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MODEL ASSESSMENT FOR DELINEATING WELLHEAD PROTECTION AREAS

FINAL REPORT

By

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EXECUTIVE SUMMARY

One element of the 1986 Amendments of the Safe Drinking Water Act (SDWA) of 1974 is the protection of wellhead areas from contaminants that may have an adverse effect on public health. In establishing wellhead protection areas (WHPA's), many factors need to be considered, such as the zone of influence around a well or wellfield, the presence of interfering neighboring wells or wellfields, water table drawdown by the wells or wellfields under consideration, various sources of contamination in the well recharge area (not necessarily the same as its zone of influence), and flow paths, transport velocities, and travel times for various contaminants under various hydrologic conditions. To determine a site-specific WHPA, a systematic analytic approach must be taken. Mathematical simulation models provide a viable and often the only method to determine the WHPA when quantitative criteria are used. Such models are useful instruments in understanding the mechanisms of ground-water systems and the processes which influence their quality. Through their predictive capabilities, models provide a means to analyze the response of the site-specific system to various management alternatives and potential public health threats.

This report is aimed at providing the information on existing ground-water flow and contaminant transport and fate models that might be considered for use in a WHPA delineation study.

Although physical ground-water models can be useful for studying certain problems, the present focus is on mathematical flow and contaminant transport models in which the causal relationships among various components of the system and the system and its environment are expressed in terms of mathematics and translated into a computer code.

Flow models are used to calculate changes in the distribution of hydraulic head of fluid pressure, drawdowns, rate and direction of flow, travel times, and the position of interfaces between immiscible fluids. Two types of models can be used to evaluate the chemical quality of ground water: hydrochemical models describing equilibrium reactions or reaction kinetics, and models to simulate solute transport and fate. Solute transport

and fate models are used for the prediction of movement, concentrations, and mass balance components of water-soluble constituents.

The major criteria in selecting a model for a particular site-specific WHPA delineation are: (1) that the model be suitable for the intended use; (2) that the model be reliable; and (3) that the model can be applied efficiently. A model's efficiency is determined by the availability of its code and documentation, and its usability, portability, modifiability, and economy with respect to human and computer resources required. It should be realized that a perfect match rarely exists between desired characteristics and those of available models. If a match is hard to obtain, reassessment of the selection criteria and their relative weight is necessary.

A major issue in model use is credibility. A model's credibility is based on its proven reliability and the extent of its use. It is often assumed that most program errors originally present in a widely used program have been detected and corrected. Besides, successful application of a program in situations comparable to that for which it was selected reduces uncertainty in its applicability to the new situation.

A model's credibility can be evaluated in terms of level of review and testing applied to it and by evaluating the success rate of its use. Testing a code consists of two phases: (1) verification to check its accuracy and to assure that the code is fully operational, and (2) field validation to determine how well the model's theoretical foundation describes the actual system behavior that the model has been designed to simulate.

Many of the models available have not been extensively reviewed and tested. Review has often been limited to peer review of theory and project reporting. Although most models have undergone some verification, the results are rarely reported, especially for the more complex models. Only a few models are reported to have undergone extensive field validation.

With respect to availability of ground-water software, a distinction can be made between public domain and proprietary software. Models that are available without restrictions in their use and distribution are considered to be in the public domain. Available proprietary software can be obtained or accessed under certain restrictions for use, duplication, and distribution.

Selected Models

Sixty-four models were screened by a computerized search in the model annotation databases of the International Ground Water Modeling Center (IGWMC). These databases have been developed and maintained over the years with major support from U.S. EPA's R.S. Kerr Environmental Research Laboratory, Ada, Oklahoma. This search was followed by an evaluation of the maintenance and update history of each model's code. The models were chosen because of their availability, level of documentation, and applicability to the wellhead protection zone delineation problem. Of the 64 models, 27 are flow and 37 are solute transport models. Fifty-one of the models are numerical, and 13 are analytical and semi-analytical. This report contains appendixes with summary descriptions and detailed information of each model, and a comparison of usability and reliability characteristics.

A major limitation of this study relates to the availability of data on model usability, reliability, and portability. Many models have not been subject to the extensive evaluation required to rate them according to the criteria presented in this report. Additional activities should be initiated to fill in the information gaps present in this report.

Although adequate models are available for analysis of most flow-related problems, this is not the case for modeling contaminant transport. Accurate modeling of ground-water pollution is limited by some fundamental problems. One limitation is mathematical: for the most complex mechanisms, available numerical techniques are not always adequate. Finally, in most cases, lack of quantity or quality of data restricts model utility.

Section 1

Introduction

In 1986 the Safe Drinking Water Act (SDWA) of 1974 was amended to strengthen the provisions for protection of underground sources of drinking water. One element of the 1986 Amendments is the requirement for the states to submit to the U.S. Environmental Protection Agency (U.S. EPA), within three years of the enactment of the Amendments, a program to protect wellhead areas within their jurisdiction from contaminants that may have an adverse affect on public health. A "wellhead protection area" (WHPA) is, according to the 1986 Amendments, "the surface and subsurface area surrounding a water well or wellfield, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or wellfield."

Because the law does not specify the exact delineation of wellhead protection areas, the actual extent of a WHPA is determined by the state in which the area is situated. In establishing these site-specific areas, many factors need to be considered, such as the zone of influence around a well or wellfield; the presence of interfering neighboring wells or wellfields; water table drawdown by the wells or wellfields under consideration; various sources of contamination in the well recharge area (not necessarily the same as its zone of influence); and flow paths, transport velocities; and traveltimes for various contaminants under various hydrologic conditions. Additional considerations in WHPA delineation are existing regulatory requirements; characteristics of and uncertainty in the description of the physical system; technical resources available for analysis and implementation of decision making; and social, economic, and political consequences.

To determine a site-specific WHPA, a systematic analytic approach must be taken. Such an approach can be based in part on the technical guidance the U.S. EPA is required to issue (by the 1986 SDWA Amendments) within a year of the Amendments enactment. Various approaches have been taken to regulate WHPA delineation, including the use of fixed circles or rings around the well, simplified variable shapes based on hydrogeologic mapping and classification, and the determination of zones with prescribed minimum traveltime or residence time (CBW 1980). Mathematical simulation models provide a viable and often the only method to determine the WHPA when quantitative criteria are available. Such models are useful instruments in understanding the mechanisms of ground-water systems and the processes that influence their quality. Through their predictive capabilities, models provide a means to analyze the response of the site-specific system to various management alternatives and potential public health threats. A study in The Netherlands (CBW 1980) indicated that for each site-specific WHPA delineation, various levels of modeling complexity should be considered, ranging from monograms and simple flow models to complex transport and fate models.

This report describes ground-water flow and contaminant transport and fate models that might be considered for use in a WHPA delineation study. Guidelines for model selection and model use are included in the technical guidance document.

Section 2

Model Selection and Evaluation Approach

The study reported here has been performed in two phases. In the first phase, the expected use of ground-water models under the WHPA delineation requirements has been analyzed and information collected on existing models. In this phase, model selection and evaluation criteria were defined. These criteria are based in part on the findings of the U.S. EPA Groundwater Modeling Study Group (van der Heijde and Park 1986).

In selecting the groundwater models evaluated here, the IGWMC model annotation databases have been searched. When necessary, additional information has been collected from the IGWMC ground-water modeling research collection, among other sources.

The second phase of the project, evaluation of models and reporting, began with a screening of all model information in order to choose models for more extensive evaluation. The final evaluation took place using the criteria defined in the first phase of the project. Models considered useful in the context of this study are described in terms of their hydrologic characteristics, technical requirements, usability, reliability, and economy. Each model has been rated with respect to applied quality assurance, user-friendliness, accessibility, portability, and modifiability.

The report concludes with a discussion of research and development needs for models and modeling methodologies.

Section 3

Mathematical Models

Although physical ground-water models can be useful for studying certain problems, this report focuses on mathematical models in which the causal relationships among various components of the system, and the system and its environment are expressed in terms of mathematics and uncertainty of information.

Ground-water models can be divided into various categories, depending on the purpose of the model and the features included. Apart from spatial resolution (one, two, or three dimensions) and temporal definition (steady-state versus time-dependent behavior), models can be distinguished based on how the nature of the system is described: by deterministic models or by probabilistic or stochastic models (Domenico 1972). A deterministic model considers the ground-water system as a deterministic system and is based on definite descriptions of cause-and-effect relationships. Cause is generally system excitation, while effect is the response of the system to such excitation. In describing a system in deterministic terms these cause-and-effect relations should be measurable and mathematically definable.

A probabilistic or stochastic model represents a system that allows no precise prediction, but may be characterized by expected values within the limitations of the probability terms that define its behavior (Domenico 1972). If one of the system variables is random, the system is stochastic regardless of its deterministic elements.

Another major distinction between ground-water models is based on the approach taken to describe the spatial characteristics of the system being considered. When the total system is located at a single point, the system is defined as a lumped-parameter system. In a distributed-parameter system the cause-and-effect relations are defined for specific points or areas. In ground-water modeling the distributed-parameter approach is most frequently used.

Input response or black box models are used to relate to each other, empirically, observations of different variables made in such systems. This approach is sometimes taken (1) to relate the rise of water levels over a certain period of time (a response variable) to recharge, without any regard for the location of wells or the manner in which the recharge reaches the water table (Domenico 1972), or (2) to relate water level decline or spring discharge to ground-water pumping. Input-response models are well suited for probabilistic analysis. However, this category of mathematical models is not discussed in this report because of their limited use in delineation of wellhead protection areas.

The mathematical framework for distributed-parameter models consists of one or more partial differential equations called field equations, of initial and boundary conditions, and of solution procedures (Bear 1979). According to the solution method adopted, a distinction can be made between analytical models, semi-analytical models, and numerical models.

Analytical models contain a closed-form solution of the field equations, continuous in space and time. As analytical solutions generally are available only for relative simple mathematical problems, using them to solve ground-water problems requires extensive simplifying assumptions regarding the nature of the ground-water system, its geometry, and external stresses (Walton 1984). These simplifications lead to a model that includes relatively few processes and thus a limited number of parameters. In addition, by simplifying the descriptions of the processes they represent, these parameters are often taken as constant in space and time.

In semi-analytical models, complex analytical solutions are approximated by numerical techniques, resulting in a discrete solution in either time or space. Models based on a closed-form solution for either the space or time domain, and which contain additional numerical approximations for the other domain, are also considered semi-analytical models. This model type includes those that provide streamline and traveltime information through numerical integration in space or time, of analytical expressions (e.g., Javandel et al. 1984).

Recently, models have been developed for study of two- and three-dimensional regional ground-water flow under steady-state conditions in which an approximate analytic solution is derived by superposition of various exact or approximate analytic functions, each representing a particular feature of the aquifer (Haitjema 1985, Strack 1987). These models are much more flexible than analytic models with respect to the hydrogeology and stresses that can be incorporated without significantly increasing the need for data.

In numerical models a discrete solution is obtained in both the space and time domains by using numerical methods to transform the field equations into a set of algebraic equations which are solved using direct or iterative matrix methods. If the equations are nonlinear, linearization precedes the matrix solution (Remson et al. 1971). Because numerical models allow for great hydrogeological detail, stresses, boundary conditions, and simulated processes, their data need is significantly greater than that of analytical models.

Various numerical solution techniques are used in ground-water models. They include finite-difference methods (FD), integral finite-difference methods (IFDM), Galerkin and variational finite-element methods (FE), collocation methods, boundary (integral) element methods (BIEM or BEM), particle mass tracking methods (e.g., random walk [RW]), and the method of characteristics (MOC) (Huyakorn and Pinder 1983).

Based on model purpose, three types of ground-water models can be distinguished (van der Heijde et al. 1985):

Prediction models, which compute the behavior of a ground-water system in response to stresses on the system;

Parameter identification models or inverse models, which determine the system parameters by using direct or indirect methods to solve inverse formulations of the prediction problem; and

Resource management models, which integrate hydrologic prediction with explicit management-decision procedures in an optimization framework. In such models the management problem is described in terms of objective function(s) and constraints, and the resulting equations are solved by an optimization technique such as linear programming (Gorelick 1983).

Prediction models comprise the largest category of ground-water models. They are emphasized here because of their relevance to the study objectives.

Prediction models for ground-water system analysis can be further subdivided into several major groups: fluid flow, solute and heat or energy transport, hydrochemical characterization, and matrix deformation caused by changing fluid and rock pressures.

Because this report provides information on existing models that could be applied in site-specific WHPA delineation, only flow and solute transport models are discussed in detail.

Flow models determine quantitative aspects of the movement of one or more fluids in porous or fractured rock. One of the fluids considered is water; the others, if present, can be air (in soil), or immiscible non-aqueous phase liquids (NAPL's) such as certain hydrocarbons. A special case of multifluid flow occurs when layers of water of distinct density are separated by a relatively small transition zone, a situation often encountered when seawater intrusion occurs. Flow models are used to calculate changes in the distribution of hydraulic head or fluid pressure, drawdowns, rate and direction of flow (e.g., determination of streamlines, particle pathways, velocities, and fluxes), traveltimes, and the position of interfaces between immiscible fluids. In modeling ground-water flow systems, a distinction is made between subsurface areas which are partially saturated with water and formations which are fully saturated.

Two types of models can be used to evaluate the chemical quality of ground water: hydrochemical models and models to simulate solute transport and fate. In hydrochemical models, the chemistry describing equilibrium reactions or reaction kinetics is posed independent of any mass transport process. These models, which are general in nature and are used for both ground water and surface water, simulate chemical processes that regulate the concentration of dissolved constituents. They can be used to identify the effects of temperature, speciation, sorption, and solubility on the concentrations of dissolved constituents (Jenne 1981).

Solute transport and fate models are used to predict movement, concentrations, and mass balance components of water-soluble constituents, and to calculate radiological doses of soluble radionuclides. In principle, a solute transport model is based on solving the partial differential equation for solute transport under given boundary and initial conditions. A complete solute transport model includes simulation of advective displacement of the contaminant and additional spreading through dispersion, allowing for transformations by chemical and microbial reactions. The final result is the computation of concentrations and solute mass balances. Under certain conditions such as low concentrations of contaminants and negligible difference in specific weight between contaminant and the resident water, changes in concentrations do not affect the flow pattern (homogeneous fluid phase). In such cases the transport equation can be solved independently from the flow equation, assuming the flow field is known. Some transport models contain a flow submodel to provide the velocities required for solving the transport equation.

In cases of high contaminant concentrations in waste water or saline water, changes in concentrations affect the flow patterns through changes in density and viscosity, which in turn affect the movement and spreading of the contaminant and hence the concentrations (heterogeneous fluid phase). To solve such problems through modeling, simultaneous solution of flow and solute transport equations or iterative solution between the flow and quality submodels is required (van der Heijde 1984). Models which consider both displacements and transformations of contaminants are called nonconservative. (Conservative models only simulate convective and dispersive displacements.) Most transport models can handle only single species. Multicomponent transport and chemical interactions are being studied, as is the case with facilitated transport (e.g., of organics by colloidal particles).

The transformations considered by nonconservative models are primarily adsorption, radioactive decay, and biochemical transformations. Thus far, the simplified linear representation of the the adsorption process has been included principally in nonconservative transport models. This approach is based on the assumption that the reaction rates are limited and thus depend on the residence time for the contaminant, or that the reactions proceed instantaneously to equilibrium. Biochemical reactions have been incorporated as a first-order decay process. Research is focused on more complex formulations based on reaction kinetics under aerobic and anaerobic conditions.

Until recently, the inclusion of geochemistry in mass transport models has concentrated on single reactions such as ion-exchange or sorption for a small number of reacting solutes (Rubin and James 1973, Valochi et al. 1981, Charbeneau 1981). Because multicomponent solutions are involved in most contamination cases, there is a need for models which incorporate all the significant chemical interactions and processes that influence the transport and fate of the contaminating chemicals (Cederberg et al. 1985).

A special group of prediction models is formed by those that can handle combinations of heat and solute transport and rock matrix displacement: the multipurpose groundwater models. The heat transport option in such models is used to evaluate thermal effects on ground-water flow and solute transport. In addition to simulating convective and dispersive heat transport in the fluid phase, such models may take into account heat conduction through the rock matrix and heat exchange between the fluid and rock (van der Heijde et al. 1985). However, current models of this type are not designed to include effects of varying temperatures on chemical and microbial transformation rates.

The deformation simulated by some multipurpose models calculates rock matrix displacements resulting from changes in water pressures. These vertical and lateral displacements can be caused by withdrawal of ground water or injection of waste water, among other causes. A complicating factor in simulating rock matrix deformation is that the permeability might be affected by the matrix displacements. Some of these multipurpose models solve the system equations in a coupled fashion to provide for analysis of complex interactions between the various physical, chemical, and biological processes involved.

Adequate models are available for analysis of most flow-related problems regarding a single liquid. However, accurate modeling of ground-water quality is limited by some fundamental problems. Not all processes identified are adequately described mathematically. Furthermore, in many cases lack of quantity or quality of data restricts model utility. This is especially the case for spatial variability of flow and transport parameters and for the rate constants needed to incorporate chemical and biological processes in solute transport models. Therefore, the use of such models is restricted to conceptual analysis of contaminant problems, to feasibility studies in technical designs, to screening of alternative actions, and to data acquisition guidance. These models generally lack predictive potential.

Note that the terms solute transport and contaminant transport have a slightly different meaning. Contaminant transport relates to the transport and fate of all chemical and biological compounds considered to be contaminating the ground-water system, including hydrophilic and hydrophobic chemicals, immiscible fluids, and exchange between phases such as across the water-air boundary. Contaminant transport includes the transport of solutes. Solute transport models are limted in that they only simulate transport and fate of in water soluable chemicals.

Section 4

Selection and Evaluation Criteria

4.1. Model Selection Process

Using models to analyze alternative solutions to ground-water problems requires a number of steps, each of which should be taken conscientiously and reviewed carefully. After the decision to use a model has been made, an appropriate model is selected by matching a detailed description of the modeling needs with well-defined, quality-assured characteristics of existing models (van der Heijde 1987). In selecting an appropriate model, both the model requirements and the characteristics of existing models must be carefully analyzed. Major elements in evaluating modeling needs are: (1) formulation of the management objective to be addressed and the level of analysis sought; (2) description of the system under study; and (3) analysis of the constraints in human and material resources available for the study. The major criteria in selecting a model are: (1) that the model be suitable for the intended use; (2) that the model be reliable, and (3) that the model can be applied efficiently.

Model selection is a process containing both objective and subjective elements. It should be realized that a perfect match rarely exists between desired characteristics and those of available models. Many of the selection criteria are subjective or weakly justified. If a match is hard to obtain, these criteria and their relative weight in the selection process must be reassessed. Hence, model selection is very much an iterative process.

4.2. Definition of Criteria

Models for use in wellhead protection zone analysis have been evaluated in two steps. First, the models selected are (1) suitable to answer some of the questions that might be raised in delineation of wellhead protection zones, (2) available and relatively easily obtainable, and (3) documented in one or another form. Second, for each of the models selected, detailed information regarding their operational characteristics was collected and evaluated.

In applying quantitative methods to delineation of a wellhead protection zone, one or more of the following characteristics and variables of the ground-water system is emphasized: (1) present and future hydraulic or piezometric head distribution; (2) shape and extent of the cone-of-depression or zone-of-influence; (3) streamlines or flow paths representing direction of flow from or toward the well or wellfield; (4) flow velocities and travel or transit time from certain locations in the ground-water system to the well or wellfield; (5) contaminant concentration distribution in the aquifer; (6) zones of contribution for the well or wellfield; (7) recharge areas where aquifer replenishment takes place; and (8) water and solute fluxes near the wells and at the boundaries of the ground-water system.

An important aspect of a model's use in ground-water management is its efficiency, which is determined by the human and computer resources required for its proper operation. A model's efficiency can be described by its usability, availability, modifiability, portability, and economy of computer use. Another important issue is the model's reliability.

4.2.1. Usability

Various problems can be encountered when a simulation code is implemented on the user's computer system. Such difficulties may arise from hardware incompatibilities or user errors in code installation, data input, or program execution.

Programs that facilitate rapid understanding and knowledge of their operational characteristics and that are easy to use are called user-friendly, and are defined by their usability. Usability addresses important management issues such as how quickly the program can be learned and put to use effectively (Carroll and Rosson 1984). User-friendly programs generally emphasize a consistent set of commands, extensive, well-edited documentation, easy input preparation and execution, and well-structured, informative output. Adequate code support and maintenance also enhance the code's usability. Generally, a program's usability is defined by its software interactiveness, documentation, and user support; these considerations are discussed below.

4.2.1.1. Interactive Software

Interactive software consists of computer application programs that facilitate human/computer interaction during program execution. Such software operates in a conversational mode through use of menus (lists of options), icons (screen pictures of optional functions), and instructive text. Such programs often allow for user input through various devices such as a mouse and touch screens, in addition to the keyboard input. Interactive software is available for the three main stages of the modeling process: presimulation, computer simulation, and postsimulation.

The first stage of the modeling process, often called preprocessing, includes data acquisition, data inspection and storage, data interpretation, and model input preparation (van der Heijde and Srinivasan 1983). In the second stage the actual modeling takes place by computer simulation calculations. The final stage involves storage, analysis, presentation of the computational results, and is often refered to as postprocessing.

Interactive preprocessing can take different forms. Data can be entered into a file from prepared data sheets, using a word processor or line editor. In this case, the user needs to ensure by way of post-entry inspection that the data formats required by the simulation program are correctly applied. Data can also be entered using a dedicated preprocessor, a program that allows for interactive data entry and editing and that automatically formats the prepared input file according to the simulation program requirements, thus limiting the chance that format errors are introduced in the datafile. Well-designed interactive preprocessors provide an excellant means to control the quality of the data-entry process. They allow for efficient interaction by providing correct order of informative data-entry instructions. Some interactive preprccessors include errorchecking features by placing upper and lower bounds on the values entered for a particular variable. An additional benefit of interactive preprocessors is that they provide a learning environment for inexperienced users, especially if "help" features (optional calls for detailed explanation and continuation instruction) are present.

The simulation program can be run in a batch mode, requiring user-specified input files. In such a case the model runs independently of any user-prepared file or user interaction. If the user has the option to interact with the program during its execution, modeling becomes more flexible. Such interaction might facilitate changing stresses during successive simulation steps, or changing such modeling variables as time step sequences. The most common user interaction currently provided by ground-water modeling software is the restart option: after specifying changes in number and size of timesteps, the last computed values are entered automatically as initial values for the new runs. Interactive execution of a simulation program can enhance the efficiency of the application by avoiding reruns caused by incorrect parameter selection.

Postprocessors might be used to reformat and display or print the model results in textual or graphic form and to analyze the results by means of a variety of manual and automated techniques (van der Heijde and Srinivasan 1983). For most models, output for graphic display such as contouring can be obtained by processing one of the output files directly, using display software, or after some simple modifications in the simulation code. It is often more difficult to generate time drawdown curves for selected locations, based directly on model output, especially in the memory-limited microcomputer environment. This problem should disappear with the next generation of microcomputers and operating systems. Display of streamlines and isochrones, among others, requires dedicated software, coupling simulation, and graphics software. User/computer interaction in postprocessing is often aimed at selecting the type of postprocessing (e.g., type of graphics), layout of display, and including problem-specific text in the display (e.g., labels of axis, site identification). Interactive graphic software aimed at grid design (e.g., grid generators for finite-element models) is available for a limited number of models.

In this report the presence of pre- and postprocessors is rated as: not present [none, N], dedicated [model-dependent, D], generic [can be used for a class of models, might include separate reformatter for specific models or display software, G], used for interactive runs [I], or status unknown [U].

4.2.1.2. Documentation

Good documentation is essential for efficient model use. It should include a complete description of the equations on which the model is based, the underlying assumptions, the boundary conditions that can be incorporated in the model, the methods used to solve the equations, and the limiting conditions resulting from the chosen method (van der Heijde 1987). Good documentation should also include a user's manual containing instructions for operating the code and preparing data files and sample problems, complete with an exact listing of input required and output produced by the code. Also necessary is a programmer's guide containing a description of the coding and its structure, a discussion of computer system requirements, and code installation procedures. Finally, a report on the initial code verification should be available.

However, in many cases information regarding computer system requirements as well as sample runs is incomplete or missing. The user's manual may be too condensed, thus extending significantly time spent in getting the model operational (van der Heijde 1985). Where documentation exists, it is often incomplete and inconsistent, at times merely a collection of published papers.

In the model evaluation process presented here, the presence of adequate description of theory, user's instructions, example data sets, and results are indicated by yes [Y] or no [N]. The availability of programmer's documentation is discussed in the section on modifiability.

4.2.1.3. Support

If a model user has decided to apply a particular model to a problem, he may encounter technical problems in running the model code on the available computer system. Such a difficulty may result from (1) compatibility problems between the computer on which the model was developed and the model user's computer; (2) coding errors in the original model; and (3) user errors in data input and model operation.

User-related errors can be reduced by becoming more familiar with the model. Here the user benefits from good documentation. If, after careful selection of the model, problems occur in implementation or execution of the model and the documentation does not provide a solution, the user needs help from someone who knows the code. Such assistance, called model support, cannot replace the need for proper training in model use; requests for support by model developers may assume such extensive proportions that model support becomes a consulting service. This potentiality is generally recognized by model developers, but not always by model users.

In this report, software support and maintenance is rated as: none [N], limited with respect to amount and level of support [L], unlimited [Y], and unknown [U].

4.2.2. Availability

A model is defined as available if the program code associated with it can be obtained or accessed easily by potential users.

The two major categories of ground-water software are public domain and proprietary software (van der Heijde 1985). In the United States, most models developed by federal or state agencies or by universities through funding from such agencies, are available without restrictions in their use and distribution, and are therefore considered to be in the public domain. In other countries the situation is often different, with most software having a proprietary status, even if developed with government support. In this case the computer code can be obtained or accessed under certain restrictions of use, duplication, and distribution.

Models developed by consultants and private industry are often proprietary. This may also be true of software developed by some U.S. universities and private research institutions. Proprietary codes are in general protected by copyright law. Although the source codes of some models have appeared in publications, their use and distribution is restricted by the publication's copyright.

There are two main options in obtaining proprietary software: (1) a site-license for a limited number of installations, either for a certain period or so-called open-ended; often includes maintenance and limited update services; and (2) royalty-based use, i.e., a royalty fee is due each time the code is accessed on a host computer.

Further restrictions occur when a code includes proprietary third-party software, such as mathematical or graphic subroutines. For public domain codes, such routines are often external and their presence on the host-computer is required to run the program successfully.

Between public domain and proprietary software is a grey area of so-called freeware or user-supported software. Although freeware can be copied and distributed freely, users are encouraged to support this type of software development with a voluntary contribution.

For some codes developed with public funding, distribution restrictions are in force, as might be the case if the software is exported, or when an extensive maintenance and support facility has been created.

This report (Appendix C) distinguishes between unrestricted and restricted public domain codes and fully proprietary codes (obtainable through site-licensing or royalty-based use). Programs accessible only on a royalty base by connecting to a host-computer on a royalty base are not listed. Appendix C lists program requirements with respect to proprietary routines residing on the host-computer, when applicable.

4.2.3. Modifiability

In the course of a computer program's useful life, the user's experiences and changing management requirements often lead to changes in functional specifications for the software. In addition, scientific developments, changing computing environments, and the persistance of errors make it necessary to modify the program. If software is to be used over a period of time, it must be designed so that it can be continually modified to keep pace with such events. A code that is difficult to modify is called fragile and lacks maintainability. Such difficulties may arise from global, program-wide implications of local changes (van Tassel 1978). Many software providers prevent maintainability problems by distributing only compiled versions. In that case, program modifications can be introduced only by the provider himself. However, this leaves the user without the means to evaluate the coding.

A code's modifiability is related to the size and complexity of the tasks it performs. Codes which are easy to modify are generally based on structured programming using modular approaches. Other important criteria of modifiability are the use of ANSI standard programming language, along with good programmer's documentation and extensive maintenance records, as the programmers are often not the original developers.

To rate modifiability of a simulation program, its source code should be reviewed. In this report such review is performed only for a limited number of codes available to the IGWMC. Of the codes evaluated in this report, only a few can be rated easily modifiable by programmers not familiar with the code's development.

4.2.4. Portability

Programs that can be easily transferred from one execution environment to another are called portable. An execution environment is defined by the type and capabilities of the computer, the presence of peripheral hardware, and the operating system under which the program will be executed. To evaluate a program's portability, both its software and hardware dependency must be considered. If the program needs to be altered to run in a new computer environment, its modifiability is important (see modifiability section above).

Hardware dependency of software is most significant for microcomputer environments. The present limitation of the widely used microcomputer Disk Operating System (DOS) to directly address more than 640 kilobytes of direct or random access memory (RAM) has divided all ground-water modeling software into two groups: software that can be adapted to this microcomputer environment, and software that runs only on mainframe computers and minicomputers. Thus, one of the major portability criteria is the program's core memory requirements. In addition, mass storage requirements for input and output files, as well for temporary files used during code execution, have to be checked. Other hardware requirements that might pertain to the microcomputer environment include the presence of a math coprocessor and a specific graphic card and monitor (e.g., CGA, EGA, PGA, or Hercules mode). Even among microcomputer systems, differences in central processor architecture might preclude software portability (e.g., between INTEL's 80286 used by the IBM AT and the Motorola 68020 used by the Apple Macintosh). Hardware dependency of microcomputer software is particularly important with regard to graphic devices such as plotters. The absence of microcomputer standards and the omnipresence of IBM PC and AT ground-water modeling software makes compatibility with IBM PC and AT virtually the only criterion a user can apply in choosing hardware components.

For mainframe and minicomputers, software compatibility problems sometimes occur because the source code needs to be recompiled each time it is implemented on a different computer. Compiling-related problems occur especially when computer codes include non-ANSI, machine-dependent language extensions. Software dependency in the microcomputer environment, insofar as it is related to ground-water modeling, occurs primarly in graphic post-processing and interactive screen-editing. This is due to the specific graphics environment of microcomputers. The latest versions of the major microcomputer FORTRAN compilers are full implementations of the ANSI FORTRAN 77 standard, as is the case with most mainframe compilers. FORTRAN software which does not require graphics can therefore be compiled in both the micro-computer and mainframe computer environments without changes in the programs.

Examples of highly portable models are the MODFLOW and SUTRA codes of the U.S. Geological Survey (see Appendix B, no. 47, 53). An example of a hardware-dependent program is THWELLS (see Appendix B, no. 56) because of graphic requirements.

In this report a model's hardware dependency is indicated as present [Y] or not [N]. Additional information on required computer environment is presented in Appendix C.

4.2.5. Computer Use-related Efficiency

Traditionally, efficiency in computer-science referred to the amount of memory required to run a program. As the recent technological advances in both semiconductor and mass-storage memory have resulted in sharply dropping costs, the need for memory efficient programs has dwindled significantly. Another major element of computer use related efficiency is the time it cost to run a program, measured as the speed of a program (Houston 1984). This speed is determined by the specific hardware-software combination being used. The speed can be evaluated by benchmarking. The best benchmarking is aimed at measuring the time to run a program under real life conditions for a problem representing the intended dominant use of the program. Thus, benchmarking is a carefully designed experiment in which the specific applications of the program is simulated as close as possible. Thusfar, no such general benchmark problems have been developed for well-head area delineation purposes, nor for more general ground-water applications.

