne National Lab | 9700 S Cass Avenue | Argonne | IL | 60439 | 972–3311 | RADRISK AIRDOS |
| 14 | Christine Daily | U.S. NRC | RES/DRA NL/S–139 | Washington | DC | 20555 | 301 492 3999 | AIRDOS–PC DECHEM v.3.02 DECOM v.2.2 RESRAD |
| | Christine Daily | U.S. NRC | RES/DRA NL/S–139 | Washington | DC | 20555 | 301 492 3999 | IMPACTS–BRC v.2.0 RAECOM MicroAIRDOS v.2.0 GENII |
| 15 | Jerry D. Davis | Westinghouse Hanford Co. | P.O. Box 1970 | Richland | WA | 99352 | | MEPAS UNSAT–H v 2.0 |
| | Jerry D. Davis | Westinghouse Hanford Co. | P.O. Box 1970 | Richland | WA | 99352 | | PATHRAE–HAZ PORFLO–3 v 1.0 PORFLO–3 v 2.0 PORMC–3 v 1.0 PATHRAE–EPA |
| 16 | T.R. Decker | U.S. NRC RII | 101 Marietta St. NS Suite 2900 | Alanta | GA | 30323 | | N/A |
| 17 | Nicoletta DiForte | Office of the Regional Ad | 26 Federal Plaza Room 906 | NY | NY | 10278 | | |
| 18 | P.G. Doctor | Pacific Northwest Lab | 3110 Port of Benton Blvd. | Richland | WA | 99352 | 509–376–4436 | SUMO |
| 19 | James G. Droppo Jr. | Pacific Northwest Lab | P.O. Box 999 | Richland | WA | 99352 | 509–376–7652 | MEPAS |
| 20 | Lisa A. Durham | Argonne National Lab | 9700 S. Cass Avenue | Argonne | IL | 60439 | 708–972–3170 | CFEST |
| 21 | Roy Eckart | Feed Materials Prod Ctr | P.O. Box 398704 | Cincinnati | OH | 45239 | 513–738–6200 | |
| 22 | Kenneth J. Eger | EBASCO Environmental | 10900 N.E. 8th Street | Bellevue | WA | 98004 | 206–451–4255 | PATH |
| 23 | Mac Ennis | Los Alamos National Lab | P.O. Box 1663 MS K490 | Los Alamos | NM | 87545 | 505–665–1573 | PRESTO–II SPUR GENII AIRDOS–EPA PART61 BIOTRAN |
| 24 | David E. Faris | Feed Materials Prod Ctr | P.O. Box 398704 | Cincinnati | OH | 45239 | 513–738–6200 | DARTAB COMPLY AIRDOS |
| 25 | Michael J. Fayer | Pacific Northwest Lab | 3110 Port of Benton | Richland | WA | 99352 | 509–376–8326 | UNSAT–H |
| 26 | Alan Fellman | Rad Branch, USEPA Reg 2 | 26 Federal Plaza 2AWM–RAD | New York | NY | 10278 | | AIRDOS |
| 27 | Joe Frazier | EG&G Idaho Inc. | P.O. Box 1625 | Idaho Falls | ID | 83415 | 208–526–9039 | FLASH/FLAME |
| 28 | Gary Gaillot | IT Corp. | 2790 Mosside Blvd. | Monroeville | PA | 15146 | | [illegible] SWIFT III GEOFLOW ODAST |
| 29 | Bruce Gallaher | Los Alamos Natl Lab | Mail Stop K490 | Los Alamos | NM | 87545 | | TRACR3d |
| 30 | David Gallegos | SNL Org 6416 | | Albuquerque | NM | 87185 | | DCM3D INUSLT |
| 31 | Richard O. Gilbert | Pacific Northwest Lab | P.O. Box 999 | Richland | WA | 99352 | 509–375–2979 | ML CODE |
| 32 | Giorgio N. Gnugnoli | USNRC | Mail Stop 5–E–4 | Washington | DC | 20555 | 301–492–0578 | RADON (RAECOM) |
| 33 | Tim Goering | Jacobs Engineering Group | 5310 Central Ave. NE, Suite 1400 | Albuquerque | NM | 87108 | 505–845–5671 | USGS–MOC UNSAT–2 |
| 34 | Mark Hansen | USEPA | 1445 Ross Avenue | Dallas | TX | 75202 | 214–655–7208 | ISCST SCREEN BIMS CHARM |
| 35 | John Haselow | Savannah River Laboratory | 773–42A | Aiken | SC | 29808 | 803–725–5219 | PATHRAE DOSTOMAN |
| 36 | Marvin W. Henderson | MK–Ferguson Company | 2309 Renard Place SE, Suite 300 | Albuquerque | NM | 87106 | 505–766–3047 | HEC–2 STEPH RAECOM SFRIPD UNSAT–2 BRUNZOG |
| | Marvin W. Henderson | MK–Ferguson Company | 2309 Renard Place SE, Suite 300 | Albuquerque | NM | 87106 | 505–766–3047 | PC–SLOPE HELP UTEXAS2 CONSOL SOIL |
| | Marvin W. Henderson | MK–Ferguson Company | 2309 Renard Place SE, Suite 300 | Albuquerque | NM | 87106 | 505–766–3047 | STABR HEC–1 SBUHYD RETC F77 SFRIPE |
| | Marvin W. Henderson | MK–Ferguson Company | 2309 Renard Place SE, Suite 300 | Albuquerque | NM | 87106 | 505–766–3047 | STABL5 |
| 37 | Bob Hlavacek | MK–Ferguson Company | 7295 Highway 94 South | St. Charles | MO | 63303 | 314–441–8086 | AIRDOS–EPA RAECOM RESRAD |
| 38 | F.O. Hoffman | Oak Ridge National Lab | P.O. Box 2008 | Oak Ridge | TN | 37831 | 615–576–2118 | AIRDOS–EPA |
| 39 | J. D. Hoover | Westinghouse Hanford Co. | P.O. Box 1970 | Richland | WA | 99352 | | PHREEQE BALANCE |
| 40 | Cheng Yeng Hung | USEPA, Office Rad. Prog | 401 M Street, SW | Washington | DC | 20460 | 202–260–9633 | PRESTO–EPA–POP PRESTO–EPA–CPG |
| 41 | Victor J. Janosik | EPA | 841 Chestnut Bldg | Philadelphia | PA | 19107 | | |
| 42 | Mark Kautsky | UNC Geotech | 2597 B 3/4 Road | Grand Junction | CO | 81503 | 303–248–6556 | HEC–1 HEC–2 RANDOM WALK |
| 43 | Mark E. Kaye | Bechtel National, Inc. | 800 Oak Ridge Turnpike, PO Box 350 | Oak Ridge | TN | 37831 | 615–576–0463 | AIRDOS–PC RESRAD COMPLY |
| 44 | Elizabeth Keicher | EPA R9 | 75 Hawthorne St | San Fransisco | CA | 94105 | | 3–d Mixing Cell SWIFT III MODFLOW |

TABLE 2 – Administrative Data and Models Used

| Count | Name | Organization | Street Address | City | State | Zip | Telephone | Models Used |
|---|---|---|---|---|---|---|---|---|
| 45 | Malcolm R. Knapp | U.S. NRC | 475 Allendale Road | King of Prussia | PA | 19406 | | |
| 46 | Robert Knowlton | U.S. DOE/Environ. Rest. 7723 | 1000 Independence Ave. | Washington | DC | 20585 | | RESRAD |
| 47 | F.C. Kornegay | | P.O. Box 2008 | Oak Ridge | TN | 37831 | 615–574–5776 | MESOI |
| 48 | Tim LeGore | Westinghouse Hanford Co. | P.O. Box 1970 | Richland | WA | 99352 | 509–376–1225 | VAM2D |
| 49 | Herbert Levine | EPA | 75 Hawthorne St. | San Francisco | CA | 94105 | | MODFLOW FLOWPATH CFEST |
| 50 | F Tom Liudstrom | SPS DWMD REECO INC. | 3281 S Highland | Las Vegas | NV | 89109 | | TDRECH23 GCDT3DH3 ODRECH8 TDRECH21 CASCADER |
| | F Tom Liudstrom | SPS DWMD REECO Inc. | 3281 S. Highland | Las Vegas | NV | 89109 | | TDRECH11 GCDT3DH4 CDRECH7 GCDT3DH5 TDRECH12 |
| 51 | Paul Mattingly | EGG Waste Mangement | 200 Woodruff Avenue | Idaho Fall | ID | 83415 | | PAGAN TRACR3D |
| 52 | Tim McCartin | U.S. NRC | | Washington | DC | 20555 | | DCM3D TOUGH NEFTRAN II DPCT SWIFT II |
| 53 | Jere Millard | Jacobs Engineering Group | 5301 Central NE | Albuquerque | NM | 87108 | 505–845–5700 | DECHEM |
| 54 | S.J. Morrison | UNC Geotech | P.O. Box 14000 | Grand Junction | CO | 81502 | 303–248–6373 | HYDROGEOCHEM |
| 55 | William E. Murphie | U.S. DOE | EM–423 | Washington | DC | 20545 | 301–353–5896 | RESRAD |
| 56 | Robert Murphy | Jacobs Engineering Group | 5301 Central Ave. NE, Suite 1400 | Albuquerque | NM | 87106 | 505–845–5713 | LTSAMP |
| 57 | R.L. Murri | UNC Geotech | P.O. Box 14000 | Grand Junction | CO | 81502 | 303–248–6024 | RESRAD |
| 58 | T.E. Myrick | Martin Marrietta Energy Systems | P.O. Box 2003, Bldg. K–1037 | Oak Ridge | TN | 37831 | 615–574–3955 | BARRIER USGS–MOC UTM |
| 59 | B.A. Napier | Battelle–Northwest | P.O. Box 999 | Richland | WA | 99352 | 509–375–3896 | DITTY ONSITE/MAXI GENII |
| 60 | Jeff Neff | USDOE | 505 King Avenue | Columbus | OH | 43201 | 614–424–3990 | AIRDOS RESRAD |
| 61 | Eric Nichols | Weiss Associates (LLNL) | 5500 Shellmound Street | Emeryville | CA | 94608 | | CFEST |
| 62 | F.R. O'Donnell | Oak Ridge National Lab | P.O. Box 2008 | Oak Ridge | TN | 37831 | 615–576–2132 | DOSES CAP–88 MACCS AIRDOS–EPA |
| | F.R. O'Donnell | Oak Ridge National Lab | P.O. Box 2008 | Oak Ridge | TN | 37831 | 615–576–2132 | CONDOS–II ISCST/ISCLT RASCAL, v 1.3 |
| 63 | Natalie Olague | SNL Org. 6416 | P.O. Box 5800 | Albuquerque | NM | 87185 | 505–844–0074 | NEFTRAN, NEFTRAN II |
| 64 | Linda Pegues | Weston/Jacobs UMTRA Proj. | 5301 Central Ave. NE Suite 1700 | Albuquerque | NM | 87108 | 505–845–4030 | HELP ver 2.02 UNSAT–H, ver 1.1 STABL UNSAT–2.1 RETC F77 |
| 65 | J.W. Ray | Battelle | 505 King Avenue | Columbus | OH | 43201 | 614–429–5522 | RESRAD |
| 66 | Larry G. Reed | EPA Office of ERR | 401 M Street SW | Washington | DC | 20466 | | |
| 67 | Jon Richards | USEPA Region IV | 4291 East Meadow Dr. | Duluth | GA | 30136 | 404–347–3907 | SWIFT II MOD3D IMPACT PATHRAE |
| 68 | Paul Rittmann | Westinghouse Hanford Co. | P.O. Box 1970 | Richland | WA | 99352 | 509–376–8191 | GENII AIRDOS–PC |
| 69 | Barry Roberts | EG&G Rocky Flats, Inc. | P.O. BOX 464 Trailer T130B EMAD | Golden | CO | 80402 | | VAM2d TARGET MODFLOW MOC |
| 70 | C.J. Roberts | West Valley Nuclear Svcs. | P.O. Box 191 | West Valley | NY | 14171 | 716–942–4271 | MINTEQ RESRAD PHREEQE ISOSHLD HELP |
| | C.J. Roberts | West Valley Nuclear Svcs. | P.O. Box 191 | West Valley | NY | 14171 | 716–942–4271 | MILDOS AFTOX PLASM MODFLO AIRDOS–PC |
| | C.J. Roberts | West Valley Nuclear Svcs. | P.O. Box 191 | West Valley | NY | 14171 | 716–942–4271 | PATHRAE–EPA INPUFF COMPLY MAXI1 |
| 71 | Rene R. Rodriguez | Decontam and Decomm | P.O. Box 1625 | Idaho Falls | ID | 83401 | 526–9078 | RESRAD |
| 72 | Budhi Sagar | Southwest Research Instit | 6220 Culebra Road | San Antonio | TX | 78228 | | DITTY |
| 73 | Susan J. Sladek | OERR/OPM/io | Waterside Mall | Washington | DC | 20460 | | |
| 74 | John L. Smoot | Pacific Northwest Lab | P.O. Box 999 | Richland | WA | 99352 | 509–376–1352 | CFEST PORFLO–3 v 1.0 |
| 75 | Dwayne R. Speer | Westinghouse Hanford Co. | P.O. Box 1970 MSIN R2–77 | Richland | WA | 99352 | 509–373–1382 | ARCL |
| 76 | Robert Stenner | Battelle–Northwest | P.O. Box 999 | Richland | WA | 99352 | 509–375–2916 | RHRS–LC HRS–I |
| 77 | David J. Thorne | UNC Geotech | 2597 B 3/4 Road | Grand Junction | CO | 81503 | 303–248–6749 | Micro AIRDOS |
| 78 | Edward C. Thorton | Westinghouse Hanford Co. | P.O. Box 1970 | Richland | WA | 99352 | | MINTEQ EQ3N |
| 79 | D. Tomasko | Argonne National Lab | 9700 S. Cass Avenue | Argonne | IL | 60439 | 708–972–3170 | CFEST |
| 80 | Thomas J. Walsh | Feed Materials Prod Ctr | P.O. Box 398704 | Cincinnati | OH | 45239 | 513–738–6200 | ISCST HARM–II |
| 81 | K.A. Walker | Oak Ridge National Lab | P.O. Box 2008 | Oak Ridge | TN | 37831 | 615–574–4432 | USGS–MOC |
| 82 | W.J. Waugh | UNC Geotech | P.O. Box 14000 | Grand Junction | CO | 81502 | 303–248–6431 | RAECOM |
| 83 | Victor L. Weeks | EPA IV/WasteMngRCRA FedFac | 345 Courtland St., N.E. | Alanta | GA | 30365 | | HELP PATH RAY RAD PATH–RAY HAZ FT WORK |
| 84 | R.K. White | Martin Marietta | P.O. Box 2008 ORNL | Oak Ridge | TN | 37831 | | RESRAD Bechtel proprietary SOURCE 2 MEPAS |
| | R.K. White | Martin Marrietta Energy Systems | P.O. Box 2008,ORNL | Oak Ridge | TN | 37831 | | MT3D HELP CREAMS SOLUTE |
| | R.K. White | Martin Marrietta Energy Systems | P.O. Box 2008, ORNL | Oak Ridge | TN | 37831 | | MODFLOW NEWBOX, FLOWTHROUGH CYLSEC SWIFT Rockware & SURFER |
| | R.K. White | Martin Marrietta Energy Systems | P.O. Box 2008, ORNL | Oak Ridge | TN | 37831 | | SEFTRAN HSPF PATHRISK MOC THEM |
| 85 | W. Alexander Williams | U.S. DOE | EM–421 | Washington | DC | 20585 | | RESRAD |
| 86 | Steve Yabusaki | Pacific Northwest Lab | P.O. Box 999 | Richland | WA | 99352 | 509–376–3290 | TEMPEST/FLESCOT |
| 87 | Charley Yu | Argonne National Lab | 9700 S Cass Avenue | Argonne | IL | 60439 | 708–972–5589 | MAT123D RESRAD PRESTO–EPA UDAD MILDOS–AREA |

TABLE 3 – Alphabetical List of Models, Model Types and References

| MODEL | Multi Media | Air | Surf Water | Grnd Water | Geochemical | Eng Perform | Screening | Detailed | Rad. Mater. | Reference 1 | Reference 2 | Reference 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3d Mixing Cell | | | | | | | | | | | | |
| AFTOX | | ● | | | | | | | | U. S. Army, 19xx | | |
| AIRDOS (–EPA, –PC) | | ● | | | | | | ● | | Moore et al., 1979 | Till et al., 1987 | U.S. EPA, 19xx |
| ARCL | ● | | | | | | | | ● | Napier & Piepel, 1988 | | |
| BALANCE | | | | | ● | | | ● | | Parkhurst et al., 1982 | | |
| BARRIER | | | | | | ● | | ● | ● | Shuman et al., 1989 | | |
| Bechtel Proprietary | | | | ● | | | | | | Bechtel Corporation, 19xx | | |
| BIOTRAN | | ● | | | | | | | ● | Gallegar et al., 1980 | | |
| BRUNZOG | | | | | | ● | | | | Chamberlain, 19xx | | |
| CAP–88 | | ● | | | | | | ● | | see AIRDOS | | |
| CASCADER | ● | | | | | | | | | | | |
| CFEST | | | | ● | | | | ● | | Gupta et al., 1982 | Gupta et al., 1987 | |
| CHARM | | ● | | | | | | | | USEPA, 19xx | | |
| COMPLY | | ● | | | | | | | ● | USEPA, 1989 | | |
| CONDOS–II | | ● | | | | | | | ● | USNRC, 19xx | | |
| CONSOL | | | | | | ● | | | | U.C. Berkeley, 19xx | | |
| CREAMS | | | ● | ● | | | | | ● | Knisel, 1980 | | |
| CYLSEC | | | | | | | | | ● | | | |
| DARTAB | | ● | | | | | | | ● | Begovich et al., 1981 | | |
| DCM3D | | | | ● | | | | | | | | |
| DECHEM | ● | | | | | | | | ● | Radiological Assessment Corp., 19xx | | |
| DECOM | ● | | | | | | | | ● | | | |
| DITTY | ● | | | | | | | | ● | Napier et al., 1986 | | |
| DOSES | ● | | | | | | | | ● | ORNL, 19xx | | |
| DOSTOMAN | ● | | | | | | | | ● | Root, 1981 | King et al., 1985 | |
| DPCT | | | | ● | | | | ● | ● | Schwartz & Crowe, 1980 | Schwartz, 1978 | |
| EQ3/6 | | | | | ● | | | | | Wolery & Watters, 1975 | Wolery et al., 1988 | Delaney, 1986 |
| FLASH/FLAME | | | | ● | | ● | | | | | | |
| FLOWPATH | | | | ● | | | | | | | | |
| FLOWTHROUGH | | | | | | | | | | | | |
| FT WORK | ● | | | | | | | | | | | |
| GCDT3DH | ● | | | | | | | | | | | |
| GENII | ● | | | | | | | | ● | Napier et al., 1988 | | |
| GENMOD | ● | | | | | | | | ● | Atomic Energy of Canada, 19xx | | |
| GEOFLOW | | | | ● | | | | | | D'Appolonia Consulting Eng., 1980 | | |
| GW FLOW | | | | ● | | | ● | | | Natural Sci. & Eng. Counc., Canada | | |
| HARM–II | | ● | | | | | | | | | | |
| HEC–1, –2 | | | ● | | | | | ● | | U.S. Army Corps of Eng., 1981 | U.S. Army Corps of Eng., 1982 | |

TABLE 3 – Alphabetical List of Models, Model Types and References

| MODEL | Multi Media | Air | Surf Water | Grnd Water | Geochemical | Eng Perform | Screening | Detailed | Rad. Mater. | Reference 1 | Reference 2 | Reference 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HELP | | | | | | ● | | | | Schroeder et al., 1984 | | |
| HRS–1 | ● | | | | | | ● | | | Stenner et al., 1986 | | |
| HSPF | | | ● | | | | | | ● | Johanson et al., 1984 | | |
| HYDROGEOCHEM | | | | | ● | | | ● | | Yeh & Tripathi, 19xx | | |
| IMPACTS (PART61) (–BRC) | ● | | | | | | ● | | ● | Oztunali et al., 1986 | Oztunali & Roles, 1986 | |
| INPUFF | | ● | | | | | | | | Peterson & Lavdas, 1986 | General Sciences Corp., 1986 | |
| ISCST/ISCLT | | ● | | | | | | | | Bowers et al., 1979 | TRC Environmental Cons., Inc., 19xx | TRC Environmental Cons., Inc., 1988 |
| ISOSHLD (–II) | ● | | | | | ● | | | ● | Engle et al., 1966 | Sumnar et al., 1967 | |
| LTSAMP | | ● | | | | | | | | Jacobs Engineering, 19xx | | |
| MACCS | | | | | | ● | | | ● | Sandia National Lab., 19xx | | |
| MAT123D | | | | ● | | | | | | Yu, 19xx | | |
| MEPAS | ● | | | | | | ● | | ● | Droppo et al., 1989 | Doctor et al., 1990 | Whelan et al., 1987 |
| MESOI | | ● | | | | | | | ● | Ramsdell, et al., 1983 | | |
| MILDOS (–AREA) | ● | | | | | | | | ● | and | Yuan et al., 1989 | |
| MINTEQ (–A1, –A2) | | | ● | | ● | | | ● | | Krupka & Morrey, 1985 | Allison et al., 1990 | Peterson et al., 1987 |
| ML CODE | | ● | | | | | | | ● | Napier, 19xx | | |
| MOC | | | | ● | | | | ● | ● | Konikow & Bredehoeft, 1978 | | |
| MOD3D | | | | ● | | | | ● | | McDonald & Harbough, 1984 | | |
| MODFLOW | | | | ● | | | | ● | | McDonald & Harbough, 1989 | | |
| NEFTRAN II | | | | ● | | | | ● | ● | Olague et al., 1991 | Longsine, Bonano & Harlan, 1987 | |
| NEWBOX | | | | | | ● | | | | | | |
| NUREG–0707 | ● | | | | | | | | ● | Eckerman & Young, 19xx | | |
| ODAST | | | | ● | | | ● | | | Javendal et al., 1984 | | |
| ODRECH6,7 | ● | | | | | | | | | | | |
| ONSITE/MAXI1 | ● | | | | | ● | | | ● | Napier et al., 1984 | Kennedy et al., 1986 | |
| PAGAN | ● | | | | | ● | | | | Kozak et al., 1990a | | |
| PATH | ● | | | | | | | | ● | Lee, 19xx | | |
| PATHRAE | ● | | | | | | | | ● | Rogers & Hinz, 1987 | | |
| PATHRISK | ● | | | | | | | | | | | |
| PC–SLOPE | | | | | | ● | | | | Geo–Slope, Inc., 19xx | | |
| PHREEQE | | | | | ● | | | ● | | Parkhurst et al., 1980 | | |
| PLASM | | | | ● | | | | | | Prickett & Lonnquist, 1971 | | |
| PORFLO–3 | | | | ● | | | | | ● | Runchal & Sagar, 1985 | | |
| PORMC–3 | | | | ● | | | | | ● | Analytic & Comput. Res., Inc., 19xx | | |
| PRESTO–II | ● | | | | | | | | ● | Fields et al., 1986 | | |
| PRESTO–EPA–CPG | ● | | | | | | | | ● | | Cheng Yeng Hung, 1989 | |
| PRESTO–EPA–POP | ● | | | | | | | | ● | Fields et al., 1987a | Fields et al., 1987b | Cheng Yeng Hung 1992 |