4.2.6. Reliability

A major issue in model use is credibility. A model's credibility is based on its proven reliability and the extent of its use. Model users and managers often have the greatest confidence in those models most frequently applied. As reliability of a program is related to the localized or terminal failures that can occur because of software errors (Yourdon and Constantine 1975), it is assumed that most such errors originally present in a widely used program have been detected and corrected. Yet no program is without programming errors, even after a long history of use and updating. Some errors will never be detected and do not or only slightly influence the program's utility. Other errors show up only under exeptional circumstances. Decisions based on the outcome of simulations will be viable only if the models have undergone adequate review and testing. However, too much reliance on field validation (if present) or frequency of model application may exclude certain well-designed and documented models, even those most efficient for solving the problem at hand.

Reliability can be assessed by a review of model principles, coding, and documentation, by testing the code in a verification and field validation mode, and by evaluating the extent and type of experience gained by independent users.

4.2.6.1. Review

A complete review procedure comprises examination of model concepts, governing equations, and algorithms chosen, as well as evaluation of documentation, general-ease-of-use, and examination of the computer coding. Many of the models available have not been subjective to an extensive review. In most cases review has been limited to peer review of theory and project reporting. Some agencies have procedures in place for review of models developed for or by the agency (e.g., U.S. Geological Survey, U.S. Nuclear Regulatory Commission, Battelle/Office of Nuclear Waste Isolation, U.S. Environmental Protection Agency).

This report identifies peer-review of theory and coding. For each category the rating is: peer-reviewed [Y], not peer-reviewed [N], and unknown [U]. A model is considered to be peer-reviewed if theory and code has been subject to a formal review process such as established by certian agencies (e.g., U.S. EPA, U.S. Geological Survey). In addition, a model's theory is considered to be peer-reviewed if it has been published in a peer-reviewed journal (e.g., ***Water Resources Research***).

4.2.6.2. Verification

The verification process carries two objectives (van der Heijde 1987): (1) to check the accuracy of the computational algorithms used to solve the governing equations, and (2) to assure that the code is fully operational. To check the code for correct coding of theoretical principles and for major programming errors, the code is run for problems for which exact or approximate solutions are available.

In this report a model's verification status is rated as extensive [Y], not verified [N], or unknown [U]. Models verified only with respect to segments of their coding or for only a part of the tasks for which they were designed are rated to have undergone partial or limited verification [L].

4.2.6.3. Field Validation

The objective of model validation or field validation is to determine how well the model's theoretical foundation, including geometry, hydrogeologic characteristics, natural and man-made stresses, and physical, chemical, and biological processes and boundary conditions, describes the actual behavior of the physical system for which the model has been designed. Model validation is performed by comparing the results of model simulation runs with numerical data independently derived from laboratory experiments or field observations, using performance or acceptance criteria (van der Heijde 1987). Acceptance criteria applied to a particular model often vary, depending on the intended use of the model in planning and decision making. Note that correct field validation does not allow for calibration of the model preceding the validation runs. Calibration uses field information and thus impairs independent comparison.

For many types of groundwater models, especially those which simulate contaminant transport and fate, no complete field data sets are available to execute an extensive field validation. This is due in part to difficulties in finding field systems with a simplicity equal to that represented in existing models. Furthermore, the data needs for model validation often exceed existing technical and economic capabilities.

In this report, model field validation is rated as extensive [Y], partial or limited [L], not validated [N], or unknown [U].

4.2.6.4. Extent of Model Use

A model used by a large number of people demonstrates significant user confidence. Extensive use often reflects the model's applicability to different types of ground-water systems and in addressing various management questions. It might also imply that the model is relatively easy to use. Finally, if a model has a large user base, many opportunities exist to discuss particular applications with knowledgeable colleagues.

The extent of model use can be rated by the number of users (derived from vendor's software distribution data such as available from IGWMC) or by the number of applications published in the open literature. In both cases actual use can only be approximated, as none of the information sources are complete.

This report evaluates the extent of a model's use by a combination of both indicators. Distinction is made between four classes: many [M, >10], few [F, 1-10], none [N], and unknown [U].

SECTION 5

Information Sources

One of the objectives of the International Ground Water Modeling Center is to collect, interpret, and disseminate information on ground-water models. In 1979, the first version of the IGWMC model information database became operational. Since then the staff of IGWMC, supported by the U.S. EPA, has maintained and updated such databases.

The two model information databases currently in use at IGWMC—MARS and PLUTO—are designed to efficiently organize, update, and access information on ground-water models for mainframe and microcomputers. Each model is described in a uniform way by annotations describing its operational characteristics, capabilities, availability, and applicability. An extensive checklist of more than 200 descriptors, the model annotation form, is developed to describe each model as completely as possible. The checklist is set up to facilitate efficient entry and retrieval, using a binary data format. A complete model annotation includes remarks made by the model author or IGWMC staff regarding its development and use, names and addresses of users, and references which are part of the documentation or considered pertinent to the model. Because most of this additional information is in text form, it is stored in a separate database, MOON. This list is used by IGWMC staff to analyze model characteristics and to enter model information into one of the databases. The databases have been implemented on Butler University's DEC VAX 11/780, using the DEC Datatrieve database management system.

As of March 1, 1987, MARS contained 632 annotations, and PLUTO 104 annotations. The MOON database contained 2,325 literature and user references pertinent to the models listed in MARS and PLUTO.

Section 6

Selected Models

6.1. Model Screening

The first level of model screening for this project was performed by a computerized search *in the IGWMC databases MARS and PLUTO to identify the* models for which a source code and/or runtime version of the code is available and for which documentation in one or another form is present. This screening reduced the list of models under consideration to 361. By requiring that models simulate discharging or recharging wells, this number was further reduced to 233.

In the second level of model screening, these models have been evaluated in more detail by visual examination of the complete annotation of each model selected. Where additional information on models was needed, the IGWMC ground-water modeling research collection was consulted. A major characteristic emphasized during this screening stage is the maintenance and update history of the code and its documentation. Note that some ground-water models constructed primarily as research tools often need extensive modification before they are suitable for general use in ground-water management. The screening process ensures that such research models are not selected. In addition, some models have become obsolete through lack of maintenance, or are superseded by new codes. The models presented here reflect the latest code and documentation information available to IGWMC.

Finally, models were screened with respect to their applicability to the wellhead protection zone delineation problem as discussed in section 4.2. The final selection contains 64 models satisfying the following criteria (see Appendix A):

- availibility of source code and/or runtime version of the code

- presence of documention

- presence of adequate maintenance record

- relevance to wellhead protection analysis.

Of the 64 models, 27 are flow and 37 are solute transport models. Most of these transport models (29) consider both displacement and transformations of contaminants (nonconservative models). The other models (8) only simulate convective and dispersive displacements (conservative models). Most of the selected models are numerical (51); (13) are analytical and semi-analytical.

For fully three-dimensional simulation of mass transport, only a few models are available and in the public domain; most are either still under development or are proprietary. Of the models selected, 5 are designed for immiscible conservative transport; 8 treat miscible conservative transport; 24 handle miscible nonconservative transport for single constituents. Five of the listed models can also handle density-dependent flow.

6.2. Model Description

The table in Appendix A introduces and summarizes available models that can be used for WHPA delineation. Many of the models listed are in the public domain and available at nominal cost to the user. The columns of the table are explained below.

Column 1:	No.	— Serial number.
Column 2:	Author(s)	— List of authors at the time of model development.
Column 3:	Contact Address	— Address at which further information on the model is available. When no name appears, any one of the authors can be contacted.
Column 4:	Model Name	— Name with which the model is referred. Year of latest update of the model is given in parentheses.
Column 5:	Model Description	— Model type, aquifer conditions, flow conditions, system geometry, numerical method, etc.

Column 6: Model Output — Type of information available from the model output that could be required in WHPA delineation. The following abbreviations are used:

- ZOI Zone of Influence (the area surrounding a pumping or recharging well within which the potentiometric surface has been changed).
- C Concentration (concentration map of contaminant throughout the simulated domain).
- COD Cone of Depression (the shape of the area of influence, in cross-section).
- F Fluxes (internal and boundary discharge rates).
- P Pathways (path of a contaminant particle in the system).
- ZOC Zone of Contribution (the area of permeable layer through which precipitation and surface water may percolate to the aquifer and eventually reach the well).
- TOT Time of Travel (isochrones).
- V Velocities (ground-water velocities).

Column 7: IGWMC Key — The last four digits of a number, the IGWMC key, determine where the annotation of each model is stored and retrieved in the IGWMC model information database. The models are listed in increasing order of IGWMC key number.

Appendix B contains information on the usability and reliability of the models selected. This table is compiled using the criteria defined in section 4. Appendix C contains detailed information about each of the models selected. The description of each model starts with information on the model team and the current contact address. It includes the model name, its purpose, and a brief statement on its update history. Each model is further described by hydrologic characteristics, input requirements and output information, model geometry, and mathematical techniques used. Each model description includes information on the program code and the computers on which it has been implemented. A separate section contains the model evaluation as performed by the IGWMC, using the criteria discussed in section 4. Finally, for each model a list of references pertinent to the model's theory and operation is included.

Section 7

Recommendations and Research Needs

A major limitation of this study relates to the availability of data on model usability, reliability, and portability. The scope of this study did not include extensive analysis of each potentially useful model, but was restricted to collecting and interpreting existing model descriptions, mainly from the databases of the International Ground Water Modeling Center. Many models have not been subject to the extensive evaluation required to rate them according to the criteria presented in this report. In selecting the right model for a site-specific situation, all potentially useful modeling approaches should be represented in the set of models one can choose from. Therefore, additional activities should be initiated to fill in the information gaps present in this report.

Although adequate models are available for analysis of most flow-related problems, this is not the case for modeling contaminant transport. Computer codes are available for situations which do not require analysis of complex transport mechanisms or chemistry. Some of these codes are extensively documented and frequently applied. These programs are generally restricted to conceptual analysis of pollution problems, to feasibility studies in design, or to remedial action strategies and data acquisition guidance. Most of these problems are too complex to utilize models in a predictive or parameter-identification mode.

Accurate modeling of ground-water pollution is limited by some fundamental problems. In the first place, not all processes involved are adequately described mathematically. For the most complex mechanisms, available numerical techniques are not always adequate. Finally, in most cases, lack of quantity or quality of data restricts model utility.

Because the movement of pollutants in the unsaturated zone is quite complex, adequate modeling of the processes involved is lacking and models are available only for simulating simplified problems. Development in the simulation of flow and solute transport in fractured or dual porosity media has recently spawned some new models (e.g., Huyakorn 1986). Further developments in this area are necessary, especially with respect to the role of the porous rock matrix in dual porosity systems.

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APPENDIX A

Description of Model Characteristics

No.	Author(s)	Contact Address	Model Name (last update)	Model Description	Model Output	IGWMC Key
1.	S.P. Neuman P.A. Wither-spoon	Dept. of Hydrology and Water Resources University of Arizona Tucson, AZ 85721	FREESURF I (1979)	A finite element model for simulation of two-dimensional vertical or axisymmetric, steady-state flow in an anisotropic, heterogeneous, confined or water-table aquifer.	ZOI,COD,ZOC,F	0020
2.	S.P. Neuman	Dept. of Hydrology and Water Resources University of Arizona Tucson, AZ 85721	UNSAT2 (1979)	A two-dimensional finite element model for horizontal, vertical or axisymmetric simulation of transient flow in a variably saturated, nonuniform, anisotropic porous medium.	ZOI,COD,ZOC,F	0021
3.	T.N. Narasimhan	Battelle Pacific NW Lab Water and Land Resources Division P.O. Box 999 Richland, WA 99352	TRUST (1981)	To compute steady and nonsteady pressure head distributions in multidimensional, heterogeneous, variably saturated, deformable porous media with complex geometry using the integral finite difference method.	ZOI,COD,ZOC,F	0120
4.	T.A. Prickett C.G. Lonnquist	T.A. Prickett and Assoc. Consulting Water Resources Engineers 6 G.H. Baker Drive Urbana, IL 61801	PLASM (1986)	A finite difference model for simulating two-dimensional or quasi-three-dimensional, transient, saturated flow model for single layer or multi-layered confined, leaky confined, or water-table aquifer systems with optional evapotranspiration and recharge from streams.	ZOI,COD,ZOC,F	0322
5.	G.F. Pinder E.O. Frind	Dept. of Civil Engineering Princeton University Princeton, NJ 08540	ISOQUAD (1982)	A finite element model to simulate transient three-dimensional groundwater flow in confined and unconfined aquifers.	ZOI,COD,ZOC,F	0510
6.	G.F. Pinder C.I. Voss	U.S. Geological Survey Water Resources Division National Center,M.S.431 Reston, VA 22092	AQUIFEM (1979)	A finite element model to simulate transient, areal ground water flow in an isotropic, heterogeneous, confined, leaky-confined or water table aquifer.	ZOI,COD,ZOC,F	0514
7.	P.S. Huyakorn	Geotrans, Inc. 250 Exchange Place #A Herndon, VA 22070	GREASE 2 (1982)	A finite element model to study transient, multidimensional, saturated groundwater flow, solute and/or energy transport in fractured and unfractured, anisotropic, heterogeneous, multilayered porous media.	ZOI,COD,ZOC,F,C,V	0582

No.	Author(s)	Contact Address	Model Name (last update)	Model Description	Model Output	IGWMC Key
8.	P.S. Huyakorn	Geotrans, Inc. 250 Exchange Place, #A Herndon, VA 22070	SATURN 2 (1982)	A finite element model to study transient, two-dimensional variable saturated flow and solute transport in anisotropic, heterogeneous porous media.	ZOI,COD,ZOC, F,C,V	0583
9.	P. Huyakorn	Geotrans, Inc. 250 Exchange Place, #A Herndon, VA 22070	SEFTRAN (1986)	A finite element model to provide simple and cost-effective analyses of two-dimensional fluid flow and contaminant or heat transport problems in areal, cross-sectional or axisymmetric configuration of saturated, heterogeneous aquifers.	ZOI,COD,ZOC, F,C,V,P	0588
10.	P. Huyakorn	IGWMC Holcomb Research Institute Butler University 4600 Sunset Avenue Indianapolis, IN 46208	TRAFRAP (1987)	A finite element model to study transient, two dimensional, saturated ground water flow and chemical or radionuclide transport in fractured and unfractured, anisotropic, heterogeneous, porous media.	ZOI,COD,ZOC, F,C,V,P	0589
11.	J.E. Reed M.S. Bedinger J.E. Terry	U.S. Geological Survey Room 2301 Federal Building 700 W. Capitol Ave. Little Rock, AR 72201	SUPERMOCK (1975)	A finite difference model to simulate transient stress and response in a saturated-unsaturated ground water flow system including a water-table aquifer overlying a confined aquifer.	ZOI,COD,ZOC	0611
12.	T.R. Knowles	Texas Water Development Board P.O. Box 13231 Austin, TX 78711	GWSIM-II (1981)	A transient, two-dimensional, horizontal finite difference model for prediction of water levels and water quality in an anisotropic heterogeneous confined and unconfined aquifer.	ZOI,COD,F,C, ZOC	0680
13.	INTERA Environmental Consultants, Inc., INTERCOMP Resource Development & Eng., Inc., K. Kipp	U.S. Geological Survey Box 25046 Mail Stop 411 Denver Federal Center Lakewood, CO 80225	SWIP/ SWIPR/ HST3D (1987)	A finite difference model to simulate coupled unsteady, three-dimensional groundwater flow, heat and contaminant transport in an anisotropic, heterogeneous aquifer.	ZOI,COD,ZOC, F,C,V	0692
14.	C.R. Faust T. Chan B.S. Ramada B.M. Thompson	Performance Assessment Dept. Office of Nuclear Waste Isolation Battelle Project Mngmt. Div. 505 King Avenue Columbus, OH 43201	STFLO (1982)	A linear finite element code for simulation of steady-state, two-dimensional (areal or vertical) plane or axisymmetric ground-water flow in anisotropic, heterogeneous, confined, leaky or water-table aquifers.	ZOI,COD,ZOC,F	0694

No.	Author(s)	Contact Address	Model Name (last update)	Model Description	Model Output	IGWMC Key
15.	L.F. Konikow J.D. Bredehoeft	U.S. Geological Survey 431 National Center Reston, VA 22092	MOC (1987)	A two-dimensional model to simulate transient, horizontal or cross-sectional groundwater flow (finite difference) and solute transport (method of characteristics) in confined, semiconfined or water table aquifers.	Z01,COD,ZOC, F,C,V	0740
16.	S.P. Garabedian L.F. Konikow	U.S. Geological Survey 431 National Center Reston, VA 22092	FRONTRACK (1983)	A finite difference model for simulation of convective transport of a conservative tracer dissolved in groundwater under steady or transient flow conditions. The model calculates heads, velocities and tracer particle positions.	Z01,COD,ZOC, F,C,V,PTOT	0741
17.	W.E. Sanford L.F. Konikow	U.S. Geological Survey 431 National Center Reston, VA 22092	MOCDENSE (1986)	A model to simulate transport and dispersion of either one or two constituents in groundwater where there is two-dimensional, density dependent flow. It uses finite-difference and method of characteristics to solve the flow and transport equations.	Z01,COD,ZOC, F,C,V	0742
18.	P.C. Trescott S.P. Larson	U.S. Geological Survey Branch of Groundwater M.S. 411 National Center Reston, VA 22092	USGS-3D-FLOW (1982)	A finite difference model to simulate transient, three-dimensional and quasi three-dimensional, saturated flow in anisotropic, heterogeneous ground water systems.	Z01,COD,ZOC,F	0770
19.	P.C. Trescott G.F. Pinder S.P. Larson	U.S. Geological Survey Branch of Ground Water M.S. 411 National Center Reston, VA 22092	USGS-2D-FLOW (1976)	A finite difference model to simulate transient, two-dimensional horizontal or vertical flow in an anisotropic and hetrogeneous, confined, leaky-confined or water-table aquifer.	Z01,COD,ZOC,F	0771
20.	Miller, I. J. Marlon-Lambert	Golder Associates 2950 Northup Way Bellevue, WA 98004	GGWP (1983)	A finite element model for steady-state or transient simulation of two-dimensional, vertical or axisymmetric and quasi-three dimensional flow and transport of reactive solutes in anisotropic, heterogeneous, multi-layered aquifer systems.	Z01,COD,ZOC, F,C,V,PTOT	1010

No.	Author(s)	Contact Address	Model Name (last update)	Model Description	Model Output	IGWMC Key
21.	G. Segol E.O. Frind	Dept. of Earth Sciences University of Waterloo Waterloo, Ontario Canada N2L 3G1	3-D SATURATED-UNSATURATED TRANSPORT MODEL (1976)	A finite element model for the determination of concentration of a conservative or nonconservative solute in transient, three-dimensional saturated-unsaturated flow systems.	Z01,COD,F,C	1070
22.	K.R. Rushton L.M. Tomlinson	Dept. of Civil Engineering Univ. of Birmingham P.O. Box 363 Birmingham, B15 2TT United Kingdom	AQU-1 (1979)	A basic finite difference transient model for transient single layered two-dimensional horizontal ground water flow.	Z01,COD,F	1230
23.	O.D.L. Strack H.M. Haitjema	Dept. of Civil Engineering Univ. of Minnesota 122 CME Building Minneapolis, MN 55455	SLAEM (1986)	A flexible analytic elements model for simulating steady-state groundwater flow in regional double aquifer systems with local interconnections.	Z01,COD,ZOC,F	1791
24.	C. Van den Akker	National Institute for Water Supply P.O. Box 150 2260 AD Leidschendam The Netherlands	FLOP FLOP-2 FRONT (1981)	Analytic models to generate pathlines for steady-state or transient flow in a confined or semi-confined, isotropic, homogeneous aquifer and to calculate residence times for a number of water particles.	C,V,P,TOT	1821 1822 1823
25.	P. Van der Veer	Rijkswaterstaat Data Processing Division P.O. Box 5809 2280 HV Rijswijk (Z.H.) The Netherlands	MOTGRO (1981)	A boundary element model for prediction of groundwater head and stream function for two-dimensional, vertical, steady and unsteady, single or multiple fluid flow in inhomogeneous, anisotropic, confined or unconfined aquifers of arbitrary shapes.	Z01,COD,F,V,P,TOT	1830
26.	S.K. Gupta C.T. Kincaid P.R. Meyer C.A. Newbill C.R. Cole	Battelle Pacific NW Labs Water and Land Resources Division P.O. Box 999 Richland, WA 99352	CFEST (1986)	A three-dimensional finite element model to simulate coupled transient flow, solute- and heat-transport in saturated porous media.	Z01,COD,F,ZOC,C,V	2070
27.	S.K. Gupta C.R. Cole F.W. Bond	Battelle Pacific NW Labs Water and Land Resources Division P.O. Box 999 Richland, WA 99352	FE3DGW (1985)	A finite element model for transient or steady state, three-dimensional simulation of flow in a large multi-layered groundwater basin.	Z01,COD,ZOC,F,V	2072
28.	A.E. Reisenauer C.R. Cole	Water and Land Resources Division Battelle Pacific NW Labs P.O. Box 999 Richland, WA 99352	VTT (1979)	A transient finite difference model to calculate hydraulic head in confined-unconfined multi-layered aquifer systems, and to generate streamlines and traveltimes.	Z01,COD,V,P,TOT	2092

No.	Author(s)	Contact Address	Model Name (last update)	Model Description	Model Output	IGWMC Key
29.	R.W. Nelson	Battelle Pacific NW Labs Sigma 5 Bldg. P.O. Box 999 Richland, WA 99352	PATHS (1983)	An analytic flow and transport model to evaluate particle transport in transient, two-dimensional, horizontal, groundwater flow systems using an analytical solution for the flow equation and a numerical solution for the pathline equations.	F,V,C,P,TOT	2120
30.	R.D. Schmidt	U.S. Dept. of the Interior Bureau of Mines P.O. Box 1660 Twin Cities, MN 55111	ISL-50 (1979)	A three-dimensional analytic model to describe transient flow behaviour of leachants and groundwater in an anisotropic, homogeneous aquifer involving an arbitrary pattern of injection and recovery wells.	V,P,TOT	2560
31.	L.R. Townley J.L. Wilson A.S. Costa	Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics Room 48-211 Massachusetts Inst. of Technology Cambridge, MA 02139	AQUIFEM-1 (1979)	A two-dimensional, finite element model for transient, horizontal groundwater flow.	ZOI,COD,ZOC,F	2630
32.	T.A. Prickett T.G. Naymik C.G. Lonnquist	Consulting Water Resources Engineers 6 G.H. Baker Drive Urbana, IL 61801	RANDOM WALK (1981)	A finite difference model to simulate one- or two-dimensional steady or unsteady flow and transport problems in heterogeneous aquifers under water table and/or artesian or leaky artesian condition. A random walk approach is used to simulate dispersion.	ZOI,COD,ZOC, F,C,V	2690
33.	D.R. Posson G.A. Hearne J.V. Tracy P.F. Frenzel	U.S. Geological Survey P.O. Box 26659 Albuquerque, NM 87125	NMFD3D (1980)	A finite difference model for simulation of unsteady two-dimensional horizontal or three-dimensional saturated ground water flow in multi-layered heterogeneous anisotropic aquifer systems.	ZOI,COD,ZOC,F	2740
34.	J. Boonstra	I.L.R.I P.O. Box 45 Wageningen The Netherlands	SGMP (1981)	An integral finite-difference model to simulate steady-state or transient, two-dimensional, horizontal flow in a saturated, anisotropic and heterogeneous, confined/semi-confined/phreatic aquifer system.	ZOI,COD,ZOC,F	2800

No.	Author(s)	Contact Address	Model Name (last update)	Model Description	Model Output	IGWMC Key
35.	O. Berney	Land and Water Development Division Food and Agriculture Organization Un Via Delle Terme Di Caracalla 00100-Rome, Italy	DISIFLAQ (1980)	A finite difference model for steady-state or transient simulation of two-dimensional, horizontal groundwater flow in a two-layered, isotropic, heterogeneous aquifer system.	Z01,COD,ZOC,F	2870
36.	J.W. Wesseling	Delft Hydraulics Laboratory P.O. Box 152 8300 Ad Emmeloord The Netherlands	GROWKWA (1982)	A finite difference/finite element model to simulate of two-dimensional horizontal groundwater movement and non-conservative solute transport in a multi-layered, anisotropic, heterogeneous aquifer system.	Z01,COD,ZOC, F,C,V	2982
37.	S. Haji-Djafari T.C. Wells	D'Appolonia Waste Mgmnt. Services, Inc. 10 Duff Road Pittsburgh, PA 15235	GEOFLOW (1982)	A finite element model to simulate steady or nonsteady, two-dimensional areal flow and mass transport in anisotropic and heterogeneous aquifers under confined, leaky confined, or water table conditions.	Z01,COD,ZOC, F,C,V	3220
38.	B.Sagar	Rockwell International P.O. Box 800 Richland, WA 99352	AQUIFER (1982)	A finite difference model for analysis of steady and non-steady state, two-dimensional real or cross-sectional, radial flow in heterogeneous, anisotropic multiaquifer systems.	Z01,COD,ZOC, F,V,P	3230
39.	B. Sagar	Rockwell International P.O. Box 800 Richland, WA 99352	FRACFLOW (1981)	An integrated finite difference model to simulate steady and unsteady state analysis of density-dependent flow, heat and mass transport in fractured confined aquifers, two-dimensionally the processes in the porous medium and one-dimensionally in the fractures, including time-dependency of properties.	Z01,COD,ZOC, F,C,V,P	3232
40.	A.K. Runchal	Analytic & Computational Research, Inc. 3106 Inglewood Blvd. Los Angeles, CA 9006	PORFLOW-II and III (1987)	An integrated finite difference model to simulate steady or transient, 2-D horizontal, vertical or radial and 3-D simulation of density dependent flow heat and mass transport in anisotropic, heterogeneous, non-deformable saturated porous media with time dependent aquifer and fluid properties.	Z01,COD,ZOC, F,C,V	3233

No.	Author(s)	Contact Address	Model Name (last update)	Model Description	Model Output	IGWMC Key
41.	B. Sagar	Rockwell International P.O. Box 800 Richland, WA 99352	FLOTRA (1982)	An integrated finite difference model to simulate steady or transient, two-dimensional, areal, cross-sectional or radial simulation of density-dependent flow, heat and mass transport in variable saturated, anisotropic, heterogeneous deformable porous media.	ZOI,COD,ZOC, F,C,V,P	3235
42.	J.A. Liggett	School of Civil and Environmental Eng. Hollister Hall Cornell University Ithaca, NY 14853	GM5 (1982)	A boundary integral equation model to simulate steady state three dimensional saturated groundwater flow in an anisotropic, heterogeneous multi-aquifer system.	ZOI,COD,ZOC, F,V	3240
43.	G.T. Yeh D.S. Ward	Environmental Sciences Division Oak Ridge National Lab. Oak Ridge, TN 37830	FEMWATER/ FECWATER (1981)	A two-dimensional finite element model to simulate transient, cross-sectional flow in saturated-unsaturated anisotropic, heterogeneous porous media.	ZOI,COD,ZOC, F,V	3370
44.	G.T. Yeh C.W. Francis	Environmental Sciences Division Oak Ridge National Lab. Oak Ridge, TN 37830	AQUIFLOW (1984)	A two-dimensional finite element model to simulate transient flow in horizontal, anisotropic, heterogeneous aquifers under confined, leaky or unconfined conditions.	ZOI,COD,ZOC,F	3372
45.	G.T. Yeh D.D. Huff	Environmental Sciences Division Oak Ridge National Lab. Oak Ridge, TN 37830	FEWA (1983)	A two-dimensional finite element model to simulate transient vertically averaged flow in confined, leaky confined, or water table aquifers.	ZOI,COD,ZOC, F,V	3373
46.	G.T. Yeh D.D. Huff	Environmental Sciences Division Oak Ridge National Lab. Oak Ridge, TN 37830	FEMA (1984)	A two-dimensional, finite element model to simulate solute transport including radioactive decay, sorption, and biological and chemical degradation. This model solves only solute transport equation and velocity field has to be generated by a flow model.	F,C	3376
47.	C.I. Voss	U.S. Geological Survey 431 National Center Reston, VA 22092	SUTRA (1984)	A finite element simulation model for two-dimensional, transient or unsteady-state, saturated-unsaturated, fluid density dependent ground water flow with transport of energy or transport of a chemically reactive solute.	ZOI,COD,ZOC, F,C,V	3830

No.	Author(s)	Contact Address	Model Name (last update)	Model Description	Model Output	IGWMC Key
48.	R.T. Dillon R.M. Cranwell R.B. Lantz S.B. Pahwa M. Reeves	Sandia National Labs Albequerque, NM 87185 GeoTrans, Inc. 250 Exchange Place #A Herndon, VA 22070	SWIFT/ SWIFT-II (1986)	A three-dimensional finite difference model for simulation of coupled, transient, density dependent flow and transport of heat, brine, tracers or radionuclides in anisotropic, heterogeneous confined aquifers.	ZOI,COD,ZOC, F,C,V,P,TOT	3840
49.	C.S. Desai	Dept. of Civil Eng. and Eng. Mech. University of Arizona Tuscon, AZ 85721	MAST-2D	A finite element model to simulate coupled transient seepage and mass transport in saturated porous media.	ZOI,COD,F,C,V	3868
50.	D.G. Jorgensen H. Grubb C.H. Baker, Jr. G.E. Hilmes E.D. Jenkins	U.S. Geological Survey Water Research Dept. 1950 Avenue A-Campus West University of Kansas Lawrence, KS 66044-3897	GWMD3 (1982)	An axisymmetric finite difference model to calculate drawdown due to a proposed well, at all existing wells in the section of the proposed well and in the adjacent 8 sections and to compare drawdowns with allowable limits; includes an optional program to evaluate allowable depletion.	ZOI,COD,ZOC,F	3870
51.	J.V. Tracy	U.S. Geological Survey Water Resource Dept. National Center Reston, VA 22092	GALERKIN FINITE ELEMENT FLOW MODEL (1979)	A finite element model for simulation of two-dimensional, transient flow in a isotropic, heterogeneous, confined or watertable aquifer in contact with a stream. The model includes the calculation of the surface water balance.	ZOI,COD,ZOC,F	3881
52.	I. Javandel C. Doughty C.F. Tsang	Lawrence Berkeley Lab Earth Sciences Division University of California Berkeley, CA 94720	RESSQ (1983)	A semi-analytical model to calculate two-dimensional contaminant transport by advection and adsorption in a homogeneous, isotropic confined aquifer of uniform thickness when regional flow, sources and sinks create a steady state flow field.	C,V,P,TOT	3940
53.	M.G. McDonald A.W. Harbaugh	Ground Water Branch, WRD U.S. Geological Survey WGS - Mail Stop 433 Reston, VA 22092	MODFLOW (1983)	A modular three-dimensional finite difference ground-water model to simulate transient flow in anisotropic, heterogeneous, layered aquifer systems.	ZOI,COD,ZOC,F	3980