TABLE 3 – Alphabetical List of Models, Model Types and References

| MODEL | Multi Media | Air | Surf Water | Grnd Water | Geochemical | Eng. Perform | Screening | Detailed | Rad. Mater. | Reference 1 | Reference 2 | Reference 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAECOM | | • | | | | | | | • | Rogers et al., 1984 | | |
| RADRISK | | • | | | | | | | • | Dunning et al., 1980 | | |
| RANDOM WALK | | | | • | | | | | | Prickett et al., 1981 | | |
| RASCAL | | | | | | • | | | • | ORNL & Phoenix Associates, 19xx | | |
| RESRAD | • | | | | | | | | • | Gilbert et al., 1988 | | |
| RETC.F77 | | | | • | | | | | | Mualem, 1976 | | |
| RHRS–LC | • | | | | | | • | | • | Stenner et al., 1986 | | |
| RSAC–3 | | • | | | | • | | | • | Wenzel, 1982 | | |
| SBUHYD | | | • | | | | | | | Stubenhaer, 1975 | | |
| SCREEN | | • | | | | | | | | USEPA, 19xx | | |
| SEFTRAN | | | | • | | | | | | | | |
| SFRIPD | | | | | | • | | | | MK Environmental, 19xx | | |
| SFRIPE | | | | | | • | | | | MK Environmental, 19xx | | |
| SIMS | | • | | | | | | | | USEPA, 19xx | | |
| SOIL | | | | • | | | | | | El–Kadi, 1985 | | |
| SOLUTE | | | | • | | | • | | | | | |
| SOURCE 2 | | | | | | | | | • | | | |
| SPUR | • | | | | | | | | | USEPA, 19xx | | |
| STABL | | | | | | • | | | | Siegel, 19xx | | |
| STABL5 | | | | | | • | | | | U.S. DOT & Purdue Univ., 19xx | | |
| STABR | | | | | | • | | | | U.C. Berkeley, 19xx | | |
| STEPH | | | | | | • | | | | MK Environmental, 19xx | | |
| STRIP 1B | • | | | | | | | | | | | |
| SUMO | • | | | | | | | | | USDOE, 19xx | | |
| SWIFT (II,III) | | | | • | | | | • | • | Reeves et al., 1986 | Reeves & Cromwell, 1981 | Ward, Reeves & Duda, 1984 |
| TARGET | | | | | | | | | | | | |
| TDRECH | • | | | | | | | | | | | |
| TEMPEST/FLESCOT | | | • | | | | | | | Trent et al., 1983 | Onishi, Trent & Klontz, 1985 | Trent & Onishi, 1989 |
| THEM | | | | | | | | | | | | |
| TOUGH | | | | • | | | | • | • | Pruess & Wang, 1984 | Pruess, 1986 | |
| TRACR3D | | | | • | | | | • | • | Travis et al., 1984 | | |
| UDAD | • | | | | | | | | • | Momeni et al., 1979 | | |
| UNSAT–2 (–H) | | | | • | | | | • | | Davis & Neuman, 1983 | Fayer et al., 1986 | |
| UTEXAS2 | | | | | | • | | | | Wright, 19xx | | |
| UTM | • | | | | | | | | • | Luxmore & Huff, 1989 | | |
| VAM2D (–3D) | | | | • | | | | • | • | Huyakorn et al., 1989 | Huyakorn, 19xx | |

Table 4–Model, Site Type,Contaminant, Endpoint, Effort, Validation, Publication

| Count | MODEL | SITE TYPE | CONTAMINANT | ENDPOINT | EFFORT | V/C* | PUBLICATION | NAME |
|---|---|---|---|---|---|---|---|---|
| 1 | 3-d Mixing Cell | EPA Superfund | VOC's | environmental concentration | unknown | YES | NO | Elizabeth Keicher |
| 2 | AFTOX | DOE | Non radiologic | environmental concentration | as needed | NO | | CJ Roberts |
| 3 | AIRDOS | DOE Defense | Radionuclides | effective dose-equivalent | | | | Alan Fellman |
| | AIRDOS | DOE National Laboratory | | dose commitment | .5 mm/yr | NO | YES ANL-E env reports | Charles L. Cheever |
| | AIRDOS | SFMP | Radionuclides | dose commitment | 4 mm | YES | NO | David E Faris |
| | AIRDOS | DOE Defense | Pu, Co, Am, U, CS | dose commitment | 6-12 mm/yr | NO | NO | Jeff Neff |
| | AIRDOS-EPA | EPA Superfund | All natural series isotopes | env conc. and dose commitment | 8 mm | NO | NO | Bob Hlavacek |
| | AIRDOS-EPA | Federal Facility | | dose commitment, risk | | NO | | F.O.Hoffman/B.G. Blaylock |
| | AIRDOS-EPA | Federal Facility | Radionuclides | enc.conc.dose-eq, risk | 6mm | YES | | F.R. O'Donnell |
| | AIRDOS-EPA | DOE Defense | Radionuclides | env. conc., comm eff dose eq, risk | 24-36mm nt | YES | NO | Mac Ennis |
| | AIRDOS-PC | FUSRAP | Alkaline earths, actinides, etc. | effective dose equivalent | as needed | | NO | Christine Daily |
| | AIRDOS-PC | DOE Defense | Radionuclides | dose commitment | as needed | NO | | C.J. Roberts |
| | AIRDOS-PC | NRC | U-238 and Th-232 decay chains | dose commitment | 1mm | NO | | Mark E. Kaye |
| | AIRDOS-PC | DOE | 41 radionuclides | dose commitment | 1 FTE/yr | NO | NO | Paul Rittmann |
| 4 | ARCL | SFMP | See manual | max allowable residual levels | | NO | | Dwayne R. Speer |
| 5 | BALANCE | DOE Defense | Non radiologic | env. conc. in aqueous systems | none | NO | NO | J. D. Hoover |
| 6 | BARRIER | DOE Defense | Nat, enr U, transuranics, fission | dose | 6my/yr | NO | NO | T.E. Myrick |
| 7 | Bechtel Proprietary | EPA Superfund | | | | | | R.K. White |
| 8 | BIOTRAN | DOE National Laboratory | Radionuclides | env. conc., comm eff dose eq, risk | 24-36mm nt | YES | NO | Mac Ennis |
| 9 | BRUNZOG | UMTRA | NA | depth of thaw penetration | | NO | NO | Marvin W. Henderson |
| 10 | CAP-88 | Federal Facility | Radionuclides | env. conc., dose-eq, risk | 3 | NO | | F.R. O'Donnell |
| 11 | CASCADER | DOE Defense | Tritium and Radon | environment-l concentration | | | | F Tom Liudstrom |
| 12 | CFEST | DOE Defense | Chlorinated aliphatics, Tritium | environmental concentration | 36mm | YES | YES LLNL 1991 | Eric Nichols |
| | CFEST | DOE Defense | Tritium, U | | 6mm, 6mm | NO | YES WHC-EP-0133,PNL-6315-2 | John L. Smoot |
| | CFEST | EPA CERCLA NPL DOE NatlLb | U-238, Th-232, metals, nitroaromat | environmental concentration | 12mm | | | Lisa A. Durham,D Tomasko |
| | CFEST | SFMP,EPA Superfund | Tritium, uranium | environmental concentration | 1.5 my | NO | | Marcel P. Bergeron |
| | CFEST, | EPA Superfund | | concentration | | NO | NO | Herbert Levine |
| 13 | CHARM | EPA Superfund | Particulates, VOC's | env. conc., risk assessment | variable | YES | NO | Mark Hansen |
| 14 | COMPLY | DOE | Radionuclides | annual dose commitment | as needed | NO | | C.J. Roberts |
| | COMPLY | FUSRAP | Radionuclides | dose commitment | 3-4 mm | NO | NO | David E. Faris |
| | COMPLY | DOE Defense | U-238 and Th-232 decay chains | dose commitment | 1mm | NO | | Mark E. Kaye |
| 15 | CONDOS-II | Federal Facility | Radionuclides | air, food conc., dose from objects | 0.5 | NO | | F.R. O'Donnell |
| 16 | CONSOL | UMTRA | NA | calculates settlement | | NO | NO | Marvin W. Henderson |
| 17 | CREAMS | EPA Superfund | NA-Water Balance | Percent Runoff, Evaporation, Infiltration etc. | | YES | | R.K. White |
| 18 | CYLSEC | EPA Superfund | All radionuclides | concentrations | 0.5mm/Update | YES | YES Bechtel Proprietary Documents | R.K. White |
| 19 | DARTAB | DOE Defense | U-234, U-235, U-236, U-238, ... | dose commitment | 4 mm | | | David E. Faris |
| | DARTAB | DOE Defense | Radionuclides | dose commitment | 4 mm | YES | NO | David E. Faris |
| 20 | DCM3D | | | | | | | David Gallegos |
| | DCM3D | | Highlevel waste radionuclides | hydrolic flow/integrated discharge | 12 mm | NO | NO | Tim McCartin |
| 21 | DECHEM | UMTRA | As, Se, V, U, Mo, Pb, limited orgs | soil, gw conc., risk (see note) | 3500 + 500 | NO | | Dr. Jans Millard |
| | DECHEM v.3.02 | DOE NRC | U,Th,Ra,As | reference value | as needed | NO | NO | Christine Daily |
| 22 | DECOM v.2.2 | NRC | U,Th,Ra | concentration, doses | 1 | NO | NO | Christine Daily |
| 23 | DITTY | NRC H-L Waste repository | More than 250 radionuclides | individual and population doses | several my | NO | YES DOE/EIS-0113 | B.A. Napier |
| | DITTY | DOE Defense | Radioisotopes-Iodine neptunium etc. | dose commitment | 2-6mm | NO | NO | Dr. Budhi Sagar |
| 24 | DOSE3 | Federal Facility | Radionuclides | dose | 2 | NO | | F.R. O'Donnell |
| 25 | DOSTOMAN | DOE Defense | Pu-238,Pu-239,Cs-137,Sr-90,3H,... | dose commitment | 24 mm | | | John Heselow |

Table 4 – Model, Site Type, Contaminant, Endpoint, Effort, Validation, Publication

| Count | MODEL | SITE TYPE | CONTAMINANT | ENDPOINT | EFFORT | V/C* | PUBLICATION | NAME |
|---|---|---|---|---|---|---|---|---|
| 26 | DPCT | | Sr-90 | concentration | 6 mm | YES | NO | Tim McCarlin |
| 27 | EQ3/6 | DOE Defense | Radionuclides and nonradiologic | env. conc., che interaction water/soil | see note | NO | NO | Dr. Edward C. Thorton |
| 28 | FLASH/FLAME | EPA Superfund | | environmental concentration | 36 mm | NO | NO | Joe Frazier |
| 29 | FLOWPATH | EPA Superfund | | concentration | | NO | NO | Herbert Levine |
| 30 | FTWORK | EPA Superfund Savannah Rv | Lead, mercury, nitrate, | constituent consentrations | 6 MM | | NO | Victor L. Weeks |
| | FTWORK | EPA Superfund (DOE) | 30 contaminants of concern | environmental concentration RA | 12 mm | YES | YES reports to SRS | Peter F. Anderson |
| 31 | GCDT3DH3 | DOE Defense | Tritium and Radon | environmental concentrations | | | | F Tom Ludstrom |
| 32 | GCDT3DH4 | DOE Defense | Tritium and Radon | environmental concentrations | | | | F Tom Ludstrom |
| 33 | GCDT3DH5 | DOE Defense | Tritium and Radon | environmental concentrations | | | | F Tom Ludstrom |
| 34 | GENII | DOE Defense,SFMP | More than 290 radionuclides | conc., dose,dose comm, integ dose | > 5 my | NO | YES PNL-6825, DOE/EIS-01190 | B.A. Napier |
| | GENII | DOE National Laboratory | Any related to decommissioning | dose | 1mm | NO | NO | Christine Daily |
| | GENII | DOE Defense | Radionuclides | dose commitment | unknown | YES | YES | Dr. Roy Eckart |
| | GENII | DOE, NRC | Radionuclides | env. conc., comm eff dose eq, risk | 24-36mm nt | NO | NO | Mac Ennis |
| | GENII | DOE Defense | 240 radionuclides | env. conc., dose commitment | 5 FTE/yr | NO | NO | Paul Rittmann |
| 35 | GENNMOD | DOE Defense | Radionuclides | internal dosimetry | 30 mm | YES | NO | Dr. Roy Eckart |
| 36 | GEOFLOW | DOE Defense | | | | | | Gary Galliot |
| 37 | GW Flow Model | Federal Facility | Flow | gw flux | 2 years ex | NO | NO | L.S. Cahn |
| 38 | HARM-II | DOE Defense | U-234, various liquids and gases | environmental concentration | 3 man-yrs | NO | NO | Thomas J. Walsh |
| 39 | HEC-1 | UMTRA | U, VOC's, toxic metals, aromatics | environmental concentration | 6 mm note | YES | YES AML symposium, 1989 | Mark Kautsky |
| | HEC-1 | DOE,DOE Defense,SFMP,SF | Flow | water levels and flow rates | | NO | YES | Marvin W. Henderson |
| 40 | HEC-2 | UMTRA | U, VOC's, toxic metals, aromatics | environmental concentration | 6 mm note | YES | YES AML symposium, 1989 | Mark Kautsky |
| | HEC-2 | DOE,DOE Defense,SFMP,SF | Flow | water levels, flow rates and veloc | | NO | YES | Marvin W. Henderson |
| 41 | HELP | DOE | | | as needed | NO | | C.J. Roberts |
| | HELP | EPA Superfund | Flow | recharge and discharge rates | | NO | YES | Marvin W. Henderson |
| | HELP | UMTRA | | | | | | R.K. White |
| | HELP | EPA Superfund - DOE Savann | Tetrachloroethylene | constituent consentrations | 6 MM | | NO | Victor L. Weeks |
| | HELP ver 2.02 | UMTRA | | | | NO | | Linda Pegues |
| 42 | HRS-I | EPA Superfund | Radionuclides and nonradiologic | HRS scores | 24 mm | NO | YES PNL-6456. | Robert Stenner |
| 43 | HSPF | EPA Superfund | All contaminants | Time series of contaminant passing a point | 13 mm | NO | NO | R.K. White |
| 44 | HYDROGEOCHEM | DOE, NE, DP | To be determined, U likely | to be determined | to be det | YES | NO | S.J. Morrison |
| 45 | IMPACT | EPA Superfund | H-3, C-14, Co-60, Sr-90, (see note) | 70 year short-term dose eq. | unknown | NO | NO | Jon Richards |
| | IMPACTS-BRC v.2.0 | NRC | Any in library | dose | 2 mm | NO | NO | Christine Daily |
| 46 | INPUFF | DOE | Non radiologic | environmental concentration | as needed | NO | | C.J. Roberts |
| 47 | INUSLT | GW | | | | | NO | David Gallegos |
| 48 | ISCST | EPA Superfund | Particulates, VOC's | env. conc., risk assessment | variable | YES | NO | Mark Hansen |
| | ISCST | DOE Defense | SO2 | environmental concentration | unknown | NO | | Thomas J. Walsh |
| | ISCST/ISCLT | SFMP | Rad, nonrad and generic releases | ground-level air conc. | 0.5 | NO | | F.R. O'Donnell |
| | ISCST/ISCLT | Federal Facility | PM10 and TSP | long/short term env. conc. | 5 mm | NO | NO | Young-Soo Cheng |
| 49 | ISOSHLD | DOE | Radionuclides | external dose and dose rates | as needed | NO | | C.J. Roberts |
| 50 | LTSAMP | UMTRA | Particulates, radon | conc. at receptor locations | unknown | NO | YES UMTRA Env. Assessments | Robert Murphy |
| 51 | MACCS | Federal Facility | Fission products | env. conc., dose-eq, risk | 2 | NO | | F.R. O'Donnell |
| 52 | MAT123D | FUSRAP/SFMP | U, radium-226 | conc. in ground water | 6 mm | YES | YES | Dr. Charley Yu |
| 53 | MAXI | DOE | Radionuclides | dose commitment | as needed | NO | | C.J. Roberts |
| 54 | MEPAS | EPA Superfund, DOE Defense | 76 rads, 318 nonradiologic | env. conc., dose comm, risk factors | $500,000 | YES | YES PNL-7102, SF'88 | Dr. James G. Droppo Jr. |
| | MEPAS | Ranking model for CERCLA | Radionuclides and nonradiologic | dose, hazard index, risk | 2 years | YES | YES Whelan et al. | Dr. Jerry D. Davis |
| | MEPAS | DOE Defense | | | | | | R.K. White |
| 55 | MESOI | Federal Facility | Toxic gases | short-term ground level conc. | 0 | YES | YES | F.C. Kornegay |
| 56 | Micro AIRDOS | SFMP | Ra-222,Ra-226,Pu-238,Pu-239 ... | env. conc., dose commitment, uptake | unknown | NO | NO | David J. Thorne |
| | Micro AIRDOS v.2.0 | NRC | U,Th,Ra | dose | 1mm | | NO | Christine Daily |

Table 4–Model, Site Type,Contaminant, Endpoint, Effort, Validation, Publication

| Count | MODEL | SITE TYPE | CONTAMINANT | ENDPOINT | EFFORT | V/C* | PUBLICATION | NAME |
|---|---|---|---|---|---|---|---|---|
| 57 | MILDOS | DOE | Radionuclides | dose commitment | as needed | NO | | C.J Roberts |
| | MILDOS–AREA | FUSRAP/SFMP | Uranium series isotopes | dose commitment | 12 mm | YES | YES ANL/ES–161 | Dr. Charley Yu |
| 58 | MINTEQ | DOE Defense | | | as needed | NO | | C.J. Roberts |
| | MINTEQ | DOE | Nonradiologic | env. conc., che interaction water/soil | see note | NO | NO | Dr. Edward C. Thorton |
| 59 | ML CODE | DOE Defense | Iodine–131 | dose commitment | 12 mm | NO | | Richard O. Gilbert |
| 60 | MOC | DOE Defense | VOC's | groundwater concentration | .5mm | YES | NO | Barry Roberts |
| | MOC | Perfromance Assessment | All contaminents | concentration as a function of time | Ongoing effort | NO | | R.K. White |
| 61 | MOD3D | DOE Defense | Radionuclides | environmental concentration | | | | Jon Richards |
| 62 | MODFLOW | DOE | Flow | | as needed | NO | | C.J. Roberts |
| | MODFLOW | EPA Superfund | | water levels | 3 mm | NO | | Barry Roberts |
| | MODFLOW | DOE Defense | VOC's | environmental concentration | unknown | YES | NO | Elizabeth Kelcher |
| | MODFLOW | EPA Superfund | | concentration | | NO | NO | Herbert Levine |
| | MODFLOW | EPA Superfund | | flow rates | | | | R.K. White |
| | MODFLOW/MOC | EPA Superfund | | | 12 mm | NO | NO | Richard W. Arnseth |
| 63 | MT3D | EPA Superfund | All contaminants and radionuclides | concentration and travel time | | | | R.K. White |
| 64 | NEFTRAN | DOE | Transuranics | intergrated discharge | 3 mm | NO | NO | Natalie Olague |
| 65 | NEFTRAN II | Generic Performance Assessment | HLW radionuclides | intergrated discharge | NA | NO | NO | Natalie Olague |
| | NEFTRAN II | DOE NRC | Nuclides I 10 CFR Part 60 | integrated discharge | 6 mm | NO | NO | Tim McCartin |
| 66 | NEWBOX, Flowthrough | Performance Assessment | Most radioisotopes | concentration and dose | 8 mm | NO | YES | R.K. White |
| 67 | NUREG–0707 | DOE | Rads and selected nonrads | dose commitment | 6 mm | NO | YES NUREG–0707 | David Abbot |
| 68 | ODAST | DOE Defense | | | | | | Gary Gallot |
| 69 | ODRECH6 | DOE Defense | Tritium and Radon | environmental concentrations | | | | F Tom Liudstrom |
| 70 | ODRECH7 | DOE Defense | Tritium and Radon | environmental concentrations | | | | F Tom Liudstrom |
| 71 | ONSITE/MAXI | DOE Defense,SFMP,FUSRAP | More than 250 radionuclides | env. conc., indiv max annual dose | several my | NO | YES DOE/EIS–0113 | B.A. Napier |
| | ONSITE/MAXI I | DOE Defense | Radionuclides | dose commitment | unknown | YES | YES | Dr. Roy Eckart |
| 72 | PAGAN | DOE | Radioisotopes and nonradiologic | environmental concentration | several | NO | NO | Paul Mattingly |
| 73 | PART61 | DOE National Laboratory | Radionuclides | env. conc., comm eff dose eq, risk | 24–36mm nt | NO | NO | Mac Ennis |
| 74 | PATH | FUSRAP | Co–60,Cs–137, Sb–125, europium–1 | dose commitment | 4mm + 8mm | NO | NO | Kenneth J. Eger |
| 75 | Path Ray Rad | EPA Superfund Savannah Rv | Tritium,radium,cesium,strontium, | constituent concentrations | 6 MM | | NO | Victor L. Weeks |
| 76 | PATHRAE | DOE Defense | see DPST–88–291 | dose commitment | 46 mm | | | John Haselow |
| | PATHRAE | DOE Defense | Radionuclides | dose | | | | Jon Richards |
| | PATHRAE–EPA | DOE | Radionuclides | dose commitment | as needed | NO | | C.J. Roberts |
| | PATHRAE–EPA | DOE Defense | Radionuclides | dose | unknown | NO | YES SRL–EIS on llw | Dr. Jerry D. Davis |
| | PATHRAE–HAZ | DOE Defense | Hazardous chemicals | hazard index, risk | unknown | NO | YES SRL EIS on llw sites | Dr. Jerry D. Davis |
| | PATHRAE–HAZ | EPA Superfund | Aresnic, Barium, Cadmium, Chromium, | constituent concentrations | 6 MM | | NO | Victor L. Weeks |
| 77 | PATHRISK | UMTRA | All radionuclides | dose | 6 mm | NO | YES ORNL/ER/Sub–87/99053/5/V3–V8 | R.K. White |
| 78 | PC–SLOPE | DOE | NA | failure surfaces, factors of safety | | NO | NO | Marvin W. Henderson |
| 79 | PHREEQE | DOE Defense | | | as needed | NO | | C.J. Roberts |
| | PHREEQE | DOE | Non radiologic | env. conc. in aquaous systems | none | NO | NO | J. D. Hoover |
| 80 | PLASM | DOE Defense | Flow | | as needed | NO | | C.J. Roberts |
| 81 | PORFLO–3 v 1.0 | DOE Defense | Radionuclides and nonradiologic | heat,gw/cont flux, conc 1,2,3–D | 3 FTE, +3mm | YES | YES Smoot and Sagar 1990 | Dr. Jerry D. Davis |
| | PORFLO–3 v 1.0 | DOE Defense | At users discretion | env. conc. | 6 mm | YES | YES PNL–7221 | John L. Smoot |
| | PORMC–3 v 1.0 | DOE Defense | Radionuclides and nonradiologic | heat,gw/cont flux, conc 1,2,3–D | 6 mm 1990 | NO | | Dr. Jerry D. Davis |
| 82 | PORFLO–3 v 2.0 | FUSRAP | Radionuclides and nonradiologic | heat,gw/cont flux, conc 1,2,3–D | 6 mm 1990 | YES | | Dr. Jerry D. Davis |
| 83 | PRESTO–EPA | Generic | Ra–226 | dose commitment | 1 mm | YES | YES Conference proceedings | Dr. Charley Yu |
| | PRESTO–EPA–CPG | Generic | 40 rads commonly found in llw | dose commitment, fatal health eff. | 4 my, dev | YES | YES | Dr. Cheng Yeng Hung |
| | PRESTO–EPA–POP | Generic | 40 rads commonly found in llw | dose commitment | 4 my, dev | YES | YES | Dr. Cheng Yeng Hung |
| | PRESTO–II | UMTRA | Radionuclides | env. conc., comm eff dose eq, risk | 24–36mm nt | NO | NO | Mac Ennis |
| 84 | RADON (RAECOM) | DOE National Laboratory | Radon–222 | surface radon flux | 3–5mm NRC | NO | YES NUREG/CR–3533 | Giorgio N. Gnugnoli |
| 85 | RADRISK | DOE NRC | | dose commitment | .5 mm/yr | NO | YES ANL–E env reports | Charles L. Cheever |
| 86 | RAECOM | UMTRA | All natural series isotopes | env conc. and dose commitment | 6 mm | NO | NO | Bob Hlavacek |