No.	Author(s)	Contact Address	Model Name (last update)	Model Description	Model Output	IGWMC Key
54.	C.R. Kolterman	Water Resources Center Desert Research Institute University of Nevada System Reno, NV	GWUSER/ CONJUN (1983)	A combined simulation-optimization model to determine optimal pumping locations and rates for confined aquifer with or without artificial recharge or for conjunctive use of aquifer-stream system. The model uses a finite difference simulator.	ZOI,COD,F	4070
55.	B.J. Travis	Los Alamos National Lab. Earth and Space Sciences Division Los Alamos, NM 87545	TRACR3D (1984)	A three-dimensional finite difference model of transient two-phase flow and multicomponent transport in deformable, heterogeneous, reactive porous/fractured media.	ZOI,COD,ZOC, F,C,V	4270
56.	P.K.M. van der Heijde	IGWMC Holcomb Research Institute Butler University 4600 Sunset Avenue Indianapolis, IN 46208	THWELLS (1987)	An analytical model to calculate head drawdown or buildup caused by multiple wells in an isotropic, homogeneous, nonleaky, confined aquifer.	ZOI,COD	6022
57.	K.R. Rushton	Dept. of Civil Engineering Univ. Of Birmingham P.O. Box 363 Birmingham, B15 2TT United Kingdom	RADIAL (1979)	A finite-difference model for the determination of heads due to radial flow towards a well and simulation of flow in vicinity of the well.	ZOI,COD,F	6062
58.	G.T. Yeh	Environmental Sciences Division Oak Ridge National Lab Oak Ridge, TN 37830	AT123D (1981)	An analytical 1, 2, or 3-D simulation of solute transport in a homogeneous, anisotropic aquifer, with decay and retardation from a variety of sources.	C,TOT	6120
59.	M.Th. van Genuchten W.J. Alves	U.S. Salinity Lab 4500 Glenwood Drive Riverside, CA 92501	ONE-D (1982)	Analytical solutions for one-dimensional convective-dispersive transport of a solute with linear adsorption in a steady-state flow field in a semi-infinite isotropic, homogeneous aquifer.	C,TOT	6220
60.	D. Koch	Koch & Associates 2921 Greenway Dr. Ellicott City, MD 21043	AQUIFER4 (1984)	A radial finite difference model to simulate transient three-dimensional groundwater flow in a leaky-confined aquifer.	ZOI,COD,F	6305
61.	INTERA Environmental Consultants	Battelle Project Management Division Performance Assessment Dept. Office of Nuclear Waste Isolation 505 King Avenue Columbus, OH 43201	VERTPAK-1 (1982)	A package of analytical solutions assembled to assist in verification of numerical codes used to simulate fluid flow, rock deformation, and solute transport in fractured and unfractured porous media.	C,V,TOT	6340

No.	Author(s)	Contact Address	Model Name (last update)	Model Description	Model Output	IGWMC Key
62.	W.C. Walton	IGWMC Holcomb Research Institute Butler University 4600 Sunset Avenue Indianapolis, IN 46208	35 MICRO-COMPUTER PROGRAMS (1984)	A series of analytical and simple numerical programs to analyze flow and transport of solutes and heat in confined, leaky or water table aquifers with simple geometry.	ZOI,COD,C,V, TOT	6350
63.	M.S. Beljin	IGWMC Holcomb Research Institute Butler University 4600 Sunset Avenue Indianapolis, IN 46208	SOLUTE (1985)	A package of 8 analytical models for solute transport simulation in groundwater. The package also includes programs for unit conversion and error function calculation.	C,TOT	6380
64.	T. Steenhuis S. Pacenka	Northeast Regional Agricultural Engineering Service Riley-Robb Hall Cornell University Ithaca, NY 14853	MOUSE (1987)	A set of four linked analytical models for tracking the movement and fate of a soluble chemical in saturated and unsaturated zones.	C,TOT	6390

APPENDIX B

Evaluation of Usability and Reliability

No.	Author(s)	Model Name	USABILITY: Preprocessor	Postprocessor	User's Instructions	Sample problems	Hardware dependency	Support	RELIABILITY: Peer Reviewed: theory	Peer Reviewed: coding	Verified	Field validation	Model users	IGWMC Key
1	S.P. Neuman P.A. Witherspoon	FREESURF 1	U	G	Y	Y	N	Y	Y	U	Y	L	F	0020
2	S.P. Neuman	UNSAT2	Y	G	Y	Y	N	Y	Y	Y	Y	L	M	0021
3	T.N. Narasimhan	TRUST	U	D	Y	Y	N	Y	Y	U	Y	U	F	0120
4	T.A. Prickett C.G. Lonnquist	PLASM	D	G	Y	Y	N	Y	Y	Y	Y	L	M	0322
5	G.F. Pinder E.O. Frind	ISOQUAD	U	G	Y	Y	N	Y	Y	U	Y	L	U	0510
6	G.F. Pinder C.I. Voss	AQUIFEM	N	G	Y	Y	N	Y	Y	U	Y	L	F	0514
7	P.S. Huyakorn	GREASE2	N	N	Y	Y	N	Y	U	U	Y	U	F	0582
8	P.S. Huyakorn	SATURN 2	N	N	Y	Y	N	Y	Y	U	Y	L	F	0583
9	P.S. Huyakorn	SEFTRAN	D	G	Y	Y	N	Y	Y	Y	Y	Y	M	0588
10	P.S. Huyakorn H.O. White, Jr., et al.	TRAFRAP	N	N	Y	Y	N	Y	Y	Y	Y	L	M	0589
11	J.E. Reed M.S. Bedinger, et al.	SUPERMOCK	U	U	Y	Y	N	U	Y	U	Y	U	F	0611
12	T.R. Knowles	GWSIM-II	U	G	Y	Y	Y	N	U	U	Y	U	F	0680
13	K. Kipp	SWIP/SWIPR HST3D	N	G	Y	Y	N	Y	Y	Y	Y	L	M	0692
14	C.R. Faust T. Chan, et al.	STFLO	U	U	Y	Y	N	U	U	U	Y	U	U	0694
15	L.F. Konikow J.D. Bredehoeft	MOC	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	M	0740
16	S.P. Garabedian L.F. Konikow	FRONTRACK	N	G	Y	Y	N	Y	Y	U	Y	U	F	0741

KEY: Y = YES N = NO U = UNKNOWN G = GENERIC D = DEDICATED L = LIMITED M = MANY F = FEW

No.	Author(s)	Model Name	USABILITY Preprocessor	Postprocessor	User's instructions	Sample problems	Hardware dependency	Support	RELIABILITY Peer Reviewed theory	coding	Verified	Field validation	Model users	IGWMC Key
17	W.E. Sanford L.F. Konikow	MOCDENSE	N	G	Y	Y	N	Y	Y	U	Y	Y	F	0742
18	P.C. Trescott S.P. Larson	USGS-3D-FLOW	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	M	0770
19	P.C. Trescott, et al.	USGS-2D-FLOW	U	Y	Y	Y	N	Y	Y	Y	Y	Y	M	0771
20	I. Miller J. Marlon-Lambert	GGWP	D	D	Y	Y	N	Y	U	U	Y	U	U	1010
21	G. Segol E.O. Frind	3-D SATURATED-UNSATURATED TRANSPORT MODEL	N	N	Y	Y	N	U	U	U	Y	U	U	1070
22	K.R. Rushton L.M. Tomlinson	AQU-1	U	U	Y	Y	N	Y	Y	Y	Y	Y	M	1230
23	O.D.L. Strack H.M. Haitjema	SLAEM	D	D	Y	Y	Y	Y	Y	U	Y	Y	F	1791
24	C. Van den Akker	FLOP/ FLOP-2/FRONT	U	U	Y	Y	Y	Y	Y	Y	Y	Y	M	1821
25	P. Van der Veer	MOTGRO	U	U	Y	Y	N	Y	Y	U	Y	L	F	1830
26	S.K. Gupta C.R. Cole	CFEST	D	D	Y	Y	Y	Y	Y	Y	Y	Y	M	2070
27	S.K. Gupta, et al.	FE3DGW	D	D	Y	Y	Y	Y	Y	Y	Y	Y	M	2072
28	A.E. Reisenauer	VTT	Y	Y	Y	Y	Y	Y	U	U	Y	L	U	2092
29	R.W. Nelson	PATHS	Y	Y	Y	Y	Y	Y	Y	Y	Y	L	M	2120
30	R.D. Schmidt	ISL-50	U	D	Y	Y	Y	Y	U	U	Y	U	U	2560
31	L.R. Townley, et al.	AQUIFEM-1	N	G	Y	Y	N	Y	Y	U	Y	L	M	2630
32	T.A. Prickett, et al.	RANDOM WALK	Y	G	Y	Y	N	L	Y	Y	Y	Y	M	2690

KEY: Y = YES N = NO U = UNKNOWN G = GENERIC D = DEDICATED L = LIMITED M = MANY F = FEW

No.	Author(s)	Model Name	USABILITY: Preprocessor	Postprocessor	User's Instructions	Sample problems	Hardware dependency	Support	RELIABILITY: Peer Reviewed: theory	Peer Reviewed: coding	Verified	Field validation	Model users	IGWMC Key
33	D.R. Posson, et al.	NMFD3D	U	U	Y	Y	Y	Y	Y	U	Y	U	U	2740
34	J. Boonstra	SGMP	N	U	Y	Y	N	Y	Y	U	Y	U	F	2800
35	O. Berney	DISIFLAQ	N	N	Y	Y	N	Y	U	U	Y	U	M	2870
36	J.W. Wesseling	GROWKWA	U	U	Y	Y	N	Y	U	U	Y	U	U	2982
37	S. Haji-Djafari T.C. Wells	GEOFLOW	U	U	Y	Y	N	Y	Y	U	Y	L	M	3220
38	B. Sagar	AQUIFER	U	U	Y	Y	N	U	U	U	Y	L	U	3230
39	B. Sagar	FRACFLOW	Y	Y	Y	Y	N	Y	U	U	Y	U	F	3232
40	A.K. Runchal	PORFLOW-II AND III	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	M	3233
41	B. Sagar	FLOTRA	U	U	Y	Y	N	Y	U	U	Y	L	U	3235
42	J.A. Liggett	GM5	N	N	Y	Y	N	N	Y	N	N	N	F	3240
43	G.T. Yeh D.S. Ward	FEMWATER/ FECWATER	N	G	Y	Y	N	Y	Y	Y	Y	Y	M	3370
44	G.T. Yeh C.W. Francis	AQUIFLOW	N	G	Y	Y	N	Y	U	U	Y	L	U	3372
45	G.T. Yeh D.D. Huff	FEWA	N	G	Y	Y	N	Y	U	U	Y	L	F	3373
46	G.T. Yeh D.D. Huff	FEMA	N	G	Y	Y	N	Y	Y	U	Y	L	F	3376
47	C.I. Voss	SUTRA	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	M	3830
48	R.T. Dillon, et al.	SWIFT/ SWIFT-II	N	G	Y	Y	N	Y	Y	Y	Y	Y	M	3840
49	C.S. Desai	MAST-2D	N	U	Y	Y	N	Y	U	U	Y	U	U	3868

KEY: Y = YES N = NO U = UNKNOWN G = GENERIC D = DEDICATED L = LIMITED M = MANY F = FEW

No.	Author(s)	Model Name	USABILITY						RELIABILITY					IGWMC Key
			Preprocessor	Postprocessor	User's Instructions	Sample problems	Hardware dependency	Support	Peer Reviewed: theory	Peer Reviewed: coding	Verified	Field validation	Model users	
50	D.G. Jorgensen, et al.	GWMD3	N	U	Y	Y	N	Y	Y	U	Y	L	U	3870
51	J.V. Tracy	GALERKIN FINITE ELEMENT FLOW MODEL	N	N	Y	Y	N	Y	Y	U	Y	U	F	3881
52	I. Javandel	RESSQ	N	Y	Y	Y	N	Y	Y	Y	Y	Y	M	3940
53	M.G. McDonald A.W. Harbaugh	MODFLOW	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	M	3980
54	C.R. Kolterman	GWUSER/ CONJUN	U	U	Y	Y	Y	Y	U	U	Y	U	U	4070
55	B.J. TRAVIS	TRACR3D	N	Y	Y	Y	Y	Y	U	U	Y	U	F	4270
56	P.K.M. Van Der Heijde	THWELLS	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	M	6022
57	K.R. Rushton	RADIAL	Y	N	Y	Y	N	Y	Y	Y	Y	Y	M	6062
58	G.T. Yeh	AT123D	D	G	Y	Y	N	Y	Y	Y	Y	L	M	6120
59	M.Th. Van Genuchten W.J. Alves	ONE-D	N	N	Y	Y	N	Y	Y	Y	Y	Y	M	6220
60	D. Koch	AQUIFER4	D	U	Y	Y	N	Y	U	U	Y	U	U	6305
61	INTERA Environ. Con.	VERTPAK-1	N	N	Y	Y	N	Y	Y	U	Y	Y	U	6340
62	W.C. Walton	35 MICRO-COMPUTER PROGRAMS	D	N	Y	Y	N	Y	Y	Y	Y	Y	M	6350
63	M.S. Beljin	SOLUTE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	M	6380
64	T. Steenhuis S. Pacenka	MOUSE	Y	Y	Y	Y	Y	Y	Y	Y	Y	L	Y	6390

KEY: Y = YES N = NO U = UNKNOWN G = GENERIC D = DEDICATED L = LIMITED M = MANY F = FEW

APPENDIX C

Detailed Annotation of Selected Models

IGWMC key= 0020

MODEL TEAM

author name(s): NEUMAN, S.P.(1) AND P.A. WITHERSPOON (2)

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UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721

phone: 602/626-4434

MODEL IDENTIFICATION

model name: FREESURF I

model purpose: A FINITE ELEMENT MODEL FOR SIMULATION OF TWO-DIMENSIONAL VERTICAL OR AXISYMMETRIC, STEADY-STATE FLOW IN AN ANISOTROPIC, HETEROGENEOUS, CONFINED OR WATER-TABLE AQUIFER

completion date: 1969
last update date: 1979

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -ANISOTROPIC -HETEROGENEOUS

flow conditions: -STEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -FREE SURFACE -SEEPAGE SURFACE -MOVABLE EXTERNAL BOUNDARY -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -DRAINAGE OR DEWATERING

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -POISSON'S EQUATION WITH OR WITHOUT FREE BOUNDARIES

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -ELEVATION OF SURFACE WATER BOTTOMS -PERMEABILITY

boundary values: -PRECIPITATION RATES

others: -GRID INTERVALS -NODE LOCATIONS OR COORDINATES -ERROR CRITERIA -SOURCE/SINK LOCATION -INITIAL LENGTH OF SEEPAGE FACE

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -PUMPAGE RATES -POSITION FREE SURFACE -LENGTH SEEPAGE FACE -BOUNDARY FLUXES

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR -TRIANGULAR -CYLINDRICAL -QUADRILATERAL

spatial characteristics:
< saturated zone > -2D HORIZONTAL -2D VERTICAL -CYLINDRICAL OR RADIAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY -VARIABLE SIZE GRID -MOVABLE GRID

number of nodes: -VARIABLE

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS ELIMINATION -IMPLICIT

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE

COMPUTERS USED---

make and model: CDC 6000, 7000

mass storage: DISKS OR TAPES

PROGRAM INFORMATION--

language: FORTRAN IV

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: $500 - 1000

MODEL EVALUATION--

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: FEW

REFERENCES--

01 NEUMAN, S.P. AND P.A. WITHERSPOON. 1970. FINITE ELEMENT METHOD OF ANALYZING STEADY SEEPAGE WITH A FREE SURFACE. WATER RESOURCES RESEARCH, VOL. 6(3), PP. 889-897.

IGWMC key= 0021

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MODEL IDENTIFICATION

model name: UNSAT2

model purpose: A TWO-DIMENSIONAL FINITE ELEMENT MODEL FOR HORIZONTAL, VERTICAL OR AXISYMMETRIC SIMULATION OF TRANSIENT FLOW IN A VARIABLY SATURATED, NONUNIFORM, ANISOTROPIC POROUS MEDIUM

completion date: 1974
last update date: 1979

MODEL CHARACTERISTICS

aquifer conditions: -WATER TABLE -ANISOTROPIC -HETEROGENEOUS

flow conditions: -UNSTEADY -SATURATED -UNSATURATED -LAMINAR

boundary conditions: -CHANGING HEADS OR PRESSURES -CHANGING FLUX -FREE SURFACE -SEEPAGE SURFACE -MOVABLE EXTERNAL BOUNDARY -INFILTRATION -GROUNDWATER RECHARGE -WELLS -WELL CHARACTERISTICS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

model processes: -CAPILLARY FORCES -EVAPOTRANSPIRATION -PLANT -UPTAKE

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -RICHARD'S EQUATION AND POISSON EQUATION.

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -POROSITY -STORAGE COEFFICIENT

boundary values: -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -GRID INTERVALS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -HEAD VS. PRESSURE -HYDRAULIC CONDUCTIVITY VS. PRESSURE -ROOT FUNCTIONS.

MODEL OUTPUT--

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -FLUXES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -GROUND WATER RECHARGE RATES -MOISTURE CONTENT

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR -LINEAR -TRIANGULAR -CYLINDRICAL -ISOPARAMETRIC QUADRILATERAL -QUADRILATERRAL

spatial characteristics: <unsaturated zone> -1D HORIZONTAL -1D VERTICAL -2D HORIZONTAL -2D VERTICAL -CYLINDRICAL OR RADIAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY -VARIABLE SIZE GRID

number of nodes: -VARIABLE

TECHNIQUES--

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS ELIMINATION -IMPLICIT

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE

COMPUTERS USED--

make and model: IBM, CDC 6000/7000, CDC CYBER 172

mass storage: DISKS OR TAPES

PROGRAM INFORMATION--

language: FORTRAN 77

terms of availability of code and user's manual: PUBLIC DOMAIN; CODE AND USER'S INSTRUCTIONS ARE PUBLISHED IN REFS. #3 AND #4. ORIGINAL VERSION AVAILABLE FROM AUTHOR

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: $600

MODEL EVALUATION---

USABILITY
- -preprocessor: YES
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: LIMITED
- -model users: MANY

REMARKS--

01 A PDP 11/23 AND HP 9845 VERSION WITH PROGRAMS FOR INTERACTIVE DATA ENTRY AND FILE EDITING IS AVAILABLE FROM: GEORGE L. BLOOMSBURG, 469 PARADISE DRIVE, MOSCOW, IDAHO 83843, PHONE: 208/885-7107.

02 AN UPDATED AND EXPANDED VERSION OF THE DOCUMENTATION IS IS PUBLISHED IN REFERENCE #4. THE COMPUTER CODE OF THIS VERSION IS AVAILABLE FROM:
DIVISION OF WASTE MANAGEMENT, OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS, U.S. NUCLEAR REGULATORY COMMISSION, 1717 H STREET, N.W., WASHINGTON, D.C. 20555.

03 AN EVALUATION OF THE MODEL IS GIVEN IN: THOMAS, S.D., B. ROSS, J.W. MERCER. 1982. A SUMMARY OF REPOSITORY SITING MODELS. NUREG/CR-2782, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

REFERENCES---

01 NEUMAN, S.P., R.A. FEDDES AND E. BRESLER. 1975. FINITE ELEMENT ANALYSIS OF TWO-DIMENSIONAL FLOW IN SOILS CONSIDERING WATER UPTAKE BY ROOTS; I. THEORY. SOIL SCI. SOC. AM. PROC., VOL. 39(2), PP. 224-230.

02 FEDDES, R.A., S.P. NEUMAN AND E. BRESLER. 1975. FINITE ELEMENT ANALYSIS OF TWO-DIMENSIONAL FLOW IN SOILS. II. FIELD APPLICATIONS. SOIL SCI. SOC. AM. PROC., VOL. 39(2), PP. 231-237.

03 NEUMAN, S.P., R.A. FEDDES AND E. BRESLER. 1974. FINITE ELEMENT SIMULATION OF FLOW IN SATURATED-UNSATURATED SOILS CONSIDERING WATER UPTAKE BY PLANTS. 3RD ANN. REPT. PROJECT A10-SWC-77, HYDRODYNAMICS AND HYDRAULIC ENGINEERING LAB., TECHNION, HAIFA, ISRAEL.

04 DAVIS, L.A. AND S.P. NEUMAN. 1983. DOCUMENTATION AND USER'S GUIDE UNSAT2 - VARIABLY SATURATED FLOW MODEL. NUREG/CR-3390, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

IGWMC key= 0120

MODEL TEAM

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MODEL IDENTIFICATION

model name: TRUST

model purpose: TO COMPUTE STEADY AND NONSTEADY PRESSURE HEAD DISTRIBUTIONS IN MULTIDIMENSIONAL, HETEROGENEOUS, VARIABLY SATURATED, DEFORMABLE POROUS MEDIA WITH COMPLEX GEOMETRY USING THE INTEGRAL FINITE DIFFERENCE METHOD.

completion date: FEB 1975
last update date: APR 1981

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -AQUITARD -LEAKY -STORAGE IN CONFINING LAYER -ANISOTROPIC -HETEROGENEOUS -DISCRETE FRACTURES -AQUIFER SYSTEM DEFORMATION -AQUIFER COMPACTION -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -UNSATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -FREE SURFACE -SEEPAGE SURFACE -TIDAL FLUCTUATIONS -INFILTRATION -GROUNDWATER RECHARGE -WELLS -WELL CHARACTERISTICS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -CAPILLARY FORCES -DRAINAGE OR DEWATERING

fluid conditions:	-HOMOGENEOUS -COMPRESSIBLE -VARIABLE DENSITY -DENSITY IS PRESSURE DEPENDENT
model processes:	-CAPILLARY FORCES -DIFFUSION -CONSOLIDATION -HYSTERESIS -EXPANSION
other model characteristics:	-ENGLISH UNITS -METRIC UNITS
equations solved:	-1-D DEFORMATION ACCORDING TO TERZAGHI AND THE GENERALIZED RICHARD'S EQUATION

MODEL INPUT---

areal values:	-ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -POROSITY -STORAGE COEFFICIENT -HYDRAULIC RESISTANCE IN RIVER BED AND LAKE BED -FLUID DENSITY -SPECIFIC WEIGHT
boundary values:	-HEADS OR PRESSURES -FLUXES -PUMPAGE RATES
others:	-GRID INTERVALS -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -INTRINSIC PERMEABILITY -VISCOSITY -FLUID COMPRESSIBILITY.

MODEL OUTPUT--

tables:	-AQUIFER GEOMETRY -HEADS OR PRESSURES -FLUXES -TOTAL SYSTEM FLUID MASS CAPACITY -MOISTURE CONTENT

GEOMETRY OF MODEL---

shape of cell:	-SQUARE -RECTANGULAR -LINEAR -TRIANGULAR -POLYGON -CYLINDRICAL -SPHERICAL -ISOPARAMETRIC QUADRILATERAL
spatial characteristics:	
< saturated zone >	-1D HORIZONTAL -1D VERTICAL -2D HORIZONTAL -2D VERTICAL -3D -CYLINDRICAL OR RADIAL
<unsaturated zone>	-1D HORIZONTAL -1D VERTICAL -2D HORIZONTAL -2D VERTICAL -3D -CYLINDRICAL OR RADIAL
grid orientation and sizing:	-PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY -VARIABLE SIZE GRID -MOVABLE GRID -SPHERICAL COORDINATES
number of nodes:	-VARIABLE

TECHNIQUES--

basic modeling technique: -INTEGRAL FINITE DIFFERENCE METHOD

equation solving technique: -GAUSS-SEIDEL OR POINT SUCCESSIVE OVER RELAXATION -POINT JACOBI -IMPLICIT -EXPLICIT -CRANK NICHOLSON

error criteria: -WATER BALANCE OVER MODEL -MAXIMUM HEAD CHANGE AT ANY ONE NODE -MASS BALANCE

COMPUTERS USED--

make and model: CDC 6400, 6600, 7600, UNIVAC, VAX 11

core storage: ABOUT 140K

PROGRAM INFORMATION---

no. of statements: 2500

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM CODE AND DOCUMENTATION PUBLISHED IN REFERENCE #8

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: DEDICATED
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: FEW

REMARKS---

01 THIS CODE CAN BE COUPLED WITH FLUX TO GENERATE VELOCITY FIELD AND MILTVL TO GENERATE PATHLINES AND TRAVELTIMES.

02 TRUST IS BASED ON THE TRUMP CODE ORIGINALLY DEVELOPED BY A.L. EDWARDS AT LAWRENCE LIVERMORE LABORATORY, LIVERMORE, CA.

03 THIS MODEL IS EVALUATED IN: THOMAS, S.D., B. ROSS, J.W. MERCER. JULY 1982. A SUMMARY OF REPOSITORY SITING MODELS. NUREG/CR-2782, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

04 MODIFICATIONS WERE MADE TO THE CODE TO SIMULATE FLOW IN FRACTURED UNSATURATED POROUS MEDIA AS DISCUSSED IN REF #9. THESE MODIFICATION INCLUDE ADDITIONAL CHARACTERISTIC CURVES AND RELATIVE PERMEABILITY CURVES, VAN GENUCHTEN FORMULAE FOR MATRIX BLOCKS, GAMMA DISTRIBUTION FORMULAE FOR DISCRETE FRACTURE GRID BLOCKS, HYPERBOLIC CHARACTERISTIC CURVES OF PICKENS, AND A NEW EFFECTIVE AREA FACTOR. THIS VERSION OF TRUST USES EITHER THE EXISTING EFFICIENT ITERATIVE SOLVER OR A NEW DIRECT SOLUTION.

05 DYNAMIX IS A CODE THAT COUPLES A VERSION OF PROGRAM TRUMP WITH THE GEOCHEMICAL CODE PHREEQE. (SEE REF. #11.)

06 THE TRUST-II UTILITY PACKAGE IS USED ON CONJUNCTION WITH THE TRUST-II MODEL. IT PROVIDES FOR GENERATION OF SOIL DATA, GRID GENERATION, AND ADVECTIVE CONTAMINANT TRANSPORT. THE PACKAGE IS DOCUMENTED IN REF. #12.

REFERENCES---

01 *NARASIMHAN, T.N. AND P.A. WITHERSPOON. 1976. AN INTEGRATED* FINITE DIFFERNCE METHOD FOR FLUID FLOW IN POROUS MEDIA. WATER RESOURCES RESEARCH, VOL. 12(1): PP. 57-64.

02 NARASIMHAN, T.N. 1975. A UNIFIED NUMERICAL MODEL FOR SATURATED-UNSATURATED GROUND-WATER FLOW. PH.D. DISSERTATION, UNIVERSITY OF CALIFORNIA, BERKELEY, CA.

03 NARASIMHAN, T.N. AND P.A. WITHERSPOON. 1977. NUMERICAL MODEL FOR SATURATED-UNSATURATED FLOW IN DEFORMABLE POROUS MEDIA; I. THEORY. WATER RESOURCES RESEARCH, VOL. 13(3), PP. 657-664.

04 NARASIMHAN, T.N., P.A. WITHERSPOON AND A.L. EDWARDS. 1978. NUMERICAL MODEL FOR SATURATED-UNSATURATED FLOW IN DEFORMABLE POROUS MEDIA; II. THE ALGORITHM. WATER RESOURCES RESARCH, VOL. 14(2): PP. 255-261.

05 NARASIMHAN, T.N. AND P.A. WITHERSPOON. 1978. NUMERICAL MODELFOR SATURATED-UNSATURATED FLOW IN DEFORMABLE POROUS MEDIA; III. APPICATIONS. WATER RESOURCES RESEARCH, VOL. 14(6), PP. 1017-1034.

06 *NARASIMHAN, T.N. AND W.A. PALEN. 1981. INTERPRETATION OF A* HYDRAULIC FEATURING EXPERIMENT, MONTICELLO, SOUTH CAROLINA. AGU GEOPHYSICAL RESEARCH LETTERS, VOL. 8(5), PP. 481-484.

07 NARASIMHAN, T.N. 1979. THE SIGNIFICANCE OF THE STORAGE PARAMETER IN SATURATED-UNSATURATED GROUNDWATER FLOW. WATER RESOURCES RESEARCH, VOL 15(3): PP. 569-576.

08 REISENAUER, A.E., K.T. KEY, T.N. NARASIMHAN AND R.W. NELSON 1982. TRUST: A COMPUTER PROGRAM FOR VARIABLY SATURATED FLOW IN MULTIDIMENSIONAL, DEFORMABLE MEDIA. NUREG/CR-2360, U.S. NUCLEAR REGULATORY COMM., WASHINGTON, D.C.

09 WANG, J.S.Y. AND T.N. NARASIMHAN. 1984. HYDROLOGIC MECHANISMS GOVERNING FLUID FLOW IN PARTIALLY SATURATED, FRACTURED, POROUS TUFF AT YUCCA MOUNTAIN. LAWRENCE BERKELEY LABORATORY, UNIVERSITY OF CALIFORNIA, BERKELEY, CA.

10 NARASIMHAN, T.N. AND S.J. DREISS. 1986. A NUMERICAL TECHNIQUE FOR MODELING TRANSIENT FLOW OF WATER TO A SOIL WATER SAMPLER. SOIL SCIENCE 14(3):230-236.

11 NARASIMHAN, T.N., A.F. WHITE, AND T. TOKUNAGA. 1985. HYDROLOGY AND GEOCHEMISTRY OF THE URANIUM MILL TAILINGS PILE AT RIVERTON, WYOMING. LAWRENCE BERKELEY LABORATORY, UNIVERSITY OF CALIFORNIA, BERKELEY, CA.

12 MCKEON, T.J., S.W. TYLER, D.W. MAYER, AND A.E. REISENAUER. 1983. TRUST-II UTILITY PACKAGE: PARTIALLY SATURATED SOIL CHARACTERIZATION, GRID GENERATION, AND ADVECTIVE TRANSPORT ANALYSIS. NUREG/CR-3443, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

IGWMC key= 0322

MODEL TEAM

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MODEL IDENTIFICATION

model name: **PLASM**

model purpose: A FINITE DIFFERENCE MODEL FOR SIMULATING TWO-DIMENSIONAL OR QUASI- THREE-DIMENSIONAL, TRANSIENT, SATURATED FLOW FOR SINGLE LAYER OR MULTI-LAYERED CONFINED, LEAKY CONFINED, OR WATER-TABLE AQUIFER SYSTEMS WITH OPTIONAL EVAPOTRANSPIRATION AND RECHARGE FROM STREAMS.

completion date: 1971
last update date: 1986

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -ANISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -WELL CHARACTERISTICS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

model processes: -EVAPOTRANSPIRATION

other model characteristics: -ENGLISH UNITS

equations solved: -DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN CONFINING LAYER -HYDRAULIC RESISTANCE IN RIVERBED

boundary values: -HEADS OR PRESSURES -FLUXES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -GRID INTERVALS -NODE LOCATIONS OR COORDINATES -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA

MODEL OUTPUT---

tables: -HEAD -FLUXES - WATER BALANCE

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -VARIABLE SIZE GRID

number of nodes: -RANGES FROM 100 TO 10,000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -GAUSS-SEIDEL OR POINT SUCCESSIVE OVER RELAXATION -LINE SUCCESSIVE OVER RELAXATION -ITERATIVE ALTERNATING DIRECTION -GAUSS ELIMINATION -IMPLICIT

error criteria: -SUM HEAD CHANGE OVER MODEL BETWEEN ITERATIONS

COMPUTERS USED---

make and model: IBM 360/75, VAX 11/780, IBM PC/XT/AT

core storage: 200K FOR 2500 NODES
(256K FOR IBM PC/XT/AT VERSION)

PROGRAM INFORMATION--

no. of statements: 2200

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM CODE LISTED IN REFERENCE #1.

available code form: -MAGNETIC TAPE -PRINTED LISTING -DISKETTES

cost: $95 from IGWMC

MODEL EVALUATION

USABILITY
- -preprocessor: DEDICATED
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: LIMITED
- -model users: MANY

REMARKS

01 A MODIFIED VERSION OF PLASM TO ANALYZE HYDROLOGIC IMPACTS OF MINING IS DOCUMENTED IN REF. #7. THESE MODIFIED PROGRAM CODES ARE AVAILABLE THROUGH BOEING COMPUTER NETWORK

02 VARIOUS SPECIAL MICROCOMPUTER VERSIONS ARE ALSO AVAILABLE. CONTACT IGWMC FOR MORE INFORMATION

REFERENCES

01 PRICKETT, T.A. AND C.G. LONNQUIST. 1971. SELECTED DIGITAL COMPUTER TECHNIQUES FOR GROUNDWATER RESOURCE EVALUATION. BULLETIN 55, ILLINOIS STATE WATER SURVEY, URBANA, IL.