Table 4—Model, Site Type, Contaminant, Endpoint, Effort, Validation, Publication

| Count | MODEL | SITE TYPE | CONTAMINANT | ENDPOINT | EFFORT | V/C* | PUBLICATION | NAME |
|---|---|---|---|---|---|---|---|---|
| | RAECOM | EPA Superfund | Ra | concentration/flux | 3 mm | YES | NO | Christine Daily |
| | RAECOM | SFMP | Ra-226 | estimated interior WLs | 1mm | NO | NO | David A. Charlton |
| | RAECOM | UMTRA | Radon | radon fluxes and concentrations | | NO | YES | Marvin W. Henderson |
| | RAECOM | DOE,DOE Defense,SFMP,SF | Radon-222 | radon emanation from soil | | NO | NO | W.J. Waugh |
| 87 | RANDOM WALK | Federal Facility | U, VOC's, toxic metals, aromatics | env. conc. | 6 mm note | YES | YES AML symposium, 1989 | Mark Kautsky |
| 88 | RASCAL, v 1.3 | DOE Defense | Reactor (fission product) rads | acute/long term dose-eq, health eff | 0 | NO | | F.R. O'Donnell |
| 89 | RESRAD | SFMP | U,Th,Ra,Co | concentration | as needed | NO | NO | Christine Daily |
| | RESRAD | DOE Fusrap | Site specific radioisotopes | dose | 3 m-m | YES | NO | Robert Knowlton |
| | RESRAD | FUSRAP | All natural series isotopes | env conc. and dose commitment | 6 mm | NO | NO | Bob Hlavacek |
| | RESRAD | FUSRAP/SFMP | Radionuclides | dose commitment | as needed | NO | | C.J. Roberts |
| | RESRAD | SFMP | Pu-238,Th | dose commitment | | NO | NO | Daniel G. Carfagno |
| | RESRAD | SFMP/FUSRAP | Pu-238, Th | dose commitment | | NO | YES Internal Reports | Daniel G. Carfagno |
| | RESRAD | DOE FUSRAP | U, Cs-137 | dose commitment | 20 mm | YES | YES ANL/ES-160, DOE/CH 8901 | Dr. Charley Yu |
| | RESRAD | DOE | Radionuclides | dose commitment | unknown | YES | NO | Dr. Roy Eckart |
| | RESRAD | DOE, NRC | Pu, Co, Am, U, CS, RCRA Haz, PCBs | dose commitment | 6-12 mm/yr | NO | NO | Jeff Neff |
| | RESRAD | SFMP | Cs, U, CO, Pu, Am | dose | | NO | NO | J.W. Ray |
| | RESRAD | DOE Defense | U-238, U-234, Th-230 | soil conc. - cleanup guidelines | 1 mm | NO | NO | L.S. Cahn |
| | RESRAD | EPA Superfund | U-238 and Th-232 decay chains | dose commitment | 1mm | YES | | Mark E. Kaye |
| | RESRAD | SFMP | Co-60, Cs-137 | dose | 1 mm | NO | NO | Rene R. Rodriguez |
| | RESRAD | DOE Defense | All radionuclides and decay products | guideline values for radionuclides | | | | R.K. White |
| | RESRAD | DOE Defense | U-238, U-234, Th-230 | soil conc. - cleanup guidelines | 1 mm | NO | NO | R.L. Marti |
| | RESRAD | SFMP | U-238, U-234, Th-230 | soil conc. - cleanup guidelines | 1 mm | NO | NO | R.L. Marti |
| | RESRAD | DOE Defense | 40 isotopes, 38 daughters | eff and comm eff dose equivalent | as needed | | | William C. Borden |
| | RESRAD | EPA Superfund | Radionuclides | dose commitment | | YES | YES | William E. Murphie |
| | RESRAD | EPA Superfund | Radioisotopes - D&D | dose commitments, clean up guides | Y | YES | | W. Alexander Williams |
| 90 | RETC.F77 | UMTRA | | | | NO | | Linda Pegues |
| | RETC.F77 | UMTRA | NA | hydraulic pars of partial sat soils | | NO | YES | Marvin W. Henderson |
| 91 | RHRS-LC | EPA Superfund | Radionuclides and nonradiologic | revised hazard ranking system score | 6-10 mm | NO | NO | Robert Stenner |
| 92 | ROCKWARE & SURFER | EPA Superfund | | | | | | R.K. White |
| 93 | RSAC | INEL | Radionuclides | Ci/m2, photon flux, exp, dose,ede | 3mm 1990 | | YES | Burton R. Baldwin |
| 94 | SBUHYD | UMTRA | NA | hydrograph computations | | NO | YES | Marvin W. Henderson |
| 95 | SCREEN | EPA Superfund | Particulates, VOC's | env. conc., risk assessment | variable | YES | NO | Mark Hansen |
| 96 | SEFTRAN | Performance Assessment | | | | | | R.K. White |
| 97 | SFRIPE | UMTRA | NA | factor of safety for riprap sizing | | NO | NO | Marvin W. Henderson |
| | SFRIPE | UMTRA | NA | factor of safety for riprap sizing | | NO | NO | Marvin W. Henderson |
| 98 | SIMS | EPA Superfund | Particulates, VOC's | env. conc., risk assessment | variable | YES | NO | Mark Hansen |
| 99 | SOIL | UMTRA | | hydraulic pars of part saturat soil | | NO | YES | Marvin W. Henderson |
| 100 | SOLUTE | EPA Superfund | | | | | | R.K. White |
| 101 | SOURCE 2 | EPA Superfund | Radionuclides | environmental concentration | .5mm/yr dates | YES | YES Bechtel proprietary documents | R.K. White |
| 102 | SPUR | DOE National Laboratory | Radionuclides | env. conc., comm eff dose eq, risk | 24-36mm nt | NO | NO | Mac Ennis |
| 103 | STABL | UMTRA | | | | NO | | Linda Pegues |
| | STABL5 | UMTRA | NA | failure surfaces, factors of safety | | NO | NO | Marvin W. Henderson |
| 104 | STABR | UMTRA | NA | failure surfaces, factors of safety | | NO | NO | Marvin W. Henderson |
| 105 | STEPH | UMTRA | NA | riprap sizing | | NO | NO | Marvin W. Henderson |
| 106 | STRIP 1B | DOE Defense | | | | | | Gary Gallot |
| 107 | SUMO | | Transuranics, Fission products | env. conc., dose, health effects | 36 mm | NO | | P.G. Doctor |
| 108 | SWIFT | EPA Superfund Porkmouth | | | | | | R.K. White |
| 109 | SWIFT II | | Radionuclides | environmental concentration | | | | Jon Richards |
| | SWIFT II | DOE Defense | | ground water flow | 6 mm | YES | YES NUREG 1249 Hydrocoin | Tim McCartin |
| 110 | SWIFT III | DOE Defense | Uranium, others as necessary | conc. at offsite receptors | 150 + 50 | YES | YES draft 6/90 | Dennis J. Carr |

Table 4--Model, Site Type,Contaminant, Endpoint, Effort, Validation, Publication

| Count | MODEL | SITE TYPE | CONTAMINANT | ENDPOINT | EFFORT | V/C* | PUBLICATION | NAME |
|---|---|---|---|---|---|---|---|---|
| | SWIFT III | EPA Superfund | VOC's | environmental concentration | unknown | YES | NO | Elizabeth Keicher |
| | SWIFT III | DOE Defense | | | | | | Gary Galliot |
| 111 | TARGET | DOE Defense | VOC's | groundwater concentration | 5mm | NO | NO | Barry Roberts |
| 112 | TDRECH11 | DOE Defense | Tritium and Radon | environmental concentrations | | | | F Tom Liudstrom |
| 113 | TDRECH12 | DOE Defense | Tritium and Radon | environmental concentrations | | | | F Tom Liudstrom |
| 114 | TDRECH21 | DOE Defense | Tritium and Radon | environmental concentrations | | | | F Tom Liudstrom |
| 115 | TDRECH23 | DOE Defense | Tritium and Radon | environmental concentrations | | | | F Tom Liudstrom |
| 116 | TEMPEST/FLESCOT | EPA Superfund | PCB's | environmental concentratione | 100 mm | YES | YES | Steve Yabusaki |
| 117 | THEM | EPA Superfund | | | | | | R.K. White |
| 118 | TOUGH | | Non-reacitve solute | two-phase flow and concentration | 6 mm | YES | NO | Tim McCartin |
| 119 | TRACR3D | DOE | TCA Pu-238,239 | environmental concentration | 6mm | YES | YES LANL Report LA-9967-MS n | Bruce Gallaher |
| | TRACR3D | DOE R&D | Radionuclides and nonradiologic | environmental concentrations | 12 mm | NO | NO | Paul Mattingly |
| 120 | UDAD | FUSRAP/SFMP | Uranium series isotopes | dose commitment | 2 mm | NO | YES publ in an EIS | Dr. Charley Yu |
| 121 | UNSAT-2 | UMTRA | Flow | hyd head distr and degree of sat | | NO | YES | Marvin W. Henderson |
| | UNSAT-2 | UMTRA | Variably saturated flow | soil tension | as needed | NO | | Tim Goering |
| 122 | UNSAT-2.1 | UMTRA | Variably saturated flow | | | NO | | Linda Pegues |
| 123 | UNSAT-H | DOE Defense | Recharge | rate of recharge to unconfined aquifer | 36mm, 36mm | YES | NO | Michael J. Fayer |
| | UNSAT-H v 2.0 | DOE Defense | Flow | gw flux of meteoric w to w table | 1-2 FTE | YES | | Dr. Jerry D. Davis |
| 124 | UNSAT-H, ver 1.1 | UMTRA | Variable saturated flow | | | NO | | Linda Pegues |
| 125 | USGS-MOC | DOE Defense | 8CE;TCE;1,1-DCE | env. conc. and worst case dose | 6 mm | YES | YES ORNL draft report 1990 | K.A. Walter |
| | USGS-MOC | DOE Defense | PCE;TCE;1,2-DCE;1,1-DCE, Barium | env. conc. and worst case dose | 9 mm | YES | YES ORNL/M-1045 | K.A. Walter |
| | USGS-MOC | DOE Defense | U, NO3, SO4 | conc. in ground water | as needed | NO | | Tim Goering |
| | USGS-MOC | UMTRA | Nat, enr U, transuranics, fission | dose | 6my/yr | YES | YES | T.E. Myrick |
| 126 | UTEXAS2 | UMTRA | NA | failure surfaces, factors of safety | | NO | NO | Marvin W. Henderson |
| 127 | UTM | Perfomance assesmnent | Most radioisotopes | concetration and dose | 2 mm | NO | YES | R.K. White |
| | UTM | DOE Defense | Nat, enr U, transuranics, fission | dose | 6my/yr | YES | YES | T.E. Myrick |
| 128 | VAM2D | DOE Defense | VOC's | groundwater concentrations | 2.5mm | NO | NO | Barry Roberts |
| | VAM2D | DOE Defense | Radionuclides and nonradiologic | conc. at water table, downstr wells | 2-3 FTE | YES | YES | Tim LeGore |

*V/C = Model Validation/Calibration as reported by survey respondent

Data from the survey allows for an analysis of both the type and numbers of unique models identified, as well as the number of model applications falling into a given category. Some models are used at many sites, particularly in the DOE community. In contrast, the survey also suggests that most sites were using models which were not reported in use elsewhere. Table 3 alphabetically lists the reported models. This Table also presents primary literature references for most of the models and gives a quick indicator of the model type (e.g., air and ground water). Finally, the Table indicates whether the model can be used for radioactive substances and whether it is a detailed or screening-level model. Codes used for the purpose of modeling non-radioactive substances were included in this table because such models are often used for radioactive materials with very long half-lives (e.g., K-40) relative to their transit time.

Table 4 lists the site type at which each model was applied (see section 4.2) as well as which contaminants were being modeled at the site, the end-points of the modeling effort (see section 4.7), and the amount of time needed to complete this effort (see section 4.5). Finally, the Table shows whether the model has been calibrated/validated at the site and whether these results have been published (see sections 4.6 and 4.8, respectively).

## 4.2 Site Type

In Figure 1 the types of sites (e.g., DOE Defense, EPA Superfund) under investigation are summarized. By far the largest representation is from DOE-related sites. These account for more than 75% of the reported site-types.

## 4.3 Sponsoring Agency

As Table 5 indicates, many of the models identified were developed by or for EPA (e.g., AIRDOS, RISC, PRESTO, RADRISK), DOE (e.g., BIOTRAN, MEPAS, RESRAD,

FIGURE 1

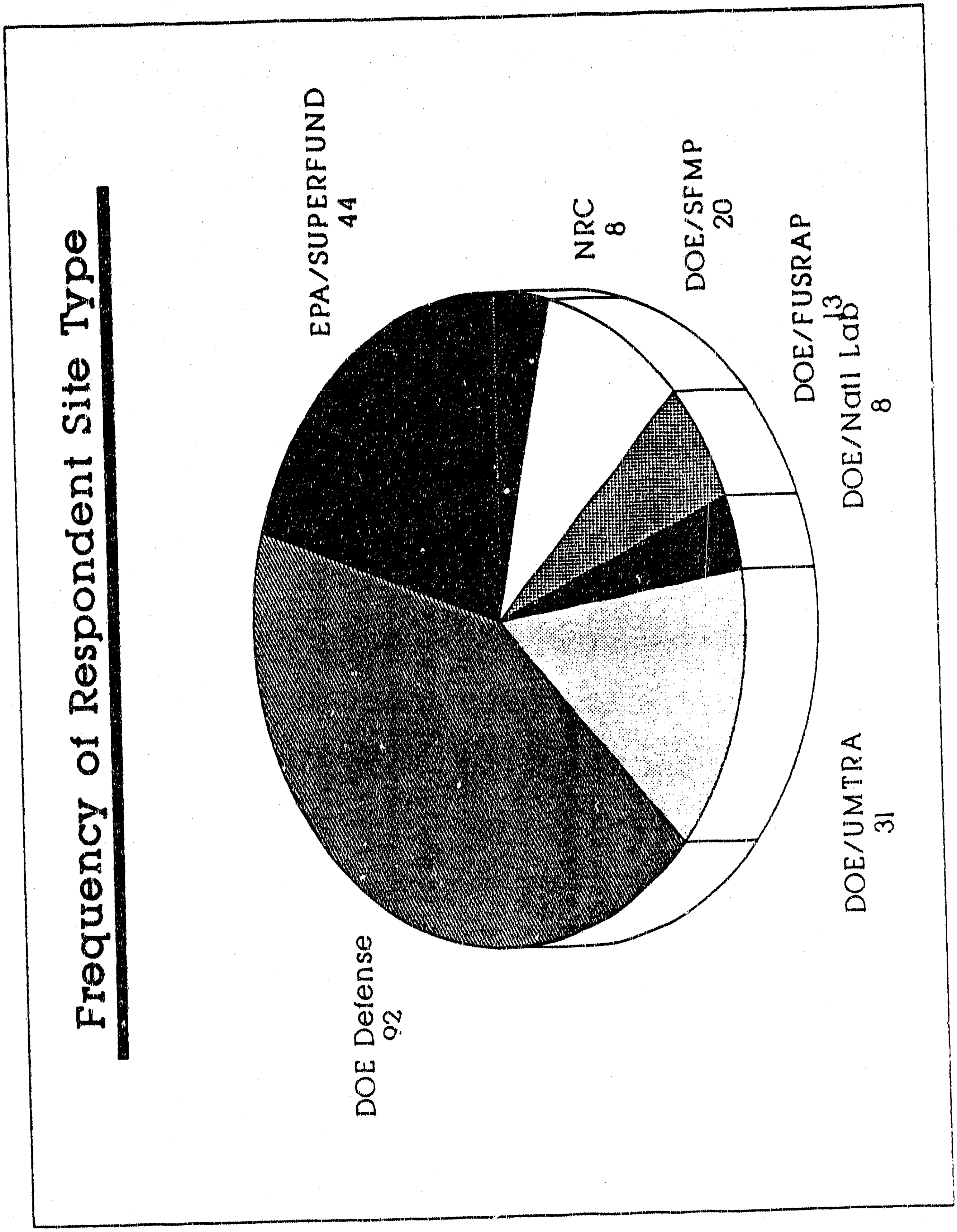

Frequency of Respondent Site Type
EPA/SUPERFUND
44
NRC
8
DOE/SFMP
20
DOE/FUSRAP
13
DOE/Nat'l Lab
8
DOE/UMTRA
31
DOE Defense
92

TABLE 5 – Model–Sponsoring Agency

| Department of Energy | | |
|---|---|---|
| ARCL | FEMWATER/FEMWASTE | MAT123D |
| BIOTRAN | GENII | PORFLO |
| CFEST | HARM–II | PORMC–3 |
| DECHEM | ISOSHLD | RHS–LC |
| DITTY | LTSAMP | RSAL |
| DOSES | MEPAS | SUMD |
| DOSTOMAN | ML CODE | TRACR3D |
| EQ3/6 | RESRAD | |

| Environmental Protection Agency | |
|---|---|
| AIRDOS (–EPA, –PC, MICRO–) | INPUFF |
| CAP–88 | ISCST,LT |
| CHARM | MINTEQ |
| COMPLY | PATHRAE (–EPA,–HAZ) |
| CREAMS | PRESTO |
| DARTAB | RADRISK |
| HELP | SCREEN |
| HRS–I | SIMS |
| HSPF | UTM |

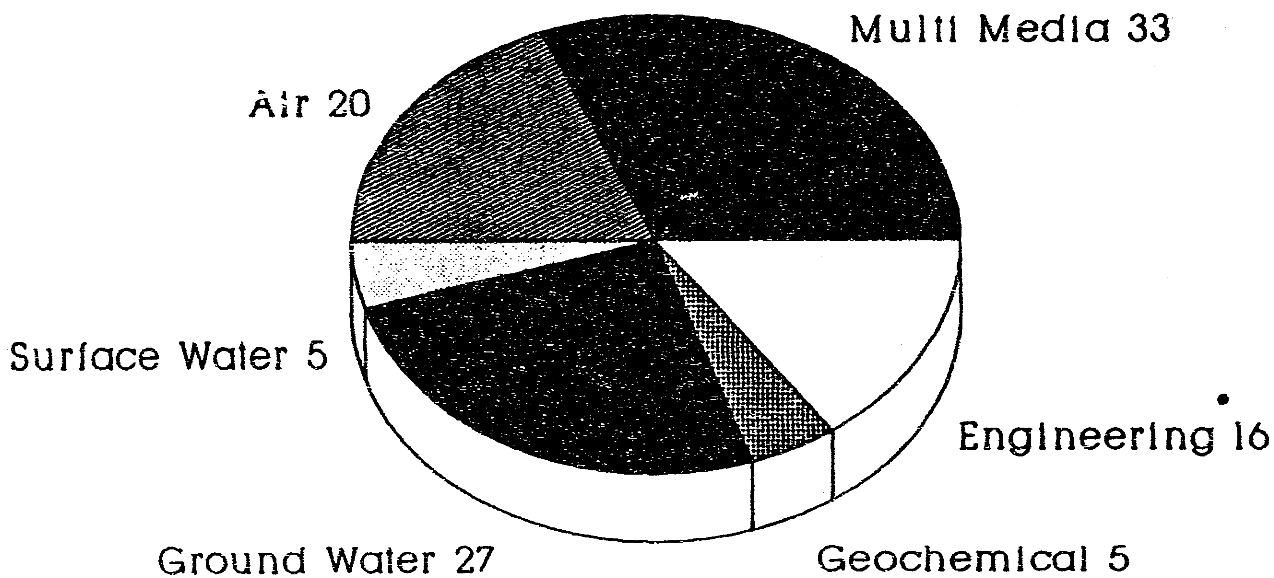
| Nuclear Regulatory Agency | |
|---|---|
| CONDOS–II | ONSITE |
| DPCT | PAGAN |
| IMPACTS (PART61,–BRC) | PATHRISK |
| MACCS | RAECOM (RADON) |
| MAXI1 | RASCAL |
| MESOI | SWIFT (–II,–III) |
| MILDOS (–AREA) | TEMPEST/FLESCOT |
| NEFTRAN II | TOUGH |
| NUREG–0707 | |

| Other | | |
|---|---|---|
| 3d Mixing Cell | MOC | SFRIPE |
| AFTOX | MODFLOW (MOD3D) | SOIL |
| BALANCE | ODAST | STABL |
| BARRIER | PATH | STABL5 |
| Bechtel | PC–SLOPE | STABLR |
| BRUNZOG | PHREEQE | STEPH |
| GENNMOD | PLASM | SURFER |
| GW FLOW | RANDOM WALK | UNSAT(–2,–H) |
| GEOFLOW | RETC.F77 | UTEXAS2 |
| HEC–1,–2 | STRIPD | VAM2D |

| Unknown | | |
|---|---|---|
| CASCADER | FLOWPATH | SOLUTE |
| CONSOL | FTWORK | SOURCE 2 |
| CYLSEC | GCDT3DH3,4,5 | SPUR |
| DCM3D | HYDROGEOCHEM | STRIP 1B |
| DECOM | NEWBOX | TDRECH11,12,21,23 |
| FLASH/FLAME | ODRECH6,7 | THEM |
| | SEFTRAN | |

FIGURE 2

## Frequency of Models/Media category




* Including Performance, Accident & Rad. Dose Models

RSAC) or the NRC (e.g., MACCS, RAECOM, UDAD). A few of the models were developed for use at a specific site by the individual organizations. Note that the number of models sponsored by groups other than the three sponsoring Agencies is substantial (30 of 127). The "Other" group includes private corporations, universities, the U.S. Geological Survey, U.S. Department of Agriculture, Canadian government agencies, State agencies, and non-profit groups. It is evident that independent model development and support is vigorous.