02 PRICKETT, T.A. AND C.G. LONNQUIST. 1976. METHODS DE ORDENADOR PARA EVALUACION DE RECURSOS HIDRAULICOS SUBTERRANEOS. BOLETIN 41, MINISTERIO DE OBRAS PUBLICAS, DIRECCION GENERAL DE OBRAS HIDRAULICOS, MADRID, SPAIN. (SPANISH VERSION OF BULLETIN 55, ISWS).

03 INSTITUTO GEOLOGICO Y MINERO DE ESPANA. 1982. MODELOS MONOCAPA EN REGIMEN TRANSITORIO-- TOMO I: MANUALES DE UTILIZACION. DIRECCION DE AGUAS SUBTERRANEAS Y GEOTECNIA, *MINISTERIO DE INDUSTRIA Y ENERGIA, COMISARIA DE LA ENERGIA* Y RECURSOS MINERALES, RIOS ROSAS 23, MADRID-3, SPAIN.

04 INSTITUTO GEOLOGICO Y MINERO DE ESPANA. 1981. MODELOS MULTICAPA-- TOMO I: MANUALES DE UTILIZACION, MINISTERIO DE INDUSTRIA Y ENERGIA, COMISARIA DE LA ENERGIA Y RECURSOS MINERALES, RIOS ROSAS 23, MADRID-3, SPAIN.

05 INSTITUTO GEOLOGICO Y MINERO DE ESPANA. 1982. MODELOS MONOCAPA EN REGIMEN TRANSITORIO-- TOMO II: LISTADOS DE ORDENADOR. MINISTERIO DE INDUSTRIA Y ENERGIA, COMISARIA DE LA ENERGIA Y RECURSOS MINERALES, INSTITUTO GEOLOGICO Y MINERO DE ESPANA, RIOS ROSAS 23, MADRID-3, SPAIN.

06 INSTITUTO GEOLOGICO Y MINERO DE ESPANA. 1981. MODELOS MULTICAPA-- TOMO II: LISTADOS DE PROGRAMAS. MINISTERIO DE INDUSTRIA Y ENERGIA, COMISARIA DE LA ENERGIA Y RECURSOS MINERALES, INSTITUTO GEOLOGICO Y MINERO DE ESPANA, RIOS ROSAS 23, MADRID-3, SPAIN.

07 U.S. DEPARTMENT OF THE INTERIOR. 1981. GROUND WATER MODEL HANDBOOK. OFFICE OF SURFACE MINING, H-D3004-021-81-1062D, DENVER, COLORADO.

IGWMC key= 0510

MODEL TEAM

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MODEL IDENTIFICATION

model name: **ISOQUAD**

model purpose: FINITE ELEMENT MODEL TO SIMULATE TRANSIENT THREE-DIMENSIONAL GROUNDWATER FLOW IN CONFINED AND UNCONFINED AQUIFERS.

completion date: 1974
last update date: 1982

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -STORAGE IN CONFINING LAYER -ANISOTROPIC -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -HEADS- FLUXES- WELLS

surface flow characteristics: -RIVERS

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -DARCY'S LAW AND CONTINUITY.

MODEL INPUT---

areal values: -ELEVATION OF AQUIFER BOTTOMS
-PERMEABILITY -STORAGE COEFFICIENT -SPECIFIC YIELD
-HYDRAULIC RESISTANCE IN CONFINING LAYER

boundary values: -HEADS-FLUXES

others: -NODE LOCATIONS OR COORDINATES -INITIAL TIME STEP
-TIME STEP SEQUENCE

MODEL OUTPUT--

tables: -HEADS -FLUXES

GEOMETRY OF MODEL---

shape of cell: -ISOPARAMETRIC QUADRILATERAL

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

TECHNIQUES--

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS ELIMINATION -BAND ALGORITHM MATRIX SOLVER

COMPUTERS USED--

make and model: IBM 360/91, 370/158

PROGRAM INFORMATION---

no. of statements: 800

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; DOCUMENTED IN REFERENCE #2

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: UNKNOWN

REMARKS---

01 EXPANDED AND MODIFIED VERSION DEVELOPED BY G.F. PINDER AND C.I. VOSS. (SEE IGWMC-KEY 0514.)

02 EXTENDED AND UPDATED BY D.K. BABU IN 1981. (SEE REF. #3).

REFERENCES--

01 PINDER, G.F. AND E.O. FRIND. 1972. APPLICATION OF GALERKIN'S PROCEDURE TO AQUIFER ANALYSIS. WATER RESOURCES RESEARCH, VOL. 8(1), PP. 108-120.

02 PINDER, G.F. 1974. A GALERKIN-FINITE ELEMENT MODEL FOR AQUIFER EVALUATION. PROGRAM DOCUMENTATION, U.S. GEOLOGICAL SURVEY, RESTON, VA.

03 BABU, D.K., G.F. PINDER, AND M.C. HILL. 1982. THREE DIMENSIONAL GROUNDWATER FLOW. 82-WR-7. WATER RESOURCES PROGR., PRINCETON UNIVERSITY, PRINCETON, NJ.

IGWMC key= **0514**

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MODEL IDENTIFICATION

model name: **AQUIFEM**

model purpose: A FINITE ELEMENT MODEL TO SIMULATE TRANSIENT, AREAL GROUND WATER FLOW IN AN ISOTROPIC, HETEROGENEOUS, CONFINED, LEAKY- CONFINED OR WATER TABLE AQUIFER

completion date: 1971
last update date: 1979

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -ISOTROPIC -HETEROGENEOUS -CHANGING AQUIFER CONDITIONS IN SPACE

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -HEAD DEPENDENT FLUX -NO FLOW -INFILTRATION -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE

fluid conditions: -HOMOGENEOUS

other model characteristics: -METRIC UNITS

equations solved: DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN CONFINING LAYER -HYDRAULIC RESISTANCE IN RIVER AND LAKE BED

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -VELOCITIES -WATER BALANCE

GEOMETRY OF MODEL--

shape of cell: -ISOPARAMETRIC QUADRILATERAL

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

number of nodes: -RANGES FROM 100 TO 10,000

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT

equation solving technique: -CHOLESKY SQUARE ROOT

COMPUTERS USED---

make and model: VAX 11/780

PROGRAM INFORMATION--

no. of statements: 1800

language: FORTRAN

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM LISTING AND DOCUMENTATION PUBLISHED IN REFERENCE #1.

available code form: -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: NO
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: FEW

REMARKS---

01 EXPANDED AND MODIFIED VERSION OF ISOQUAD BY G.F. PINDER (1971) AND G.F. PINDER AND E.O. FRIND (1974); SEE IGWMC KEY 0510. REVISIONS MADE IN 1974 (P.C. TRESCOTT) AND IN 1979 (C.I. VOSS).

REFERENCES--

01 PINDER, G.F. AND C.I. VOSS. 1979. AQUIFEM, A FINITE ELEMENT MODEL FOR AQUIFER SIMULATION. REPT. 7911, DEPT. OF WATER RESOURCES ENG., ROYAL INST. OF TECHNOLOGY, S-100 44 STOCKHOLM, SWEDEN

02 PINDER, G.F. AND E.O. FRIND. 1972. APPLICATION OF GALERKIN'S PROCEDURE TO AQUIFER ANALYSIS. WATER RESOURCES RESEARCH, VOL. 8, PP. 108-120.

03 PINDER, G.F., E.O. FRIND AND S.S. PAPADOPULOS 1973. FUNCTIONAL COEFFICIENTS IN THE ANALYSIS OF GROUND WATER FLOW. WATER RESOURCES RESEARCH, VOL. 9, PP. 222-226.

IGWMC key= 0582

MODEL TEAM

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MODEL IDENTIFICATION

model name: **GREASE 2**

model purpose: A FINITE ELEMENT MODEL TO STUDY TRANSIENT, MULTI-DIMENSIONAL, SATURATED GROUNDWATER FLOW, SOLUTE AND/OR ENERGY TRANSPORT IN FRACTURED AND UNFRACTURED, ANISOTROPIC, HETEROGENEOUS, MULTILAYERED POROUS MEDIA

completion date: JUL 1982
last update date: JUL 1982

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -STORAGE IN CONFINING LAYER -DELAYED YIELD FROM STORAGE -ANISOTROPIC -HETEROGENEOUS -DISCRETE FRACTURES -DUAL POROSITY FRACTURE SYSTEM -AQUIFER COMPACTION -THREE OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -INFILTRATION -GROUNDWATER RECHARGE -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS -TEMPERATURE DEPENDENT -COMPRESSIBLE -VARIABLE DENSITY

model processes: -CONVECTION -CONDUCTION -DISPERSION -DIFFUSION -ADSORPTION

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -EQUATIONS FOR GROUNDWATER FLOW, SOLUTE TRANSPORT, AND ENERGY TRANSPORT WITH COUPLING OF FLOW AND ENERGY TRANSPORT

MODEL INPUT--

areal values: -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -DIFFUSIVITY -HYDRAULIC RESISTANCE IN CONFINING LAYER -DISPERSIVITY -THERMAL CONDUCTIVITY -THERMAL CAPACITY -SPECIFIC HEAT -TEMPERATURE -FLUID DENSITY

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -PRESCRIBED TEMPERATURE OR HEAT FLUX -PRESCRIBED CONCENTRATION OR MASS FLUX OF CONTAMINANTS

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -LEAKAGE RATES

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -FLUXES -VELOCITIES -TEMPERATURE -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL--

shape of cell: -RECTANGULAR

spatial characteristics:
< saturated zone > -1D HORIZONTAL -1D VERTICAL -2D HORIZONTAL -2D VERTICAL -3D -CYLINDRICAL OR RADIAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY

number of nodes: -RANGES FROM 100 TO 1000

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS ELIMINATION

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE -MASS BALANCE

COMPUTERS USED--

make and model: PRIME OR CDC

PROGRAM INFORMATION---

no. of statements: APPROX. 2000

language: FORTRAN

terms of availability of code and user's manual: PROPRIETARY

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: > $5,000

MODEL EVALUATION--

USABILITY
- -preprocessor: NO
- -postprocessor: NO
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: FEW

REFERENCES--

01 HUYAKORN, P.S. 1983. GREASE 2- USER'S MANUAL. GEOTRANS, INC. HERNDON, VIRGINIA.

IGWMC key= **0583**

MODEL TEAM

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MODEL IDENTIFICATION

model name: **SATURN 2**

model purpose: A FINITE ELEMENT MODEL TO STUDY TRANSIENT, TWO-DIMENSIONAL VARIABLY SATURATED FLOW AND SOLUTE TRANSPORT IN ANISOTROPIC, HETEROGENEOUS POROUS MEDIA

completion date: JUL 1982
last update date: JUL 1982

MODEL CHARACTERISTICS

aquifer conditions: -WATER TABLE -STORAGE IN CONFINING LAYER -ANISOTROPIC -HETEROGENEOUS

flow conditions: -UNSTEADY -SATURATED -UNSATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -INFILTRATION

fluid conditions: -HOMOGENEOUS

model processes: -CAPILLARY FORCES -CONVECTION -CONDUCTION -DISPERSION -DIFFUSION -ADSORPTION -ABSORPTION -DECAY -REACTIONS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -RICHARD'S EQUATION AND SOLUTE TRANSPORT EQUATION

MODEL INPUT--

areal values: -HEADS OR PRESSURES -PERMEABILITY -POROSITY -STORAGE COEFFICIENT -DIFFUSIVITY -DISPERSIVITY

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -RELATIVE PERMEABILITY VS. SATURATION -PRESSURE HEAD VS. SATURATION -SOIL PROPERTIES

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -FLUXES -VELOCITIES -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL--

shape of cell: -RECTANGULAR -CYLINDRICAL

spatial characteristics:

< saturated zone > -2D HORIZONTAL -2D VERTICAL

<unsaturated zone> -2D HORIZONTAL -2D VERTICAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW

number of nodes: -RANGES FROM 100 TO 1000

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS ELIMINATION

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE -MASS BALANCE

COMPUTERS USED---

make and model: CDC OR PRIME

PROGRAM INFORMATION--

no. of statements: APPROX. 2000

language: FORTRAN

terms of availability of code and user's manual: PROPRIETARY

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: > $5,000

MODEL EVALUATION

USABILITY
- -preprocessor: NO
- -postprocessor: NO
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: FEW

REFERENCES

01 HUYAKORN, P.S. AND S.D. THOMAS. 1984. TECHNIQUES FOR MAKING FINITE ELEMENTS COMPETITIVE IN MODELING FLOW IN VARIABLY SATURATED POROUS MEDIA. WATER RESOURCES RESEARCH, VOL. 20, NO. 8, PP. 1099-1115.

02 HUYAKORN, P.S., J.W. MERCER AND D.S. WARD. 1985. FINITE ELEMENT MATRIX AND MASS BALANCE COMPUTATIONAL SCHEMES FOR TRANSPORT IN VARIABILITY SATURATED POROUS MEDIA. WATER RESOURCES RESEARCH 21(3): PP. 346-358.

IGWMC key= 0588

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MODEL IDENTIFICATION

model name: SEFTRAN

model purpose: A FINITE ELEMENT MODEL TO PROVIDE SIMPLE AND COST-EFFECTIVE ANALYSES OF TWO-DIMENSIONAL FLUID FLOW AND CONTAMINANT OR HEAT TRANSPORT PROBLEMS IN AREAL, CROSS-SECTIONAL OR AXISYMMETRIC CONFIGURATION OF SATURATED, HETEROGENEOUS AQUIFERS

completion date: 1983
last update date: 1986

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -ANISOTROPIC -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -CONCENTRATION -SOLUTE FLUXES

fluid conditions: -HOMOGENEOUS

model processes: -CONVECTION -DISPERSION -DIFFUSION -ADSORPTION -DECAY

equations solved: -DARCY'S LAW -FICK'S LAW -CONVECTIVE-DISPERSIVE MASS TRANSPORT EQUATION

MODEL INPUT--

areal values: -THICKNESS OF AQUIFER -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -DIFFUSIVITY -DISPERSIVITY -THERMAL CONDUCTIVITY -THERMAL CAPACITY -SPECIFIC HEAT -TEMPERATURE -FLUID DENSITY -DECAY RATE -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -RETARDATION COEFFICIENT -CONCENTRATION AND SOLUTE FLUX BOUNDARIES -INJECTED SOLUTE FLUX -NODAL COORDINATES CAN BE RECTANGULAR ELEMENTS -A SEPERATE AUTOMATIC MESH GENERATOR PROGRAM STRPGN IS ALSO AVAILABLE

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -FLUXES -VELOCITIES -TEMPERATURE -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR -TRIANGULAR

spatial characteristics:
< saturated zone > -1D HORIZONTAL -1D VERTICAL -2D HORIZONTAL -2D VERTICAL -CYLINDRICAL OR RADIAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY -VARIABLE SIZE GRID

number of nodes: -RANGES FROM 1000 TO 10,000

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT -ELEMENT CHARACTERISTICS ARE DESCRIBED USING INFLUENCE COEFFICIENT TECHNIQUE

equation solving technique: -STRONGLY IMPLICIT PROCEDURE -EXPLICIT -CRANK NICHOLSON

COMPUTERS USED

make and model: PRIME 400 -VAX 11/780 -IBM/PC

core storage: 200K

mass storage: DISK FILE ACCESS FOR INTERMEDIATE STORAGE OF VELOCITIES

PROGRAM INFORMATION

no. of statements: 1830

language: FORTRAN IV

terms of availability of code and user's manual: PROPRIETARY

available code form: -MAGNETIC TAPE (TYPE: ASCII -EBCDIC) -PRINTED LISTING -DISKETTES

cost: $800

MODEL EVALUATION

USABILITY
- -preprocessor: DEDICATED
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REMARKS

01 AN INTERACTIVE PREPROCESSOR HAS BEEN DEVELOPED FOR VERSION 1.0 AT IGWMC AND IS DOCUMENTED IN REFERENCE #1. DATA VALIDITY CHECKS AND ERROR RECOVERY PROCEDURES IN THE PROGRAM ENABLE THE USER TO PREPARE AN ERROR-FREE DATA FILE FOR SEFTRAN. A DOCUMENTED IBM PC VERSION OF THE UPDATED CODE AND PREPROCESSOR IS AVAILABLE FROM GEOTRANS, INC.

02 CODE VALIDATION IS DISCUSSED IN: HUYAKORN, P.S., ET AL. 1984. TESTING AND VALIDATION OF MODELS FOR SIMULATING SOLUTE TRANSPORT IN GROUND-WATER: DEVELOPMENT, EVALUATION AND COMPARISON OF BENCHMARK TECHNIQUES. GWMI 84-13, INTERN. GROUND WATER MODELING CENTER, HOLCOMB RES. INST., INDIANAPOLIS, IN.

REFERENCES

01 SRINIVASAN, P. 1983. PRESEF - DOCUMENTATION OF A PREPROCESSOR FOR THE FINITE ELEMENT FLOW AND TRANSPORT MODEL, SEFTRAN, GWMI 83-08, INTERNATIONAL GROUND WATER MODELING CENTER, HOLCOMB RESEARCH INSTITUTE, INDIANAPOLIS, INDIANA, 125 PP.

IGWMC key= **0589**

MODEL TEAM

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MODEL IDENTIFICATION

model name: **TRAFRAP**

model purpose: TRAFRAP IS A 2-DIMENSIONAL FINITE ELEMENT CODE WHICH SIMULATES GROUNDWATER FLOW AND SOLUTE TRANSPORT IN FRACTURED POROUS MEDIA. MODEL PROCESSES INCLUDE INTERACTIONS BETWEEN FRACTURES AND POROUS MATRIX BLOCKS, ADVECTIVE-DISPERSIVE TRANSPORT IN FRACTURES, DIFFUSION, AND CHAIN REACTIONS OF RADIONUCLIDES.

completion date: MAY 1986
last update date: MAR 1987

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -ANISOTROPIC -DISCRETE FRACTURES -DUAL POROSITY FRACTURE SYSTEM

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX

fluid conditions: -HOMOGENEOUS

model processes: -CONVECTION -CONDUCTION -DISPERSION -DIFFUSION -ADSORPTION -DECAY -REACTIONS equations solved: -FLOW EQUATION AND EQUATION FOR HEAT OR SOLUTE TRANSPORT WITH CONVECTION, DISPERSION, DECAY, LINEAR ADSORPTION.

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -POROSITY -DISPERSIVITY -DECAY RATE -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES

others: -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -FRACTURE APERTURE -FRACTURE THICKNESS

MODEL OUTPUT---

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -CONCENTRATIONS OF WATER CONSTITUENTS -TEMPERATURES

GEOMETRY OF MODEL--

shape of cell: -RECTANGULAR -TRIANGULAR

spatial characteristics:
< saturated zone > -2D HORIZONTAL -2D VERTICAL -CYLINDRICAL OR RADIAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY

number of nodes: -VARIABLE

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT

equation solving technique: -WEIGHTED RESIDUALS -THOMAS ALGORITHM

COMPUTERS USED---

make and model: PRIME, VAX 11/780

PROGRAM INFORMATION--

language: FORTRAN 77

terms of availability of code and user's manual: PUBLIC DOMAIN; DISTRIBUTED BY IGWMC

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: $250 from IGWMC

MODEL EVALUATION---

USABILITY
- -preprocessor: NO
- -postprocessor: NO
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: LIMITED
- -model users: MANY

REMARKS--

01 TRAFRAP IS A MODIFIED AND EXTENDED VERSION OF FTRANS, A FINITE ELEMENT CODE WHICH WAS DEVELOPED BY GEOTRANS FOR INTERA ENVIRONMENTAL CONSULTANTS, INC.; TRAFRAP HAS BEEN DEVELOPED FOR THE IGWMC.

02 IGWMC ORGANIZES AN ANNUAL SHORT COURSE ON THE USE OF THIS MODEL

REFERENCES---

01 INTERA ENVIRONMENTAL CONSULTANTS. 1983. FTRANS: A TWO-DIMENSIONAL CODE FOR SIMULATING FLUID FLOW AND TRANSPORT OF RADIOACTIVE NUCLIDES IN FRACTURED ROCK FOR REPOSITORY PERFORMANCE ASSESSMENT. HOUSTON, TEXAS : INTERA ENVIRONMENTAL CONSULTANTS, INC.

02 HUYAKORN, P.S., H.O. WHITE, JR., V.M. GUVANASEN, AND B.H. LESTER. 1986. TRAFRAP: A TWO-DIMENSIONAL FINITE ELEMENT CODE FOR SIMULATING FLUID FLOW AND TRANSPORT OF RADIONUCLIDES IN FRACTURED POROUS MEDIA. FOS-33, INTERNATIONAL GROUNDWATER MODELING CENTER, HOLCOMB RESEARCH INSTITUTE, BUTLER UNIVERSITY, INDIANAPOLIS, IN.

IGWMC key= 0611

MODEL TEAM

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MODEL IDENTIFICATION

model name: **SUPERMOCK**

model purpose: A FINITE DIFFERENCE MODEL TO SIMULATE TRANSIENT STRESS AND RESPONSE IN A SATURATED-UNSATURATED GROUND WATER FLOW SYSTEM INCLUDING A WATER-TABLE AQUIFER OVERLYING A CONFINED AQUIFER

completion date: 1975
last update date: 1975

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -ANISOTROPIC -HETEROGENEOUS -TWO OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -UNSATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -NO FLOW -INFILTRATION -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -DRAINAGE

fluid conditions: -HOMOGENEOUS

model processes: -PRECIPITATION
-EVAPOTRANSPIRATION

other model characteristics: -ENGLISH UNITS -CALIBRATION

equations solved: -TWO-DIMENSIONAL, HORIZONTAL FLOW EQUATION FOR THE CONFINED AQUIFER.
-ONE-DIMENSIONAL, VERTICAL FLOW EQUATION FOR ZONE DIRECTLY OVERLYING THE WATER-TABLE AQUIFER.
-PARAMETRIC RAINFALL ACCRETION FOR SOIL-MOISTURE ACCOUNTING COMPONENT.

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -HYDRAULIC RESISTANCE IN CONFINING LAYER -HYDRAULIC RESISTANCE IN RIVER BED AND LAKE BED

boundary values: -HEADS OR PRESSURES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -GRID INTERVALS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -SOIL PARAMETERS -ROOT DEPTH -RIVER STAGES -THICKNESS OF STREAMBED

MODEL OUTPUT---

tables: -HEADS OR PRESSURES

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics:
< saturated zone > -2D HORIZONTAL
<unsaturated zone> -1D VERTICAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

number of nodes: -RANGES FROM 1000 TO 10,000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -ALTERNATING DIRECTION -IMPLICIT

error criteria: -WATER BALANCE OVER MODEL

COMPUTERS USED--

make and model: IBM 360/65,370/155

core storage: 350K

other requirements: USUALLY RUN WITH TWO ADDITIONAL PROGRAMS, WHICH DISPLAY COMPUTED DATA AND COMPARE WITH OBSERVED DATA

PROGRAM INFORMATION---

no. of statements: :1610

language: :FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM CODE AND USER'S MANUAL PUBLISHED IN REFERENCE #1

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: UNKNOWN

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: FEW

REMARKS---

01 TO AID IN DATA PREPARATION AND IN CALIBRATING THE MODEL SEVERAL PROGRAMS HAVE BEEN DEVELOPED AND PUBLISHED IN REFERENCE #2. THESE INCLUDE PROGRAMS FOR HARMONIC MEAN WATER-LEVEL, HARMONIC MEAN CONDUCTIVITY FOR LAYERED MATERIALS, EVAPOTRANSPIRATION AND POTENTIAL UPWARD MOVEMENT OF WATER DUE TO EVAPOTRANSPIRATION, MAIN-STEM AND TRIBUTARY STREAM-STAGE AND RATE CHANGE IN EVAPOTRANSPIRATION, CAUSED BY CHANGES IN HEAD.

REFERENCES--

01 REED, J.E., M.S. BEDINGER AND J.E. TERRY. 1976. SIMULATION PROCEDURE FOR MODELING TRANSIENT WATER-TABLE AND ARTESIAN STRESS AND RESPONSE. OPEN FILE REP. 76-792, U.S. GEOL. SURVEY, RESTON, VA.

02 LUDWIG, A.H. 1979. PRE-CONSTRUCTION AND POST-CONSTRUCTION GROUND-WATER LEVELS, LOCK AND DAM 2, RED RIVER VALLEY, LOUSIANA, OPEN FILE REP. 79-919, U.S. GEOL. SURVEY, RESTON, VA.

03 LUDWIG, A.H. AND J.E. TERRY. 1980. METHODS AND APPLICATIONS OF DIGITAL MODEL SIMULATION OF THE RED RIVER ALLUVIAL AQUIFER, SHREVEPORT TO THE MOUTH OF THE BLACK RIVER, LOUISIANA. WRI-79-114, U.S. GEOL. SURVEY, RESTON, VA.

IGWMC key= 0680

MODEL TEAM

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MODEL IDENTIFICATION

model name: **GWSIM-II**

model purpose: A TRANSIENT, TWO-DIMENSIONAL, HORIZONTAL FINITE DIFFERENCE MODEL FOR PREDICTION OF WATER LEVELS AND WATER QUALITY IN AN ANISOTROPIC HETEROGENEOUS CONFINED AND UNCONFINED AQUIFER.

completion date: MAY 1978
last update date: AUG 1981

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -ANISOTROPIC -HETEROGENEOUS -CHANGING AQUIFER CONDITIONS IN TIME (CONFINED - WATER TABLE CONVERSION) -CHANGING AQUIFER CONDITIONS IN SPACE (CONFINED AND WATER TABLE CONDITION IN SAME AQUIFER)

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -INFILTRATION -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

model processes: -EVAPOTRANSPIRATION -CONVECTION -DISPERSION

other model characteristics: -ENGLISH UNITS

equations solved: -DARCY'S LAW AND CONTINUITY; TRANSPORT EQUATION FOR SINGLE CONSERVATIVE DISSOLVED CONSTITUENT

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD -DIFFUSIVITY -DISPERSIVITY -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -FLUXES -CONCENTRATIONS OF WATER CONSTITUENTS -PUMPAGE RATES -ARTIFICIAL RECHARGE RATES -GROUNDWATER RECHARGE RATES

plotted graphics:
<time series> -HEADS -CONCENTRATIONS
<areal maps > -HEADS -FLUXES -CONCENTRATIONS

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -VARIABLE SIZE GRID

number of nodes: -RANGES FROM 1000 TO 10,000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -ITERATIVE ALTERNATING DIRECTION -IMPLICIT
error criteria: -SUM HEAD CHANGE OVER MODEL BETWEEN ITERATIONS
-SUM QUALITY CHANGE OVER MODEL BETWEEN ITERATIONS

COMPUTERS USED--

make and model: UNIVAC 1100

core storage: 65K WORDS (2400 CELLS)

PROGRAM INFORMATION---

no. of statements: 1800

language: FORTRAN IV G

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: NO

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding:UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: FEW

REMARKS---

01 THE FLOW SUBMODEL OF GWSIM-II IS BASED ON THE PRICKETT-LONNQUIST FLOW MODEL 'PLASM' VERSION 1971 (IGWMC-KEY 0322)

02 PROGRAM CODE MAY BE ORDER FROM:
TEXAS NATURAL RESOURCES INFORMATION SYSTEM
P.O. BOX 13231
AUSTIN, TX 78711
ATTENTION: MARCY BERBRICK

REFERENCES--

01 TEXAS DEPARTMENT OF WATER RESOURCES. 1978. DATA COLLECTION AND EVALUATION SECTION, GWSIM-II - GROUNDWATER SIMULATION PROGRAM, PROGRAM DOCUMENTATION AND USER'S MANUAL. REPORT UM-16, TEXAS WATER DEVELOPMENT BOARD, AUSTIN, TEXAS

IGWMC Key= **0692**

MODEL TEAM

author name(s): INTERA ENVIRONMENTAL CONSULTANTS, INC. AND INTERCOMP RESOURCE DEVELOPMENT & ENG., INC. (1)

K.L. KIPP (2)

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(2) U.S. GEOLOGICAL SURVEY
LAKEWOOD, CO 80225

phone:

CONTACT ADDRESS

contact person: KIPP, K.L.

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DENVER FEDERAL CENTER
LAKEWOOD, CO 80225

MODEL IDENTIFICATION

model name: **SWIP/SWIPR/HST3D**

model purpose: A FINITE DIFFERENCE MODEL TO SIMULATE COUPLED UNSTEADY, THREE-DIMENSIONAL GROUNDWATER FLOW HEAT AND CONTAMINANT TRANSPORT IN AN ANSIOTROPIC HETEROGENEOUS AQUIFER

completion date: 1975
last update date: 1987

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -UNCONFINED -ANISOTROPIC -HETEROGENEOUS

flow conditions: -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -VARYING HEADS OR PRESSURES -CHANGING FLUX -FREE SURFACE -WELL CHARACTERISTICS -VARYING PUMPAGE OR INJECTION -HEAT LOSS TO OVERBURDEN -TEMERATURES -CONCENTRATIONS -SOLUTE FLUX

fluid conditions: -HETEROGENEOUS -TEMPERATURE DEPENDENT -VARIABLE DENSITY -VARIABLE VISCOSITY

model processes: -CONVECTION -CONDUCTION -DISPERSION -DIFFUSION -ADSORPTION -DECAY -DESORPTION -HEAT LOSS -PRESSURE EFFECTS ON ENTHALPY other model characteristics: -ENGLISH OR METRIC UNITS

equations solved: -CONSERVATION OF TOTAL LIQUID MASS USING DARCY'S LAW CONSERVATION OF ENERGY, AND CONSERVATION OF THE MASS OF A SPECIFIC CONTAMINANT DISSOLVED IN THE FLUID

MODEL INPUT---

areal values: -PERMEABILITY -POROSITY -TEMPERATURE -FLUID DENSITY -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE OR INJECTION RATES -TEMPERATURES
-CONCENTRATIONS -HEAT AND SOLUTE SOURCES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -NUMBER OF TIME INCREMENTS

MODEL OUTPUT--

tables: -HEADS OR PRESSURES -VELOCITIES -TEMPERATURE
-CONCENTRATIONS OF WATER CONSTITUENTS -FLUXES

GEOMETRY OF MODEL---

shape of cell: -RECTANGULAR -CYLINDRICAL

spatial characteristics:
< saturated zone > -3D -CYLINDRICAL OR RADIAL

grid orientation and sizing: -AXIAL SYMMETRY -3-D ORTHOGONAL CARTESIAN GRID

TECHNIQUES--

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -LINE SUCCESSIVE OVER RELAXATION -GAUSS ELIMINATION

error criteria: -MASS BALANCE

COMPUTERS USED--

make and model: CDC 6600, IBM 370/158, DEC PDP 10

core storage: 42K (DECIMAL) WORDS

PROGRAM INFORMATION--

no. of statements: 15,000
language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; SEE REMARKS
available code form: -MAGNETIC TAPE

cost: UNKNOWN

MODEL EVALUATION---

USABILITY
- -preprocessor: NO
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: LIMITED
- -model users: MANY

REMARKS--

01 SWIPR IS REVISED VERSION OF 1976 USGS/INTERCOMP MODEL SWIP. AVAILABLE FROM NTIS, 5285 PORT ROYAL RD, SPRINGFIELD, VA 22161. TEL:(703)487-4763 SOFTWARE ID: PB-80122534

02 SWIFT AND SWIFT II ARE EXTENSIVELY MODIFIED VERSIONS OF SWIPR, PREPARED BY SANDIA NATIONAL LABORATORIES AND GEOTRANS, INC. (SEE IGWMC KEY #3840).

03 SWENT IS AN EXTENSIVELY MODIFIED VERSION OF SWIPR, DEVELOPED BY OAK RIDGE NATIONAL LABORATORIES FOR ONWI. THE CODE IS AVAILABLE FROM: PERFORMANCE AND ASSESSMENT BRANCH, OFF. NUCL. WASTE ISOLATION, BATTELLE, 505 KING AVE., COLUMBUS, OH 43201 (SEE REF. 3).

04 HST3D IS AN EXTENSIVELY MODIFIED VERSION OF SWIPR AND SUPERCEDES SWIPR WITHIN THE U.S. GEOLOGICAL SURVEY. IT IS AVAILABLE FROM THE USGS AND THE IGWMC.

REFERENCES---

01 INTERCOMP RESOURCE DEVELOPMENT AND ENG. INC. 1976. A MODEL FOR CALCULATING EFFECTS OF LIQUID WASTE DISPOSAL IN DEEP SALINE AQUIFER, PART I DEVELOPMENT, PART II DOCUMENTATION. U.S. GEOLOGICAL SURVEY, WATER RESOURCES INVESTIGATION 76-61, RESTON, VA. (AVAILABLE FROM NTIS, NO. PB-256903.)

02 INTERA, INC. 1979. REVISION OF THE DOCUMENTATION FOR A MODEL FOR CALCULATING EFFECTS OF LIQUID WASTE DISPOSAL IN DEEP SALINE AQUIFER. U.S. GEOLOGICAL SURVEY, WATER RESOURCES INVESTIGATION 79-96, RESTON, VA. (AVAILABLE FROM NTIS, NO. PB 122542.)

03 INTERA, INC. 1983. SWENT: A THREE-DIMENSIONAL FINITE-DIFFERENCE CODE FOR THE SIMULATION OF FLUID, ENERGY, AND SOLUTE RADIONUCLIDE TRANSPORT, ONWI-457, OFF. OF NULCEAR WASTE ISOLATION, BATTELLE, COLUMBUS, OHIO.

04 WILSON, J.L., B.S. RAMARAO, AND J.A. McNEISH, INTERA, INC. 1986. GRASP: A COMPUTER CODE TO PERFORM POST-SWENT ADJOINT SENSITIVITY ANALYSIS OF STEADY-STATE GROUND-WATER FLOW. ONWI-625, OFF. OF NUCLEAR WASTE ISOLATION, BATTELLE, COLUMBUS, OHIO.

05 KIPP, JR., K.L. 1987. HST3D: A COMUTER CODE FOR SIMULATION OF HEAT AND SOLUTE TRANSPORT IN THREE-DIMENSIONAL GROUNDWATER FLOW SYSTEMS. WRI 86-4095, U.S. GEOLOGICAL SURVEY, LAKEWOOD, CO.

IGWMC key= **0694**

MODEL TEAM

author name(s): FAUST, C.R. (1), T. CHAN, B.S. RAMADA AND B.M. THOMPSON (2)

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2) INTERA, HOUSTON, TX

CONTACT ADDRESS

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address: PERFORMANCE ASSESSMENT DEPT.
OFFICE OF NUCLEAR WASTE ISOLATION
BATTELLE PROJECT MANAGEMENT DIV.
505 KING AVENUE
COLUMBUS, OH 43201

phone: 614/424-4326/5472

MODEL IDENTIFICATION

model name: STFLO

model purpose: A LINEAR FINITE ELEMENT CODE FOR SIMULATION OF STEADY-STATE, TWO-DIMENSIONAL (AREAL OR VERTICAL) PLANE OR AXISYMMETRIC GROUND-WATER FLOW IN ANISOTROPIC, HETEROGENEOUS, CONFINED, LEAKY OR WATER-TABLE AQUIFERS.

completion date: OCT 1982
last update date: OCT 1982

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -ISOTROPIC -ANISOTROPIC -HETEROGENEOUS

flow conditions: -STEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS -METRIC UNITS -CONSISTENT UNITS

equations solved: -DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -PERMEABILITY -HYDRAULIC RESISTANCE IN CONFINING LAYER

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

others: -NODE LOCATIONS OR COORDINATES

MODEL OUTPUT---

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -FLUXES

GEOMETRY OF MODEL--

shape of cell: -ISOPARAMETRIC QUADRILATERAL

spatial characteristics: < saturated zone > -2D HORIZONTAL -2D VERTICAL -CYLINDRICAL OR RADIAL

number of nodes: -RANGES FROM 100 TO 1000

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT

equation solving technique: -CHOLESKY DECOMPOSITION

COMPUTERS USED---

make and model: CDC CYBER 176

core storage: 74K

PROGRAM INFORMATION--

no. of statements: 625

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; -CODE AND USER'S MANUAL PUBLISHED IN REF. #1.

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: UNKNOWN

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: UNKNOWN

REFERENCES--

01 INTERA ENVIRONMENTAL CONSULTANTS INC. 1983. STFLO: A FINITE-ELEMENT CODE FOR STEADY-STATE FLOW IN POROUS MEDIA. ONWI-428 OFFICE OF NUCLEAR WASTE ISOLATION BATTELLE, COLUMBUS, OH.

IGWMC key= 0740

MODEL TEAM

author name(s): KONIKOW, L.F. AND J.D. BREDEHOEFT

address: U.S. GEOLOGICAL SURVEY
431 NATIONAL CENTER
RESTON, VA 22092

phone: 703/648-5878

CONTACT ADDRESS

contact person: KONIKOW, L.F.

address: U.S. GEOLOGICAL SURVEY
431 NATIONAL CENTER
RESTON, VA 22092

phone: 703/648-5878

MODEL IDENTIFICATION

model name: MOC

model purpose: A TWO-DIMENSIONAL MODEL TO SIMULATE TRANSIENT, HORIZONTAL OR CROSS-SECTIONAL GROUNDWATER FLOW (FINITE DIFFERENCE) AND SOLUTE TRANSPORT (METHOD OF CHARACTERISTICS) IN CONFINED, SEMI-CONFINED OR WATER-TABLE AQUIFERS

completion date: NOV 1976
last update date: MAR 1987

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED LEAKY CONFINED -WATER TABLE -ISOTROPIC -ANISOTROPIC -HOMOGENEOUS -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -HEAD DEPENDENT FLUX -NO FLOW -INFILTRATION -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -CONSTANT CONCENTRATION

fluid conditions: -HOMOGENEOUS

model processes: -EVAPOTRANSPIRATION -CONVECTION -DISPERSION -DIFFUSION -ADSORPTION -DECAY

other model characteristics: -ENGLISH UNITS -CAN BE COUPLED TO 1-D STREAMFLOW MODEL

equations solved: -GROUNDWATER FLOW EQUATION AND SOLUTE TRANSPORT EQUATION WITH FIRST-ORDER DECAY AND LINEAR REACTIONS

MODEL INPUT---

areal values: -THICKNESS OF AQUIFER -HEADS OR PRESSURES -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -HYDRAULIC RESISTANCE IN CONFINING LAYER -HYDRAULIC RESISTANCE IN RIVER BED AND LAKE BED -DISPERSIVITY -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -PARTICLE TRACKING OPTIONS

MODEL OUTPUT--

tables: -HEADS OR PRESSURES -FLUXES -VELOCITIES -HYDRAULIC RESISTANCE IN CONFINING LAYER -HYDRAULIC RESISTANCE IN RIVER BED OR LAKE BED -DISPERSIVITY -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -CONCENTRATIONS OF WATER CONSTITUENTS -PUMPAGE RATES -GROUND WATER RECHARGE RATES

GEOMETRY OF MODEL---

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics:
< saturated zone > -2D HORIZONTAL -2D VERTICAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW

number of nodes: -VARIABLE

TECHNIQUES--

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -ITERATIVE ALTERNATING DIRECTION -METHOD OF CHARACTERISTICS -PARTICLE IN A CELL -IMPLICIT

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE -MASS BALANCE

COMPUTERS USED--

make and model: IBM 370, DEC 10, IBM PC/XT/AT, VAX 11/780, MICROVAX II

core storage: 200K WORDS (1000 NODES); 512K FOR IBM-PC/XT/AT

PROGRAM INFORMATION---

no. of statements: 2000

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; -CONTACT IGWMC

available code form: -TAPE -PRINTED LISTING -DISKETTES

cost: $200 from IGWMC

MODEL EVALUATION--

USABILITY	RELIABILITY
-preprocessor: YES	-peer reviewed
-postprocessor: YES	-theory: YES
-user's instructions: YES	-coding: YES
-sample problems: YES	-verified: YES
-hardware dependency: NO	-field validation: YES
-support: YES	-model users: MANY

REMARKS---

01 NOTES ON COMPUTER PROGRAM UPDATES HAVE BEEN PUBLISHED BY USGS, RESTON, VIRGINIA ON THE FOLLOWING DATES:

1. MAY 16, 1979	7. JUL. 26, 1985	13. MAR. 5, 1987
2. MAR. 26, 1980	8. JUL. 31, 1985	
3. DEC. 4, 1980	9. AUG. 2, 1985	
4. AUG. 26, 1981	10. AUG. 8, 1985	
5. OCT. 12, 1983	11. AUG. 12, 1985	
6. JUN. 10, 1985	12. JUL. 2, 1986	

02 A MODIFICATION OF THIS MODEL TO TRACK REPRESENTIVE WATER OR TRACER PARTICLES INITIALLY LOADED ALONG SPECIFIC LINES IS DEVELOPED BY GARABEDIAN AND KONIKOW (1983) (SEE IGWMC KEY 0741.)

03 A VERSION OF MOC IDENTICAL TO THE MOST RECENT USGS MAINFRAME VERSION IS AVAILABLE FOR IBM PC FROM IGWMC. MINIMUM SYSTEM CONFIGURATION IS AN IBM PC WITH 512K. EXECUTABLE VERSIONS FOR INSTALLATIONS WITH OR WITHOUT THE INTEL 8087 NUMERICAL CO-PROCESSOR ARE PROVIDED. CONTACT IGWMC FOR MORE INFORMATION.

04 THE CODE HAS BEEN MODIFIED BY HUTCHINSON (SEE REF. #8) TO ALLOW HEAD-DEPENDENT FLUX AS A BOUNDARY CONDITION.

REFERENCES--

01 PINDER, G.F. AND H.H. COOPER. 1970. A NUMERICAL TECHNIQUE FOR CALCULATING THE TRANSIENT POSITION OF THE SALTWATER FRONT. WATER RESOURCES RESEARCH, VOL. 6(3): PP. 875-882.

02 BREDEHOEFT, J.D. AND G.F. PINDER. 1973. MASS TRANSPORT IN FLOWING GROUNDWATER. WATER RESOURCES RESEARCH, VOL. 9(1), PP. 194-210.

03 KONIKOW, L.F. AND J.D. BREDEHOEFT. 1974. MODELING FLOW AND CHEMICAL QUALITY CHANGES IN AN IRRIGATED STREAM-AQUIFER SYSTEM. WATER RESOURCES RESEARCH, VOL. 10(3), PP. 546-562.

04 ROBERTSON, J.B. 1974. DIGITAL MODELING OF RADIOACTIVE AND CHEMICAL WASTE TRANSPORT IN THE SNAKE RIVER PLAIN AQUIFER AT THE NATIONAL REACTOR TESTING STATION, IDAHO. U.S. GEOLOGICAL SURVEY, OPEN FILE REPORT IPO-22054, MOSCOW, ID.

05 KONIKOW, L.F. AND J.D. BREDEHOEFT. 1978. COMPUTER MODEL OF TWO-DIMENSIONAL SOUTE TRANSPORT AND DISPERSION IN GROUND WATER, U.S. GEOLOGICAL SURVEY, TECHNIQUES OF WATER-RESOURCES INVESTIGATIONS, BK 7, CH. C2, RESTON, VA.

06 KONIKOW, L.F. 1975. MODELING SOLUTE TRANSPORT IN GROUNDWATER. INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SENSING AND ASSESSMENT, THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, ANNALS NO. 75CH1004-I 20-3.

07 TRACY, J.V. 1982. USERS GUIDE AND DOCUMENT FOR ADSORPTION AND DECAY MODIFICATIONS TO THE USGS SOLUTE TRANSPORT MODEL. NUREG/CR-2502, U.S. NUCLEAR REGULATORY COMM., WASHINGTON, D.C.

08 HUTCHINSON, C.B. et al. 1981. HYDROGEOLOGY OF WELL-FIELD AREAS NEAR TAMPA, FLORIDA. U.S.G.S. OPEN-FILE REPORT 81-630. PP. 129, TALLAHASSEE, FL.

IGWMC key= 0741

MODEL TEAM

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431 NATIONAL CENTER
RESTON, VA 22092

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MODEL IDENTIFICATION

model name: **FRONTRACK**

model purpose: A FINITE DIFFERENCE MODEL FOR SIMULATION OF CONVECTIVE TRANSPORT OF A CONSERVATIVE TRACER DISSOLVED IN GROUNDWATER UNDER STEADY OR TRANSIENT FLOW CONDITIONS. THE MODEL CALCULATES HEADS, VELOCITIES AND TRACER PARTICLE POSITIONS.

completion date: 1983
last update date: 1983

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -ISOTROPIC -ANISOTROPIC -HOMOGENEOUS -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

model processes: -ADVECTION

other model characteristics: -METRIC UNITS -AUTOMATIC TIMESTEP SUBDIVISION TO KEEP PARTICLE MOVEMENT WITHIN CELL WIDTH equations solved: -DARCY'S LAW AND CONTINUITY RESULTING IN TWO UNCOUPLED PARTIAL DIFFERENTIAL EQUATIONS, ONE FOR HEAD AND ONE FOR SEEPAGE VELOCITY

MODEL INPUT--

areal values: -TRANSMISSIVITY -STORAGE COEFFICIENT

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -INITIAL TIME STEP

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -VELOCITIES -PARTICLE POSITION AND PATHLINES

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

TECHNIQUES---

basic modeling technique: -BLOCK-CENTERED -FINITE DIFFERENCE

equation solving technique: -ITERATIVE ALTERNATING DIRECTION -METHOD OF CHARACTERISTICS -IMPLICIT -PARTICLE TRACKING

COMPUTERS USED---

make and model: HARRIS S125, PRIME

PROGRAM INFORMATION--

no. of statements: 1425

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; CODE AND DOCUMENTATION PUBLISHED IN REFERENCE #1.

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: < $100

MODEL EVALUATION--

USABILITY	RELIABILITY
-preprocessor: NO	-peer reviewed
-postprocessor: GENERIC	-theory: YES
-user's instructions: YES	-coding: UNKNOWN
-sample problems: YES	-verified: YES
-hardware dependency: NO	-field validation: UNKNOWN
-support: YES	-model users: FEW

REMARKS---

01 THE CONVECTIVE TRANSPORT MECHANISM REPRESENTED IN THIS MODEL HAS BEEN ADAPTED FROM THE SOLUTE TRANSPORT MODEL, DEVELOPED BY KONIKOW AND BREDEHOEFT (1978). THE THEORETICAL BACKGROUND IS DISCUSSED IN REFERENCE #2.

REFERENCES--

01 GARABEDIAN, S.P., AND L.F. KONIKOW. 1983. FRONT-TRACKING MODEL FOR CONVECTIVE TRANSPORT IN FLOWING GROUND WATER. WRI-83-4034, U.S. GEOLOGICAL SURVEY, RESTON, VA.

02 KONIKOW, L.F. AND J.D. BREDEHOEFT. 1978. COMPUTER MODEL OF TWO-DIMENSIONAL SOLUTE TRANSPORT AND DISPERSION IN GROUND WATER. TECHN. OF WATER RESOURC. INVESTIGATION, BOOK 7, CH. C2, U.S. GEOLOGICAL SURVEY, RESTON, VA.

IGWMC key= 0742

MODEL TEAM

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affiliation: -FEDERAL/NATIONAL GOVERNMENT

CONTACT ADDRESS

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MODEL IDENTIFICATION

model name: MOCDENSE

model purpose: A MODEL TO SIMULATE TRANSPORT AND DISPERSION OF EITHER ONE OR TWO CONSTITUENTS IN GROUNDWATER WHERE THERE IS TWO-DIMENSIONAL, DENSITY DEPENDENT FLOW. IT USES FINITE-DIFFERENCE AND METHOD OF CHARACTERISTICS TO SOLVE THE FLOW AND TRANSPORT EQUATIONS.

completion date: 1985
last update date: 1986

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -ISOTROPIC -ANISOTROPIC -HOMOGENEOUS -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -PRESCRIBED CONCENTRATION

fluid conditions: -HETEROGENEOUS -SALT WATER/FRESH WATER INTERFACE -VARIABLE DENSITY

model processes: -DISPERSION -ADVECTION

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -POROSITY -DIFFUSIVITY -HYDRAULIC RESISTANCE IN CONFINING LAYER -DISPERSIVITY -FLUID DENSITY -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES -CONCENTRATIONS

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -FLUXES -VELOCITIES -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics:
< saturated zone > -2D VERTICAL
<unsaturated zone>

grid orientation and sizing: -CROSS SECTIONAL OR VERTICAL VIEW

number of nodes: 400

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE - METHOD OF CHARACTERISTICS

equation solving technique: -STRONGLY IMPLICIT PROCEDURE

error criteria: -MASS BALANCE

COMPUTERS USED---

make and model: VAX 11/780, PRIME, IBM PC

core storage: 640K

mass storage: 360K

PROGRAM INFORMATION---

no. of statements: 3000

language: FORTRAN

terms of availability of code and user's manual: PUBLIC DOMAIN; -CONTACT IGWMC

available code form: -MAGNETIC TAPE -PRINTED LISTING -DISKETTES

cost: $150 from IGWMC

MODEL EVALUATION---

USABILITY
- -preprocessor: NO
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: FEW

REFERENCES---

01 SANFORD, W.E. AND L.F. KONIKOW. 1985. A TWO-CONSTITUENT SOLUTE TRANSPORT MODEL FOR GROUND WATER HAVING VARIABLE DENSITY. U.S.G.S. WATER RESOURCES INVESTIGATIONS REPORT 85-4279, U.S. GEOLOGICAL SURVEY, RESTON, VA

IGWMC key= 0770

MODEL TEAM

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phone: 703/ 860-7000

MODEL IDENTIFICATION

model name: **USGS-3D-FLOW**

model purpose: A FINITE DIFFERENCE MODEL TO SIMULATE TRANSIENT, THREE-DIMENSIONAL AND QUASI-THREE-DIMENSIONAL, SATURATED FLOW IN ANISOTROPIC, HETEROGENEOUS GROUND WATER SYSTEMS

completion date: 1975
last update date: 1982

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -STORAGE IN CONFINING LAYER -ANISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

model processes: -EVAPOTRANSPIRATION

other model characteristics: -METRIC UNITS

equations solved: -DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN CONFINING LAYER

boundary values: -HEADS OR PRESSURES -FLUXES -GROUND WATER RECHARGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -THICKNESS AND SPECIFIC STORAGE OF CONFINING BED.

MODEL OUTPUT---

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -HYDRAULIC RESISTANCE IN CONFINING LAYER -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD -DRAWDOWN

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics: < saturated zone > -2D HORIZONTAL -3D

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -VARIABLE SIZE GRID

number of nodes: -RANGES FROM 1000 TO 10,000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -STRONGLY IMPLICIT PROCEDURE -IMPLICIT -CRANK NICHOLSON

error criteria: -WATER BALANCE OVER MODEL -USER SPECIFIED

COMPUTERS USED---

make and model: IBM 370/155, VAX 11/780, PRIME

core storage: 756K (10000 NODES)

PROGRAM INFORMATION---

no. of statements: 1600

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM CODE LISTED IN REFERENCE #1 AND #2.

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: < $100

MODEL EVALUATION---

USABILITY
- -preprocessor: YES
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REMARKS--

01 TWO VERSIONS OF THE CODE ARE AVAILABLE, AND RESIDE ON THE AMDAHL COMPUTER IN RESTON, VIRGINIA.
(1) MODIFIED AND CORRECTED VERSION CAN BE ACCESSED AS:
DSN=VG4E91L.HEDDEP.FORTGI.FORT,UNIT=3330-1,VOL=SER=SYS312, DISP=SHR
(2) CORRECTED VERSION CAN BE ACCESSED AS:
DSN=VG4E91L.STANDTD.FORTGI.FORT,UNIT=3330-1,VOL=SER=SYS010, DISP=SHR

02 PROGRAM CODE (CARD OR TAPE) AND DOCUMENTATION OF BOTH VERSIONS ARE AVAILABLE FROM:
U.S. GEOLOGICAL SURVEY
COMPUTER CENTER DIVISION, BTP
NATIONAL CENTER, MAIL STOP 804
RESTON, VA 22092
PHONE: (703)860-7931

03 MODIFICATIONS AND CORRECTIONS FOR THE ORIGINAL VERSION ARE PUBLISHED IN REFERENCE #10. THIS REPORT INCLUDES MODIFIED SOURCE CODE.

04 A VERSION FOR DEC VAX-11/780 IS AVAILABLE FROM IGWMC

05 A PROGRAM WRITTEN TO CALCULATE INPUT ARRAYS FOR TRANSMISSIVITY TO BE USED WITH USGS-3D-FLOW MODEL IS DESCRIBED IN REFERENCE #6.

06 A LISTING OF A MODIFIED VERSION TO INCLUDE EVAPOTRANSPIRATION AND INTERACTION BETWEEN A RIVER AND THE UPPER AQUIFER IS PRESENTED IN REFERENCE #8.

07 THE PROGRAM HAS ALSO BEEN MODIFIED IN 1982 TO EXTEND ITS APPLICATION TO HEAD-DEPENDENT SOURCES AND SINKS. CHANGES WERE ALSO MADE TO ENHANCE CONVERGENCE OF AN ITERATIVE SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE. THE MODIFICATIONS AND CORRECTIONS ARE PUBLISHED AS IN REFERENCE #7.

08 MICROCOMPUTER VERSIONS FOR IBM/PC, FOR DEC VAX, PDP-11 & PRO 350, AND FOR H/P 200 & 9000 AVAILABLE FROM J.S. LLOYD, DPMS-DESIGN PROFESSIONALS MANAGEMENT SYSTEMS, P.O. BOX 2364, KIRKLAND, WA 98033, TEL. 206/822-2872.

09 A PRE-PROCESSOR ENABLING THE USE OF THE THREE-DIMENSIONAL FLOW MODEL FOR SIMULATION OF VARIABLE DENSITY GROUND-WATER FLOW HAS BEEN PUBLISHED IN REFERENCE #13. THIS PROGRAM REQUIRES INFORMATION ON AQUIFER ELEVATION, THICKNESS, AND GROUND-WATER DENSITY. THE PROGRAM THEN CALCULATES PSEUDO-INPUT TERMS FOR TRANSMISSIVITY, WELL INPUT AND LEAKANCE.

10 A MODIFICATION THAT EFFECTIVELY HANDLES CONFINING-BED AND AQUIFER PINCHOUTS AND REDUCES COMPUTER-MEMORY REQUIREMENTS FOR SITUATIONS WITH COMPLEX BOUNDARIES, HAS BEEN PUBLISHED IN REF. #11. THIS REFERENCE INCLUDES PROGRAM LISTING AND USER INSTRUCTIONS.

11 A MODIFIED VERSION IS PUBLISHED IN REFERENCE #12. THESE MODIFICATIONS CONCERN LEAKAGE BETWEEN LAYERS, SPRING DISCHARGE, STREAM-AQUIFER INTERCHANGE, SPRINGFLOW RECHARGE TO MIDDLE LAYER, WATER-BUDGET DETERMINATION FOR EACH LAYER, LOCATION OF LARGEST HEAD CHANGES AND FLOW TO EACH CONSTANT HEAD NODE. REF. #12 INCLUDES MODIFIED PROGRAM LISTING.

12 AN EXTENSIVELY MODIFIED VERSION IS ANNOTATED AS IGWMC KEY 2740. THIS VERSION IS PUBLISHED IN REF. #9

13 A VERSION WITH TRANSIENT LEAKAGE FROM CONFINING LAYERS IS ANNOTATED AS IGWMC KEY 3880. USER'S INSTRUCTIONS ARE INCLUDED HEREIN, AS WELL AS A PROGRAM FOR PARAMETER ESTIMATION BASED ON HEAD COMPUTATION

14 THE USGS-3D-FLOW MODEL HAS BEEN EVALUATED IN; THOMAS, S.D., B. ROSS, J.W. MERCER. 1982. A SUMMARY OF REPOSITORY SITING MODELS. NUREG/CR-2782, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

15 A MODIFIED VERSION OF THIS THREE-DIMENSIONAL MODEL HAS BEEN PUBLISHED IN REFERENCE #14. THIS MODIFIED VERSION ALLOWS SIMULATION OF LEAKAGE ALONG STREAMS FROM ALL LAYERS OF THE MODEL AND SIMULATION OF RECHARGE FROM THE LAND SURFACE TO ALL LAYERS.

REFERENCES---

01 TRESCOTT, P.C. 1975. DOCUMENTATION OF FINITE DIFFERENCE MODEL FOR SIMULATION OF THREE-DIMENSIONAL GROUND WATER FLOW. U.S. GEOLOGICAL SURVEY, OPEN-FILE REPORT 75-438, RESTON, VA.

02 TRESCOTT, P.C. AND S.P. LARSON. 1976. SUPPLEMENT TO OPEN-FILE REPORT 75-438. U.S. GEOL. SURVEY, OPEN-FILE REPORT 76-591, RESTON, VA.

03 TRESCOTT, P.C. AND S.P. LARSON. 1977. SOLUTION OF THREE-DIMENSIONAL GROUND WATER FLOW EQUATIONS USING THE STRONGLY IMPLICIT PROCEDURE. J. HYDROL., VOL. 35, PP. 49-60.

04 BENNET, G.D., A.L. KONTIS, AND S.P. LARSON. 1982. REPRESENTATION OF MULTI-AQUIFER WELL EFFECTS IN THREE-DIMENSIONAL GROUNDWATER FLOW SIMULATION. GROUND WATER, VOL. 20(3), PP. 334-341.

05 BRIZ-KISHORE, B.H. AND R.V.S.S. ARADHANULU. 1982. A COMPACT MODIFIED THREE-DIMENSIONAL AQUIFER SIMULATION PROGRAM FOR SMALL COMPUTERS. GROUND WATER, VOL. 20(3), PP. 342-344.

06 WEISS, E. 1982. A COMPUTER PROGRAM FOR CALCULATING RELATIVE TRANSMISSIVITY INPUT ARRAYS TO AID MODEL CALIBRATION. U.S. GEOL. SURVEY, OPEN-FILE REPORT 82-447, DENVER, COLORADO.

07 GUSWA, J.H. AND D.R. LE BLANC. 1981. DIGITAL MODELS OF GROUND WATER FLOW IN THE CAPE COD AQUIFER SYSTEM, MASSACHUSSETS. U.S. GEOLOGICAL SURVEY, OPEN-FILE REPT. 80-67, BOSTON, MA.

08 RYDER, P.D., D.M. JOHNSON AND J.M. GERHART. 1980. MODEL EVALUATION OF THE HYDROGEOLOGY OF THE MORRIS BRIDGE WELL FIELD AND VICINITY IN WEST-CENTRAL FLORIDA. U.S. GEOLOGICAL SURVEY, OPEN-FILE REPORT 80-29, TALLAHASSEE, FLORIDA.

09 POSSON D.R., G.A. HEARNE, J.V. TRACY AND P.F. FRENZEL. 1980. COMPUTER PROGRAM FOR SIMULATING GEOHYDROLOGIC SYSTEMS IN THREE DIMENSIONS. U.S. GEOLOGICAL SURVEY, OPEN-FILE REPORT 80-421 (MODIFIED VERSION), RESTON, VA.

10 TORAK, L.J. 1982. MODIFICATIONS AND CORRECTIONS TO THE FINITE-DIFFERENCE MODEL FOR SIMULATION OF THREE-DIMENSIONAL GROUND-WATER FLOW. U.S. GEOLOGICAL SURVEY, OPEN-FILE REPORT 82-4025, RESTON VIRGINIA.

11 LEAHY, P.P. 1982. A THREE-DIMENSIONAL GROUNDWATER-FLOW MODEL MODIFIED TO REDUCE COMPUTER-MEMORY REQUIREMENTS AND BETTER SIMULATE CONFINING-BED AND AQUIFER PINCHOUTS. WATER-RESOURCES INVESTIGATIONS 82-4023, U.S. GEOLOGICAL SURVEY, TRENTON, NEW JERSEY.

12 HELGESEN, J.O., S.P. LARSON AND A.C. RAZEM. 1982. MODEL MODIFICATIONS FOR SIMULATION OF FLOW THROUGH STRATIFIED ROCKS IN EASTERN OHIO. U.S. GEOLOGICAL SURVEY WATER RESOURCES INVESTIGATIONS 82-4019, COLUMBUS, OHIO.

13 WEISS, E. 1982. A MODEL FOR THE SIMULATION OF FLOW OF VARIABLE DENSITY GROUND WATER IN THREE DIMENSIONS UNDER STEADY-STATE CONDITIONS. U.S. GEOLOGICAL SURVEY, OPEN-FILE REPT. 82-352, DENVER, COLORADO.

14 MORRISSEY, D.J., G.C. LINES AND S.D. BARTHOLOMA. 1980. THREE DIMENSIONAL DIGITAL-COMPUTER MODEL OF THE FERRON SANDSTONE AQUIFER NEAR EMERY, UTAH. WATER-RESOURC. INVESTIG. 80-62, U.S. GEOLOGICAL SURVEY, SALT LAKE CITY, UTAH, 101 P.

IGWMC key= 0771

MODEL TEAM

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MODEL IDENTIFICATION

model name: **USGS-2D-FLOW**

model purpose: A FINITE DIFFERENCE MODEL TO SIMULATE TRANSIENT, TWO-DIMENSIONAL HORIZONTAL OR VERTICAL FLOW IN AN ANISOTROPIC AND HETEROGENEOUS, CONFINED, LEAKY-CONFINED OR WATER-TABLE AQUIFER.

completion date: 1975
last update date: 1976

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -STORAGE IN CONFINING LAYER -ANISOTROPIC -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN CONFINING LAYER

boundary values: -EVAPOTRANSPIRATION RATES

others: -GRID INTERVALS -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -THICKNESS OF CONFINING LAYER

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -FLUXES

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics: < saturated zone > -2D HORIZONTAL -2D VERTICAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -VARIABLE SIZE GRID

number of nodes: -RANGES FROM 1000 TO 10,000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -LINE SUCCESSIVE OVER RELAXATION -ITERATIVE ALTERNATING DIRECTION -STRONGLY IMPLICIT PROCEDURE -IMPLICIT -CRANK NICHOLSON

error criteria: -MASS BALANCE

COMPUTERS USED---

make and model: IBM 370/155

core storage: 756K (6250 NODES)

PROGRAM INFORMATION--

no. of statements: 2400

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; TO OBTAIN PROGRAM CODE, CONTACT ADDRESS GIVEN IN REMARK #1; CODE ALSO PUBLISHED IN REFERENCE #1.

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: < $100

MODEL EVALUATION---

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REMARKS--

01 CODE AND DOCUMENTATION TO BE ORDERED FROM:
RALPH N. EICHER, CHIEF
OFFICE OF TELEPROCESSING, M.S. 805
U.S. GEOLOGICAL SURVEY
RESTON, VA 22092

02 THIS MODEL HAS BEEN UNDER DEVELOPMENT AT THE USGS SINCE 1968 AS ILLUSTRATED BY REFERENCES #11 AND #12.

03 A MODIFICATION OF THE SOLUTION TECHNIQUE USING THE DIRECT-SOLUTION ALGORITHM (DS) INSTEAD OF THE STRONGLY IMPLICIT PROCEDURE (SIP) IS GIVEN IN REFERENCE #2.