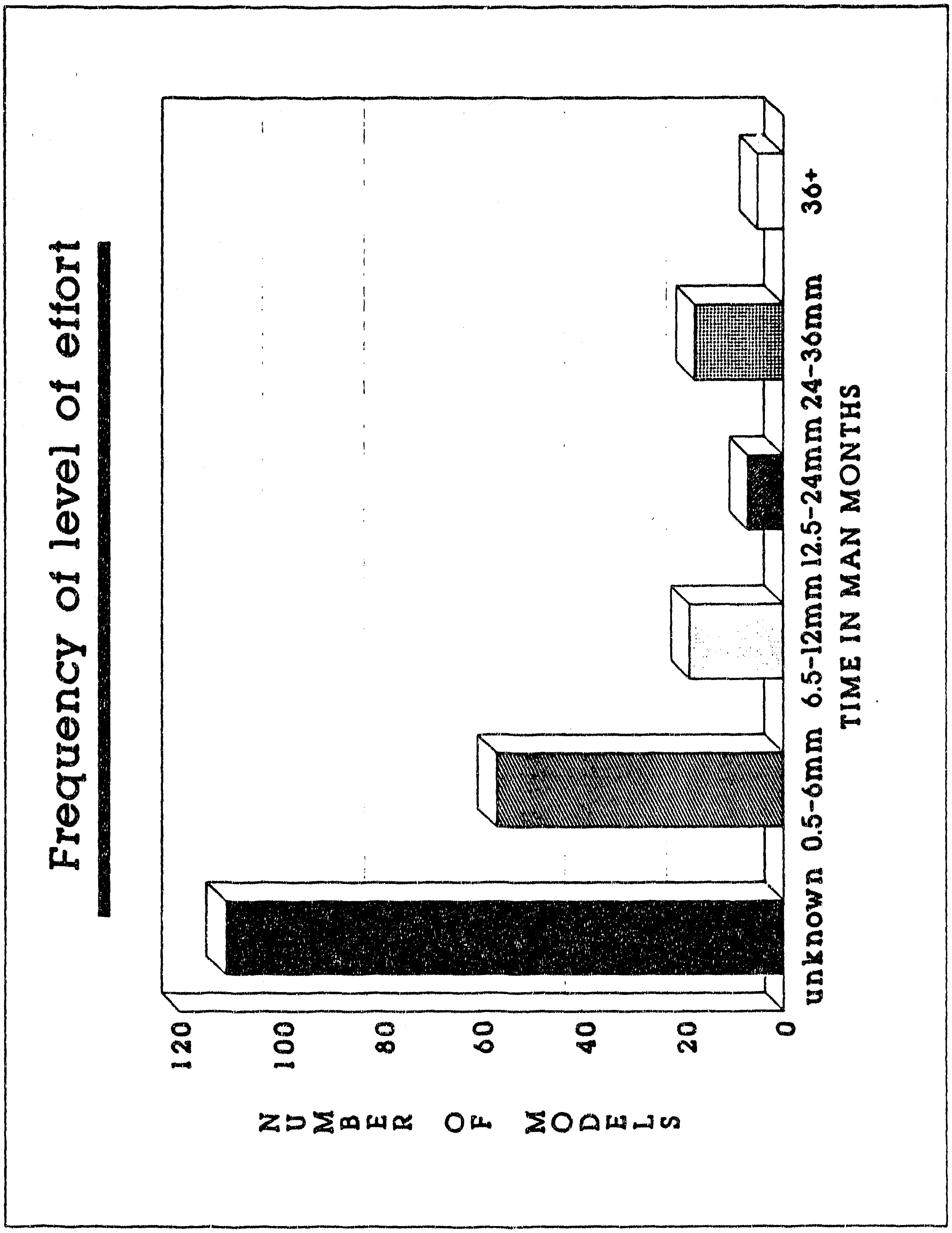
### 4.4 Media/Category

There are two important ways to look at the data further; by model, or by application. The models identified in the survey responses were categorized into the groupings discussed in Section 3. Figure 2 shows the distribution of the unique models identified among these categories. The largest number of models fall into the Multi-media category were 33 models were reported. This was closely followed by the physical transport categories (i.e., air, surface and ground water) where 32 different models were identified. Engineering models which include Performance Assessment, Accident and Radiation Dose models was the next largest group with 16 models identified. Five Geochemical models were also reported.

### 4.5 Level-of-Effort

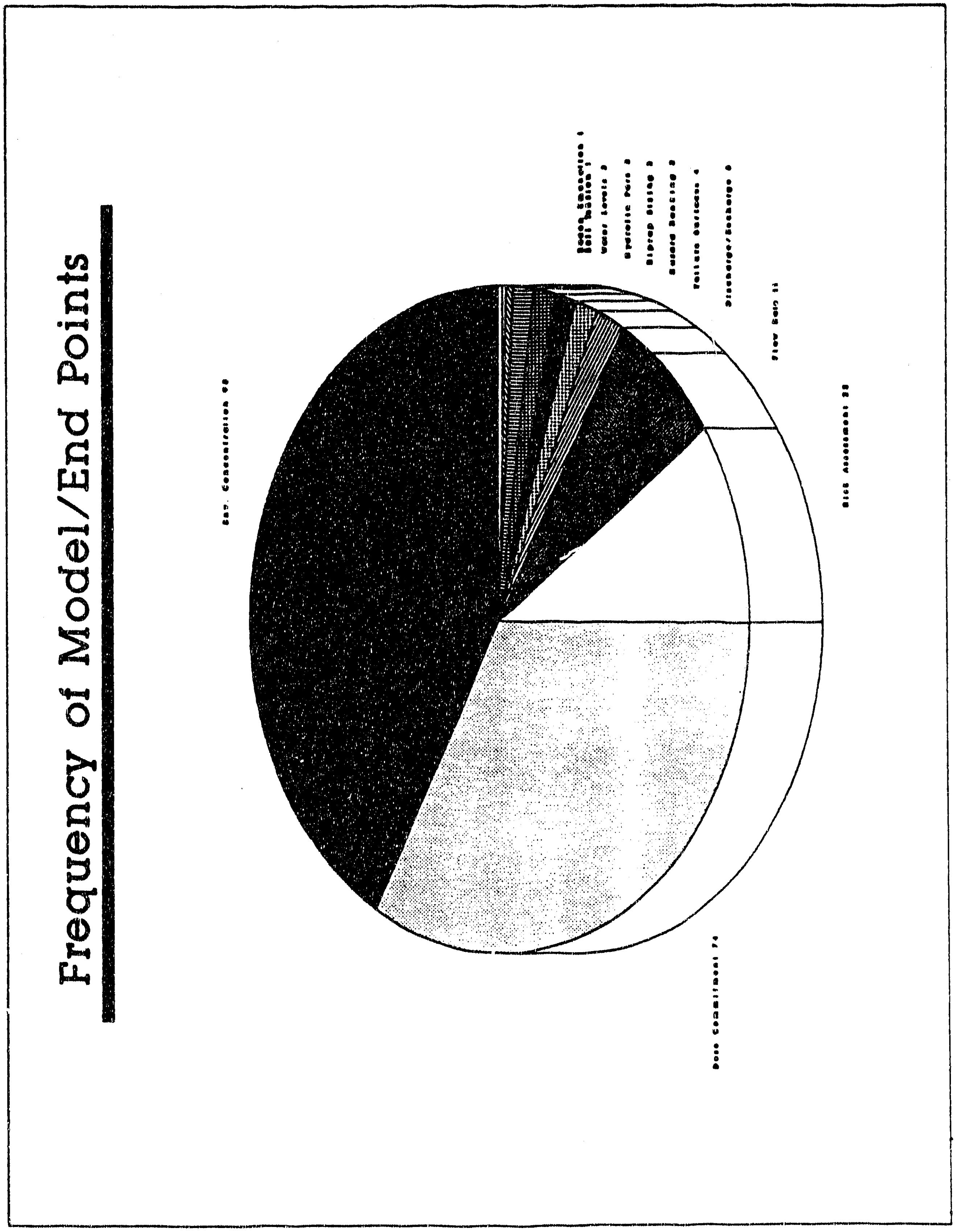
The level-of-effort required for the completion of a modeling task appears to be project specific, as opposed to model specific. The data obtained from both surveys show a wide range of man-months needed to complete a project. However, most respondents failed to answer this question. Figure 3 presents these data in groups of man-months needed to complete each reported model.

FIGURE 3



Frequency of level of effort
NUMBER OF MODELS
120
100
80
60
40
20
0
unknown
0.5-6mm
6.5-12mm
12.5-24mm
24-36mm
36+
TIME IN MAN MONTHS

FIGURE 4



## 4.6 Validation/Calibration

Site-specific model validation/calibration efforts were conducted for 53 model applications. No validation/calibration studies were conducted for the remaining 121 applications. This survey does not, however, describe how, or what level-of-effort was spent on validation/calibration. Further inquiry is needed here to determine which models have been validated/calibrated, and what was actually done.

## 4.7 End-Points

Figure 4 depicts the frequency of end-points being evaluated by the reported models. The overwhelming majority of models are being used for the more general purpose of finding environmental concentrations of contaminants and radiation dose commitment. Several more task specific models are also reported with less frequency.

## 4.8 Publications

Results of the reported modeling and validation/calibration efforts of 53 respondents were published in various journals and papers. There are no publications for 87 respondents. Furthermore, 90 respondents did not answer the question.

**TABLE 6: Index of Existing Environmental Pathway Models**

| | Survey I | Survey II | None | Agency |
|---|---|---|---|---|
| **Multi-Media** | | | | |
| *Hazard Ranking* | | | | |
| DPM | | | ● | DOD |
| HRS-I | ● | | | EPA |
| RHRS-LC | ● | | | DOE |
| *Radioactive Materials Fate & Transport* | | | | |
| COMPLY (-II) | ● | | | EPA |
| DECHEM | ● | ● | | DOE |
| DECOM | | ● | | |
| DITTY | ● | ● | | DOE |
| DOSES | ● | | | ORNL/DOE |
| DOSTOMAN | ● | | | DOE |
| GENII | ● | ● | | Hanford/DOE |
| GENMOD | ● | | | AECL |
| GRDFLX | | | ● | NRC |
| IMPACTS (PART61) (-BRC) | ● | ● | | RSIC/NRC |
| MILDOS (-AREA) | ● | | | NRC |
| NUREG-0707 | ● | | | NRC |
| ONSITE/MAXI1 | ● | | | PNL/NRC |
| PAGAN | | ● | | NRC |
| PATH | ● | | | General Electric Corp. |
| PATHRAE (-EPA, -HAZ) | ● | ● | | EPA |
| PRESTO (-II, -EPA-DEEP, -EPA-BRC, -EPA-CPG) | ● | | | DOE/EPA |
| RESRAD | ● | ● | | ANL/DOE |
| UDAD | ● | | | NRC |
| *General Purpose* | | | | |
| ARCL | ● | | | DOE |
| Bechtel proprietary | | ● | | Bechtel Corp. |
| CASCADER | | ● | | |
| CONDOS (-II) | ● | | | NRC |
| ENPART (cf. GEMS) | | | ● | EPA |
| FLOWPATH | | ● | | |
| FTWORK | | ● | | |
| GCDT3DH (-3, -4, -5) | | ● | | |
| GEMS | | | ● | EPA |
| MICROBE-SCREEN (cf GEMS) | | | ● | EPA |
| MEPAS | ● | ● | | DOE |
| MULTIMED | | | ● | |
| ODRECH(-6, -7) | | ● | | |
| PATHRISK | | | ● | NRC |
| SPUR | ● | | | |
| STRIP 1B | | ● | | |
| SUMO | ● | | | DOE |
| TDRECH (-11, -12, -21, -23) | | ● | | |
| TOX-SCREEN (cf. GEMS) | | | ● | EPA |
| UTM (-TOX) (cf. GEMS) | ● | ● | | ORNL/EPA |
| *Foodchain* | | | | |
| BIOTRAN | ● | | | LASL/DOE |
| INGDOS | | | ● | |
| TERRA | | | ● | |
| THEM | | ● | | |

**TABLE 6: Index of Existing Environmental Pathway Models**

| | | | | Survey I | Survey II | None | Agency |
|---|---|---|---|---|---|---|---|
| **Air** | | | | | | | |
| | | | ADPIC | | | • | |
| | | | AFTOX | • | | | U.S. Army |
| | | | AIRDOS (–EPA, –PC, MICRO–, –AIRI) | • | • | | RSIC/ORNL/EPA/Galson T. S. Inc. |
| | | | ANEMOS (CRRIS) | | | • | |
| | | | AVACTRA II | | | • | AeroEnvironment Inc. |
| | | | AVLAGPAR | | | • | AeroEnvironment Inc. |
| | | | BOXMOD | | | • | |
| | | | CALINE–3 | | | • | California DOT |
| | | | CAP–88 | • | | | EPA |
| | | | CHARM (EIS) | • | | | EPA/Radian Corp./Res. Alt. Inc. |
| | | | COMPLY | • | | | EPA |
| | | | COMPLEX–1 | | | • | |
| | | | CRAC2 | | | • | |
| | | | DACRIN | | | • | |
| | | | DARTAB | • | • | | EPA |
| | | | GAMS | | | • | |
| | | | GASPAR | | | • | |
| | | | HARM–II | • | | | DOE |
| | | | INPUFF (cf. GEMS) | • | | | EPA/Bowman Env |
| | | | ISC (–LT, –ST, BREEZE –AIR, –HAZ, –WAY) | • | | | EPA/Bowman Env/Trinity Cons. |
| | | | KRONIC | | | • | |
| | | | LTSAMP | • | | | DOE |
| | | | MESOI | • | | | NRC |
| | | | ML CODE | • | | | DOE |
| | | | PAVAN | | | • | |
| | | | PHAST | | | • | Technica Inc. |
| | | | PTPLU–2 | | | • | |
| | | | RAECOM | • | • | | NRC |
| | | | RSAC–3 | • | | | |
| | | | RISKPRO–ACSI | | | • | General Services Corp. |
| | | | SCREEN | • | | | EPA |
| | | | SIMS | • | | | EPA |
| | | | SUBDOSA | | | • | |
| | | | TECJET | | | • | Technica Inc. |
| | | | TOXBOX | | | • | |
| | | | UNAMRP | | | • | Bowman Env./Env. Inc./Clary Ass. |
| | | | XOQ/DOQ | | | • | NRC |

**TABLE 6: Index of Existing Environmental Pathway Models**

| | | | Model | Survey I | Survey II | None | Agency |
|---|---|---|---|---|---|---|---|
| Surface Water | | | | | | | |
| | Runoff | | | | | | |
| | | *Agricultural* | | | | | |
| | | | GLEAMS (CREAMS) | | • | | USDA |
| | | | HSPF | | | • | EPA |
| | | | MRI | | | • | |
| | | | PRZM (PREPRZM) (cf. GEMS) | | | • | EPA |
| | | | STREAMS | | | • | |
| | | | WQAM | | | • | |
| | | *Urban/Suburban* | | | | | |
| | | | HSPF | | • | | EPA |
| | | | MRI | | | • | |
| | | | STORM | | | • | |
| | | | SWMM | | | • | EPA |
| | | | WQAM | | | • | |
| | | *Landfill* | | | | | |
| | | | HELP | • | • | | EPA |
| | | | MRI | | | • | |
| | | | SARAH | | | • | |
| | | | WQAM | | | • | |
| | | *Undeveloped* | | | | | |
| | | | GLEAMS (CREAMS) | | • | | USDA |
| | | | HSPF | | • | | EPA |
| | | | MRI | | | • | |
| | | | WQAM | | | • | |
| | Streams | | | | | | |
| | | *Flow* | | | | | |
| | | | DYNHYD5 (see WASP4) | | | • | |
| | | | HEC (-1,-2) | • | | | Army Corps of Engineers |
| | | | HYDRO2D-V | | | • | |
| | | | QUALZE | | | • | |
| | | | SBUHYD | • | | | Univ. Calif. Santa Barbara |
| | | | TEMPEST/FLESCOT | • | | | NRC |
| | | | TR-20 | | | • | |
| | | *Transport* | | | | | |
| | | | DYNTOX | | | • | |
| | | | EUTRO4 (see WASP4) | | | • | |
| | | | MEXAMS | | | • | |
| | | | MICHRIV | | | • | |
| | | | REACHSCAN | | | • | |
| | | | SARAH2 | | | • | |
| | | | SLSA | | | • | |
| | | | TOXI4 (cf. WASP4) | | | • | EPA |
| | | | WQAM | | | • | |

**TABLE 6: Index of Existing Environmental Pathway Models**

| | | | | Survey I | Survey II | None | Agency |
|---|---|---|---|---|---|---|---|
| | | *Flow and Transport* | | | | | |
| | | | CEQUALRIV1 | | | • | |
| | | | CEQUALW2 | | | • | |
| | | | CODELL | | | • | NRC |
| | | | HSPF | | • | | EPA |
| | | | QLPLOT | | | • | |
| | | | QUAL2E (AQUAL2) | | | • | |
| | | | RIVMOD | | | • | |
| | | | WASP4 | | | • | EPA |
| | | *Multiple Surface Water Flow and Transport* | | | | | |
| | | | CORMIX | | | • | |
| | | | EXAMS2 (II) (cf. GEMS) | | | • | EPA |
| | | *Foodchain* | | | | | |
| | | | BIODOSE | | | • | |
| | | | FGETS | | | • | |
| | | | LADTAP II | | | • | |
| | | | PABLM (FOOD.ARRRG) | | | • | |

**TABLE 6: Index of Existing Environmental Pathway Models**

| Category | Model | Survey I | Survey II | None | Agency |
|---|---|---|---|---|---|
| **Ground Water** | | | | | |
| *Ground Water Flow* | | | | | |
| *Well Analysis* | | | | | |
| | AQUIX | | | • | |
| | FASTEP | | | • | |
| | GWAP | | | • | |
| | PARADOP | | | • | |
| | PTDPS (-I,-II,III) | | | • | |
| | PUMP | | | • | |
| | PUMPING TEST PROGRAM PACKAGE | | | • | |
| | SLUGIX | | | • | |
| | STEP-MATCH | | | • | |
| | THEISFIT | | | • | |
| | TS-MATCH | | | • | |
| | TYPCURV | | | • | |
| | WELLFRAC | | | • | |
| | WHIP | | | • | |
| *Drawdown* | | | | | |
| | ANALYTICAL MODELS | | | • | |
| | GLOVER | | | • | |
| | HYDROPAL/1 | | | • | |
| | THEIS | | | • | |
| | THEIS2 | | | • | |
| | UTIL2 | | | • | |
| | WATER-VEL | | | • | |
| *Unsaturated-1d* | | | | | |
| | HELP | • | | | EPA |
| | VADOFT (cf. RUSTIC) | | | • | EPA |
| *Unsaturated-2d* | | | | | |
| | MLTRAN | | | • | |
| *Unsaturated-3d* | | | | | |
| | DCM3D | | • | | |
| | VADOSE | | | • | |
| *Saturated-1d* | | | | | |
| | ODAST | | • | | American Geophys. Union |
| | SOIL | | • | | IGWMC |
| *Saturated-2d* | | | | | |
| | AQUIFEM | | | • | |
| | BEWTA | | | • | Nova Scotia Dept. Env. |
| | COOLEY | | | • | R.L. Cooley, Nevada Univ. |
| | FLUMP | | | • | S.P. Neuman, Univ. Arizona |
| | FRESURF (-1,-2) | | | • | |
| | NUSEEP | | | • | Northwestern Univ., Dept. CE |
| | USGS2D | | | • | USGS |
| | V3 | | | • | Illinois State Water Surv. |
| | VTT | | | • | PNL/DOE |
| | WELFLO | | | • | |

TABLE 6: Index of Existing Environmental Pathway Models

| | | | | Survey I | Survey II | None | Agency |
|---|---|---|---|---|---|---|---|
| | | *Saturated–3d* | | | | | |
| | | | DPCT | | ● | | |
| | | | EPA–WHPA | | | ● | |
| | | | FE3DGW | | | ● | PNL/WISAP |
| | | | GWFL3D | | | ● | |
| | | | MAT123D | ● | ● | | |
| | | | RADIAL FINITE DIFFERENCE MODEL | | | ● | |
| | | | RETC.F77 | ● | | | USDA |
| | | | TERZAGI | | | ● | T.N. Narasimhan, Univ. California |
| | | | USGS3D (Modular,Trescott) | | | ● | USGS |
| | | | WELLFLO | | | ● | |
| | | *Unsaturated/Saturated–1d* | | | | | |
| | | | UNSAT1D | | | ● | U.S. Salinity Lab/DOE/NRC/PNL |
| | | *Unsaturated/Saturated–2d* | | | | | |
| | | | FEMWATER (cf. FEMWASTE) | | | ● | DOE |
| | | | MAGNUM 2D | | | ● | EG&G Idaho |
| | | | MMT | | | ● | |
| | | | TRUST (–II) | | | ● | |
| | | | UNSAT (–H,–2) | ● | | | U.S. Salinity Lab./DOE/NRC/PNL |
| | | | MOD2D (–FD) | | | ● | USGS |
| | | | PATHS | | | ● | PNL/WISAP |
| | | *Unsaturated/Saturated–3d* | | | | | |
| | | | FREEZE | | | ● | R.A. Freeze, Univ. Waterloo |
| | | | GEOFLOW | | ● | | |
| | | | GW FLOW | ● | | | NSEL,Canada |
| | | | MAGNUM 3D | | | ● | EG&G Idaho |
| | | | MOD3D (–FD) (MODFLOW) (MODINV) (MACMODFLOW) | ● | ● | | USGS |
| | | | PATH3D | | | ● | |
| | | | PC HST3D | | | ● | |
| | | | PLASM | ● | | | Illinois State Water Survey |

**TABLE 6: Index of Existing Environmental Pathway Models**

| | | Survey I | Survey II | None | Agency |
|---|---|---|---|---|---|
| **Ground Water Flow and Transport** | | | | | |
| *Unsaturated--1d* | | | | | |
| | CHEMFLO | | | • | |
| | GLEAMS | | | • | |
| | ICE-1 | | | • | |
| | PRZM (cf. RUSTIC) | | | • | |
| | RITZ | | | • | |
| | TETRANS | | | • | |
| | VADOFT | | | • | |
| *Unsaturated--2d* | | | | | |
| | BIOPLUMEII | | | • | |
| | FLOWS | | | • | |
| | GS2 | | | • | |
| | PORFLO-2D | | | • | Hanford/DOE |
| | TRIPM | | | • | |
| | WAFE | | | • | |
| *Unsaturated--3d* | | | | | |
| | CHAMP | | | • | |
| | GS3 | | | • | |
| | PERCOL | | | • | ANL/PNL/ORNL |
| | PORFLO-3D | • | | | Hanford/DOE |
| | PORMC-3 | • | | | Hanford/DOE |
| | TOUGH | | • | | |
| *Saturated--1d* | | | | | |
| | AGU-10 PKG (ODAST) | | • | | American Geophys. Union |
| | GETOUT | | | • | PNL/DOE |
| | GWMTM1,2 | | | • | Princeton Univ. |
| | LAYFLO | | | • | |
| | MMT | | | • | PNL/DOE |
| | NEFTRAN II | | | • | |
| *Saturated--2d* | | | | | |
| | ASM | | | • | |
| | CATTI | | | • | |
| | CONMIG | | | • | |
| | DPCT | | • | | CGS, Inc. |
| | DUGUID-REEVES | | | • | ORNL |
| | EPA-VHS | | | • | EPA |
| | FTRANS | | | • | |
| | GWMTM2 | | | • | |
| | GWTHERM | | | • | Dames & Moore, Inc. |
| | HYDROPAL | | | • | |
| | ISQUAD (-2) | | | • | Princeton Univ./Univ. Waterloo |
| | KONBRED (cf. MOC (USGS)) | • | • | | USGS |
| | MAGNUM2D-CHAINT | | | • | |
| | OGRE | | | • | LLNL |
| | PATHS | | | • | |
| | PLUME (-2D) | | | • | |
| | PORFLO2D | | | • | EPA |
| | PTC | | | • | |
| | RANDOM WALK | • | | | Illinois State Water Survey |
| | RESTOR | | | • | |
| | ROBERTSON (-1,-2) | | | • | USGS |
| | SAFTMOD (cf. RUSTIC) | | | • | |
| | SALTRP | | | • | |
| | SHALT | | | • | AECL |