04 A VERSION USING SUBSTANTIAL REDUCED MEMORY FOR SAME SIZE PROBLEM HAS BEEN PUBLISHED IN REFERENCE #7. THIS PUBLICATION ALSO INCLUDES LISTING OF THE FORTRAN CODE.

05 A MODIFIED VERSION HAS BEEN PUBLISHED IN REFERENCE #4. THIS VERSION INCLUDES HEAD CONTROLLED FLUX BOUNDARY CONDITIONS. ONLY THE SOR SOLUTION METHOD IS USED. REFERENCE #4 CONTAINS PROGRAM CODE, USER INSTRUCTIONS AND EXAMPLE IN- AND OUTPUT USING FIELD CASE DATA.

06 A VERSION FOR DEC VAX-11/780 IS AVAILABLE FROM IGWMC, INDIANAPOLIS.

07 MICROCOMPUTER VERSIONS FOR IBM/PC, FOR DEC VAX, PDP-11 & PRO 350, AND FOR H/P 200 & 9000 AVAILABLE FROM
J.S. LLOYD, DPMS-DESIGN PROFESSIONALS MANAGEMENT SYSTEMS
P.O.BOX 2364, KIRKLAND, WA 98033, TEL. 206/822-2872.

08 AN EARLY VERSION OF THIS CODE HAS BEEN PUBLISHED IN REFERENCE #8, INCLUDING USER'S INSTRUCTIONS.

09 A MODIFIED VERSION INCLUDING STREAM FLOW ACCOUNTING PROCEDURE HAS BEEN PUBLISHED IN REFERENCE #9 AND ITS USE IS DESCRIBED IN REFERENCE #10.

10 THE MODEL HAS BEEN EVALUATED IN: THOMAS, S.D., B. ROSS, J.W. MERCER. JULY 1982. A SUMMARY OF REPOSITORY SITING MODELS. NUREG/CR-2782, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

11 A VERSION OF THIS USGS-2D FLOW MODEL, IN WHICH THE ORIGINAL EQUATION SOLVING SUBROUTINES IS REPLACED BY ONE WHICH IS BASED ON THE CONJUGATE-GRADIENT METHOD HAS BEEN PUBLISHED IN REFERENCE #13. THIS METHOD HAS A HIGHER EFFICIENCY FOR CERTAIN KINDS OF PROBLEMS BECAUSE IT DOES NOT REQUIRE THE USE OF ITERATION PARAMETERS. THE NEWLY WRITTEN SUBROUTINES ARE LISTED IN THE REPORT.

12 THE CONJUGATE-GRADIENT METHOD IS APPLIED TO SOLVE THE MATRIX SYSTEM. SUBROUTINE IS GIVEN IN REFERENCE #13.

13 A MODIFIED VERSION TO ENABLE SIMULATION OF THE INTERACTION BETWEEN SURFACE WATER AND GROUND WATER DURING PERIODS OF LOW STREAMFLOW IS LISTED IN REFERENCE #14.

REFERENCES--

01 TRESCOTT, P.C., G.F. PINDER AND S..P. LARSON. 1976. FINITE-DIFFERENCE MODEL FOR AQUIFER SIMULATION IN TWO DIMENSIONS WITH RESULTS OF NUMERICAL EXPERIMENTS. TECHN. OF WATER RESOURCES INVESTIGATION. BOOK 7 CHAPTER C1, U.S. GEOL. SURVEY, RESTON, VA

02 LARSON, S.P. 1978. DIRECT SOLUTION ALGORITHM FOR THE TWO-DIMENSIONAL GROUND WATER FLOW MODEL. OPEN FILE REPORT 79-202, U.S. GEOLOGICAL SURVEY, RESTON, VA.

03 RAZEM, A.C. AND S.D. BARTHOLMA. 1980. DIGITAL-COMPUTER MODEL OF GROUND-WATER FLOW IN TOOELE VALLEY, UTAH. OPEN-FILE REPORT 80-446, U.S. GEOLOGICAL SURVEY SALT LAKE CITY, UT.

04 HUTCHINSON, C.B., D.M. JOHNSON AND J.M. GERHART. 1981. HYDROGEOLOGY OF WELL-FIELD AREAS NEAR TAMPA, FLORIDA, PHASE I - DEVELOPMENT AND DOCUMENTATION OF A TWO-DIMENSIONAL FINITE-DIFFERENCE MODEL FOR SIMULATION OF STEADY-STATE GROUND-WATER FLOW. OPEN-FILE REPORT 81-630, U.S. GEOLOGICAL SURVEY, TALLAHASSEE, FL.

05 TRESCOTT, P.C. AND S.P. LARSON. 1977. COMPARISON OF ITERATIVE METHODS OF SOLVING TWO-DIMENSIONAL GROUNDWATER FLOW EQUATIONS. WATER RESOURCES RESEARCH, VOL. 13(1):PP.125-136.

06 LARSON, S.P. AND P.C. TRESCOTT. 1977. SOLUTION OF WATER-TABLE AND ANISTROPIC FLOW PROBLEMS BY USING THE STRONGLY IMPLICIT PROCEDURE. J. RESEARCH, USGS, VOL. 5(6):815-821.

07 BRIZ-KISHORE, B.H. AND R.V.S.S. AVADHANULU. 1983. AN EFFICIENT PROCEDURE IN THE DIGITAL SIMULATION OF AQUIFER SYSTEMS. J. HYDROLOGY, VOL. 64, PP. 159-174.

08 THOMAS, R.G. 1973. GROUNDWATER MODELS. FAO IRRIGATION AND DRAINAGE PAPER 21, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, ROME, ITALY.

09 CRIST, M.A. 1983. COMPUTER PROGRAM AND DATA LISTING FOR TWO-DIMENSIONAL GROUND-WATER MODEL FOR LARAMIE COUNTY, WYOMING. WRI-4137, U.S. GEOLOGICAL SURVEY, CHEYENNE, WYOMING.

10 CRIST, M.A. 1980. EFFECT OF PUMPAGE ON GROUNDWATER LEVELS AS MODELED IN LARAMIE COUNTY, WYOMING. WRI-80-1104, U.S. GEOLOGICAL SURVEY, CHEYENNE, WYOMING.

11 TRESCOTT, P.C. 1973. ITERATIVE DIGITAL MODEL FOR AQUIFER EVALUATION. OPEN FILE REPT. U.S. GEOLOGICAL SURVEY, RESTON, VIRGINIA.

12 PINDER, G.F. 1970. AN ITERATIVE DIGITAL MODEL FOR AQUIFER EVALUATION. OPEN FILE REPT. U.S. GEOLOGICAL SURVEY, RESTON, VIRGINIA.

13 MANTEUFFEL, T.A., D.B. GROVE AND L.F. KONIKOW. 1983. APPLICATION OF THE CONJUGATE-GRADIENT METHOD TO GROUNDWATER MODELS. WRI 83-4009, U.S. GEOLOGICAL SURVEY, DENVER, COLORADO.

14 OZBILGIN, M.M. AND D.C. DICKERMAN. 1984. A MODIFICATION OF THE FINITE-DIFFERENCE MODEL FOR SIMULATION OF TWO DIMENSIONAL GROUND-WATER FLOW TO INCLUDE SURFACE-GROUND WATER RELATIONSHIPS. WATER-RESOURCES INVESTIGATIONS REPORT 83-4251, U.S. GEOLOGICAL SURVEY, PROVIDENCE, RI.

IGWMC key= 1010

MODEL TEAM

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2950 NORTHUP WAY
BELLEVUE, WASHINGTON 98004
U.S.A.

phone: 206/827-0777

MODEL IDENTIFICATION

model name: **GGWP (GOLDER GROUNDWATER COMPUTER PACKAGE)**

model purpose: A FINITE ELEMENT MODEL FOR STEADY-STATE OR TRANSIENT SIMULATION OF TWO-DIMENSIONAL, VERTICAL OR AXISYMMETRIC AND QUASI- THREE-DIMENSIONAL FLOW AND TRANSPORT OF REACTIVE SOLUTES IN ANISOTROPIC, HETEROGENEOUS, MULTI-LAYERED AQUIFER SYSTEMS.

completion date: 1978
last update date: 1983

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -STORAGE IN CONFINING LAYER -ANISOTROPIC -HETEROGENEOUS -DISCRETE FRACTURES -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -FREE SURFACE -SEEPAGE SURFACE -MOVABLE EXTERNAL BOUNDARY -TIDAL FLUCTUATIONS -INFILTRATION -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS
model processes: -PRECIPITATION -EVAPOTRANSPIRATION -CONVECTION -DISPERSION -DIFFUSION -ADSORPTION -ABSORPTION -ION EXCHANGE -DECAY -REACTIONS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: DARCY'S LAW AND CONTINUITY -NONCONSERVATIVE CONVECTIVE DISPERSIVE MASS TRANSPORT EQUATION

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN CONFINING LAYER -HYDRAULIC RESISTANCE

boundary values: -HEADS OR PRESSURES -FLUXES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -GROUND WATER RECHARGE RATES -PRESCRIBED CONCENTRATIONS

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA

MODEL OUTPUT---

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -FLUXES -VELOCITIES -CONCENTRATIONS OF WATER CONSTITUENTS -FLOWNET

plotted graphics:
<areal maps > -HEADS -FLUXES -VELOCITIES -CONCENTRATIONS -FINITE ELEMENT MESH -STREAMLINES -FLOWNET

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR -TRIANGULAR -ISOPARAMETRIC QUADRILATERAL

spatial characteristics:
< saturated zone > -2D HORIZONTAL -2D VERTICAL -CYLINDRICAL OR RADIAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY -VARIABLE SIZE GRID -MOVABLE GRID -FOR PLANAR AND AXISYMMETRIC FLOW REGIMES

number of nodes: -RANGES FROM 1000 TO 10,000

TECHNIQUES--

basic modeling technique: -FINITE ELEMENT

equation solving technique: -CHOLESKY SQUARE ROOT -DOOLITTLE -WEIGHTED RESIDUALS -IMPLICIT -OPTIONAL UPWIND WEIGHTING FOR TRANSPORT SIMULATION

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE -MAXIMUM QUALITY CHANGE AT ANY ONE NODE

COMPUTERS USED--

make and model: CDC 6600 AND CYBER 70 AND 170 SERIES

core storage: 36K WORDS (1000 NODES)

mass storage: 63K WORDS (1000 NODES)

PROGRAM INFORMATION---

no. of statements: 25,000

language: FORTRAN IV ANSI X3.9-1966

terms of availability of code and user's manual: PROPRIETARY

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: DEDICATED
- -postprocessor: DEDICATED
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: UNKNOWN

REMARKS---

01 THE GOLDER GROUNDWATER PACKAGE IS A SUITE OF SIX PROGRAMS FOR MODELING GROUNDWATER FLOW AND SOLUTE TRANSPORT. IT INCLUDES: MLTMSH AND AFPOL, PREPROCESSORS, AFPM FOR QUASI-3D FINITE ELEMENT SOLUTION OF LAYERED AQUIFER SYSTEMS, FPM FOR CROSS-SECTIONAL OR AXISYMMETRIC FLOW SOLUTIONS, SOLTR FOR SOLUTE TRANSPORT IN FLOW FIELDS COMPUTED BY EITHER AFPM OR FPM, AND FLOCON, A PLOTTING PROGRAM.

02 FOUR LEVELS OF DOCUMENTATION HAVE BEEN PREPARED FOR THE GROUND WATER COMPUTER PACKAGE.

1. MANAGEMENT SUMMARY:
GOLDER GROUNDWATER COMPUTER PACKAGE, TECHNICAL SUMMARY, 19P

2. USER'S MANUALS:
USER'S MANUALS ARE AVAILABLE FOR INPUT DATA PREPARATION, HYDRAULIC SOLUTION FOR SINGLE LAYER OR MULTI-LAYER PROBLEMS, SOLUTE TRANSPORT SOLUTION, AND OUTPUT PRESENTATION AND PLOTTING.

3. SYSTEM MANUALS:
THESE CONTAIN THE EXPLICIT MATHEMATICAL FORMULATION AND FUNDAMENTAL ASSUMPTIONS FOR THE VARIANTS OF THE FINITE ELEMENT METHOD INCORPORATED IN THE PACKAGE.

4. PROGRAMMER'S MANUALS:
THESE MANUALS CONTAIN THE DETAILED LOGIC AND CODING REFERENCES OF THE COMPONENT PROGRAMS IN THE PACKAGE. THERE ARE PROGRAMMER'S MANUALS FOR THE DATA PREPARATION, HYDRAULIC AND SOLUTE TRANSPORT AND OUTPUT PRESENTATION PROGRAMS AS WELL AS FOR COMMON SYSTEM SUBROUTINES/FUNCTIONS

REFERENCES--

01 MARLON-LAMBERT, J. 1978. COMPUTER PROGRAMS FOR GROUND WATER FLOW AND SOLUTE TRANSPORT ANALYSIS, REPT. NO. N25090, GOLDER ASSOCIATES, VANCOUVER, CANADA.

02 MARLON-LAMBERT, J.R., P.J. MANOEL AND R.G. FRIDAY. 1981. THE DEVELOPMENT OF A GENERAL GROUNDWATER COMPUTER MODELLING PACKAGE. TRANS. I.E. AUSTRALIAN CIVIL ENG., CE 23, NO. 4, PP. 264-271.

03 MILLER, I. AND K. ROMAN. 1979. NUMERICAL MODELING OF SOLUTE TRANSPORT IN GROUNDWATER. GOLDER ASSOCIATES, VANCOUVER, CANADA, 23P.
(AVAILABLE FROM NTIS, SPRINGFIELD, VA, #UCRL 15179)

IGWMC key= 1070

MODEL TEAM

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MODEL IDENTIFICATION

model name: **3-D SATURATED-UNSATURATED TRANSPORT MODEL**

model purpose: A FINITE ELEMENT MODEL FOR THE DETERMINATION OF A CONCENTRATION OF CONSERVATIVE OR NONCONSERVATIVE SOLUTE IN TRANSIENT, 3-DIMENSIONAL SATURATED-UNSATURATED FLOW SYSTEMS

completion date: AUG 1976
last update date: AUG 1976

MODEL CHARACTERISTICS

aquifer conditions: -WATER TABLE -ANISOTROPIC -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -UNSATURATED

boundary conditions: -CONSTANT HEADS OR PRESSURES -NO FLOW -SEEPAGE SURFACE

fluid conditions: -HETEROGENEOUS -VARIABLE DENSITY

model processes: -CONVECTION -DISPERSION -ABSORPTION -DECAY

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -DARCY'S LAW AND CONTINUITY; SOLUTE TRANSPORT EQUATION.

MODEL INPUT--

areal values: -POROSITY -DISPERSIVITY -DECAY RATE -INITIAL QUALITY

boundary values: -PUMPAGE RATES

others: -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -INITIAL PRESSURES -INITIAL POSITION OF SEEPAGE FACE -UNSATURATED ZONE PROPERTIES -RETARDATION COEFFICIENT.

MODEL OUTPUT--

tables: -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL--

shape of cell: -ISOPARAMETRIC QUADRILATERAL -3-D ELEMENTS WITH LINEAR QUADRATIC OR CUBIC SIDES

spatial characteristics:
< saturated zone > -3D
<unsaturated zone> -3D

TECHNIQUES--

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS ELIMINATION -CHOLESKY SQUARE ROOT -IMPLICIT

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE -FLUX AT ATMOSPHERIC BOUNDARIES

COMPUTERS USED--

make and model: IBM 360/75

PROGRAM INFORMATION--

language: FORTRAN IV

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: NO
- -postprocessor: NO
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: UNKNOWN

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: UNKNOWN

REFERENCES--

01 SEGOL, G., 1976. A THREE-DIMENSIONAL GALERKIN FINITE ELEMENT MODEL FOR THE ANALYSIS OF CONTAMINANT TRANSPORT IN VARIABLY SATURATED POROUS MEDIA, USER'S MANUAL. DEPT. OF EARTH SCIENCES, UNIV. OF WATERLOO, WATERLOO, ONTARIO, CANADA.

IGWMC key= **1230**

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MODEL IDENTIFICATION

model name: **AQU-1**

model purpose: A BASIC FINITE DIFFERENCE MODEL FOR TRANSIENT, SINGLE LAYERED TWO-DIMENSIONAL HORIZONTAL GROUND WATER FLOW.

completion date: 1979
last update date: 1979

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -DELAYED YIELD FROM STORAGE -ANISOTROPIC -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -MOVABLE EXTERNAL BOUNDARY -INFILTRATION -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD

boundary values: -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -GRID INTERVALS -NODE LOCATIONS OR COORDINATES -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -RIVER FLOW -SPRING FLOW

MODEL OUTPUT---

tables: -HEADS OR PRESSURES

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics: < saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

number of nodes: -RANGES FROM 1000 TO 10,000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -LINE SUCCESSIVE OVER RELAXATION

error criteria: -WATER BALANCE IN EACH NODE

COMPUTERS USED---

make and model: ICL 1906A, CDC 6600, CYBER 72

core storage: 40K FOR 2000 NODES

PROGRAM INFORMATION--

no. of statements: 350

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM CODE LISTED IN REFERENCE #1

available code form: -PRINTED LISTING -MAGNETIC TAPE

cost: UNKNOWN

MODEL EVALUATION

USABILITY	RELIABILITY
-preprocessor: UNKNOWN	-peer reviewed
-postprocessor: UNKNOWN	-theory: YES
-user's instructions: YES	-coding: YES
-sample problems: YES	-verified: YES
-hardware dependency: NO	-field validation: YES
-support: YES	-model users: MANY

REFERENCES

01 RUSHTON, K.R. AND S.C. RESHAW. 1979. SEEPAGE AND GROUNDWATER FLOW. WILEY, CHICHESTER, 332 P. (CODE APPEARS IN APPENDIX TWO).

02 RUSHTON, K.R. 1974. AQUIFER ANALYSIS USING BACKWARD DIFFERENCE METHODS. J. HYDROL., VOL. 22, PP. 253-262.

03 RUSHTON, K.R. 1975. AQUIFER ANALYSIS OF THE LINCOLNSHIRE LIMESTONE USING MATHEMATICAL MODELS. J. INST. WATER ENG. (LONDON), VOL. 29, PP. 373-389.

04 FOX, I.A. AND K.R. RUSHTON. 1976. RAPID RECHARGE IN A LIMESTONE AQUIFER. GROUNDWATER, VOL. 14, PP. 21-27.

IGWMC key= **1791**

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MODEL IDENTIFICATION

model name: **SLAEM**

model purpose: A FLEXIBLE ANALYTIC ELEMENTS MODEL FOR SIMULATING STEADY-STATE GROUNDWATER FLOW IN REGIONAL DOUBLE AQUIFER SYSTEMS WITH LOCAL INTERCONNECTIONS.

completion date: 1981
last update date: 1986

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -ISOTROPIC -HETEROGENEOUS -TWO OVERLYING AQUIFERS

flow conditions: -STEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -INFILTRATION -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -LINE SINKS

surface flow characteristics: -WATER BALANCE OF SURFACE WATER INCLUDED -LAKES -RIVERS -PONDS

fluid conditions: -HOMOGENEOUS

other model characteristics: -ANY CONSISTENT SYSTEM OF UNITS equations solved: -POISSON'S EQUATION

MODEL INPUT--

areal values: -THICKNESS OF AQUIFER -PERMEABILITY

boundary values: -HEADS OR PRESSURES -FLUXES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

others: -INFINITE DOMAIN WITH CREEKS -LAKES -SPRINGS -INTERIOR BOUNDARIES

MODEL OUTPUT---

tables: -HEADS -VELOCITIES

plotted graphics: < areal maps > -CONTOUR LINES -CROSS SECTIONAL PLOTS

GEOMETRY OF MODEL--

shape of cell: -NONE -

spatial characteristics: < saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

TECHNIQUES---

basic modeling technique: -ANALYTIC ELEMENT METHOD

equation solving technique: -GAUSS ELIMINATION -GAUSS-JORDAN ELIMINATION

error criteria: -MASS ERROR IN BOUNDARY CONDITIONS

COMPUTERS USED---

make and model: PERKIN, ELMER 32/20, VAX 11/780 AND IBM PC

core storage: 170K (520K FOR IBM PC)

mass storage: 50KB

peripherals: TEKTRONIX 4010 (OR EMULATOR) AND PRINTER

other requirements: TUTER ACTIVE GRAPHICS FOR MINICOMPUTER

PROGRAM INFORMATION--

language: FORTRAN VI

terms of availability of code and user's manual: PROPRIETARY

available code form: -MAGNETIC TAPE -DISKETTES

cost: > 2500 FOR TOTAL PACKAGE

MODEL EVALUATION--

USABILITY
- -preprocessor: DEDICATED
- -postprocessor: DEDICATED
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: YES
- -model users: FEW

REMARKS--

01 THE LATEST VERSION OF CODE IS CALLED SLAEM AND RUNS ON IBM-PC. EARLIER VERSIONS WRE CALLED SYLENS AND SL.

REFERENCES--

01 HAITJEMA, H.M. AND O.D.L. STRACK. 1979. A STEADY-STATE COMPUTER SIMULATION OF THE DEWATERING ACTIVITIES IN THE DIVIDE-CUT SECTION OF THE TENNESSEE-TOMBIGBEE WATERWAY. REPT. TO U.S. ARMY CORPS OF ENGINEERING, NASHVILLE DISTRICT, NASHVILLE, TN.

02 STRACK, O.D.L. AND H.M. HAITJEMA. 1981. MODELING DOUBLE AQUIFER FLOW USING A COMPREHENSIVE POTENTIAL AND DISTRIBUTED SINGULARITIES I. SOLUTION FOR HOMOGENEOUS PERMEABILITY. WATER RESOURCES RESEARCH, VOL. 17(5), PP. 1535-1549.

03 STRACK, O.D.L. AND H.M. HAITJEMA. 1981. MODELING DOUBLE AQUIFER FLOW USING A COMPREHENSIVE POTENTIAL AND DISTRIBUTED SINGULARITIES II. SOLUTION FOR INHOMOGENEOUS PERMEABILITES. WATER WATER RESOURCES RESEARCH, VOL. 17(5), PP. 1551-1549.

04 HAITJEMA, H.M. 1985. MODELING THREE-DIMENSIONAL FLOW IN CONFINED AQUIFERS BY SUPERPOSITION OF BOTH TWO- AND THREE-DIMENSIONAL ANALYTIC FUNCTIONS. WATER RESOURCES RESEARCH 21(10): 1557-1566.

05 STRACK, O.D.L. 1984. THREE-DIMENSIONAL STREAMLINES IN DUPUIT-FORCHHEIMER MODELS. WATER RESOURCES RESEARCH 20(7): PP. 812-822.

IGWMC key= **1821/1822/1823**

MODEL TEAM

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MODEL IDENTIFICATION

model name: **FLOP/FLOP-2/FRONT**

model purpose: ANALYTIC MODELS TO GENERATE PATHLINES AND PROVIDE FOR FRONT TRACKING FOR STEADY-STATE OR TRANSIENT FLOW IN A CONFINED OR SEMI-CONFINED, ISOTROPIC, HOMOGENEOUS AQUIFER AND TO CALCULATE RESIDENCE TIMES FOR A NUMBER OF WATER PARTICLES.

completion date: 1975
last update date: 1981

MODEL CHARACTERISTICS

aquifer conditions: - CONFINED -LEAKY -ISOTROPIC -HOMOGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -GROUNDWATER RECHARGE -WELLS -VARIABLE PUMPAGE -INFINITE AQUIFER

fluid conditions: -HOMOGENEOUS

other model characteristics: -METRIC UNITS

equations solved: -DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values: -THICKNESS OF AQUIFER -TRANSMISSIVITY -POROSITY -HYDRAULIC RESISTANCE OF CONFINING BEDS

boundary values: -PUMPAGE RATES

others: -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -NATURAL GROUNDWATER FLOW RATE AND DIRECTION -RESISTANCE OF SEMIPERVIOUS LAYER -REQUIRED NUMBER OF PATHLINES TO ALL SOURCES AND SINKS

MODEL OUTPUT---

tables: -DRAWDOWNS -TRAVELTIMES

plotted graphics:
<areal maps > -PATHLINES -CONTOURS

GEOMETRY OF MODEL--

shape of cell: -NONE

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

TECHNIQUES---

basic modeling technique: -ANALYTICAL METHOD (SEMI-ANALYTICAL)

equation solving technique: -RUNGE-KUTTA

error criteria: -USER SPECIFIED

COMPUTERS USED---

make and model: IBM 370/158 & CDC 6600, HP 9830

core storage: 256K (IBM), 8K (HP)

PROGRAM INFORMATION--

language: FORTRAN IV, BASIC (FLOP AND FLOP-2)

cost: UNKNOWN

MODEL EVALUATION--

USABILITY	RELIABILITY
-preprocessor: UNKNOWN	-peer reviewed
-postprocessor: UNKNOWN	-theory: YES
-user's instructions: YES	-coding: YES
-sample problems: YES	-verified: YES
-hardware dependency: YES	-field validation: YES
-support: YES	-model users: MANY

REMARKS---

01 PROBLEMS SOLVED WITH THIS MODEL:
(A) CALCULATION OF PROTECTION ZONES AROUND PUMPING SITES
(B) CALCULATION OF RESIDENT TIMES FOR INFILTRATED WATER
(C) TRACKING DISPLACEMENT OF SALT-FRESH WATER INTERFACE

02 FLOP (CONFINED AQUIFER) AND FLOP-2 (LEAKY-CONFINED AQUIFER) ARE PROGRAMS FOR STEADY-STATE FLOW WHILE FRONT ALLOWS FOR TRANSIENT FLOW CONDITIONS

REFERENCES--

01 VAN DEN AKKER, C. , J.M. PETERS, AND J.B.S. GAN. 1981. USER'S MANUAL FOR THE COMPUTER PROGRAM FLOP. WORKING GROUP HYDROLOGY OF INJECTION WELL SYSTEMS, KIWA, RIJSWIJK(ZH), THE NETHERLANDS. (IN DUTCH.)

02 VERMEER, P.A., AND C. VAN DEN AKKER. 1976. PERFORMANCE OF A RECHARGE AND RECOVERY SYSTEM IN AN AQUIFER WITH UNIFORM FLOW. HYDROL. SC. BULL. VOL. 21(3).

03 VAN DEN AKKER, C. 1976. A NUMERICAL CALCULATION METHOD FOR STREAMLINES OR FLOW PATHS WITH SUBSEQUENT RESIDENCE TIMES. H_2O, VOL. 9(21). (IN DUTCH.)

04 VAN DEN AKKER, C., AND G.J.M. CREMERS. 1978. THE CONSEQUENCES OF SEWAGE WATER INFILTRATION IN "HET GOOI" ON THE QUALITY OF THE GROUNDWATER TO BE WITHDRAWN FOR DRINKING WATER PRODUCTION. H_2O, VOL. 11(3). (IN DUTCH.)

05 VAN DEN AKKER, C., AND J.M. PETERS. 1981. STREAMLINES AND TRAVELTIMES OF GROUNDWATER IN A TWO-LAYERED AQUIFER SYSTEM. PROCEED. INTERN. SYMP. ON QUALITY OF GROUNDWATER, NOORDWIJKERHOUT, THE NETHERLANDS, MARCH 1981.

IGWMC key= 1830

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MODEL IDENTIFICATION

model name: **MOTGRO**

model purpose: PREDICTION OF GROUNDWATER HEAD AND STREAM FUNCTION FOR TWO-DIMENSIONAL, VERTICAL, STEADY AND UNSTEADY, SINGLE OR MULTIPLE FLUID FLOW IN HETEROGENEOUS, ANISOTROPIC, CONFINED OR UNCONFINED AQUIFERS OF ARBITRARY SHAPES.

completion date: JAN 1976
last update date: DEC 1981

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -LEAKY CONFINED -WATER TABLE -ANISOTROPIC -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -FREE SURFACE -SEEPAGE SURFACE -GROUNDWATER RECHARGE -WELLS -WELL CHARACTERISTICS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HETEROGENEOUS -VARIABLE DENSITY

other model characteristics: -METRIC UNITS

MODEL INPUT--

areal values: -HEADS OR PRESSURES -PERMEABILITY -POROSITY -HYDRAULIC RESISTANCE OF CONFINING BED -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD

boundary values: -HEADS OR PRESSURES -FLUXES -PRECIPITATION RATES -PUMPAGE RATES

others: -NUMBER OF INHOMOGENEITIES -NUMBER OF FLUIDS -FLUID DENSITY

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -FLUXES -TRAVELTIMES -STREAMLINES

plotted graphics:
<time series> -HEADS
<areal maps> -HEADS -FLUXES -STREAMFUNCTION -STREAMLINES -FRONTS -VELOCITIES

GEOMETRY OF MODEL--

shape of cell: -VARIABLE

spatial characteristics:
< saturated zone > -2D VERTICAL

grid orientation and sizing: -CROSS SECTIONAL OR VERTICAL VIEW

number of nodes: -RANGES FROM 10 TO 1000

TECHNIQUES---

basic modeling technique: -ANALYTICAL FUNCTION METHOD (OR BOUNDARY ELEMENT METHOD)

equation solving technique: -PSOR -GAUSS ELIMINATION

COMPUTERS USED---

make and model: IBM 360/65, PHILLIPS P 1400, UNIVAC 1100-40

core storage: 185K (100 LINEAR EQUATIONS)

PROGRAM INFORMATION--

no. of statements: 3000

language: FORTRAN 77

terms of availability of code and user's manual: PROPRIETARY; EARLY VERSION OF CODE PUBLISHED IN REFERENCE #1.

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: TO BE NEGOTIATED

MODEL EVALUATION---

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: FEW

REFERENCES---

01 VAN DER VEER, P. 1978. CALCULATION METHODS FOR TWO-DIMENSIONAL GROUND WATER FLOW. RIJKSWATERSTAAT COMMUNICATIONS, NO. 28, THE HAGUE, THE NETHERLANDS, 172 PP.

02 VAN DER VEER, P. 1979. MOTGRO MODEL FOR TWO-DIMENSIONAL GROUNDWATER FLOW: USER'S MANUAL. RIJKSWATERSTAAT, THE HAGUE, THE NETHERLANDS

03 AUATER, R., 1979. SOME RESULTS OBTAINED WITH A BOUNDARY ELEMENT METHOD. IN: REPORT 26, CHO-TNO, THE HAGUE, THE NETHERLANDS.

IGWMC key= 2070

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MODEL IDENTIFICATION

model name: CFEST

model purpose: A THREE-DIMENSIONAL FINITE ELEMENT MODEL FOR SIMULATION OF COUPLED TRANSIENT FLOW, SOLUTE AND HEAT TRANSPORT IN SATURATED POROUS MEDIA.

completion date: 1981
last update date: 1986

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -STORAGE IN CONFINING LAYER -DELAYED YIELD FROM STORAGE -ANISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -PRESCRIBED CONCENTRATIONS -SOLUTE FLUX -HEAT FLUX -PRESCRIBED TEMPERATURES

fluid conditions: -HETEROGENEOUS -TEMPERATURE DEPENDENT -COMPRESSIBLE model processes: -CONVECTION -CONDUCTION -DISPERSION -DIFFUSION -ADSORPTION -DECAY

other model characteristics: -METRIC UNITS

equations solved: -COUPLED SOLUTION OF FLOW, ENERGY AND SOLUTE TRANSPORT EQUATIONS

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD -DISPERSIVITY -THERMAL CONDUCTIVITY -SPECIFIC HEAT -TEMPERATURE

boundary values: -HEADS OR PRESSURES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -NUMBER OF TIME INCREMENTS -FLUID DENSITY

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -TEMPERATURE -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL--

shape of cell: -ISOPARAMETRIC QUADRILATERAL

spatial characteristics:
< saturated zone > -2D HORIZONTAL -2D VERTICAL -3D

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -VARIABLE SIZE GRID

number of nodes: -RANGES FROM 1000 TO 10,000

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS ELIMINATION -SPARSE EQUATION SOLVER

COMPUTERS USED--

make and model: PDP 11/45, VAX 11/780

core storage: 32K 16-BYTE-WORDS

other requirements: 'FILE Q' SYSTEM FOR I/O

PROGRAM INFORMATION--

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: < $100

MODEL EVALUATION--

USABILITY
- -preprocessor: DEDICATED
- -postprocessor: DEDICATED
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REMARKS--

01 IMPROVEMENTS ARE UNDERWAY TO INCLUDE CAPABILITIES FOR DOUBLE POROSITY, DISCRETE FRACTURES FLOW AND MODELING UNCERTAINTIES IN HYDRAULIC PROPERTIES AND BOUNDARY CONDITIONS.

02 CFEST IS AN EXTENSION OF THE FINITE ELEMENT THREE-DIMENSIONAL GROUNDWATER CODE FE3DGW BY GUPTA ET AL. (IGWMC KEY 2072).

REFERENCES---

01 GUPTA, S.K., C.R. COLE, C.T. KINCAID AND F.E. KASZETA. 1982. DESCRIPTION AND APPLICATIONS OF THE FE3DGW AND CFEST THREE-DIMENSIONAL FINITE ELEMENT MODELS, BATTELLE PACIFIC NW LABORATORIES, RICHLAND, WA, P. 9

02 GUPTA, S.K., C.T. KINCAID, P. MEYER, C. NEWBILL, AND C.R. COLE. 1982 CFEST-MULTI-DIMENSIONAL FINITE ELEMENT CODE FOR THE ANALYSIS OF COUPLED FLUID, ENERGY AND SOLUTE TRANSPORT. PNL-4260, BATTELLE PACIFIC NW LABORATORIES, RICHLAND, WA.

IGWMC key= 2072

MODEL TEAM

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MODEL IDENTIFICATION

model name: **FE3DGW**

model purpose: A FINITE ELEMENT MODEL FOR TRANSIENT OR STEADY STATE, THREE-DIMENSIONAL SIMULATION OF FLOW IN A LARGE MULTI-LAYERED GROUNDWATER BASIN.

completion date: 1975
last update date: 1985

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -STORAGE IN CONFINING LAYER -DELAYED YIELD FROM STORAGE -ANISOTROPIC -HETEROGENEOUS -AQUIFER COMPACTION -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -FREE SURFACE -INFILTRATION -GROUNDWATER RECHARGE -WELLS -WELL CHARACTERISTICS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -DRAINAGE OR DEWATERING

fluid conditions: -HOMOGENEOUS -COMPRESSIBLE

other model characteristics: -ENGLISH UNITS -METRIC UNITS

MODEL INPUT---

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD

boundary values: -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS

MODEL OUTPUT--

tables: -HEADS -FLUXES

GEOMETRY OF MODEL---

shape of cell: -MIXED, CURVED ISOPARAMETRIC

spatial characteristics: < saturated zone > -3D

grid orientation and sizing: -VARIABLE SIZE GRID

number of nodes: -RANGES FROM 1000 TO 10,000

TECHNIQUES--

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS ELIMINATION -SPARSE MATRIX SOLVER

error criteria: -MASS BALANCE

COMPUTERS USED--

make and model: PDP 11/45, VAX 11/780

core storage: 32K 16-BYTE-WORDS

PROGRAM INFORMATION--

language: FORTRAN IV PLUS

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM CODE AND USER'S MANUAL LISTED IN REFERENCE #11

available code form: -PRINTED LISTING -MAGNETIC TAPE

cost: < $100

MODEL EVALUATION--

USABILITY
- -preprocessor: DEDICATED
- -postprocessor: DEDICATED
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REMARKS--

01 SUPPORTING SOFTWARE HAS BEEN DEVELOPED AT PACIFIC NORTHWEST LABORATORY, RICHLAND, WASHINGTON FOR INTERACTIVE GRAPHIC COMPUTATION AND RESULT DISPLAY.

02 THE MODEL HAS BEEN EVALUATED IN: THOMAS, S.D., B. ROSS, J.W. MERCER. 1982. A SUMMARY OF REPOSITORY SITING MODELS. NUREG/CR-2782, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

REFERENCES--

01 GUPTA, S.K., C.R. COLE AND F.W. BOND. 1979. FINITE-ELEMENT THREE-DIMENSIONAL GROUND-WATER (FE3DGW) FLOW MODEL - FORMULATION, PROGRAM LISTING AND USER'S MANUAL. PNL-2939, BATTELLE PACIFIC NW LABORATORIES, RICHLAND, WA.

02 GUPTA, S.K., C.R. COLE, C.T. KINCAID AND F.E. KASZETA. 1982 DESCRIPTION AND APPLICATIONS OF THE FE3DGW AND CFEST THREE-DIMENSIONAL FINITE-ELEMENT MODELS. BATTELLE PACIFIC NW LABORATORIES, RICHLAND, WA. P. 9.

03 GUPTA, S.K. AND G.F. PINDER. 1978. THREE-DIMENSIONAL FINITE-ELEMENT MODEL FOR MULTILAYERED GROUND-WATER RESERVIOR OF LONG ISLAND, NEW YORK. WATER RESOURCES PROGRAM, DEPT. OF CIVIL ENG., PRINCETON UNIV., PRINCETON, NJ.

04 COLE, C.R. AND S.K. GUPTA. 1978. A BRIEF DESCRIPTION OF THE THREE-DIMENSIONAL FINITE-ELEMENT GROUND-WATER FLOW MODEL ADOPTED FOR THE WASTE ISOLATION SAFETY ASSESSMENT PROGRAM, PNL-2652, BATTELLE PACIFIC NW LABORATORIES, RICHALND, WA.

05 GUPTA, S.K., K.K. TANJI AND J.N. LUTHIN. 1975. A THREE-DIMENSIONAL FINITE-ELEMENT GROUND-WATER MODEL. CONTRIBUTION NO. 152, CALIFORNIA WATER RESOURCES CENTER, UNIVERSITY OF CALIFORNIA, DAVIS, CA.

06 GUPTA, S.K. AND K.K. TANJI. 1978. A THREE-DIMENSIONAL GALERKIN FINITE-ELEMENT SOLUTION OF FLOW THROUGH MULTIAQUIFERS IN SUTTER BASIN, CALIFORNIA. WATER RESOURCES RESEARCH, VOL. 12(2).

07 GUPTA, S.K. AND K.K. TANJI. 1977. COMPUTER PROGRAM FOR SOLUTION OF LARGE, SPARSE, UNSYMMETRIC SYSTEMS OF LINEAR EQUATIONS. INTERNL. J. FOR NUM. METH. IN ENG., VOL. 11, PP. 1251-1259.

08 GUPTA, S.K., M.W. MORRISSEY, J. LONCZAK AND K.K TANJI. 1976. COMPUTER PROGRAM FOR THREE-DIMENSIONAL PLOTTING FROM IRREGULAR FINITE-ELEMENT GRID. WATER SCIENCE AND ENG. PAPERS 4010, DEPT. OF WATER SCIENCE AND ENG., UNIV. OF CALIFORNIA, DAVIS, CA.

09 GUPTA, S.K., M.W. MORRISSEY, J. LONCZAK AND K.K TANJI. 1976. CONVERSION OF IRREGULAR FINITE-ELEMENT GRID DATA TO REGULAR GRID FOR THREE-DIMENSIONAL COMPUTER PLOTTING. WATER RESOURCES RESEARCH, VOL. 12(4), PP. 809-811.

10 GUPTA, S.K., C.R. COLE AND G.F. PINDER. 1984. A FINITE-ELEMENT THREE-DIMENSIONAL GROUNDWATER (FE3DGW) MODEL FOR A MULTIAQUIFER SYSTEM. WATER RESOURCES RESEARCH, VOL. 20(5), PP. 553-563.

11 GUPTA, S.K., C.R. COLE, F.W. BOND, AND A.M. MONTI. 1984. FINITE-ELEMENT THREE-DIMENSIONAL GROUND-WATER (FE3DGW) FLOW MODEL: FORMULATION, COMPUTER SOURCE LISTINGS, AND USER'S MANUAL. ONWI-548, OFF. NUCL. WASTE ISOLATION, BATTELLE MEM. INST., COLUMBUS, OHIO.

IGWMC key= 2092

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MODEL IDENTIFICATION

model name: VTT (VARIABLE THICKNESS TRANSIENT GROUND WATER FLOW MODEL)

model purpose: A TRANSIENT FINITE DIFFERENCE MODEL TO CALCULATE HYDRAULIC HEAD IN CONFINED-UNCONFINED MULTI-LAYERED AQUIFER SYSTEMS, AND TO GENERATE STREAMLINES AND TRAVELTIMES.

completion date: 1976
last update date: 1979

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -ISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -NO FLOW -FREE SURFACE -TIDAL FLUCTUATIONS -INFILTRATION -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS

equations solved: -DARCY'S LAW AND CONTINUITY; DUPUIT-FORCHHEIMER ASSUMPTIONS.

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD

boundary values: -PUMPAGE RATES

others: -GRID INTERVALS -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA

MODEL OUTPUT---

tables: *-HEADS -FLUXES -TRAVELTIMES*

plotted graphics:
<areal maps > -HEADS -STREAMLINES

GEOMETRY OF MODEL--

shape of cell: -SQUARE

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

number of nodes: -RANGES FROM 1000 TO 100,000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -LINE SUCCESSIVE OVER RELAXATION

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE

COMPUTERS USED---

make and model: PDP 11/45, 11/70

core storage: 64K

mass storage: 50K 256-WORD BLOCK

peripherals: DISK STORAGE

PROGRAM INFORMATION--

no. of statements: 2000

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM CODE LISTED IN REFERENCE #5

available code form: -PRINTED LISTING -MAGNETIC TAPE

cost: < $100

MODEL EVALUATION---

USABILITY
- -preprocessor: YES
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: UNKNOWN

REMARKS--

01 AN AUXILIARY PROGRAM TO THE VTT MODEL IS AVAILABLE WHICH CALCULATES ARRIVAL TIMES FOR GROUNDWATER BASED ON THE STREAMTUBES CALCULATED BY THE VTT MODEL.

02 VTT INCLUDES PROGRAM MXPLT TO CALCULATE PATHLINES AND TRAVELTIMES

03 THE MODEL HAS BEEN EVALUATED IN: THOMAS, S.D., B. ROSS, J.W. MERCER. 1982. A SUMMARY OF REPOSITORY SITING MODELS. NUREG/CR-2782, U.S. NUCLEAR REGULATORY COMM., WASHINGTON, D.C.

REFERENCES---

01 KIPP, K.L., A.E. REISENAUER, C.R. COLE AND C.A. BRYAN. 1972. (REVISED 1976). VARIABLE THICKNESS TRANSIENT GROUNDWATER FLOW MODEL- THEORY AND NUMERICAL IMPLEMENTATION. BNWL-1703, BATTELLE PACIFIC NW LABORATORIES, RICHLAND, WA.

02 DEMIER,W.V., A.E. REISENAUER AND K.L. KIPP. 1974. VARIABLE THICKNESS TRANSIENT GROUNDWATER FLOW MODEL -USER'S MANUAL. BNWL-1704, BATTELLE PACIFIC NW LABORATORIES, RICHLAND, WA.

03 REISENAUER, A.E. 1979. VARIABLE THICKNESS TRANSIENT GROUND-WATER FLOW MODEL, VOL. 1 - FORMULATION. PNL-3160-1, BATTELLE PACIFIC NW LABORATORIES, RICHLAND, WA.

04 REISENAUER, A.E. 1979. VARIABLE THICKNESS TRANSIENT GROUND-WATER FLOW MODEL, VOL. 2 - USER'S MANUAL. PNL-3160-2, BATTELLE PACIFIC NW LABORATORIES, RICHLAND, WA.

05 REISENAUER, A.E. 1979. VARIABLE THICKNESS TRANSIENT GROUND-WATER FLOW MODEL, VOL. 3 - PROGRAM LISTINGS. PNL-3160-3, BATTELLE PACIFIC NW LABORATORIES, RICHLAND, WA.

06 BOND, F.W., C.A. NEWBILL, AND P.J. GUTKNECHT. 1981. VARIABLE THICKNESS TRANSIENT GROUNDWATER FLOW MODEL-USER'S MANUAL. BATTELLE PACIFIC NW LABORATORIES, RESEARCH PROJECT 1406-1, FINAL REPORT, RICHLAND, WASHINGTON.

IGWMC key= 2120

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MODEL IDENTIFICATION

model name: PATHS

model purpose: AN ANALYTIC FLOW AND TRANSPORT MODEL TO EVALUATE PARTICLE TRANSPORT IN TRANSIENT, TWO-DIMENSIONAL, HORIZONTAL, GROUNDWATER FLOWSYSTEMS USING AN ANALYTICAL SOLUTION FOR THE FLOW EQUATION AND A NUMERICAL SOLUTION FOR THE PATHLINE EQUATIONS

completion date: JUN 1978
last update date: JUN 1983

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -ISOTROPIC -HOMOGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -HEAD DEPENDENT FLUX -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

model processes: -CONVECTION -ADSORPTION

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -CONSERVATION OF MASS, DARCY'S LAW, AND KINEMATIC PATHLINES OR THE CONVECTIVE DERIVATIVE THEREOF (EXPRESSED AS CHARACTERISTIC DIFFERENTIAL EQUATIONS CONSIDERING EQUILIBRIUM SORPTION OF ONE CONTAMINANT SPECIES)

MODEL INPUT---

areal values: -THICKNESS OF AQUIFER -HEADS OR PRESSURES -TRANSMISSIVITY -POROSITY -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -PUMPAGE RATES

others: -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS

MODEL OUTPUT--

tables: -FLUXES -VELOCITIES -CONCENTRATIONS OF WATER CONSTITUENTS -PUMPAGE RATES -ADVANCE OF CONTAMINANT FRONTS AND PATHLINES

plotted graphics:
<time series> -ADVANCING FRONTS
<areal maps > -ADVANCING FRONTS -STREAMLINES

GEOMETRY OF MODEL---

shape of cell: -NONE

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CONTINUOUS SYSTEM

TECHNIQUES--

basic modeling technique: -ANALYTICAL METHOD (ON FLUID FLOW PORTION) -CHARACTERISTIC PATHLINE EQUATIONS SOLVED USING FINITE DIFFERENCE METHOD

equation solving technique: -RUNGE-KUTTA

error criteria:

COMPUTERS USED--

make and model: UNIVAC 1100/44-EXEC8, CDC 6600, DEC 1170

core storage: 40K DECIMAL

peripherals: MASS STORAGE, 1 PLOT TAPE

other requirements: REQUIRES (HARD COPY) TERMINAL

PROGRAM INFORMATION--

no. of statements: 3215

language: INTERACTIVE FORTRAN AND FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM CODE ON MICROFICHE OR CAN BE PROVIDED ON TAPE. DOCUMENTATION LISTED IN REFERENCE #1.

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: < $100

MODEL EVALUATION---

USABILITY
- -preprocessor: YES
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
  - -verified: YES
- -field validation: LIMITED
- -model users: MANY

REMARKS--

01 MODEL EVALUATED IN: THOMAS, S.D., B. ROSS, J.W. MERCER. 1982. A SUMMARY OF REPOSITORY SITING MODELS. NUREG/CR-2782, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

REFERENCES---

01 NELSON, R.W. AND J.A. SCHUR. 1980. PATHS GROUNDWATER HYDROLOGIC MODEL. PNL-3162, BATTELLE PACIFIC NW LABORATORIES, RICHLAND, WA.

02 NELSON, R.W. 1976. EVALUATING THE ENVIRONMENTAL CONSEQUENCES OF GROUNDWATER CONTAMINATION, MANAGEMENT SUMMARY AND TECHNICAL PAPERS. BCSR-6/4C-11, BCS RICHLAND, INC., RICHLAND, WA.

03 NELSON, R.W. 1978. EVALUATING THE ENVIRONMENTAL CONSEQUENCES OF GROUNDWATER CONTAMINATION, 1.- AN OVERVIEW OF CONTAMINANT ARRIVAL DISTRIBUTIONS AS GENERAL EVALUATION REQUIREMENTS. WATER RESOURCES RESEARCH, VOL. 14(3), PP. 409-415.

04 NELSON, R.W. 1978. EVALUATING THE ENVIRONMENTAL CONSEQUENCES OF GROUNDWATER CONTAMINATION, 2.- OBTAINING LOCATION/ARRIVAL TIME AND LOCATION/OUTFLOW QUANTITY DISTRIBVUTIONS FOR STEADY FLOW SYSTEMS. WATER RESOURCES RESEARCH, VOL. 14(3), PP. 416-428.

05 NELSON, R.W. 1978. EVALUATING THE ENVIRONMENTAL CONSEQUENCES OF GROUNDWATER CONTAMINATION, 3.- OBTAINING CONTAMINANT ARRIVAL DISTRIBUTIONS FOR STEADY FLOW IN HETEROGENEOUS SYSTEMS. WATER RESOURCES RESEARCH, VOL. 14(3), PP. 429-440.

06 NELSON, R.W. 1978. EVALUATING THE ENVIRONMENTAL CONSEQUENCES OF GROUNDWATER CONTAMINATION, 4.- OBTAINING AND UTILIZING CONTAMINANT ARRIVAL DISTRIBUTIONS IN TRANSIENT FLOW SYSTEMS. WATER RESOURCES RESEARCH, VOL. 14(3), PP. 441-450.

07 NELSON, R.W. AND J.A. SCHUR. 1978. A PRELIMINARY EVALUATION CAPABILITY FOR SOME TWO-DIMENSIONAL GROUNDWATER CONTAMINATION PROBLEMS. BCSR-38/4C-11, BCS RICHLAND, IN., RICHLAND, WA.

08 ALLENSWORTH, J.A., J.T. FINGER, J.A. MILLOY, W.B. MURFIN, R. RODEMAN AND S.G. VANDEVENDER. 1977. UNDERGROUND SITING OF NUCLEAR POWER PLANTS - POTENTIAL BENEFITS AND PENALTIES. SAND76-0412, SANDIA LABORATORIES, ALBUQUERQUE, NM

IGWMC key= 2560

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MODEL IDENTIFICATION

model name: ISL-50

model purpose: A THREE-DIMENSIONAL ANALYTIC MODEL TO DESCRIBE TRANSIENT FLOW BEHAVIOUR OF LEACHANTS AND GROUNDWATER IN AN ANISOTROPIC, HOMOGENEOUS AQUIFER INVOLVING AN ARBITRARY PATTERN OF INJECTION AND RECOVERY WELLS.

completion date: 1979
last update date: 1979

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -LEAKY -STORAGE IN CONFINING LAYER -ANISOTROPIC -HOMOGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -HEAD DEPENDENT FLUX -NO FLOW -WELLS -SPECIFIED WELL CHARACTERISTICS -CONSTANT PUMPAGE

fluid conditions: -HOMOGENEOUS

model processes:

other model characteristics: -ENGLISH UNITS

equations solved: -RADIAL FLOW EQUATIONS; DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values:	-THICKNESS OF AQUIFER -PERMEABILITY -POROSITY -SPECIFIC WEIGHT
boundary values:	-HEADS OR PRESSURES -PUMPAGE RATES
others:	-INITIAL TIME STEP -ERROR CRITERIA -SCREEEN PENETRATION -COMPRESSIBILITY OF FLUID

MODEL OUTPUT--

tables:	-HEADS OR PRESSURES -VELOCITIES -FRONT BREAKTHROUGH TIME
plotted graphics: <areal maps >	-HEADS -VELOCITIES -STREAMLINES -ISOCHRONES

GEOMETRY OF MODEL--

shape of cell:	-NONE
spatial characteristics: < saturated zone >	-2D HORIZONTAL -3D -CYLINDRICAL OR RADIAL
grid orientation and sizing:	-PLAN OR HORIZONTAL VIEW -AXIAL SYMMETRY

TECHNIQUES---

basic modeling technique:	-ANALYTICAL METHOD
error criteria:	-SUM HEAD CHANGE OVER MODEL BETWEEN ITERATIONS

COMPUTERS USED---

make and model:	CDC 6600 OR BURROUGHS B6700
core storage:	150K (OCTAL)
other requirements:	FOR ADDITIONAL CONTOURING AND STREAMLINE PLOTTING CALCOMP PLOTTER

PROGRAM INFORMATION--

language:	FORTRAN IV
terms of availability of code and user's manual:	PUBLIC DOMAIN; CDC VERSION IN REFERENCE #1. CONTACT AUTHOR FOR BURROUGHS VERSION.

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: DEDICATED
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: UNKNOWN

REMARKS--

01 AN EARLIER AND SIMPLER VERSION OF THIS MODEL IS 5-SISL, PUBLISHED AND DOCUMENTED IN REFERENCE #2.

REFERENCES--

01 SCHMIDT, R.D. 1980. COMPUTER MODELING OF FLUID FLOW DURING PRODUCTION AND ENVIRONMENTAL RESTORATION PHASES OF IN SITU URANIUM LEACHING. RI-8479, BUREAU OF MINES, U.S. DEPT. OF THE INTERIOR, TWIN CITIES, MN.

02 KURTH, D.I. AND R.D. SCHMIDT. 1978. COMPUTER MODELING OF FIVE-SPOT WELL PATTERN FLUID FLOW DURING INSITU URANIUM LEACHING. RI-8287, BUREAU OF MINES, U.S. DEPT. OF INTERIOR, TWIN CITIES, MN.

IGWMC key= **2630**

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MODEL IDENTIFICATION

model name: **AQUIFEM-1**

model purpose: A TWO-DIMENSIONAL, FINITE-ELEMENT MODEL FOR TRANSIENT, HORIZONTAL GROUNDWATER FLOW.

completion date: NOV 1979
last update date: NOV 1979

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -ANISOTROPIC -HETEROGENEOUS -MULTIPLE AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -DIFFERENTIAL EQUATION FOR TWO-DIMENSIONAL GROUND- WATER FLOW IN A NON-HOMOGENEOUS, ANISOTROPIC AQUIFER WITH LEAKAGE.

MODEL INPUT--

areal values:	-ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN CONFINING LAYER
boundary values:	-HEADS OR PRESSURES -FLUXES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES
others:	-NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA

MODEL OUTPUT---

tables:	-AQUIFER GEOMETRY -HEADS OR PRESSURES -FLUXES -VELOCITIES

GEOMETRY OF MODEL--

shape of cell:	-TRIANGULAR
spatial characteristics: < saturated zone >	-2D HORIZONTAL -CYLINDRICAL OR RADIAL
grid orientation and sizing:	-PLAN OR HORIZONTAL VIEW
number of nodes:	-VARIABLE

TECHNIQUES---

basic modeling technique:	-FINITE ELEMENT
equation solving technique:	-STRONGLY IMPLICIT PROCEDURE -CROUT'S METHOD
error criteria:	-SUM HEAD CHANGE OVER MODEL BETWEEN ITERATIONS -MAXIMUM HEAD CHANGE AT ANY ONE NODE

COMPUTERS USED---

make and model:	VAX 11/780, IBM PC
core storage:	VARIABLE
peripherals:	CALCOMP PLOTTER

PROGRAM INFORMATION--

no. of statements:	2350
language:	FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; CODE IS LISTED IN REFERENCE #2

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: $500 - 1,000

MODEL EVALUATION---

USABILITY
- -preprocessor: NO
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: MANY

REMARKS---

01 MICROCOMPUTER VERSION AVAILABLE FROM ALFREDO URZUA, 63 FRANKLIN ROAD, WINCHESTER, MA. 01830

REFERENCES--

01 WILSON, J.L., L.R. TOWNLEY AND A.S. DA COSTA. 1979. MATHEMATICAL DEVELOPMENT AND VERIFICATION OF A FINITE-ELEMENT AQUIFER FLOW MODEL AQUIFEM-1. TECHN. REPT. 248, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASSACHUSETTS.

02 TOWNLEY, L.R. AND J.L. WILSON. 1980. DESCRIPTION OF A USER'S MANUAL FOR A FINITE-ELEMENT AQUIFER FLOW MODEL AQUIFEM-1. TECHN. REPT. 252, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASSACHUSETTES.

IGWMC key= 2690

MODEL TEAM

author name(s): PRICKETT, T.A., T.G. NAYMIK AND C.G. LONNQUIST

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MODEL IDENTIFICATION

model name: **RANDOM WALK**

model purpose: A FINITE DIFFERENCE MODEL TO SIMULATE ONE- OR TWO-DIMENSIONAL STEADY OR UNSTEADY FLOW AND TRANSPORT PROBLEMS IN HETEROGENEOUS AQUIFERS UNDER WATER TABLE AND/OR ARTESIAN OR LEAKY ARTESIAN CONDITIONS. A RANDOM WALK APPROACH IS USED TO SIMULATE DISPERSION.

completion date: JUL 1981
last update date: JUL 1981

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -AQUITARD -LEAKY -ANISOTROPIC -HETEROGENEOUS -CHANGING AQUIFER CONDITIONS IN TIME -CHANGING AQUIFER CONDITIONS IN SPACE

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -WELL CHARACTERISTICS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -SOURCES - PRESCRIBED CONCENTRATION

fluid conditions: -HOMOGENEOUS

model processes: -EVAPOTRANSPIRATION -CONVECTION -DISPERSION -RANDOM MOVEMENT -ADSORPTION -DECAY

other model characteristics: -ENGLISH UNITS
equations solved: -UNSTEADY 2-D FLOW, DISPERSION BY STATISTICAL METHODS

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -DISPERSIVITY

boundary values: -HEADS OR PRESSURES -FLUXES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -PRESCRIBED CONCENTRATIONS

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -DISPERSIVITY -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

number of nodes: -VARIABLE

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE -RANDOM WALK

equation solving technique: -ITERATIVE ALTERNATING DIRECTION -PARTICLE IN A CELL
error criteria: -SUM HEAD CHANGE OVER MODEL BETWEEN ITERATIONS

COMPUTERS USED---

make and model: CDC CYBER 175, VAX 11/780, IBM/PC/XT/AT

core storage: 256K

PROGRAM INFORMATION --

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM CODE LISTED IN REFERENCE #1 SEE ALSO REMARK #2 FOR ADDRESS

available code form: -MAGNETIC TAPE -PRINTED LISTING -DISKETTES

cost: $95 from IGWMC

MODEL EVALUATION--

USABILITY
- -preprocessor: YES
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: LIMITED

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REMARKS--

01 MAINFRAME AND VARIOUS MICROCOMPUTER VERSIONS ARE AVAILABLE FROM IGWMC.

02 CODE IS ALSO AVAILABLE FROM:
BOB SINCLAIR, DIR. OF COMPUTER SERVICE
ILLINIOS STATE WATER SURVEY
BOX 5050 STATION A
CHAMPAIGN, IL 61820
TELEPHONE: (217) 333-4952

03 A MODIFIED VERSION OF PLASM AND RANDOM WALK TO ANALYZE HYDROLOGIC IMPACTS OF MINING IS DOCUMENTED IN REF. NO. 5. PROGRAM CODES ARE AVAILABLE THROUGH BOEING COMPUTER NETWORK

REFERENCES---

01 PRICKETT, T.A., T.G. NAYMIK AND C.G. LONNQUIST. 1981. A RANDOM-WALK SOLUTE TRANSPORT MODEL FOR SELECTED GROUNDWATER QUALITY EVALUATIONS. BULLETIN 65, ILLINOIS STATE WATER SURVEY, CHAMPAIGN, ILL.

02 PRICKETT, T.A. AND C.G. LONNQUIST. 1971. SELECTED DIGITAL COMPUTER TECHNIQUES FOR GROUNDWATER RESOURCE EVALUATION. BULLETIN 55, ILLINOIS STATE WATER SURVEY, CHAMPAIGN, ILL.

03 NAYMIK, T.G. AND M.J. BARCELONA. 1981. CHARACTERIZATION OF A CONTAMINANT PLUME IN GROUNDWATER, MEREDESIA, ILLINOIS. GROUNDWATER, VOL. 19(5): PP. 517-526.

04 NAYMIK, T.G. AND M.E. SIEVERS. 1983. GROUNDWATER TRACER EXPERIMENT (II) AT SAND RIDGE STATE FOREST, ILLINOIS. STATE WATER SURVEY DIVISION. REPORT 334, ILLINOIS DEPT. OF ENERGY AND NATURAL RESOURCES, CHAMPAIGN, ILLINOIS, PP. 1-105.

05 OFFICE OF SURFACE MINING. 1981. GROUND WATER MODEL HANDBOOK. H-D3004-021-81-1062D, U.S. DEPT. OF THE INTERIOR, DENVER, CO.

IGWMC key= 2740

MODEL TEAM

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MODEL IDENTIFICATION

model name: **NMFD3D**

model purpose: A FINITE DIFFERENCE MODEL FOR SIMULATION OF UNSTEADY TWO-DIMENSIONAL HORIZONTAL OR THREE-DIMENSIONAL SATURATED GROUND WATER FLOW IN MULTI-LAYERED HETEROGENEOUS ANISOTROPIC AQUIFER SYSTEMS.

completion date: MAR 1980
last update date: MAR 1980

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -STORAGE IN CONFINING LAYER -ANISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN CONFINING LAYER -HYDRAULIC RESISTANCE IN RIVER BED AND LAKE BED

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -INITIAL TIME STEP -ERROR CRITERIA -ANISOTROPY FACTORS -FLOW INTO RIVER BRANCHES FROM OUTSIDE MODEL -ITERATION PARAMETERS -NUMBER OF LAYERS

MODEL OUTPUT--

tables: -HEADS OR PRESSURES -WATER BALANCE

plotted graphics:
<areal maps > -HEADS

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics:
< saturated zone > -2D HORIZONTAL -3D

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW - THREE-DIMENSIONAL

number of nodes: -RANGES FROM 100 TO 10,000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -STRONGLY IMPLICIT PROCEDURE

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE

COMPUTERS USED---

make and model: CDC CYBER 7600 & 176, CRAY-1

PROGRAM INFORMATION--

no. of statements: 10,000

language: FORTRAN IV, FLECS

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION---

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: UNKNOWN

REMARKS--

01 THIS PROGRAM CODE IS HEAVELY MACHINE-DEPENDENT.

02 THIS PROGRAM IS AN EXTENSIVELY MODIFIED VERSION OF THE TWO-DIMENSIONAL FLOW MODEL OF TRESCOTT ET AL. (1976), AND THE THREE-DIMENSIONAL FLOW MODEL OF TRESCOTT AND LARSON (1975).

03 AN EXPANDED AND UPDATED VERSION OF THIS MODEL HAS BEEN PUBLISHED IN REF.# 2. CHANGES AS OF JANUARY 1981 INCLUDE (1) TREATMENT OF HEAD-DEPENDANT BOUNDARIES AND SPECIFIED FLOW BOUNDARIES, AND (2) CODE WHICH EXECUTES ON THE CRAY-1 VECTOR COMPUTER. REFERENCE #2 PROVIDES INSTRUCTIONS FOR COMPILING AND EXECUTING THE COMPUTER PROGRAM ON A CRAY-1.