**TABLE 6: Index of Existing Environmental Pathway Models**

| | | | | | | | Agency |
|---|---|---|---|---|---|---|---|
| | | | | Survey I | Survey II | None | Agency |
| | | | TRAFRAP-WT | | | • | |
| | | | TRANS | | | • | USGS |
| | | *Saturated–3d* | | | | | |
| | | | AT123D (cf. GEMS) | | | • | ORNL |
| | | | CFEST | • | • | | PNL/DOE |
| | | | GROVE/GALERKIN | | | • | USGS/Water Resorces |
| | | | GWTR3D | | | • | |
| | | | HST3D | | | • | |
| | | | PINDER | | | • | Princeton Univ. |
| | | | PLUME | | | • | |
| | | | PRINCETON | | | • | |
| | | | SOLUTE PKG | | • | | |
| | | | SWENT | | | • | INTERA Env. Cons. Inc. |
| | | | SWIP2 | | | • | SNL/USGS/INTERA Env. Cons. Inc. |
| | | | TRANSAT2 | | | • | GTC, Canada |
| | | *Unsaturated/Saturated–1d* | | | | | |
| | | | CHAIN | | | • | EG&G Idaho |
| | | | CHAINT | | | • | Hanford |
| | | | CXPMPM | | | • | |
| | | | HYDRUS | | | • | |
| | | | ONE-D | | | • | |
| | | | PULSE | | | • | |
| | | | SESOIL (cf. EMS) | | | • | |
| | | | SUMATRA-I | | | • | U.S. Salinity Lab. |
| | | | WORM | | | • | |
| | | *Unsaturated/Saturated–2d* | | | | | |
| | | | FEMWASTE (cf. FEMWATER) | | | • | DOE |
| | | | GROUNDWATER PACKAGE | | | • | |
| | | | LPMM | | | • | |
| | | | MOC (USGS) | • | • | | USGS |
| | | | MOD3D | | | • | USGS |
| | | | RW-ANALYT | | | • | |
| | | | SATURN | | | • | GEOTRANS, Inc. |
| | | | SUTRA | | | • | USGS/IGWMC/NWWA |
| | | | TDPLUME | | | • | |
| | | | TRANUSAT | | | • | GTS, Ltd. |
| | | | TWODPLME | | | • | |
| | | | VAM2D | • | • | | Hydrogeologic |
| | | | VS2DT | | | • | USGS |
| | | | WQAM | | | • | |

**TABLE 6: Index of Existing Environmental Pathway Models**

| | | | | Survey I | Survey II | None | Agency |
|---|---|---|---|---|---|---|---|
| | | *Unsaturated/Saturated–3d* | | | | | |
| | | | 3-d MIXING CELL | | • | | |
| | | | BEAVERSOFT | | | • | |
| | | | FLOWTHROUGH | | • | | |
| | | | KINZALBACH | | | • | |
| | | | MAT123D | | • | | DOE |
| | | | MT3D (cf MODFLOW) | | | • | S.S. Popadopulos & Associates |
| | | | NUTRAN | | | • | |
| | | | NWFT/DVM | | | • | SNL/NRC |
| | | | PORFLO3D | • | | | Hanford/DOE |
| | | | RUSTIC | | | • | |
| | | | SEFTRAN | | • | | |
| | | | SEGOL | | | • | |
| | | | SLM | | | • | |
| | | | SWANFLOW | | | • | |
| | | | SWIFT (–II,–III) | • | • | | SNL/NRC/GeoTrans, Inc. |
| | | | TARGET | | • | | |
| | | | TRACER3D | | • | | LANL/DOE |
| | | | TRIPM | | | • | |
| | | | TRUST (MLTRAN) (–II) | | | • | LBL/NRC |
| | | | WALTON PKG (35) | | | • | |

**TABLE 6: Index of Existing Environmental Pathway Models**

| Category | Subcategory | Model | Survey I | Survey II | None | Agency |
|---|---|---|---|---|---|---|
| Aqueous Geochemistry | | | | | | |
| | *Geochemical* | | | | | |
| | | BALANCE | • | | | USGS |
| | | ECHEM | | | • | |
| | | EQ3/6 | • | | | DOE |
| | | EQUILB | | | • | |
| | | GCSOLAR | | | • | |
| | | HYDROGEOCHEM | • | | | |
| | | MINTEQ (−A2) (PRODEFA) | • | | | EPA |
| | | PHREEQE | • | | | USGS |
| | | SOILCHEM | | | • | |
| | | TRANSCHEM | | | • | |
| | | WATEQ4F | | | • | |
| | *Hydrochemical* | | | | | |
| | | CHEMTRN | | | • | |
| | | CHEMTRNS | | | • | |
| | | CPT | | | • | |
| | | CTMID | | | • | |
| | | DYNAMIX | | | • | |
| | | FASTCHEM (cf. ECHEM) | | | • | |
| | | FIESTA | | | • | |
| | | MININR | | | • | |
| | | TRANQL | | | • | |
| | | THCC | | | • | |
| Engineering/Performance/Accident | | | | | | |
| | | ANISN | | | • | |
| | | BARRIER | • | | | EPRI |
| | | BRUNZOG | • | | | U.S. Army |
| | | BLT (cf. FEMWASTE) | | | • | DOE/EPA |
| | | CONSOL | • | | | |
| | | DOT | | | • | |
| | | FLASH/FLAME | • | | | |
| | | HELP | • | | | EPA |
| | | MACCS | • | | | NRC |
| | | MORSE−SGS/S | | | • | |
| | | NUTRAN | | | • | AECL/UCRL |
| | | NEWBOX | | • | | |
| | | ORIGEN−S | | | • | |
| | | PC−SLOPE | • | | | Geo−Slope, Canada |
| | | RADTRAN (−II) | | | • | |
| | | RASCAL | • | | | NRC |
| | | RSAC | • | | | DOE/EXXON |
| | | SFRIPD | • | | | MK Environmental, Inc |
| | | SFRIPE | • | | | MK Environmental, Inc |
| | | STABL5 | • | | | DOT |
| | | STABL | • | | | R.A. Siegel, Purdue Univ. |
| | | STABR | • | | | Univ. Calif. Berkeley |
| | | STEPH | • | | | MK Environmental, Inc |
| | | UTEXAS2 | • | | | Texas St. Dept. Hwy. & Pub. Trans. |

**TABLE 6: Index of Existing Environmental Pathway Models**

| | | | | Survey I | Survey II | None | Agency |
|---|---|---|---|---|---|---|---|
| **Radiation Dose** | | | | | | | |
| | | | ANDROS | | | ● | |
| | | | ANISN/PC | | | ● | RSIC/ANL |
| | | | CRAC2 | | | ● | |
| | | | CYLSBC | | ● | | |
| | | | DACRIN (cf. PABLM) | | | ● | |
| | | | DOSHEM | | | ● | |
| | | | HUMTRN | | | ● | |
| | | | ISOSHLD | ● | | | RSIC/BNWL/DOE |
| | | | LADTAP | | | ● | NRC |
| | | | ORIGEN2 | | | ● | RSIC/ORNL/DOE |
| | | | QAD–FN | | | ● | RSIC/INEL |
| | | | RADRISK | ● | | | EPA |
| | | | REDIQ | | | ● | |
| | | | SOURCE 2 | | ● | | |
| **Utilities** | | | | | | | |
| | | | ANNIE--IDE | | | ● | |
| | | | GKS | | | ● | ANSI/Spectragraphics, Inc. |
| | | | SURFER | | ● | | Golden Software, Inc. |

## 5. DISCUSSION AND CONCLUSIONS

In any voluntary survey it is essential to question the representativeness of the results. In this context, the results of the two surveys reported here can be compared with each other and with previously published technical literature.

In comparing the data collected within the two surveys reported here, one of the most striking aspects of the results is the small overlap between the two. As Table 6 indicates only 17 models (13% of the total) were reported in both surveys. While this may suggest that each of the surveys sampled distinctly different populations, there is one very important reason that this might not be true. That is, we had originally hypothesized that because no formal guidance for model use exists, models would be chosen on an *ad hoc*, site-by-site basis. This hypothesis appears to be correct. Approximately 60% of the identified models in both surveys were used at only one site. This could also imply that there may be a substantial amount of model redundancy, especially in the application of General Purpose or Multi-Media models.

Based on published literature which includes surveys (e.g., Mangold and Tsang, 1991), review articles (e.g., Case, 1989) and technical literature on model development and application oriented studies, we know that many other models exist other than the models identified in this survey. In Table 6, we list and categorize many of these "unidentified" models. Whether these models are actually being used to support cleanup decisions remains unanswered. We speculate that these models were not identified because of the dynamic nature of the modeling community in which models and model applications are constantly being upgraded and changed. An index of known environmental pathway models, extrapolated from all referenced literature and revues, and the agency which sponsored their development is also presented in Table 6. Models reported in the current survey represent approximately 25% of the known models used in environmental pathway analysis. One important example of an "unidentified" model is FEMWATER/FEMWASTE. No users of the model were identified in the survey, yet the use of FEMWATER/FEMWASTE has been reported in the literature (Sullivan and Suen, 1989).

In conclusion, it is clear that a unified approach to model selection is needed. Ultimately, this will reduce administrative cost, while improving the technical quality of the decision-making process. Proactive guidance from the sponsoring Agencies for model selection is preferable to retroactive correction and improvement, through modification, of an inappropriately applied model.

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## Appendix A - BACKGROUND INFORMATION ON IDENTIFIED MODELS

### Model Descriptions and References

NOTE: This appendix includes expanded listings for all of the models reported in the two Surveys and some models not reported by respondents but known by the authors to be in use. Model descriptions included here have been taken with minor editing from descriptions contained in the references. Any errors or omissions in these descriptions are unintentional and are the responsibility of the authors of this report. We would appreciate receiving notice of any such errors or omissions so that we can correct any future editions of the text.

## MULTI-MEDIA - HAZARD RANKING

**Model Name:** HRS-1 (Hazard Ranking System-I)
**Sponsor:** USDOE

**Description:** Hazard ranking.

**Reference:** Stenner, R.D., R.A. Peloquin and K.A. Hawley. 1986. Modified Hazard Ranking System/Hazard Ranking System for Sites With Mixed Radioactive and Hazardous Wastes - Software Documentation. PNL-6066. Pacific Northwest Laboratory, Richland, Washington.

**Model Name:** MEPAS (Multimedia Environmental Pollutant Assessment System)
**Sponsor:** USDOE

**Description:** MEPAS is a risk computation system developed for hazard ranking applications. MEPAS is designed to integrate the information available for defining chronic public health risks associated with a problem, or a series of problems. This system includes multi-pathway transport and fate models. Potential problems may be characterized by either modeling the environment transport or by input of concentrations at the receptor.

Individual and population environmental risks are evaluated from radioactive materials, chemical carcinogens, and noncarcinogens by considering all major exposure pathways. An internal database provides chemical, physical, and risk evaluation parameters for 297 constituents. Outputs include intermediate files (input values, emission rates, environmental concentrations) and a file with impact information including maximum individual and total population impact magnitudes, timing, and location.

Models are imbedded for air emissions (VOLATE), air transport processes (RAPSCD) and water transport processes (RADCOND), and effects computation (HAZ). Gaseous and particulate emissions/fluxes may be estimated based on site conditions, or input as known parameters. The air transport is a sector average Gaussian model with deposition and complex terrain modules that account for local terrain influences. The soil transport can use dimensional advection and dispersion. In the vadose zone, the model has one dimensional advection and dispersion. In the saturated zone, the model has one dimensional advection and three dimensional dispersion. Various linkages of transport through soil, ground water, surface water and overland runoff are supported.

MEPAS is implemented in MS-DOS for use on an IBM-PC or compatible with a computer shell designed for application to a large number of problems. This Shell allows problem definition, data entry, reference tracking, and model running. A set of data input worksheets are generated for each problem for purposes such as external review or project records.

**Reference:** Doctor, P.G., T.M. Miley and C.E. Cowan. 1990. Multimedia Environmental Pollutant Assessment System (MEPAS) Sensitivity Analysis of Computer Codes. Prepared for the U.S. Department of Energy. PNL-7296, UC-602, 630. Pacific Northwest Laboratory, Richland, Washington.

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Whelan. G., D.L. Strenge, J.G. Droppo Jr., and B.L. Steelman. 1987. The Remedial Action Priority System (RAPS): Mathematical Formulations. PNL-6200. Pacific Northwest Laboratory, Richland, Washington.

## MULTI-MEDIA - RADIOACTIVE MATERIALS TRANSPORT AND FATE

**Model Name:** ARCL
**Sponsor:** USDOE

**Description:** Method to evaluate decommissioning alternatives by using a site-specific radiation scenario/exposure pathway analysis to determine the acceptable levels of residual radioactive contaminants that remain.

**Reference:** Napier, B.A., and G.F. Piepel. 1988. A Manual for Applying the Allowable Residual Contamination Level Method For Decommissioning Facilities On The Hanford Site. Pacific Northwest Laboratory, Richland, Washington. PNL-6348/UC602.

**Model Name:** DECHEM
**Sponsor:** USDOE

**Description:** Multiple pathway model developed for use in determining acceptable levels of chemicals in soil after clean-up of Uranium Mill Tailings Remedial Action Project Sites (UMTRA). The model considers exposure through ingestion of contaminated drinking water, ingestion of contaminated food and inhalation of resuspended soil contaminants.

**Reference:** Model prepared by the Radiological Assessments Corporation, Neeses, South Carolina. Complete citation not provided by respondents.

**Model Name:** DITTY (Dose Integrated Over Ten Thousand Years)
**Sponsor:** USDOE

**Description:** DITTY was developed to determine the collective dose from long term nuclear waste disposal sites resulting from ground water pathways. DITTY estimates the time integral of collective dose over a ten-thousand year period for time-variant radionuclide releases to surface waters, wells or the atmosphere.

**Reference:** Napier, B.A., R.A. Peloquin, and D.L. Strenge. 1986. DITTY- A Computer Program for Calculating Population Dose Integrated Over Ten Thousand Years. PNL-4456. Pacific Northwest Laboratories, Richland, Washington.

**Model Name:** DOSES
**Sponsor:** ORNL

**Description:** Being developed/used to simplify QC requirements. DOSES calculates dose to man from measured environmental samples.

**Reference:** Developed by ORNL for use at ORNL. Complete citation not provided by respondents.

**Model Name:** DOSTOMAN
**Sponsor:** USDOE

**Description:** Model is designed to provide estimates of long-term dose to man from buried waste. The model consists of compartments which represent different portions of the environment, including vegetation, herbivores, atmosphere, ground water, surface water and man.

**Reference:** Root, R.W. 1981. Documentation and User's Guide for DOSTOMAN - A Pathways Computer Model of Radionuclide Movement. DPST-81-549, E.I. DuPont de Nemours & Co.

C.M. King, E.L. Wilhite, R.W. Root, Jr., D.J. Fauth, K.R. Routt, R.H. Emslie and R.R. Beckmeyer, R.A. Fjeld, G.A. Hutto and J.A. Vandeven. 1985. The Savannah River Laboratory DOSTOMAN Code - A Compartmental Pathways Model of Contaminant Transport. Proceedings of the DOE Low-Level Waste Management Program Seventh Annual Participants Information Meeting, Las Vegas, Nevada, 1985. CONF-8509121-13.

**Model Name:** GENII (Hanford Env. Dosimetry System Generation II)
**Sponsor:** USDOE

**Description:** Comprehensive set of environmental pathway and internal dosimetry models. Composed of seven linked computer codes and their associate data libraries

**Reference:** Napier, B.A., R.A. Peloquin, D.L. Strenge and J.V. Ramsdell. 1988. Hanford Environmental Dosimetry Upgrade Project. GENII - The Hanford Environmental Radiation Dosimetry System. 3 Volumes. PNL-6584. Pacific Northwest Laboratories, Richland, Washington.

**Model Name:** GENMOD
**Sponsor:** Atomic Energy of Canada

**Description:** Calculation of internal dose.

**Reference:** Prepared by Atomic Energy of Canada for use by the Canadian Nuclear Industry. Complete citation not provided by respondents.

**Model Name:** MILDOS
**Sponsor:** USNRC

**Description:** MILDOS was designed to compute environmental radiation doses from uranium recovery operations.

**Reference:** Strenge, D.L. and T.J. Bander. 1981. MILDOS - A Computer Program For Calculating Environmental Radiation Doses From Uranium Recovery Operations. NUREG/CR-2011, PNL-3767. Pacific Northwest Laboratory, Richland, Washington.

**Model Name:** MILDOS-AREA
**Sponsor:** USDOE

**Description:** MILDOS-AREA is an improved version of MILDOS. The MILDOS-AREA code provides improved capability for handling large area sources and updates the dosimetry calculations. Runs on an IBM-PC computer.

**Reference:** Yuan, Y.C., J.H.C. Wang; and A. Zielen. 1989. MILDOS-AREA: An Enhanced Version of MILDOS for Large Area Sources. ANL/ES-161. Argonne National Laboratory, Illinois.

**Model Name:** NUREG-0707
**Sponsor:** NRC

**Description:** Site-specific limits for allowable residual contamination.

**Reference:** Eckerman and Young. Complete citation not provided by respondents.

**Model Name:** PATH
**Sponsor:** GE

**Description:** Used to implement residual radioactive material guidelines during decommissioning.

**Reference:** Prepared by Dr. Jaikai Lee for use at the General Electric Shippingport Station. Based on guidelines in: A Manual for Implementing Residual Radioactive Material Guidelines, USDOE.

**Model Name:** PATH1
**Sponsor:** USNRC - SNL

**Description:** . PATH1 models the physical and biological processes that result in the transport of radionuclides through the Earth's surface environment and eventual human exposure to these radionuclides. PATH1 is divided into two submodels. The Environmental Transport Submodel represents the long-term distribution and accumulation of radionuclides in the environment. The Transport-to-Man Submodel simulates the movement of radionuclides from the environment to humans.

PATH1 uses a generalized approach to the simulation of radionuclide transport from the ground water through the environment and food chain to humans. The code is not tied to any specific site characteristics. The Environmental Transport Submodel of PATH1 requires that the study area be divided into a number of compartments, and radionuclide movement between these compartments is represented by a system of linear differential equations. The user must specify the transfer and decay coefficients for this system of compartments. In the Transport-To-Man Submodel, radionuclide ingestion is calculated on the basis of simple food chains and concentration ratios, while the amount of each radionuclide inhaled is determined from the amount of radionuclide-containing soil suspended in the air. These calculated ingestion and inhalation rates are input to the Sandia Dose and Health Effects model, DOSHEM which is incorporated into PATH1.

The code can be run with the ground water code NWFT/DVM using a Latin hypercube sampling routine.

**Reference:** Helton, J.C., and Kaestner, P.C., 1981. Risk Methodology for Geologic Disposal of Radioactive Waste: Model Description and User's Manual, the Pathways Model, NUREG/CR-1636, vol. 1, SAND 78-1711 AN.

Campbell, J.E., Longsine, D.E., and Cranwell, R.M., 1981. Risk Methodology for Geologic Disposal of Radioactive Waste: The NWFT/DVM Computer Code User's Manual, NUREG/CR-2081, Sandia National Laboratory.

**Model Name:** RESRAD
**Sponsor:** USDOE

**Description:** RESRAD (Gilbert, 1988) is an implementation of the analytical methodology recommended by the Department of Energy in its guidelines (DOE Order 5400.5, Gilbert et al., 1989) for allowable concentrations of residual radioactive material in soil encompassed by the Formerly Utilized Sites Remedial Action Program (FUSRAP) and Surplus Facilities Management Program (SFMP). RESRAD is a multi-media model which incorporates within it a number of media-specific models all of which have been chosen for their reliability but general conservatism. Guideline values derived by the models are based on the method of concentration factors (NRC, 1977; ICRP, 1984; Till and Meyer, 1983; NCRP, 1984).

Pathway analysis for deriving soil concentration guidelines for a specified dose limit is done in four stages:

- Source analysis
- Environmental transport analysis
- Dose/response analysis
- Scenario Analysis

Source analysis is done using a nondispersive equilibrium model of the leaching process. This is an idealized process in which the rate of leaching is constant until a radionuclide has been completely removed from the contaminated zone. Ingrowth and decay of radioactive materials are treated as if they occurred entirely in the contaminated zone. A contaminated zone is treated as a single homogeneous or inhomogeneous source of changing thickness, depth, and radionuclide concentrations due to leaching, erosion, ingrowth, and decay. Principal radionuclides are those with half-lives greater than 1 year.

Environmental transport pathways include air (dust, radon, and other gases) and water (surface and ground water). Air transport is accomplished by use of a simple mixing model rather than a Gaussian plume model. The surface water is assumed to be a pond or lake for which (1) the water inflow and outflow are in steady-state equilibrium, and, (2) the annual inflow of radioactivity into the pond or lake equals the annual quantity of radioactivity leached from the contaminated zone. Two models are used for calculating the water/soil concentration ratio for the ground water pathway segment of RESRAD: a mass balance (MB) model and a dispersionless flow (DF) model. The ground water pathway models implemented in the RESRAD code apply only to situations for which the hydrological strata can reasonably be approximated by a sequence of uniform, horizontal layers.

Dose equivalents in organs or tissues of the body are calculated with models that :(1) describe the entrance of materials into the body (respiratory and gastrointestinal tract) and the deposition and subsequent retention of the radionuclides in body organs (referred to as metabolic models); and, (2) estimate the energy deposition in tissues of the body (ICRP, 1979).

Soil guidelines are based on a family-farm exposure scenario. RESRAD code was developed by Argonne National Laboratory for AEC/NRC.

**Reference:** T.L. Gilbert, M.J. Jusko, K.F. Eckerman. W.R. Hansen, W.E. Kennedy, Jr., B.A. Napier and J.K. Soldat. 1988. A Manual for Implementing Residual Radioactive Material Guidelines, January 1988. For the U.S. Department of Energy.

T.L., Gilbert, C.Yu, Y.C. Yuan, A.J. Zielen, M.J. Jusko, and A. Wallo III, 1989. A Manual for Implementing Residual Radioactive Material Guidelines, June 1989. For the U.S. Department of Energy.

**Model Name:** IMPACTS (PART61)
**Sponsor:** USNRC

**Description:** IMPACTS is used to determine disposal facility radiological impacts, including ground water migration and overflow impacts, intrusion and exposed waste impacts and exposures from potential operational accidents.

PART61 is a system of codes and data files that implements an expansion of the IMPACTS analysis methodology used during the development of the 10 CFR 61 rule and includes:

- CLASIFY: Classifies waste streams into four classes
- IMPACTS: Determines radiological impacts
- INVERSE: Activity or concentration limits
- ECONOMY: Costs of disposal
- INTRUDE: Impacts of an intruder
- VOLUMES: Waste stream annual volumes

Modifications of the IMPACTS methodology included in PART61 are:

1. an update of the low-level radioactive waste source term
2. consideration of additional alternative disposal technologies
3. expansion of the methodology used to calculate disposal costs
4. consideration of an additional exposure pathway involving direct human contact with disposed waste due to a hypothetical drilling scenario; and,
5. use of updated health physics analysis procedures (ICRP-30)

Based on input from CLASIFY, IMPACTS is used to determine most disposal facility radiological impacts for a given combination of:

1. waste streams and processing options
2. disposal technology alternatives, and
3. disposal site environmental settings.

**Reference:** Oztunali, O.I., W.D. Pon, R. Eng and G.W. Roles. 1986. Update of Part 61 Impacts Analysis Methodology. Codes and Example Problems. Volume 2. NUREG/CR-4370-Vol.2

Oztunali, O.I., and G.W. Roles. 1986. Update of Part 61 Impacts Analysis Methodology. Methodology Report. Volume 1. NUREG/CR-4370-Vol.1

**Model Name:** ONSITE/MAXI1
**Sponsor:** NRC - PNL

**Description:** ONSITE/MAXI1 was developed for use by NRC in reviewing license applications for onsite disposal of radioactive waste. Several exposure pathways can be simulated to conduct a dose pathway analysis for human intrusion scenarios.

Exposure pathways that can be evaluated include direct external exposure to contaminated soil or building surfaces, inhalation of resuspended material, and ingestion of drinking water or terrestrial or aquatic foods. The user may optionally select ICRP-26 or ICRP-30 dose conversion factors.

**Reference:** Napier, B.A., R.A. Peloquin, W.E. Kennedy, Jr., and S.M. Neuder. 1984. Intruder Dose Pathway Analysis for the Onsite Disposal of Radioactive Wastes: The ONSITE-/MAXI1 Computer Program. NUREG/CR-3620 (PNL-4054).

Kennedy, W.E., R.A. Peloquin, B.A. Napier and S.M. Neuder. 1986, 1987. Intruder Dose Pathway Analysis for the Onsite Disposal of Radioactive Wastes: The ONSITE/MAXI1 Computer Program. NUREG/CR-3620, Supplement 1, 1986, Supplement 2, 1987.

**Model Name:** PATHRAE (-EPA)
**Sponsor:** USEPA

**Description:** Estimates annual whole-body doses to a critical population group from the land disposal of below regulatory concern (BRC) wastes. PATHRAE-EPA is expanded from the PRESTO-EPA-CPG and PRESTO-EPA-BRC models.

PATHRAE-EPA can be used to calculate maximum annual effective dose equivalent to a critical population group and to an offsite population at risk. Maximum annual doses are calculated to workers during disposal operations, to offsite personnel after site closure, and to reclaimers and inadvertent intruders after site closure. The offsite pathways include ground water transport to a river and to a well, surface (wind or water) erosion, disposal facility overflow, and atmospheric transport. The onsite pathways of concern arise principally from worker doses during operations and from postclosure site reclamation or intruder activities such as living and growing edible vegetation on site and drilling wells for irrigation or drinking water.

**Reference:** Rogers, V. and C. Hung. 1987. PATHRAE-EPA: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code, Methodology and Users' Manual. EPA 520/1-87-028

**Model Name:** PRESTO-II (Prediction of Radiation Effects from Shallow Trench Operations)
**Sponsor:** USDOE

**Description:** PRESTO-II is designed to serve as a non-site-specific screening model to evaluate possible health effects from shallow land and waste disposal trenches for a 1000-year period following the end of disposal operations. PRESTO-II has been applied to simulate radionuclide transport at several DOE low-level waste sites and for the USNRC in support of a *de minimis* classification for waste.

Human exposure scenarios considered include normal releases (including leaching and operational spillage), human intrusion, and limited site farming or reclamation. Pathways and processes of transit from the trench to an individual or population include ground water transport, overland flow, erosion, surface water dilution, suspension, atmospheric transport, deposition, inhalation, external exposure, and ingestion of contaminated beef, milk, crops, and water. Both population doses and individual doses, as well as doses to the intruder and farmer, may be calculated. Cumulative health effects in terms of cancer deaths are calculated for the population over the 1000-year period using a life-table approach.

**Reference:** Fields. D.E., C.J. Emerson, R.O. Chester, C.A. Little and H. Hiromoto. 1986. PRESTO-II: A Low-Level Waste Environmental Transport and Risk Assessment Code. Oak Ridge National Laboratory, Oak Ridge, Tennessee. ORNL-5970.

**Model Name:** PRESTO-EPA
**Sponsor:** USEPA

**Description:** Simulates transport of low-level radioactive waste material from a shallow trench site and assesses human risks associated with such transport. This model was modified and added to create the PRESTO family of models: PRESTO-EPA-POP, PRESTO-EPA-CPG, PRESTO-EPA-DEEP, PRESTO-EPA-BRC and PATHRAE.

**Reference:** PRESTO-EPA: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code - Methodology and User's Manual, 1983.

**Model Name:** PRESTO-EPA-CPG
**Sponsor:** USEPA

**Description:** Estimates maximum annual whole-body dose to a critical population group from land disposal of low-level waste by shallow or deep methods. The maximum annual dose associated with the post-operational phase of low-level waste disposal facilities is determined. All major non-intrusive human exposure pathways are considered. Time periods up to 10,000 years following the end of disposal may be assessed.

The conceptual logic and control modifications made in developing the PRESTO-EPA-CPG code include the simultaneous modeling of leaching from multiple waste forms, the output of organic dose summaries for specified intervals of time, the calculation of nuclide-specific dose conversion factors used in determining the total dose for each year, the determination of the maximum annual dose and the year in which it occurs, and the output of the corresponding dose summaries and detailed DARTAB tables..

**Reference:** Rogers. V. and C. Hung. 1987. PRESTO-EPA-CPG: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code, Methodology and User's Manual. EPA 520/1-87-026.

Cheng Yeng Hung, 1989. User's Guide for the SYSCPG Program - A PC Version of the Presto-EPA-CPG Operation System. EPA 520/1-89-017

**Model Name:** PRESTO-EPA-DEEP
**Sponsor:** USEPA

**Description:** Estimate cumulative population health effects to local and regional populations from land disposal of low-level waste by deep methods. The PRESTO-EPA-DEEP code considers low-level waste disposal by deep well injection, hydrofracture, and deep geologic disposal. The code can be used for simulating the behavior of a facility for up to 10,000 years following the end of disposal operations.

The deep disposal scenarios implemented in the PRESTO-EPA-DEEP code consider only the naturally occurring pathways such as natural ground water and surface water flows and atmospheric transport. Intrusion scenarios such as accidental drilling, geological faulting, and the failure of the access shaft sealing, have a probabilistic nature and are not considered. However, a reinterpretation of certain PRESTO-EPA-DEEP variables will permit a consideration of such stochastic events.

**Reference:** Rogers, V., and Hung, C., 1987. PRESTO-EPA-DEEP A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code - Methodology and User's Manual. EPA 520/1-87-025.

**Model Name:** PRESTO-EPA-POP
**Sponsor:**

**Description:** Estimates cumulative population health effects from land disposal of low level waste by shallow methods. Health effects to the basin population are calculated for a time period of up to 10,000 years. The code simulates the leaching of radionuclides from the waste matrix, hydrological, hydrogeological, and biological transport, the resultant human exposures, and finally the assessment of the probable health effects for the entire regional water basin population.

The PRESTO-EPA-POP code allows the user to select special human exposure scenarios such as an inadvertent intruder residing or farming the site, as well as routine migration of radionuclides from the trench through the hydrologic and atmospheric environmental pathways to crops and drinking water.

**Reference:** Fields. D.E., C.A. Little, F. Parraga, V. Rogers and C. Hung. 1987. PRESTO-EPA-POP: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code, Volume 1, Methodology Manual. EPA 521/1-87-024-1.

Fields. D.E., C.A. Little, F. Parraga, V. Rogers and C. Hung. 1987. PRESTO-EPA-POP: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code, Volume 2, User's Manual. EPA 521/1-87-024-2.

Cheng Yeng Hung, 1992. User's Guide for the SYSPOP Program - A PC Version of the Presto-EPA-POP Operation System. EPA 400R 92003.

**Model Name:** UDAD
**Sponsor:** USNRC

**Description:** UDAD provides estimates of potential radiation exposure to individuals and to the general population in the vicinity of a uranium processing facility.

**Reference:** M.H. Momeni, Y. Yuan and A.J. Zielen. 1979. Uranium Dispersion and Dosimetry (UDAD) Code. NUREG/CR-0553. Argonne National Laboratory, Illinois.

## MULTI-MEDIA - GENERAL PURPOSE

**Model Name:** CONDOS-II
**Sponsor:** USNRC

**Description:**

**Reference:** Complete citation not provided by respondents.

**Model Name:** FLASH/FLAME
**Sponsor:**

**Description:**

**Reference:** Complete citation not provided by respondents.

**Model Name:** SPUR
**Sponsor:**

**Description:**

**Reference:** Complete citation not provided by respondents.

**Model Name:** SUMO
**Sponsor:** USDOE

**Description:**

**Reference:** Complete citation not provided by respondents.

**Model Name:** UTM
**Sponsor:** ORNL

**Description:** UTM does complete ecological interactions modeling (ground water and surface water transport, vegetation uptake, nutrient recycling) through compartments in a watershed system.

UTM's air, land, and aquatic sub-systems are designed to be run in sequence. The atmospheric component is based upon a Gaussian plume model and calculates deposition rate of aerosols for any point within a watershed. Concentrations of airborne aerosols at ground level are also calculated. The model includes point, area, line, and windblown sources for air pollutants. Deposition occurs by dry fallout and also by washout caused by rain falling through the plume. Air concentrations and depositions depend upon source strength, atmospheric stability, and wind speed and direction patterns. The deposition values calculated by the atmospheric model are used for input to the land component of UTM.

The basic assumption underlying the land component of the UTM is that water is the major carrier of material through the terrestrial system. Thus, trace-material transport can be modeled by combining hydrologic calculations with consideration of the chemistry of trace materials in aqueous media. The terrestrial component is structured to receive atmospheric wet- and dryfall input to a watershed canopy and then to simulate its movement until it is discharged in stream flow. The model simulates the amount of material washed from the canopy to the land surface during rainfall and allows for the exchange and uptake or adsorption of materials on surface soil. Surface runoff and scouring of soil particles are considered, together with leaching of trace elements into the soil profile. An experimentally derived equilibrium distribution coefficient is used to estimate the concentrations of contaminants in subsurface soil water. This estimated concentration and the rate of soil water drainage are combined to estimate a subsurface input to the stream channel.

The outputs from the terrestrial component of UTM enter the channel component, where flows are calculated using the Chezy-Manning equation. This portion of the program simulates transport of dissolved and particulate materials in stream flow. Suspended and bed-load transport are considered by the model. Mixing ands exchange between aqueous and solid phases for the particular chemical species of concern are also simulated. If point-source discharges of known strength are released in the stream, the channel component is capable of simulating their introduction and subsequent transport.

**Reference:** Patterson, M.R., et. al., 1974. A User's Manual for the FORTRAN IV Version of Wisconsin Hydrologic Transport Model. ORNL-NSF-EATC-7, Oak Ridge National Laboratory, Oak Ridge, TN.

R.J. Luxmore and D.D. Huff. 1989. Analysis of Biogeochemical Cycling in Walker Branch Watershed. pp. 164-196. Springer and Verlag, New York, New York.

**Model Name:** BIOTRAN
**Sponsor:** LASL

**Description:** Model is used to predict the flow of transuranic elements (TRU) through specified plant and animal environments using biomass as a vector.

**Reference:** Gallegos, A.F., B.J. Garcia. and C.M. Sutton. 1980. Documentation of TRU Biological Transport Model (BIOTRAN). LA-8213-MS. Los Alamos Scientific Laboratory.

## AIR TRANSPORT

**Model Name:** AFTOX

**Sponsor:** U.S. Army

**Description:** Atmospheric transport.

**Reference:** Complete citation not provided by respondents.

**Model Name:** AIRDOS (MICROAIRDOS, AIRDOS-PC)
**Sponsor:** USEPA - Radiological Assessments Corporation

**Description:** A modified Gaussian plume equation is used to estimate horizontal and vertical dispersion of radionuclides released from one (MICROAIRDOS) to six (AIRDOS) stacks or area sources within a polar-gridded assessment area. Radionuclide concentrations (up to 12 in MICROAIRDOS and 36 in AIRDOS) in food are estimated by coupling the output of the atmospheric transport code to the USNRC Regulatory Guide 1.109 terrestrial food chain models. Dose conversion factors are input to the code, and doses to man for each distance and direction specified are estimated for total body, red marrow, lungs, endosteal cells, stomach wall, LLI wall, thyroid, liver, kidneys, testes, and ovaries throughout the following exposure modes:

1) immersion in air containing radionuclides
2) exposure to ground surfaces contaminated by deposited radionuclides
3) immersion in contaminated water
4) inhalation of radionuclides in air
5) ingestion of food in the area.

The code may be run to estimate highest annual individual dose in the area or annual population dose. Ground concentrations of radionuclide and intake rates by man are tabulated for each environmental location. Exposures are also calculated and tabulated for inhalation of $^{222}$Rn short-lived progeny.

**Reference:** Moore, R.E., C.F. Baes III, L.M. McDowell-Boyer, A.P. Watson, F.O. Hoffman, J.C. Pleasant and C.W. Miller. 1979. AIRDOS-EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man From Airborne Releases of Radionuclides. ORNL-5532, EPA 520/1-79-009, U.S. EPA, Office of Radiation Programs, Washington, D.C..

Till, J.E., K.R. Meyer and R.E. Moore. 1987. MICROAIRDOS User's Manual and Documentation. Radiological Assessments Corporation, Neeses, South Carolina.

**Model Name:** CAP88 (-PC) (Clean Air Act Assessment Package-1988)
**Sponsor:** USEPA -USDOE - RSIC

**Description:** The CAP-88 model is a set of computer programs, databases and associated utility program for estimation of dose and risk from radionuclide emissions to air. CAP-88 is composed of modified versions of AIRDOS-EPA and DARTAB.

CAP88 allows users to perform full-featured dose and risk assessments for the purpose of demonstrating compliance with 40 CFR 61.93. CAP88 differs from the dose assessment software AIRDOS in that it estimates risk as well as dose, it offers a wider selection of radionuclide and meteorological data, it provides the capability for collective population assessments, and it allows users greater freedom to alter values of environmental variables.

CAP88 uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six sources. The sources may be either elevated stacks, such as a smokestack, or uniform area sources, such as a pile of uranium mill tailings. Plume rise can be calculated assuming either a momentum or buoyancy-driven plume. Assessments are done for a circular grid of distances and directions for a radius of 80 km around the facility.

The program computes radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food and intake rates to people from ingestion of food products produced in the assessment area. Estimates of the radionuclide concentrations in produce, leafy vegetables, milk and meat consumed by humans are made by coupling the output of the atmospheric transport models with the USNRC Guide 1.109 terrestrial food chain models.

Dose and risk are estimated by combining the inhalation and ingestion intake rates, air and ground surface concentrations with the does and risk conversion factors in ICRP Publication 26.

**Reference:** Parks, B.S., 1991. User's Guide for CAP88-PC: Version 1.0. EPA 520/6-91/022, U. S. Environmental Protection Agency, Washington D.C.

**Model Name:** CHARM (Complex Hazardous Air Release Model)
**Sponsor:** USEPA/Radian Corp.

**Description:** Atmospheric transport and risk estimates.

**Reference:** Radian Corp., CHARM, 8501 Mopac Blvd., P.O. Box 9948, Austin TX 78766.

**Model Name:** COMPLY
**Sponsor:** USEPA

**Description:** Model is used to demonstrate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAPS) for Radionuclides in 40 CFR 61, Subpart I. It has various levels of complexity, the simplest being a list of tables of concentration and possession limits in EPA89. The most complicated level is an air dispersion calcula ion using a wind rose.

**Reference:** U.S. Environmental Protection Agency, 1989. User's Guide for the COMPLY Code. EPA 520/1-89-003, U.S. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C.

**Model Name:** DARTAB
**Sponsor:** USEPA

**Description:** DARTAB combines radionuclide environmental exposure data with dosimetric and health effects data to generate tabulations of the predicted impact of radioactive airborne effluents. DARTAB is independent of the environmental transport code used to generate the environmental exposure data and the codes used to produce the dosimetric and health effects data. DARTAB is often used with AIRDOS and RADRISK.

**Reference:** Begovich, C.L., K.F. Eckerman, E.C. Schlatter, S.Y. Ohr and R.O. Chester. 1981. DARTAB: A Program to Combine Airborne Radionuclide Environmental Exposure Data with Dosimetric and Health Effects Data to Generate Tabulations of Predicted Health Impacts. ORNL-5692. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

**Model Name:** HARM-II (Hazardous Atmosphere Release Model)
**Sponsor:** USDOE

**Description:** HARM-II performs dispersion calculations for both chemical and radiological releases. Both heavy and simple gases can be modeled.

**Reference:** NOAA Atmosphere and Diffusion Turbulence Laboratory. Complete citation not provided by respondents.

**Model Name:** INPUFF
**Sponsor:** USEPA - Bowman Engineering

**Description:** INPUFF simulates dispersion from semi-instantaneous or continuous point sources over a spatially and temporally variable wind field. The algorithm is based upon Gaussian puff assumptions including a vertically uniform wind direction field and no chemical reactions. The code can estimate concentrations at up to 100 from multiple point sources.

INPUFF uses three distinct dispersion algorithms. For short travel time dispersion, the user has the option of using either the Pasquill-Gifford (P-G) scheme or the on-site scheme. The third dispersion algorithm was designed for use in conjunction with the P-G or on-site scheme when there are long travel times involved.

Features of the code include:

- Optional stack downwash
- Optional buoyancy induced dispersion
- Wind speed extrapolated to release height
- Temporally variable source characteristics
- Temporally and spatially variable wind field (user supplied)
- Consideration of terrain effects through user-supplied wind field
- Consideration of moving source
- Optional user-supplied subroutine for selecting dispersion coefficients
- Optional user-supplied subroutine for estimating plume rise, and
- Removal through gravitational settling and deposition.

**Reference:** Peterson, W.B. and L.G. Lavdas. 1988. INPUFF 2.0 - A Multiple Source Gaussian Puff Dispersion Algorithm User's Guide. U. S. Environmental Protection Agency, 1986 and Supplement, 1988.

**Model Name:** ISC(LT/ST) (Industrial Source Complex Dispersion Model)
**Sponsor:** USEPA

**Description:** Combines and enhances dispersion model algorithms to consider pollutant sources other than emissions from isolated stacks, such as fugitive emissions, aerodynamic wake effects, gravitational settling and dry deposition in assessing the air quality impact of emissions from a wide variety of industrial source complex sources. Two major programs: the ISC Short Term (ISCST) and ISC Long Term (ISCLT).

ISCST uses hourly meteorological data to calculate concentrations for time periods up to 24 hours. ISCLT is and advance Gaussian plume model for atmospheric dispersion of pollutants, using statistical wind summaries to calculate quarterly or annual ground-level concentrations of emissions.

**Reference:** Bowers, J.F., J.B. Bjorklund, and C.S. Cheney. 1979. Industrial Source Complex (ISC) Dispersion Model User's Guide. EPA-45015-79-030. H.E. Cramer Co., Salt Lake City, Utah.

**Model Name:** LTSAMP
**Sponsor:** USDOE

**Description:** air transport?

**Reference:** Prepared by Jacobs Engineering for DOE UMTRA Project. Complete citation not provided by respondents.

**Model Name:** MESOI
**Sponsor:** USNRC

**Description:** Atmospheric transport and dispersion model.

**Reference:** Ramsdell, J.V., G.F. Athey and C.S. Glantz. 1983. MESOI Version 2.0: An Interactive Mesoscale Lagrangian Puff Dispersion Model With Deposition and Decay. NUREG/CR-3344 , PNL-4753. Pacific Northwest Laboratory, Richland, Washington.

**Model Name:** MLCODE
**Sponsor:** USDOE

**Description:** Used to estimate dose and uncertainties in dose estimates resulting from air releases.

**Reference:** Prepared by B. Napier for use in the Hanford Dose Reconstruction Project. Complete citation not provided by respondents.

**Model Name:** PREPAR
**Sponsor:** USEPA

**Description:** Pre-processor for AIRDOS-EPA

**Reference:** Oak Ridge National Laboratory, 19xx . PREPAR: A User-Friendly Preprocessor to Create AIRDOS-EPA Input Data Sets. ORNL-5952, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

**Model Name:** RAECOM
**Sponsor:** USNRC

**Description:** Code is used to calculate cover thickness and surface fluxes of radon emissions from uranium mill tailings.

**Reference:** Rogers, V.C., K.K. Nielson and D.R. Kalkwarf. 1984. Radon Attenuation Handbook for Uranium Mill Tailings Cover Design. NUREG/CR-3533

**Model Name:** SCREEN
**Sponsor:** USEPA

**Description:** SCREEN incorporates a number of simple screening procedure for estimating the maximum ground-level concentration of radionuclides for sources in simple flat or elevated terrain. SCREEN:

- accepts user-specified distances,
- performs inversion break-up and shoreline fumigation estimates,
- includes building downwash effects in the wake region,
- performs calculations for the cavity region, and
- includes an optional complex terrain screening procedure based on the VALLEY Model 24-hour screening technique

**Reference:** Brode, R.W., 1988. Screening Procedures for estimating the air quality impact of stationary sources. EPA-450/4-88-010.

**Model Name:** SIMS
**Sponsor:** USEPA

**Description:**

**Reference:** Complete citation not provided by respondents.

**Model Name:** XOQ/DOQ
**Sponsor:** USNRC

**Description:** XOQ/DOQ is used in the meteorological evaluation of routine releases from commercial nuclear power reactors. The model uses a steady-state Gaussian plume assumption to implement Section C of Regulatory Guide 1.111.

XOQ/DOQ calculates average relative effluent releases and average relative deposition values at locations specified by the user and at standard radial distances and segments for downwind sectors. The code also calculates these values at the specified locations for intermittent releases. XOQ/DOQ provides the following options:

- both elevated and ground-level sources can be modeled;
- the effluent plume of elevated releases can undergo plume rise due to buoyancy and/or momentum;
- ground-level releases can be affected by the additional dispersion due to local building or terrain induced wakes;
- measured wind speeds can be extrapolated to other elevations;

- topography can be varied;
- the plume may be depleted by dry deposition; and
- relative effluent concentrations and average relative deposition values can be amended to reflect the effects of local air recirculation or stagnation.

This code can be used to estimate ground-level radionuclide concentrations and deposition amounts associated with atmospheric releases from waste repository operations. XOQ/DOQ calculates only normalized radionuclide concentrations and deposition rates; it does not model the subsequent transport of these radionuclides through the environment and food chain to man.

Reference: Sagendorf, J.F., and Gall, J.T., 1977. XOQ/DOQ program for meteorological evaluation of routine effluent releases at nuclear power stations, USNRC, Washington, D.C., NUREG/CR-0324.

## SURFACE WATER FLOW AND TRANSPORT

**Model Name:** Codell Models
**Sponsor:** USNRC

**Description:** The Codell series of models are a collection of simple programs used by the Hydrologic Engineering Section for computing the fate of routinely or accidentally released radionuclides in surface water and ground water. The models are straightforward simulations of dispersion with constant coefficients in simple geometries. Models included can be used for rivers, lakes and ground water. Programs STTUBE and TUBE are useful for two-dimensional dispersion of a continuous source into a river after steady-state has been attained. Program RIVLAK also simulates dispersion in a river, but the source can be either steady or unsteady. RIVLAK can be used to calculate two-dimensional dispersion in the near-shore regime of large lakes. The surface water models in the Codell codes ignore uptake of radionuclide on sediments.

GROUND is used for calculating dispersion in a three-dimensional aquifer and is most useful for determining the concentration at wells downgradient of a source released from a vertical plane. Program GRDFLX provides the same function, but it considers the source to be horizontal.

**Reference:** Codell, R.B., Key, K.T., and Whelan, G., 1982. A Collection of Mathematical Models for Dispersion in Surface Water and Ground Water. NUREG-0868, U.S. Nuclear Regulatory Commission, Washington, D.C.

**Model Name:** CREAMS
**Sponsor:** USDA-Agricultural Research Service, Southeast Watershed Research Lab

**Description:** The CREAMS model can simulate pollutant movement on and from a field site, including such constituents as fertilizers (N & P), pesticides, and sediment. The effects of alternative agricultural practices on water and land resources can be assessed by simulation of the potential water, soil, nutrient, and pesticide losses in runoff from agricultural fields. By integrating climatic, geomorphic, agronomic, and soil data with structural, cultural, and management systems, the model computes relative yields of sediment, nutrients, and pesticides at the edge of field-sized units. The model structure consists of three major components: hydrology, erosion/sedimentation, and chemistry. The hydrology component estimates the volume and rate of runoff, evapotranspiration, soil moisture content, and percolation. The erosion/sedimentation portion of the model considers the processes of soil detachment, transport, and deposition. The chemistry portion of the model considers nutrients and pesticides. The transport of soluble and sediment-attached chemicals is evaluated. Interaction between plants and chemicals within the root zone is also considered. The model is designed to require a bare minimum of calibration parameters and land use strategies. The spatial scale of the model is intended to be the size of an agricultural field. When calibrated with observed data CREAMS can be used to provide predictive information.

**Reference:** Knisel, W.G., ed., 1980. CREAMS: A Field-Scale Model for Chemical, Runoff, and Erosion from Agricultural Management Systems. U.S. Department of Agriculture, Science and Education Administration, Conservation Research Report 26, 643 pp.

**Model Name:** HEC-1
**Sponsor:** U.S. Army Corps of Engineers

**Description:** Calculation of flood hydrographs.

**Reference:** HEC-1 Flood Hydrograph Package, User's Guide. 1981. U.S. Army Corps of Engineers, The Hydrologic Engineering Center.

**Model Name:** HEC-2
**Sponsor:** U.S. Army Corps of Engineers

**Description:** The HEC -2 model calculates water surface profiles for open channels with steady, gradually-varied flow. The effects of obstructions such as bridges etc. can be considered.

**Reference:** HEC-2 Water Surface Profiles, User's Manual. 1982. U.S. Army Corps of Engineers, The Hydrologic Engineering Center.

**Model Name:** HSPF
**Sponsor:** USEPA, Environmental Research Lab, Athens, GA

**Description:** HSPF is a continuous simulation model that simulates the time history of the quantity and quality of runoff from multiple-use watersheds and simulates processes occurring in streams or fully-mixed lakes receiving watershed runoff. Water quality algorithms include BOD/DO dynamics, carbon, nitrogen, and phosphorous cycles, suspended and attached phytoplankton, and one species of zooplankton. Submodels also include sediment transport, pesticide routing and degradation kinetics, and sediment-pesticide interaction. HSPF is a series of coupled computer codes designed to simulate: 1) watershed hydrology; 2) land surface runoff; and 3) the fate and transport of pollutants in receiving water bodies. The hydrologic portions of the model include 1) a watershed hydrology model similar to the Stanford Watershed Model; 2) a runoff model using algorithms similar to the Non-Point Source (NPS) model; and 3) a stream routing component using a kinematic wave approximation. The degradation/transformation process included in the model are: hydrolysis, photolysis, oxidation, volatilization, and biodegradation. The kinetic reactions are formulated as second-order processes. Secondary or "daughter" chemicals are also simulated; up to two daughter chemicals can be analyzed in a single simulation. The one dimension formulation limits application of the model to river systems where pollutants are uniformly mixed both laterally and vertically; the kinematic wave formulation of flow in rivers is not applicable to rivers where the gradient is very small or where backwater effects are present; data requirements for the model may be quite extensive depending on the particular application; and the zero-dimensional representation of lakes assumes that pollutants are uniformly mixed throughout and that the lake is not stratified.

**Reference:** Johanson, R.C., Imhoff, J.C., Kittle, Jr., J.L., and Donigian, Jr., A.S., 1984. Hydrological Simulation Program – FORTRAN (HSPF): User's Manual for Release 8.0. EPA-600/3-84-066, NTIS PB84 157155.

**Model Name:** SBUHYD
**Sponsor:** U.C. Santa Barbara

**Description:** Calculates hydrographs.

**Reference:** Stubenhaer, J.M. 1975. The Santa Barbara Urban Hydrograph Method. National Symposium on Urban Hydrology and Sediment Control. University of Kentucky, July 1975.

**Model Name:** TEMPEST/FLESCOT
**Sponsor:** USNRC

**Description:** FLESCOT simulates radionuclide transport in estuaries to obtain accurate radionuclide distributions which are affected by time-variance, three-dimensional flow, temperature, salinity and sediments. FLESCOT is a modification of the hydrothermal model TEMPEST.

**Reference:** Trent, D.S. and Y. Onishi. 1989. Proceedings of the ASCE Specialty Conference: Estuarine and Coastal Circulation and Transport Modeling. Model - Data Comparison. November 15-17, 1989, Newport Rhode Island.

Onishi, Y. and D.S. Trent. 1982. Mathematical Simulation of Sediment and Radionuclide Transport in Estuaries: FLESCOT. Battelle Pacific Northwest Labs, Richland, Washington. Prepared for USNRC. NUREG/CR-2423.

Onishi, Y. and D.S. Trent. 1985. Three-Dimensional Simulation of Flow, Salinity, Sediment and Radionuclide Movements in the Hudson River Estuary. Proceedings of the Specialty Conference, Hydraulics and Hydrology in the Small Computer Age. Hydrology Division/ASCE, Lake Buena Vista, Florida, August 12-17, 1985.

Onishi, Y., D.S. Trent and A.S. Koontz. 1985. Three-Dimensional Simulation of Flow and Sewage Effluent Migration in the Strait of Juan de Fuca, Washington. Proceedings of the 1985 Specialty Conference on Environmental Engineering. EE Division/ASCE. Northeastern University, Boston, Mass. July 1-5, 1985.

**Model Name:** FEMWATER
**Sponsor:** USDOE - AECL

**Description:** FEMWATER simulates ground water dynamics in saturated-unsaturated subsurface systems and is a complimentary code to FEMWASTE which simulates waste transport .

FEMWATER is a revised finite-element model of water flow through porous media. Modifications from a previous version include:

1. computing the flow field in a way consistent with the finite-element approach;
2. evaluating the moisture content increasing rate within the region by a new method consistent with solving for moisture content and pressure fields; and
3. treating the terms to ensure that a unique relationship between any nonlinear variable and pressure is preserved.

The expansion provides four alternative numerical schemes that are more appropriate for many situations.

**Reference:** Pickens, J.F. and Grisak, G.E., 1979. Finite Element Analysis of Liquid Flow, Heat Transport and Solute Transport in a Ground Water Flow System: Governing Equations and Model Formulation. AECL-TEC-REC-81, National Hydrology Research Institute Inland Waters Directorate, Environment Canada, for Atomic Energy of Canada Limited, Whiteshell Nuclear Research Establishment.

**Model Name:** GW FLOW
**Sponsor:** Natural Sciences and Engineering Council of Canada.

**Description:** Saturated ground water flow. Stochastic, finite-element, two-dimensional, fully saturated steady state ground water flow.

**Reference:** Complete citation not provided by respondents.

**Model Name:** MAGNUM (2D/3D)
**Sponsor:** USDOE - EG&G Idaho

**Description:** MAGNUM simulate coupled heat and ground water flow in a saturated, fractured-porous media. The MAGNUM computer code is available in two versions - a two-dimensional version, MAGNUM-2D; and a three-dimensional version, MAGNUM-3D.

MAGNUM-2D simulates transient or steady-state ground water flow and/or coupled heat transport in a two-dimensional Cartesian or axisymmetric domain. MAGNUM-3D simulates heat conduction or ground water flow but does not account for the fully coupled processes. Both versions of the code have been extensively verified and benchmarked.

Both versions of MAGNUM use a dual permeability approach to represent the hydraulic behavior of a fractured-porous media. The porous zones in the domain are modeled using standard two- and three-dimensional isoparametric finite elements. Discrete fractures are modeled using line or plate elements which are embedded along the sides of the continuum elements. MAGNUM provides flow field calculations for input to transport and pathline-travel time models.

Both MAGNUM codes are interfaced with a number of pre- and postprocessors for input/output generation. In addition, MAGNUM-2D is generally used in conjunction with the CHAINT mass transport model. In a similar fashion, MAGNUM-3D is interfaced with the FECTRA mass transport code.

**Reference:** Baca, R.G., Arnett, R.C., and Langford, D.W., 1984. "Modeling fluid flow in fractured porous-rock masses by finite element techniques," International Journal for Numerical Methods in Fluids, v. 4, p. 337-348.

England, R.L., Kline, N.W., Ekblad, K.J., and Baca, R.G., MAGNUM-2D Computer Code: User's Guide, RHO-CR-143 P, Rockwell Hanford Operations, Richland, Washington.

Estey, S.A. Arnett, R.C., and Aichele, D.B., 1985. User's Guide for MAGNUM-3D: A Three-Dimensional Ground Water Flow Numerical Model, RHO-BW-ST-67 P, Rockwell Hanford Operations, Richland, Washington.

**Model Name:** MOD3D
Sponsor: USGS

**Description:** MOD3D simulates three-dimensional ground water flow in a porous, heterogeneous and anisotropic medium with irregular boundaries.

**Reference:** McDonald, G., and Harbraugh, A.W., 1989. A Modular Three-Dimensional Finite Difference Ground Water Flow Model: MOD3D. U.S.G.S. Techniques of Water Resource Investigations, Book, 6, Chapter A1, TWI 6-A1, Washington, D.C.

**Model Name:** MODFLOW
**Sponsor:** USGS/IGWNC

**Description:** MODFLOW is a finite-difference model that simulates flow in three dimensions. Ground Water flow within the aquifer is simulated using a block-centered finite-difference approach. Layers can be simulated as confined, unconfined, or a combination of the two. Flow associated with external stresses, such as wells, can also be simulated. The finite-difference equations can be solved using either the Strongly Implicit Procedure (SIP) or Slice-Successive-Overrelaxation (SSOR).

**Reference:** McDonald, M.G. and A.W. Harbaugh. 1984. A Modular Three-Dimensional Finite Difference Ground Water Flow Model: MODFLOW. U.S. Geological Survey Open File Report. 83-875.

Harbaugh, A.W., 1990. A Computer program for Calculating Subregional Water Budgets Using Results from the U.S. Geological Survey Modular Three-Dimensional Finite-Difference Ground Water Flow Model: MODFLOW. USGS Open-File Report 90-392, 46 pp.

Harbaugh, A.W., 1990. A Simple Contouring Program for Gridded Data. USGS Open-File Report 90-144, 37 pp.

**Model Name:** PLASM
**Sponsor:** Illinois State Water Survey

**Description:** Saturated, two dimensional ground water flow. Available for mainframe or PC computers.

**Reference:** Prickett, T.A. and C.G. Lonnquist. 1971. Selected Digital Computer Techniques for Ground Water Resource Evaluation. Illinois State Water Survey, Urbana, Illinois.

**Model Name:** RETC.F77
**Sponsor:** USDA

**Description:** Estimation of hydraulic conductivity of unsaturated and porous media.

**Reference:** Mualem, Y. 1976. A New Model for Predicting the Hydraulic Conductivity of Unsaturated and Porous Media. Water Resources Research, Vol 12, No.3

**Model Name:** SOIL
**Sponsor:** IGWMC

**Description:** Variably Saturated Flow.

**Reference:** El-Kadi, 1985. SOIL, version IBM-PC 1.0, International Ground Water Modeling Center, Butler University, Indianapolis, Indiana.

**Model Name:** TRUST
**Sponsor:** USNRC - PNL

**Description:** TRUST provides a versatile tool to solve a wide spectrum of fluid flow problems arising in variably-saturated, deformable, porous media. The governing equations express the conservation of fluid mass in an elemental volume that has a constant volume of solid. Deformation of the skeleton may be nonelastic.

Permeability and compressibility coefficients may be nonlinearly related to effective stress. Relationships between permeability and saturation with pore water pressure in the unsaturated zone may include hysteresis. The code developed by T.N. Narasimhan grew out of the original TRUMP code written by A.L. Edwards. The code uses an integrated finite difference algorithm for numerically solving the governing equation. Marching in time is performed by a mixed explicit-implicit numerical procedure in which the time step is internally controlled. The time step control and related feature in the TRUST code provide an effective control of the potential numerical instabilities that can arise in the course of solving this difficult class of nonlinear boundary value problems.

**Reference:** Reisenauer, A.E., Key, K.T., Narashimhan, T.N., and Nelson, R.W., 1982. TRUST: A Computer Program for Variably Saturated Flow in Multidimensional, Deformable Media. NUREG/CR-2360, PNL-3975, U.S. Nuclear Regulatory Commission, Washington, D.C..

Edwards, A.L., 1968. TRUMP: A Computer Program for Transient and Steady State Temperature Distributions in Multidimensional Systems. Rep. UCRL-14754, NTIS, Springfield, VA (Third Revision, 1972)

**Model Name:** UNSAT2 (-H)
**Sponsor:** USDOE

**Description:** The UNSAT-H model simulates the water and heat balance of soils to predict ground water recharge rates and to assess the ability of earthen covers to prevent drainage into underlying waste zones. Version 2.0 of the UNSAT-H model simulates the process of water infiltration, redistribution, evaporation, soil-water extraction by plants, deep drainage that becomes recharge, surface energy balance, and soil heat flow. The mathematical bases are Richards equation for liquid flow, Fick's law for diffusion of water vapor, Fourier's law for heat conduction, and the theory of coupled water and heat flow in soils proposed by Philip and de Vries. The model is implemented in FORTRAN as a 1-dimensional finite-difference code with variable time stepping and mass balance control. Verification and validation testing has been performed. Future versions of the model are expected to address hysteresis, snow melt, freezing soil, the temperature dependence of soil properties, a separate air phase, and multiple dimensions.

**Reference:** L.A. Davis and S.P. Neuman, 1983. Documentation and User's Guide UNSAT-2. NUREG/CR-3390.

Fayer, M.J., G.W. Gee and T.L. Jones. 1986. UNSAT-H Version 1.0: Unsaturated Flow Code: Documentation and Applications for the Hanford Site. PNL-5899, Pacific Northwest Laboratory, Richland, Washington.

Fayer, M.J., and T.L., Jones, 1990. UNSAT-H Version 2.0: Unsaturated Soil Water and Heat Flow Model. PNL-6779, Pacific Northwest Laboratory, Richland, Washington.

## GROUND WATER - TRANSPORT

**Model Name:** CFEST
**Sponsor:** USDOE

**Description:** Energy and Solute Transport.

**Reference:** Gupta, S.K., C.R. Cole, C.T. Kincaid and A.M. Monti. 1987. Coupled Fluid, Energy and Solute Transport (CFEST) Model: Formulation and User's Manual BMI-ONWI-660. Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus Ohio.

**Model Name:** CHAINT
**Sponsor:** USDOE - Hanford

**Description:** CHAINT simulates multicomponent mass transport in a saturated, fractured-porous media.

The CHAINT computer code can simulate transient or steady-state mass transport including chain decay. The two-dimensional code has been extensively verified and benchmarked.

The CHAINT code utilizes a dual permeability approach to represent a fractured-porous medium. The code can handle heterogeneous, anisotropic systems with networks of discrete fractures. The porous zones in the domain are modeled using standard two-dimensional isoparametric finite elements, i.e., triangles and quadrilaterals. Discrete fractures are modeled using line elements which are embedded along the sides of the continuum elements. In addition, the code can accommodate a variety of initial and boundary conditions.

The primary outputs of the CHAINT code are contaminant concentrations and fluxes at specified locations. CHAINT is interfaced with MAGNUM-2D and with several pre- and post-processes.

**Reference:** Baca, R.G., Arnett, R.C., and Langford, D.W., 1984. "Modeling fluid flow in fractured porous-rock masses by finite element techniques," International Journal for Numerical Methods in Fluids, v. 4, p. 337-348.

Kline, N.W., England, R.L., and Baca, R.G., 1986. CHAINT Computer Code: User's Guide' RHO-CR-144 P, Rockwell Hanford Operations, Richland, Washington.

**Model Name:** DPCT
**Sponsor:** NRC

**Description:** DPCT (Deterministic-Probabilistic Contaminant Transport) predicts ground water flow and contaminant transport accounting for advection, dispersion, radioactive decay, and equilibrium sorption for a single contaminant.

The code treats a two-dimensional vertical cross-section. Almost any water table and geologic configuration is permissible, and there are a variety of allowable boundary conditions. Water flow is steady state.

The cross section is divided into a rectangular array of cells. The head distribution is found by the finite-element method. Solute transport is then treated by tracking the motion of individual particles.

The principal assumptions of the code are:

1. a treatment in two-dimensional cross-section is acceptable;
2. the solute transport equation is valid;
3. sorption may be represented as equilibrium adsorption with a specified distribution coefficient;
4. principal axes of the transmissivity tensor are parallel to coordinate axes everywhere; and
5. ground water flows are steady state.

**References:** Schwartz, F.W., Crowe, A., 1980. A Deterministic-Probabilistic Model for Contaminant Transport: DPCT. U.S. Nuclear Regulatory Commission Report NUREG/CR-1609.

**Model Name:** FEMWASTE
**Sponsor:** USDOE - AECL

**Description:** FEMWASTE simulates waste transport through porous media under dynamic ground water conditions.

FEMWASTE is a finite-element model of waste transport through porous media which simulates the spatial and temporal distributions of both waste concentration and flux under dynamic ground water conditions. The transport mechanisms include advection, hydrodynamic dispersion, chemical sorption, and first-order decay.

**Reference:** Pickens, J.F. and Grisak, G.E., 1979. Finite Element Analysis of Liquid Flow, Heat Transport and Solute Transport in a Ground Water Flow System: Governing Equations and Model Formulation. AECL-TEC-REC-81, National Hydrology Research Institute Inland Waters Directorate, Environment Canada, for Atomic Energy of Canada Limited, Whiteshell Nuclear Research Establishment.

**Model Name:** MAT123D
**Sponsor:** USDOE

**Description:** The computer model MAT123D was developed to simulate waste disposal systems. It can be used to analyze the environmental impacts resulting from disposal of radioactive and chemical wastes in geologic media. The process of infiltration through disposal cell caps, transient source leaching and solute transport in geologic media are included. Situations involving saturated-unsaturated media under either fractured or homogeneous conditions can be modeled.

**Reference:** Yu, C., 1987. A Simulation Model for Analyzing the Environmental Impact of Waste Disposal Systems. Argonne National Laboratory, Illinois.

**Model Name:** MT3D
**Sponsor:** Papadopolus Inc.

**Description:** MT3D is a modular three-dimensional transport model capable of simulating advection, dispersion, and chemical reactions of dissolved constituents in ground water flow systems (Geeing 1990). MT3D was developed with support from the U.S. EPA and is distributed by the Kerr Laboratory.

MT3D was developed using a similar modular structure as MODFLOW, the U.S. Geological Survey modular three-dimensional finite-difference ground water flow model (McDonald and Harbaugh 1988). The modular structure facilitates linking of the program with a ground water flow model such as MODFLOW, simulating transport processes independently thereby conserving computer memory for unused options, and also simplifies code modifications. It can be used in conjunction with any block-centered finite-difference flow model, but is especially well-suited for linking with MODFLOW. The ground water flow model is constructed and calibrated independently assuming that changes in the concentration field will not affect the flow field measurably. MT3D uses the same spatial discretization and layer types ad MODFLOW. In addition, the following transport boundary conditions are supported: 1) specified concentration or mass flux boundaries; and 2) the solute transport effects of external sources and sinks such as wells, drains, rivers, areal recharge and evapotranspiration.

MT3D includes four methods for solving the three-dimensional advective-dispersive-reactive equation: Method of Characteristics (MOC), Modified Method of Characteristics (MMOC), Hybrid Method of Characteristics, and the explicit finite-difference technique. The first three techniques solve the advection term using a method-of characteristics scheme and the other terms using the finite-difference technique. The MOC technique uses a conventional particle tracking technique for solving the advection term. MOC virtually eliminates numerical dispersion, but can be slow and computationally intensive. This technique is well-suited for problems where sharp concentration fronts exist. The MMOC technique is similar to MOC in that it uses particle tracking techniques, but it involves fewer computations. The MMOC technique is best suited for problems where sharp concentration fronts are not present and the error caused by numerical dispersion can be considered insignificant. The HMOC technique is a mixture of MOC and MMOC, and attempt to combine the strength of both through an automatic adaptive procedure. The HMOC technique is well-suited for problems where sharp concentration fronts are present and can be more efficient computationally than the standard MOC technique. The finite-difference technique uses Taylor-series to approximate the derivatives, and is susceptible to numerical dispersion. The finite-difference technique is normally more efficient computationally than the three method-of-characteristics schemes and is best-suited for problems where sharp concentration fronts are not present.

When modeling dispersion, MT3D can accept a different value for longitudinal dispersivity at each node. One value per layer is then accepted for the horizontal and vertical transverse dispersivity ratios. Chemical reaction currently supported by the MT3D model include equilibrium-controlled sorption reactions and first-order irreversible rate reactions, such as radioactive decay or biodegradation. A single value per layer is specified for bulk density of the porous medium and distribution coefficient. Porosity can be specified individually for each node in the model. These parameters are used by MT3D to compute a retardation factor.

**Reference:** Zheng, C., 1990. A Modular Three-Dimensional Transport Model for Simulation of Advection, Dispersion and Chemical Reactions of Contaminants in Ground Water Systems. U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK.

**Model Name:** NEFTRAN (-II)
**Sponsor:** USNRC - SNL

**Description:** NEFTRAN simulates ground water flow and radionuclide transport in the saturated zone, and in the unsaturated zone if moisture content and flow are constant. The code assumes that all flow is along one-dimensional paths which are then assembled into multidimensional networks. Flow is determined by the application of Darcy's law and by requiring conservation of mass at segment junctions. Dispersion is accounted for by the distributed velocity method described by Campbell et al. (1981). The code accounts for multiple straight and branched decay chains. The code has the capability to model the source term either as a leach-limited or a solubility-limited source. In addition, the source term is decoupled from the flow and transport sections so that each can be run independently. NEFTRAN is an improved version of the NWFT/DVM (Campbell et al., 1981) code and has been shown to reproduce NWFT/DVM results.

**Reference:** Longsine, D.E., Bonano, E.J., and Harlan, C.P., 1987. User's Manual for the NEFTRAN Computer Code. NUREG/CR-4766, SAND86-2405.

Olague, N.E., Longsine, D.E., Campbell, J.E., and Leigh, C.D., 1991 User's Manual for the NEFTRAN II Computer Code, NUREG/CR-5618, SAND90-2089, Sandia National Laboratories, Albuquerque, N.M.

**Model Name:** ODAST
**Sponsor:** IGWMC - AGU

**Description:** ODAST is one program within the AGU-10 package of ground water flow and transport models which includes the following subprograms:

LTIRD simulates dispersion in a radial flow field, calculating the dimensionless concentration of a particular solute, injected into an aquifer, as a function of time and radius. It assumes fully penetrating injection wells with constant injection rate and concentration at source in a homogeneous and isotropic aquifer of uniform thickness. Background concentration of the contaminant is assumed to be zero. The evaluation of the analytical solution is based on numerical inversion of Laplace transform equations.

ODAST evaluates one-dimensional analytical solute transport including convection, dispersion, decay (at the source and in the aquifer) and adsorption. It can calculate relative concentration at any point downstream from the contaminant source at any specified time. It assumes a homogeneous isotropic aquifer of uniform thickness, steady-state flow field, and zero background concentration.

TDAST evaluates two-dimensional analytical solute transport. Convection, dispersion, decay (at source and in the aquifer), and adsorption. Relative concentration can be calculated at any point downstream from a finite strip source (orthogonal to the direction of flow) at any specified time. The model assumes a homogeneous, isotropic aquifer of uniform thickness, steady-state flow field, and zero background concentration.

RESSQ is a semi-analytical model of two-dimensional solute transport that calculates the streamline pattern in an aquifer, location of contaminant fronts about sources at specified times, and concentration versus time at sinks. The model assumes a homogeneous, isotropic, confined aquifer of uniform thickness, steady-state flow field, and advection and adsorption only (no dispersion or decay). Sources are represented by fully penetrating recharge wells and ponds, and sinks are represented by pumping wells.

RT converts a time series of concentration data from one or more observation wells into a spatial concentration distribution in the aquifer at specified times. The model assumes a single fully penetrating production well, steady-state radial flow field, and negligible regional flow.

**Reference:** Javendal, I., Doughty, C., and Tsang, C.F., 1984. Ground Water Transport: Handbook of Mathematical Models, American Geophysical Union, Water Resources Monograph 10, Washington, D.C.

**Model Name:** PATHS
**Sponsor:** PNL/DOE

**Description:** PATHS provides an approximate contaminant transport evaluation by direct solution of the pathline equations. The steady cases are evaluated by holding the uniform gradient, the head in the pond, and the well strengths constant. Under such steady-state conditions, only one set of flow paths, advancing fronts, and travel times must be calculated. In the transient cases, each new set of fluid particles leaving the pond or wells encounters changing velocity effects. Therefore, a range of typical departure times is selected and the flow paths, front configurations, and travel times are calculated successively for each selected set of fluid particles leaving the contaminant source. The approximate equilibrium coefficient approach is used to give the ion exchange delay effects for a single constituent. There are, however, no dispersion effects considered in the preliminary model. The model can consider as many as 35 wells at optional locations. Wells are represented as numerically solved by the code to give the paths of the fluid particles and their advance within time toward the outflow boundary.

The main assumptions of the code are:

1) two-dimensional (horizontal plane) infinite aquifer of constant thickness;
2) confined flow;
3) homogeneous, isotropic material with constant properties;
4) uniform flow direction may include transient gradient (flow) strength;
5) round, fully-penetrating wells and caverns;
6) dissipation of the well and cavern heads occurs over a specific radial distance;
7) diffusion and dispersion processes are neglected; and
8) contaminant adsorption is based on linear equilibrium isotherms.

**Reference:** Nelson R.W. and Schur, J.S., 1980. PATHS – Ground Water Hydraulic Assessment of Effectiveness of Geologic Isolation Systems. PNL-3162, Pacific Northwest Laboratory, Richland, WA.

**Model Name:** PORFLO (2D/3D)
**Sponsor:** Hanford - PNL

**Description:** PORFLO simulates coupled heat, ground water flow and solute transport in a saturated or unsaturated, porous media. The code is available in either two-dimensional, saturated flow (2D) or three-dimensional (3D), unsaturated flow versions.

Both versions of PORFLO utilize the equivalent porous continuum analogy to represent a porous medium. The codes can handle heterogeneous, anisotropic systems and can accommodate a variety of boundary conditions. In addition, the codes use a free-format input mode which makes it exceptionally easy to setup an input file. The codes also have various options that allow the user to select the processes to be modeled and the solution method to be used. The codes provide flow field calculations for input to pathline-travel time models and can be interfaced with a number of post-processors for graphical output.

**References:** Runchal, A.K., Sagar, B., R.B. Baca, and N.W. Kline, 1985. PORFLO - A Continuum Model for Fluid Flow, Heat Transfer and Mass Transport in Porous Media: Model Theory , Numerical Methods, and Computational Tests.. Rep. RHO-CR.150 P, Basalt Waste Isolation Project, Rockwell Hanford Operations, Richland, WA.

Runchal, A.K., and Sagar, B., 1989. PORFLO-3: A Mathematical Model for Fluid Flow, Heat and Mass Transport in Variably Saturated Geologic Media - User's Manual - Version 1.0. Westinghouse Hanford Operations, Richland, Washington.

Sagar, B., and Runchal, A.K., , 1990. PORFLO-3: A Mathematical Model for Fluid Flow, Heat and Mass Transport in Variably Saturated Geologic Media - Theory and Numerical Methods. WHC-EP-0042, Westinghouse Hanford Operations, Richland, Washington.

**Model Name:** PORMC-3
**Sponsor:** Hanford

**Description:** Heat and solute transport.

**Reference:** Prepared by Analytic & Computational Research Inc. Complete citation not provided by respondents.

**Model Name:** RANDOM WALK
**Sponsor:** Illinois State Water Survey

**Description:** Solute transport, two-dimensional porous media.

**Reference:** Prickett, T.A., T.G. Naymik, and C.G. Lonnquist, 1981. A Random Walk Solute Transport Model For Selected Ground Water Quality Evaluations. Bulletin 65, Illinois State Water Survey, Champaign, Illinois.

**Model Name:** SUTRA
**Sponsor:** USGS - International Ground Water Modeling Center - National Water Well Association

**Description:** SUTRA (Saturated-Unsaturated Transport) simulates fluid movement and the transport of either energy or dissolved substances in a subsurface environment. The model employs a two-dimensional hybrid finite-element and integrated finite-difference method to approximate the governing equations that describe the two interdependent processes that are simulated:

1. fluid density-dependent, saturated or unsaturated, ground water flow; and

2. a. transport of a solute in the ground water, in which the solute may be subject to equilibrium adsorption on the porous matrix, and both first-order and zero-order production or decay, or

2. b. transport of thermal energy in the ground water and solid matrix of the aquifer.

**Reference** Voss, C.I., 1984. SUTRA - Saturated-unsaturated Transport: A Finite-Element Simulation Model for Saturated-Unsaturated, Fluid density-Dependent Ground Water Flow with Energy Transport or Chemically-Reactive Single-Species Solute Transport. U.S. Geological Survey, Reston, Virginia.

**Model Name:** SWIFT (II,III)
**Sponsor:** USNRC

**Description:** SWIFT II & III simulate the flow and transport of energy, solute and radionuclides in a geologic medium.

**Reference:** Reeves, M., D.S. Ward, N.J. Johns and R.M. Cranwell. 1986. The Sandia Waste-Isolation Flow and Transport Model For Fractured Media: Release 4.84: Theory and Implementation. USNRC, Washington, D.C. NUREG/CR-3328.

Reeves, M. and R.M. Cranwell. 1981. User's Manual for the Sandia Waste-Isolation Flow Transport Model (SWIFT). USNRC, Washington, D.C. NUREG/CR-2324.

**Model Name:** TRACR3D
**Sponsor:** USDOE - LANL

**Description:** TRACR3D simulates fluid flow and mass transport in a saturated or unsaturated, porous medium. The code is primarily applied to field problems involving unsaturated conditions.

TRACR3D utilizes the equivalent porous continuum analogy to represent a porous media. The code can handle heterogeneous, anisotropic systems and can accommodate a variety of boundary conditions. The code is relatively easy to use but can be run on a Cray computer only. The code has various options that allow the user to select the processes to be modeled and the solution method to be used.

**Reference:** Travis, B.J., 1984. TRACR3D: A Model of Flow and Transport in Porous Media, LA-9667-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

**Model Name:** USGS MOC
**Sponsor:** USGS

**Description:** MOC is a two-dimensional model for the simulation of non-conservative solute transport in saturated ground water systems. The model is both general in its applicability and flexible in its design. Thus, it can be applied to a wide range of problems. It computes changes in the spatial concentration distribution over time caused by convective transport, hydrodynamic dispersion, mixing or dilution from recharge, and chemical reactions. The chemical reactions include first order irreversible rate reaction (such as radioactive decay), reversible equilibrium controlled sorption with linear, Fruendlich or Langmuir isotherms, and reversible equilibrium controlled ion exchange for monovalent or divalent ions. The model assumes that fluid density variations, viscosity changes, and temperature gradients do not affect the velocity distribution. MOC does allow modeling heterogeneous and/or anisotropic aquifers.

MOC couples the ground water flow equation with the non-conservative solute-transport equation. The computer program uses the ADI or SIP procedure to solve the finite difference approximation of the ground water flow equation. The SIP procedure for solving the ground water flow equation is most useful when areal discontinuities in transmissivity exist or when the ADI solution does not converge. MOC uses the method of characteristics to solve the solute transport equation. It uses a particle tracking procedure to represent convective transport and a two-step explicit procedure to solve the finite difference equation that describes the effects of hydrodynamic dispersion, fluid sources and sinks, and divergence of velocity. The explicit procedure is subject to stability criteria, but the program automatically determines and implements the time step limitations necessary to satisfy the stability criteria.

MOC uses a rectangular, block-centered, finite difference grid for flux and transport calculations. The grid size for flow calculations is limited to 40 rows and 40 columns. The grid size for transport calculations is limited to 20 rows and 20 columns which can be assigned to any area of the flow grid. The program allows spatially varying diffuse recharge or discharge, saturated thickness, transmissivity, boundary conditions, initial heads and initial concentrations and an unlimited number of injection or withdrawal wells. Up to five nodes can be designated as observation points for which a summary table of head and concentration versus time is printed at the end of the calculations.

An interactive preprocessor, PREMOC, is included with the program to facilitate user friendly data entry and editing.

**Reference:** Konikow, L.F. and J.D. Bredehoft. 1978. Computer Model of Two-Dimensional Transport and Dispersion in Ground Water. USGS. Techniques of Water Resource Investigation, Book 7, Chapter 2.

Goode, D.J. and L.F. Konikow. 1989. Modification of a Method-of-Characteristics Solute Transport Model to Incorporate Decay and Equilibrium-Controlled Sorption or Ion Exchange. USGS Water Resources Investigations Report 89-4030.

**Model Name:** VAM2D (H,3D,3DCG)
**Sponser:** Hydrogeologic Inc.

**Description:** VAM2D (NRC, 1989) is a finite element model that couples porous media water flow and contaminant transport through the saturated and unsaturated zones. The code was developed for the NRC. Specific features of the code and processes that the code is capable of simulating include:

- Two dimensional flow and transport
- Chain-decay transport
- Dispersion
- Retardation
- Anisotropic and/or heterogeneous lithology
- Confined and/or unconfined aquifers
- Aquitards
- Steady state or transient conditions
- Pulse and step releases from contaminated sources
- Point, line or areal sources

There are a whole range of flow and transport processes that VAM2D cannot simulate including vapor transport, complex geochemical reactions, three-dimensional fate and transport, and a variety of processes that may be essential in the evaluation of selected remedial alternatives. However, these limitations would generally not preclude the successful application of VAM2D to support the baseline risk assessment and characterization program.

VAM2D has been extensively tested through the INTERVAL Program and has been applied at numerous sites contaminated with radionuclides including: Los Alamos, West Valley, and Maxey Flats.

**Reference:** Huyakorn, P.S., 1989. VAM2D - Variably Saturated Analysis Model in Two Dimensions. NUREGY/CR-5352, Hydrogeologic Inc. for the U.S. Nuclear Regulatory Commission, Washington, DC.

Huyakorn, P.S., White, H.O., Kool, J.B., and Buckley, J.E., 1988. VAN2DH Version 1.0: A Variably Saturated Flow and Transport Analysis Model in 2-Dimensions. Documentation and User's Guide. Hydrogeologic Inc., Herndon, Virginia.

Huyakorn, P.S., and Panday, S., 1990. VAM3DCG: Variable Saturated Analysis Model in Three Dimensions with Preconditioned Conjugate Matrix Solvers - Documentation and User's Manual. Version 2.0, Hydrogeologic, Inc., Herndon, Virginia.

## GEOCHEMICAL/HYDROCHEMICAL

**Model Name:** BALANCE (-A)
**Sponsor:** USGS

**Description:** Hydrochemical model.

**Reference:** Parkhurst, D.L., L.N. Plummer and D.C. Thorstenson, 1982. BALANCE-A Computer Program for Calculating Mass Transfer for Geochemical Reactions in Ground Water. U.S. Geological Survey, Water Resources Investigations 82-0014, 33 pp.

**Model Name:** EQ3/6
**Sponsor:** USDOE

**Description:** Solute transport.

**Reference:** Wolery, T.J., Jackson, K.J., Boucier, W.L., Bruton, C.J., Viani, B.E., and Delany, J.M., 1988. The EQ3/6 software package for geochemical modeling: Current status. American Chemical Society, Division of Geochemistry, 196th ACS National Meeting, Los Angeles, California, Se[pt. 25-30 (abstract).

Wolery, T.J., et al., 1990. Current Status of the EQ3/6 Software Package for Geochemical Modeling. Chemical Modeling in Aqueous Systems II. D.C. Melchior and R.L. Basset, eds., ACS Symposium Series 416, American Chemical Society, Washington, D.C.

**Model Name:** HYDROGEOCHEM
**Sponsor:**

**Description:** Hydrochemical model

**Reference:** G.T. Yeh and V.S. Tripathi. Complete citation not provided by respondents.

**Model Name:** MINTEQ (A1)(Equilibrium Metal Speciation Model)
**Sponsor:** USEPA

**Description:** Geochemical model; calculates equilibrium aqueous speciation, adsorption, gas phase partitioning, solid phase saturation states and precipitation-dissolution of eleven metals.

**Reference:** Brown, D.S. and J.D. Allison. 1987. MINTEQA1 Metal Speciation Model: A User's Manual. EPA/600/3-87/012, USEPA, Athens, Georgia.

Felmy, A.R., D.C. Girvin and E.A. Jenne. 1984. MINTEQ - A Program For Calculating Geochemical Equilibria. EPA/600/3-84-032, USEPA, Athens Georgia.

**Model Name:** PHREEQE
**Sponsor:** USGS

**Description:** PHREEQE is a FORTRAN IV computer program designed to model geochemical reactions. Based on an ion pairing aqueous model, PHREEQE can calculate pH, redox potential, and mass transfer as a function of reaction progress. The composition of solutions in equilibrium with multiple phases can be calculated. The aqueous model, including elements, aqueous species, and mineral phases, is exterior to the computer code and is completely user definable. PHREEQE can simulate several types of reactions including (1) addition of reactants to a solution, (2) mixing of two waters, and (3) titrating one solution with another. In each of these cases PHREEQE can simultaneously maintain the reacting solution at equilibrium with multiple phase boundaries. The program calculates the following quantities during the reaction simulation:

1) pH;
2) pe;
3) total concentration of elements;
4) amounts of minerals (or other phases) transferred into or out of the aqueous phase;
5) distribution of aqueous species; and
6) saturation state of the aqueous phase with respect to specified mineral phases.

**Reference:** D.L. Parkhurst, D.C. Thorstenson and L.N. Plummer, 1980. PHREEQE - A Computer Program for Geochemical Calculations. U.S. Geological Survey, Water-Resources Investigations 80-96, 209 pp.

**Model Name:** BARRIER
**Sponsor:** EPRI

**Description:** Simulates the long-term performance of low-level radioactive waste disposal facilities. Predicts: long-term water balance; degradation of concrete structures over time and cracking and failure of concrete structures.

BARRIER projects the failure of facility structural components and water flow through the facility prior to and following failure. Unsaturated ground water flow modeling is based on Darcy's Law for water flow as extended to unsaturated systems. Facility degradation is modeled mechanistically, employing concrete deterioration and structural analysis algorithms pertinent to each facility design.

**Reference:** Shuman, R., V.C. Rogers, N. Chau and G.B. Merrel. 1989. The BARRIER Code: A Tool for Estimating the Long-Term Performance of Low-Level Radioactive Waste Disposal Facilities. NP-6218-CCML.

**Model Name:** BRUNZOG
**Sponsor:** US ARMY

**Description:** Calculates depth of thaw penetration.

**Reference:** Prepared by E.J. Chamberlin, U.S. Army Cold Regions Research and Engineering Laboratory. Complete citation not provided by respondents.

**Model Name:** CONSOL
**Sponsor:** ?

**Description:** Calculates settlement.

**Reference:** Prepared by U.C. Berkeley. Complete citation not provided by respondents.

**Model Name:** HELP (Hydrologic Evaluation of Landfill Performance)
**Sponsor:** USEPA

**Description:** Estimates the amount of surface runoff, subsurface drainage and leachate that may result from the operation of various landfill designs. The program models the effects of hydrologic processes including precipitation, surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage using a quasi-two-dimensional approach.

**Reference:** Schroeder, P.R., J.M. Morgan, T.M. Walski and A.C. Gibson. 1984. The Hydrologic Evaluation of Landfill Performance (HELP) Model. EPA/530-SW-84-009.

**Model Name:** MACCS (Reactor Accident Consequence Analysis Code)
**Sponsor:** USNRC

**Description:** Estimates environmental concentrations, intakes, dose-equivalents and risks resulting from a reactor accident.

**Reference:** Developed by Sandia National Laboratories. Complete citation not provided by respondents.

**Model Name:** ORIGEN2
**Sponsor:** RSIC

**Description:** ORIGEN2 is a revised and updated version of ORIGEN (Oak Ridge Isotope Generation). ORIGEN2 performs a point-depletion calculation on reactor fuel, irradiation of reactor components, and determines the composition, radiation, and spectra of any part of the fuel cycle. A matrix exponential technique is applied to compute nuclide concentrations. In some cases the Bateman equation and secular equilibrium are used. The cross sections are assumed to be constant, except for a number of key actinide reactions that are varied with burnup. Nuclear libraries supplied with the code provide space and spectrum-averaged cross-sections. One-group flux is assumed. Output values are used as source terms for radiation exposure and radiation shielding codes.

**Reference:** Croff, A.G., 1980. A User's Manual for the ORIGEN2 Computer Code. ORNL/TM-7175

**Model Name:** PAGAN (Performance Assessment Ground Water Analysis of low-level Nuclear waste)
**Sponsor:** USNRC - SNL

**Description:** The PAGAN code is used to assess the performance of low-level waste and contains the transport codes DISPERSE and SURFACE (Kozak et al., 1990). PAGAN calculates release from a source using either a rinse-release or a leach-limited source-term model. This release term is used as an area source into the aquifer at the water table, and radionuclide concentrations at various locations and times can be calculated. If the contaminated aquifer also discharges into a surface water body, the flux of radionuclides into the surface water can be calculated in a separate run of PAGAN. If the surface water body is a small flowing river, the radionuclide concentration in the river may be calculated using a simple dilution factor in PAGAN.

The surface and ground water capabilities of PAGAN have been incorporated into the GENII code (Napier et al., 1988).

**Reference:** Chu, M.S.Y., Kozak, M.W., Campbell, J.E., and Thompson, B.M., 1991. A Self-Teaching Curriculum for the NRC/SNL Low-Level Waste Performance Assessment Methodology, NUREG/CR-5539, SAND90-0585, U.S. Nuclear Regulatory Commission, Washington, D.C.

**Model Name:** PC-SLOPE
**Sponsor:** Geo-slope, Inc., commercial product

**Description:** Failure surface calculations.

**Reference:** Geo-Slope, Calgary Canada. Complete citation not provided by respondents.

**Model Name:** RASCAL
**Sponsor:** USNRC

**Description:** Estimates dose-equivalents and health effects due to reactor accidents.

**Reference:** Model prepared by ORNL and Phoenix Associates Inc. Complete citation not provided by respondents.

**Model Name:** RSAC (Radiological Safety Analysis Computer Program)
**Sponsor:** USDOE

**Description:** Evaluation of the impact of nuclear facilities, operation and accidents. The program can calculate: fission product buildup and decay, meteorological diffusion and/or depletion values, and individual or population doses resulting from inhalation, deposition or ingestion of or direct exposure to radionuclides released to the environment.

**Reference:** Wenzel, D.R. 1982. RSAC-3: Radiological Safety Analysis Computer Program. ENICO-1002. Exxon Nuclear Idaho Co., Inc., Idaho Falls.

**Model Name:** SFRIPD
**Sponsor:** MK Environmental

**Description:** Calculates safety factors for riprap sizing.

**Reference:** Developed in-house by MK Environmental, San Francisco, California. Complete citation not provided by respondents.

**Model Name:** SFRIPE
**Sponsor:** MK Environmental

**Description:** Calculates safety factors for riprap sizing.

**Reference:** Developed in-house by MK Environmental, San Francisco, California. Complete citation not provided by respondents.

**Model Name:** STABL
**Sponsor:** Indiana

**Description:** Calculates failure surfaces, factors of safety ?

**Reference:** Prepared by R.A. Siegel, Purdue University, for the Indiana State Highway Commission. Complete citation not provided by respondents.

**Model Name:** STABL5
**Sponsor:** US DOT

**Description:** Calculates failure surfaces, factors of safety.

**Reference:** Prepared by Purdue University for The Joint Highway Research Project, Federal Highway Administration, U.S. Department of Transportation. Complete citation not provided by respondents.

**Model Name:** STABR
**Sponsor:**

**Description:**

**Reference:** Prepared by U.C. Berkeley. Complete citation not provided by respondents.

**Model Name:** STEPH
**Sponsor:** MK Environmental

**Description:** Calculates riprap sizing.

**Reference:** Developed in-house by MK Environmental, San Francisco, California. Complete citation not provided by respondents.

**Model Name:** UTEXAS2
**Sponsor:** Texas

**Description:** Calculates failure surfaces and factors of safety.

**Reference:** Prepared by Stephen G. Wright for the Texas State Department of Highways and Public Transportation. Complete citation not provided by respondents..

**Model Name:** ISOSHLD (-II)
**Sponsor:** USDOE

**Description:** ISOSHLD is used to calculate radiation dose at a point from bremsstrahlung and/or gamma rays emitted from radioisotope sources. ISOSHLD-II is an extension of ISOSHLD with the added bremsstrahlung mode. Five shield regions can be handled with up to twenty materials per shield region, the source is considered to be the first shield region, i.e., bremsstrahlung and gamma rays are produced only in the source. Point kernel integration (over the source region) is used to calculate the radiation doses at a field point.

Data needed to calculate fission-product isotopic concentrations, source spectrum distributions, and attenuation coefficients are contained in libraries used by the code. Problem input data is thereby minimized; and information required specifies the source-shield configuration and identifies the relevant materials and their densities.

**Reference:** Engle, R.L., J. Greenborg and M.M. Hendrickson. 1966. ISOSHLD - A Computer Code For General Purpose Isotope Shielding Analysis. BNWL-236. Pacific Northwest Laboratory, Richland, Washington.

Simmons, G.L., J.J. Regimbal, J. Greenborg, E.L. Kelley, Jr., H.H. Van Tuyl. 1967. ISOSHLD-II: Code Revision to Include calculation of Dose Rate From Shielded Bremsstrahlung Sources. BNWL-236 Supplement 1, Pacific Northwest Laboratory, Richland Washington.

**Model Name:** LADTAP
**Sponsor:** USNRC/Oak Ridge NL

**Description:**

**Reference:** Simpson, D.B., and McGill, 1980. Users' Manual for LADTAP II - A computer Program for calculating radiation exposure to man from routine release of Nuclear Reactor Liquid Effluents, Oak Ridge National Lab., Oak Ridge, TN, NUREG/CR-1276 (ORNL/NUREG/TOMC-1).

**Model Name:** RADRISK
**Sponsor:** USEPA

**Description:** Life-table methodology to derive dosimetric and health effects data. Often used with AIRDOS and DARTAB.

**Reference:** Dunning, D.E., Jr., R.W. Leggett and M.G. Yalcintas. 1980. A Combined Methodology for Estimating Dose Rates and Health Effects From Radioactive Pollutants. ORNL/TM-7105.

## UTILITIES

**Model Name:** SURFER
**Sponsor:** Golden Software

**Description:** 3-dimensional gridding, contouring and surface plotting software.

**Reference:** SURFER, Golden Software, Golden, CO.

# END

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