REFERENCES---

01 POSSON, D.R., G.A. HEARNE, J.V. TRACY, AND P.F. FRENZEL. 1980. A COMPUTER PROGRAM FOR SIMULATING GEOHYDROLOGIC SYSTEMS IN THREE DIMENSIONS. U.S. GEOLOGICAL SURVEY, OPEN FILE REPT., 80-421.

02 HEARNE, G.A. 1982. SUPPLEMENT TO THE NEW MEXICO THREE-DIMENSIONAL MODEL (SUPPLEMENT TO OPEN FILE REP. 80-421). OPEN-FILE REP. 82-857, U.S GEOL. SURVEY, ALBUQUERQUE, NEW MEXICO, 90P.

IGWMC key= 2800

MODEL TEAM

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MODEL IDENTIFICATION

model name: SGMP

model purpose: AN INTEGRAL FINITE DIFFERENCE MODEL FOR SIMULATING STEADY-STATE OR TRANSIENT, TWO- DIMENSIONAL, HORIZONTAL FLOW IN A SATURATED, ANISOTROPIC AND HETEROGENEOUS, CONFINED/SEMI-CONFINED/PHREATIC AQUIFER SYSTEM

completion date: JUN 1981
last update date: JUN 1981

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -STORAGE IN CONFINING LAYER -DELAYED YIELD FROM STORAGE -ANISOTROPIC -HETEROGENEOUS -TWO OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -INFILTRATION -GROUNDWATER RECHARGE -WELLS -WELL CHARACTERISTICS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -DRAINAGE LEVELS

fluid conditions: -HOMOGENEOUS

other model characteristics: -METRIC UNITS

equations solved: -DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -STORAGE COEFFICIENT -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN CONFINING LAYER

boundary values: -HEADS OR PRESSURES -FLUXES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -ERROR CRITERIA

MODEL OUTPUT---

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -PRECIPITATION -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -ARTIFICIAL RECHARGE RATES -GROUND WATER RECHARGE RATES

plotted graphics:
<time series> -HEADS

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR -POLYGON

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

number of nodes: -VARIABLE

TECHNIQUES---

basic modeling technique: -INTEGRAL FINITE DIFFERENCE

equation solving technique: -GAUSS-SEIDEL OR POINT SUCCESSIVE OVER RELAXATION -GAUSS ELIMINATION

error criteria: -WATER BALANCE OVER MODEL

COMPUTERS USED---

make and model: CDC, IBM, HP, PDP

core storage: 7K (71 NODES)

PROGRAM INFORMATION--

no. of statements: 672 (TOTAL- PROGRAM IN 4 PARTS)

language: FORTRAN IV (BASIC UNDER PREPARATION)

terms of availability of code and user's manual: PROGRAM DOMAIN; PROGRAM CODE AND DOCUMENTATION PUBLISHED IN REFERENCE #1; TWO-LAYERED VERSION AVAILABLE FROM AUTHOR

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: < $100

MODEL EVALUATION---

USABILITY
- -preprocessor: NO
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: FEW

REFERENCES---

01 BOONSTRA, J. AND N.A. DE RIDDER. 1981. NUMERICAL MODELLING OF GROUNDWATER BASINS - A USER MANUAL, ILRI PUBLICATION NO. 29, INTERN. INST. LAND RECLAMATION AND IMPROVEMENT, WAGENINGEN, THE NETHERLANDS, 250 PP.

IGWMC key= 2870

MODEL TEAM

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MODEL IDENTIFICATION

model name: DISIFLAQ (DIGITAL SIMULATION OF FLOW THROUGH A TWO-LAYERED AQUIFER SYSTEM)

model purpose: A FINITE DIFFERENCE MODEL FOR STEADY-STATE OR TRANSIENT SIMULATION OF TWO-DIMENSIONAL, HORIZONTAL GROUNDWATER FLOW IN A TWO-LAYERED, ISOTROPIC, HETEROGENEOUS AQUIFER SYSTEM.

completion date: 1963
last update date: 1980

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -ISOTROPIC -HETEROGENEOUS -TWO OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -MOVABLE EXTERNAL BOUNDARY -INFILTRATION -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

other model characteristics: -METRIC UNITS

MODEL INPUT---

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -STORAGE COEFFICIENT -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN CONFINING LAYER -HYDRAULIC RESISTANCE IN RIVER BED AND LAKE BED

boundary values: -HEADS OR PRESSURES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -NUMBER OF POLYGONS

MODEL OUTPUT--

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -FLUXES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -ARTIFICIAL RECHARGE RATES -GROUND WATER RECHARGE RATES

plotted graphics:
<areal maps > -HEADS

GEOMETRY OF MODEL---

shape of cell: -SQUARE -RECTANGULAR -TRIANGULAR -POLYGON

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -VARIABLE SIZE GRID

number of nodes: -VARIABLE 1000

TECHNIQUES--

basic modeling technique: -FINITE DIFFERENCE -TYSON AND WEBER FORMULATION

equation solving technique: -GAUSS-SEIDEL OR POINT SUCCESSIVE OVER RELAXATION

error criteria: -WATER BALANCE OVER MODEL

COMPUTERS USED--

make and model: IBM 370/148

core storage: 256K
mass storage: 200K

PROGRAM INFORMATION--

no. of statements: 2428

language: FORTRAN

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM CODE AND DOCUMENTATION PUBLISHED IN REFERENCE #1.

available code form: -PRINTED LISTING -MAGNETIC TAPE

cost: UNKNOWN

MODEL EVALUATION---

USABILITY
- -preprocessor: NO
- -postprocessor: NO
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: MANY

REMARKS--

01 PREVIOUS VERSIONS HAVE BEEN USED IN MANY COUNTRIES BY FAO STAFF AND CONSULTANTS. TO NAME A FEW: IRAN, CYPRUS, GREECE, JAMAICA, PHILIPPINES, EGYPT, LIBYA, SPAIN, ROMANIA, AND LEBANON.

REFERENCES---

01 BERNEY, O. 1981. DIGITAL SIMULATION OF FLOW THROUGH TWO-LAYERED AQUIFER SYSTEMS - DISIFLAQ, USER ORIENTED PROGRAMME PACKAGE. LAND AND WATER DEVELOPMENT DIVISION, FAO, ROME, ITALY

IGWMC key= **2982**

MODEL TEAM--

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phone: (0)/5274-2922

MODEL IDENTIFICATION---

model name: **GROWKWA**

model purpose: A COMBINED FINITE DIFFERENCE AND FINITE ELEMENT MODEL FOR TRANSIENT SIMULATION OF TWO-DIMENSIONAL HORIZONTAL GROUNDWATER MOVEMENT AND NON-CONSERVATIVE SOLUTE TRANSPORT IN A MULTI-LAYERED, ANISOTROPIC, HETEROGENEOUS AQUIFER SYSTEM.

completion date: 1982
last update date: 1982

MODEL CHARACTERISTICS--

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -ANISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -TIDAL FLUCTUATIONS -INFILTRATION -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -CONCENTRATION -SOLUTE FLUXES

fluid conditions: -HOMOGENEOUS

model processes: -PRECIPITATION -EVAPOTRANSPIRATION -CONVECTION -DISPERSION -DIFFUSION -ADSORPTION -ABSORPTION -ION EXCHANGE -DECAY -REACTIONS

other model characteristics: -METRIC UNITS

equations solved: -FLOW AND MASS TRANSPORT EQUATIONS FOR NONCONSERVATIVE SOLUTE

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD -DIFFUSIVITY -HYDRAULIC RESISTANCE IN CONFINING LAYER -DISPERSIVITY -DECAY RATE -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -GROUND WATER RECHARGE RATES -CONCENTRATIONS -SOLUTE FLUXES

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS

MODEL OUTPUT---

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -FLUXES -VELOCITIES -DIFFUSIVITY -HYDRAULIC RESISTANCE IN CONFINING LAYER -DISPERSIVITY -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD -CONCENTRATIONS OF WATER CONSTITUENTS -PRECIPITATION -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -ARTIFICIAL RECHARGE RATES -GROUND WATER RECHARGE RATES

plotted graphics:
<areal maps > -HEADS -FLUXES -VELOCITIES -CONCENTRATIONS

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR -LINEAR -ISOPARAMETRIC QUADRILATERAL

spatial characteristics:
< saturated zone > -2D HORIZONTAL -2D VERTICAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL VIEW

number of nodes: -VARIABLE

TECHNIQUES--

basic modeling technique: -FINITE DIFFERENCE -FINITE ELEMENT

equation solving technique: -GAUSS ELIMINATION -CHOLESKY SQUARE ROOT -DOOLITTLE -WEIGHTED RESIDUALS -PREDICTOR CORRECTOR -CRANK NICHOLSON

COMPUTERS USED--

make and model: CYBER 176

core storage: 38,000 CYBER WORDS

PROGRAM INFORMATION---

no. of statements: 5000

language: FORTRAN IV

terms of availability of code and user's manual: PROPRIETARY; TO BE NEGOTIATED

available code form: -MAGNETIC TAPE

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: UNKNOWN

IGWMC key= 3220

MODEL TEAM

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MODEL IDENTIFICATION

model name: GEOFLOW

model purpose: A FINITE ELEMENT MODEL TO STIMULATE STEADY OR NONSTEADY, TWO-DIMENSIONAL AREAL FLOW AND MASS TRANSPORT IN ANISOTROPIC AND HETEROGENEOUS AQUIFERS UNDER CONFINED, LEAKY CONFINED, OR WATER TABLE CONDITIONS.

completion date: AUG 1982
last update date: AUG 1982

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -ANISOTROPIC -HETEROGENEOUS -CHANGING AQUIFER CONDITIONS IN TIME

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -INFILTRATION -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -RESTART CAPABILITY PERMITS ANY VARIATION -CONCENTRATIONS

fluid conditions: -HOMOGENEOUS

model processes: -CONVECTION -DISPERSION -DIFFUSION -DECAY -REACTIONS -RETARDATION

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -FLOW AND MASS TRANSPORT EQUATIONS FOR NONCONSERVATIVE SOLUTE

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD -DIFFUSIVITY -HYDRAULIC RESISTANCE IN CONFINING LAYER -HYDRAULIC RESISTANCE IN RIVER BED AND LAKE BED -DISPERSIVITY -DECAY RATE -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -GROUND WATER RECHARGE RATES -CONCENTRATIONS -SOLUTE FLUXES

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -RETARDATION FACTORS

MODEL OUTPUT---

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -VELOCITIES -CONCENTRATIONS OF WATER CONSTITUENTS

plotted graphics:
<areal maps > -HEADS -VELOCITIES -CONCENTRATIONS -SATURATED THICKNESS -RETARDATION FACTOR

GEOMETRY OF MODEL--

shape of cell: -ISOPARAMETRIC QUADRILATERAL

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -VARIABLE SIZE GRID

number of nodes: -RANGES FROM 1000 TO 10,000

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS ELIMINATION

COMPUTERS USED---

make and model: PRIME 750

core storage: 5MB @ REV 3.1 DIMENS.

mass storage: VARIES DEPENDING ON OUTPUT.

PROGRAM INFORMATION--

no. of statements: 5000 IN MAIN PROGRAM

language: FORTRAN IV

terms of availability of code and user's manual: PROPRIETARY

available code form: MAGNETIC TAPE

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: MANY

REFERENCES--

01 HAJI-DJAFARI, S. 1976. TWO-DIMENSIONAL FINITE ELEMENT ANALYSIS OF TRANSIENT FLOW AND TRACER MOVEMENT IN CONFINED AND PHREATIC AQUIFERS. PH.D. THESIS, MICHIGAN STATE UNIV.

02 HAJI-DJAFARI, S. 1983. USER'S MANUAL GEOFLOW GROUND WATER FLOW AND MASS TRANSPORT COMPUTER PROGRAM. D'APPOLONIA, PITTSBURG, PA.

03 HAJI-DJAFARI, S., P.E. ANTOMMARIA, AND H.L. CROUSE. 1981. ATTENUATION OF RADIONUCLIDES AND TOXIC ELEMENTS BY IN SITU SOILS AT A URANIUM TAILINGS POND IN CENTRAL WYOMING, PERMEABILITY AND GROUNDWATER CONTAMINANT TRANSPORT. ASTM STP 746, T.F. ZIMMIE AND C.O. RIGGS, EDS., AMERICAN SOC. FOR TESTING AND MATERIALS, PP. 221-242.

IGWMC key= 3230

MODEL TEAM

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MODEL IDENTIFICATION

model name: AQUIFER

model purpose: A FINITE DIFFERENCE MODEL FOR ANALYSIS OF STEADY-STATE AND TRANSIENT TWO-DIMENSIONAL AREAL, CROSS-SECTIONAL, OR RADIAL FLOW IN HETEROGENEOUS, ANISOTROPIC MULTI-AQUIFER SYSTEMS.

completion date: APR 1982
last update date: APR 1982

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -ANISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -FREE SURFACE -SEEPAGE SURFACE -TIDAL FLUCTUATIONS -INFILTRATION -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD

boundary values: -HEADS OR PRESSURES -FLUXES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA

MODEL OUTPUT---

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -FLUXES -VELOCITIES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -ARTIFICIAL RECHARGE RATES -GROUND WATER RECHARGE RATES

plotted graphics:
<areal maps > -HEADS -FLUXES -VELOCITIES -STREAMLINES

GEOMETRY OF MODEL--

shape of cell: -RECTANGULAR

spatial characteristics:
< saturated zone > -2D HORIZONTAL -2D VERTICAL -CYLINDRICAL OR RADIAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY -VARIABLE SIZE GRID

number of nodes: -VARIABLE

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -GAUSS-SEIDEL OR POINT SUCCESSIVE OVER RELAXATION

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE

COMPUTERS USED---

make and model: CRAY, PRIME & MICRO

PROGRAM INFORMATION--

no. of statements: 2000

language: FORTRAN 77

available code form: MAGNETIC TAPE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION---

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: UNKNOWN

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: UNKNOWN

IGWMC key= 3232

MODEL TEAM

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MODEL IDENTIFICATION

model name: **FRACFLOW**

model purpose: AN INTEGRATED FINITE DIFFERENCE MODEL TO SIMULATE STEADY AND UNSTEADY STATE ANALYSIS OF DENSITY-DEPENDENT FLOW, HEAT AND MASS TRANSPORT IN FRACTURED CONFINED AQUIFERS SIMULATING TWO-DIMENSIONALLY THE PROCESSES IN THE POROUS MEDIUM AND ONE-DIMENSIONALLY IN THE FRACTURES, INCLUDING TIME-DEPENDENCY OF PROPERTIES

completion date: OCT 1981
last update date: OCT 1981

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -AQUITARD -LEAKY -STORAGE IN CONFINING LAYER -ANISOTROPIC -HETEROGENEOUS -DISCRETE FRACTURES -DUAL POROSITY FRACTURE SYSTEM -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -CONCENTRATIONS

fluid conditions: -HETEROGENEOUS -TEMPERATURE DEPENDENT -VARIABLE DENSITY

model processes: -CONVECTION -CONDUCTION -DISPERSION -DIFFUSION -CONSOLIDATION -ADSORPTION -DECAY -REACTIONS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -COUPLED 2-D EQUATIONS FOR FLOW, AND HEAT AND MASS TRANSPORT IN POROUS MEDIA AND DYNAMICALLY LINKED 1-D EQUATIONS FOR FLOW AND TRANSPORT IN PLANAR FRACTURES

MODEL INPUT---

areal values: -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD -DISPERSIVITY -THERMAL CONDUCTIVITY -THERMAL CAPACITY -SPECIFIC HEAT -TEMPERATURE -FLUID DENSITY -DECAY RATE

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -NUMBER OF TIME INCREMENTS -SIZE AND ORIENTATION OF FRACTURES IN THE FORM OF COORDINATES OF THE BEGINNING AND END POINTS OF THE FRACTURES -USER OUTPUT REQUIREMENTS

MODEL OUTPUT--

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -FLUXES -VELOCITIES -DISPERSIVITY -THERMAL CONDUCTIVITY -TEMPERATURE -FLUID DENSITY -PERMEABILITY -STORAGE COEFFICIENT -CONCENTRATIONS OF WATER CONSTITUENTS -PUMPAGE RATES -ARTIFICIAL RECHARGE RATES -STREAM FUNCTION

plotted graphics:
<areal maps > -HEADS -FLUXES -VELOCITIES -TEMPERATURE -CONCENTRATIONS -STREAMLINES -ISOCHRONES

GEOMETRY OF MODEL---

shape of cell: -RECTANGULAR

spatial characteristics:
< saturated zone > -2D HORIZONTAL -2D VERTICAL -CYLINDRICAL OR RADIAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY -VARIABLE SIZE GRID

number of nodes: -VARIABLE

TECHNIQUES---

basic modeling technique: -INTEGRATED FINITE DIFFERENCE METHOD

equation solving technique: -GAUSS-SEIDEL OR POINT SUCCESSIVE OVER RELAXATION
-ALTERNATING DIRECTION -IMPLICIT

error criteria: -SUM HEAD CHANGE OVER MODEL BETWEEN ITERATIONS

COMPUTERS USED---

make and model: CRAY, UNIVAC, PRIME, MICRO/CPM BASED

core storage: 140K FOR 2500 NODES

PROGRAM INFORMATION--

no. of statements: 3500

language: FORTRAN 77

terms of availability of code and user's manual: PROPRIETARY

available code form: MAGNETIC TAPE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION---

USABILITY
- -preprocessor: YES
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
  - -model users: FEW

REFERENCES---

01 FRACFLOW: A MODEL FOR SIMULATING FLOW, HEAT AND MASS TRANSPORT IN FRACTURED MEDIA. 1981 ACRI, LOS ANGELES

IGWMC key= **3233**

MODEL TEAM

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MODEL IDENTIFICATION

model name: **PORFLOW- II AND III**

model purpose: AN INTEGRATED FINITE DIFFERENCE MODEL TO SIMULATE STEADY OR TRANSIENT, 2-D HORIZONTAL, VERTICAL OR RADIAL AND 3-D SIMULATION OF DENSITY DEPENDENT FLOW HEAT AND MASS TRANSPORT IN ANISOTROPIC, HETEROGENEOUS, NON-DEFORMABLE SATURATED POROUS MEDIA WITH TIME DEPENDENT AQUIFER AND FLUID PROPERTIES. MODEL ALLOWS FOR PHASE CHANGE, COMPRESSIBLE FLUIDS, AND 3-PHASES (WATER, STEAM, AIR).

completion date: 1979
last update date: 1987

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -AQUITARD -LEAKY -STORAGE IN CONFINING LAYER -ANISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS -CHANGING AQUIFER CONDITIONS IN TIME (PERMEABILITY, THERMAL PROPERTIES, FLUID PROPERTIES)

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -TIDAL FLUCTUATIONS -GROUNDWATER RECHARGE -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HETEROGENEOUS -SALT WATER/FRESH WATER INTERFACE -STEAM/WATER INTERFACE -TEMPERATURE DEPENDENT -COMPRESSIBLE -VARIABLE DENSITY model processes: -CONVECTION -CONDUCTION -DISPERSION -DIFFUSION -CHANGE OF PHASE -ADSORPTION -DECAY -REACTIONS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -TWO- OR THREE-DIMENSIONAL DYNAMICAL COUPLED EQUATIONS OF FLOW, HEAT AND MASS TRANSPORT IN POROUS MEDIA WITH PHASE CHANGE EQUATIONS

MODEL INPUT--

areal values: -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -POROSITY -STORAGE COEFFICIENT -DISPERSIVITY -THERMAL CONDUCTIVITY -THERMAL CAPACITY -SPECIFIC HEAT -TEMPERATURE -FLUID DENSITY -DECAY RATE -INITIAL QUALITY -EQUATION OF STATE

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -TEMPERATURE -SATURATION

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS

MODEL OUTPUT---

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -FLUXES -VELOCITIES -THERMAL CONDUCTIVITY -TEMPERATURE -FLUID DENSITY -CONCENTRATIONS OF WATER CONSTITUENTS

plotted graphics:

<time series> -HEADS -FLUXES -VELOCITIES -TEMPERATURE -CONCENTRATIONS

<areal maps > -HEADS -FLUXES -VELOCITIES -TEMPERATURE -CONCENTRATIONS

<surface maps> -3-D SURFACE REPRESENTATION OF STATE VARIABLES

GEOMETRY OF MODEL--

shape of cell: -RECTANGULAR OR ARC SEGMENT, TRIANGULAR

spatial characteristics:

< saturated zone > -2D HORIZONTAL -2D VERTICAL -3D -CYLINDRICAL OR RADIAL

<unsaturated zone>

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY -VARIABLE SIZE GRID

number of nodes: -VARIABLE

TECHNIQUES--

basic modeling technique: -INTEGRATED FINITE DIFFERENCE METHOD (NODAL POINT INTEGRATION)

equation solving technique: -ALTERNATING DIRECTION -IMPLICIT/SOR/CHOLESKY

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE

COMPUTERS USED--

make and model: CRAY, PRIME, UNIVAC, VAX, MICRO

core storage: VARIABLE

PROGRAM INFORMATION---

no. of statements: 2800

language: FORTRAN 77

terms of availability of code and user's manual: PROPRIETARY AND PUBLIC DOMAIN VERSIONS

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: YES
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REMARKS---

01 THIS CODE HAS BEEN USED EXTENSIVELY IN REAL LIFE PROBLEM SOLVING. A VERSION OF THIS MODEL IS BEING USED CONTINUOUSLY TO SIMULATE THE NEAR-FIELD BEHAVIOR OF HIGH LEVEL NUCLEAR WASTE REPOSITORY IN BASALT.

02 OPTIONAL COUPLING WITH A THERMO-MECHANICAL STRESS MODEL

03 A PUBLIC DOMAIN VERSION IS AVAILABLE FROM ROCKWELL HANFORD OPERATIONS, ENERGY SYSTEMS GROUP, RICHLAND, WA.

REFERENCES--

01 PORFLOW: A SERIES OF POROUS MEDIA MODELS TO SIMULATE COUPLED FLOW, HEAT AND MASS TRANSPORT. BROCHURE ACRI.

02 EYLER, L.L. AND M.J. BUDDEN. 1984. VERIFICATION AND BENCHMARKING OF PORFLO: AN EQUIVALENT POROUS CONTINUUM CODE FOR REPOSITORY SCALE ANALYSIS. BASALT WASTE ISOLATION PROJECT. PNL-5044. PACIFIC NORTHWEST LABORATORY. RICHLAND, WA.

03 KLINE, N.W., A.K. RUNCHAL, R.G. BACA. 1983. PORFLO COMPUTER CODE: USERS GUIDE. RHO-BW-CR-138P. ROCKWELL HANFORD OPERATIONS. RICHLAND, WA.

04 RUNCHAL, A.K. 1981. AN EQUIVALENT CONTINUUM MODEL FOR FLUID FLOW, HEAT AND MASS TRANSPORT IN GEOLOGIC MATERIALS. ASME PUBL. 81-HT-54. NEW YORK, NY.

05 RUNCHAL, A., B. SAGAR, R.G. BACA, N.W. KLINE. PORFLOW - A CONTINUUM MODEL FOR FLUID FLOW, HEAT TRANSFER, AND MASS TRANSPORT IN POROUS MEDIA. RHO-BW-CR-150P. ROCKWELL HANFORD OPERATIONS. RICHLAND, WA.

06 RUNCHAL, A.K. 1985. PORFLOW: A GENERAL PURPOSE MODEL FOR FLUID FLOW, HEAT TRANSFER AND MASS TRANSPORT IN ANISOTROPIC, INHOMOGENEOUS, EQUIVALENT POROUS MEDIA, VOLUME I: THEORY, VOLUME II: USER'S MANUAL. ACRI/TN-011. ANALYTIC AND COMPUTATIONAL RESEARCH, INC. WEST LOS ANGELES, CA.

07 RUNCHAL, A.K. 1985. THEORY AND APPLICATION OF THE PORFLOW MODEL FOR ANALYSIS OF COUPLED FLOW, HEAT AND RADIONUCLIDE TRANSPORT IN POROUS MEDIA. PROCEEDINGS, INTERNATIONAL SYMPOSIUM ON COUPLED PROCESSESS AFFECTING THE PERFORMANCE OF A NUCLEAR WASTE REPOSITORY, BERKELEY, CA.

IGWMC key= **3235**

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MODEL IDENTIFICATION

model name: **FLOTRA**

model purpose: AN INTEGRATED FINITE DIFFERENCE MODEL TO SIMULATE STEADY OR TRANSIENT, TWO-DIMENSIONAL, AREAL, CROSS-SECTIONAL OR RADIAL SIMULATION OF DENSITY-DEPENDENT FLOW, HEAT AND MASS TRANSPORT IN VARIABLY SATURATED, ANISOTROPIC, HETEROGENEOUS DEFORMABLE POROUS MEDIA

completion date: DEC 1981
last update date: FEB 1982

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -AQUITARD -LEAKY -STORAGE IN CONFINING LAYER -ANISOTROPIC -HETEROGENEOUS -AQUIFER SYSTEM DEFORMATION -AQUIFER COMPACTION -MANY OVERLYING AQUIFERS -CHANGING AQUIFER CONDITIONS IN TIME (POROSITY, PERMEABILITY, STORATIVITY, THERMAL CONDUCTIVITY, FLUID DENSITY, DISPERSION COEFICIENT) -CHANGING AQUIFER CONDITIONS IN SPACE (ALL HYDRAULIC, THERMAL AND MASS TRANSPORT PROPERTIES EXCEPT FLUID DENSITY)

flow conditions: -STEADY -UNSTEADY -SATURATED -UNSATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -NO FLOW -MOVABLE EXTERNAL BOUNDARY -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE fluid conditions: -HETEROGENEOUS -TEMPERATURE DEPENDENT -COMPRESSIBLE -VARIABLE DENSITY

model processes: -CONVECTION -CONDUCTION -DISPERSION -DIFFUSION -CONSOLIDATION -ADSORPTION -DECAY -REACTIONS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -COUPLED EQUATIONS FOR FLOW, AND HEAT AND MASS TRANSPORT IN EULERIAN CORDINATES -DEFORMATION EQUATION IN LAGRANGIAN COORDINATES

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -POROSITY -STORAGE COEFFICIENT -DISPERSIVITY -THERMAL CONDUCTIVITY -THERMAL CAPACITY -SPECIFIC HEAT -TEMPERATURE -FLUID DENSITY -DECAY RATE -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -NUMBER OF TIME INCREMENTS -REQUIRED OUTPUT

MODEL OUTPUT---

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -FLUXES -VELOCITIES -DIFFUSIVITY -DISPERSIVITY -THERMAL CONDUCTIVITY -TEMPERATURE -FLUID DENSITY -PERMEABILITY -STORAGE COEFFICIENT -SPECIFIC YIELD -CONCENTRATIONS OF WATER CONSTITUENTS

plotted graphics:

<time series> -HEADS -FLUXES -VELOCITIES -TEMPERATURE -CONCENTRATIONS -POROSITIES -PERMEABILITIES

<areal maps > -HEADS -FLUXES -VELOCITIES -TEMPERATURE -CONCENTRATIONS -POROSITIES -STREAMLINES -ISOCHRONES -PERMEABILITIES

GEOMETRY OF MODEL--

shape of cell: -RECTANGULAR

spatial characteristics:

< saturated zone > -2D HORIZONTAL -CYLINDRICAL OR RADIAL

<unsaturated zone> -2D HORIZONTAL -2D VERTICAL -CYLINDRICAL OR RADIAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY -VARIABLE SIZE GRID -MOVABLE GRID

number of nodes: -VARIABLE

TECHNIQUES--

basic modeling technique: -INTEGRATED FINITE DIFFERENCE METHOD (NODAL POINT INTEGRATION)

equation solving technique: -GAUSS-SEIDEL OR POINT SUCCESSIVE OVER RELAXATION -ALTERNATING DIRECTION -IMPLICIT

error criteria: -MAXIMUM HEAD CHANGE AT ANY ONE NODE

COMPUTERS USED--

make and model: CRAY, UNIVAC, PRIME, MICRO/CPM

core storage: 120K FOR 2500 NODES

PROGRAM INFORMATION---

no. of statements: 3000

language: FORTRAN 77

terms of availability of code and user's manual: PROPRIETARY

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
  - -model users: UNKNOWN

IGWMC key= **3240**

MODEL TEAM

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MODEL IDENTIFICATION

model name: **GM5**

model purpose: A BOUNDARY INTEGRAL EQUATION MODEL TO SIMULATE STEADY STATE THREE DIMENSIONAL SATURATED GROUNDWATER FLOW IN AN ANISOTROPIC, HETEROGENEOUS MULTI-AQUIFER SYSTEM.

completion date: AUG 1982
last update date: SEP 1982

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -AQUITARD -LEAKY -ANISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS -CHANGING AQUIFER CONDITIONS IN SPACE

flow conditions: -STEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE

fluid conditions: -HETEROGENEOUS -

equations solved: -LAPLACE EQUATION, MODIFIED HELMHOLTZ EQUATION

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -DIFFUSIVITY

boundary values: -HEADS OR PRESSURES -FLUXES -GROUND WATER RECHARGE RATES

others: -BOUNDARY NODES

MODEL OUTPUT---

tables: -AQUIFER GEOMETRY -HEADS OR PRESSURES -VELOCITIES

GEOMETRY OF MODEL--

shape of cell: -NONE

spatial characteristics: < saturated zone > -2D HORIZONTAL -2D VERTICAL -3D

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW

number of nodes: -VARIABLE

TECHNIQUES---

basic modeling technique: -BOUNDARY INTEGRAL EQUATION METHOD

equation solving technique: -GAUSS ELIMINATION

COMPUTERS USED---

make and model: CDC CYBER, IBM 370

core storage: VARIABLE

PROGRAM INFORMATION--

language: FORTRAN

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: NO
- -postprocessor: NO
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: NO

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: NO
- -verified: NO
- -field validation: NO
- -model users: FEW

REMARKS---

01 THREE RELATED PROGRAMS ARE PUBLISHED IN REFERENCE #02. 'GM8' SOLVES THE LAPLACE EQUATION IN A CLOSED REGION WITH EITHER NEUMANN OR DIRICHLET TYPE BOUNDARY CONDITIONS OR A MIXTURE OF BOTH. 'GM9' IS AN EXTENSION OF 'GM8' ALLOWING INSERTION OF SPECIAL ELEMENTS. 'DAM' CALCULATES UNSTEADY, FREE SURFACE FLOW THROUGH AN EARTH DIKE OF CONSTANT PERMEABILITY.

02 PRIMARILY A RESEARCH MODEL WITH INEFFICIENT CODING; DRAFT USER'S MANUAL AVAILABLE

REFERENCES--

01 LAFE, O.E., J.A. LIGGETT, AND P.L-F. LUI. 1981. BIEM SOLUTIONS TO COMBINATIONS OF LEAKY, LAYERED, CONFINED, UNCONFINED, NONISOTROPIC AQUIFERS. WATER RESOURCES RESEARCH VOL.17(5), PP.1431-1444.

02 LIGGETT, J.A. AND P.L-F. LIU. 1983. THE BOUNDARY INTEGRAL EQUATION METHOD FOR POROUS MEDIA FLOW. GEORGE ALLEN AND UNWIN, LONDON, 255 PP.

03 LAFE, O.E. 1981. BOUNDARY INTEGRAL SOLUTIONS TO NEARLY HORIZONTAL FLOWS IN MULTIPLY ZONED AQUIFERS. PHD THESIS, CORNELL UNIVERSITY, ITHACA, NEW YORK.

IGWMC key= 3370

MODEL TEAM

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MODEL IDENTIFICATION

model name: **FEMWATER/FECWATER**

model purpose: A TWO-DIMENSIONAL FINITE ELEMENT MODEL TO SIMULATE TRANSIENT, CROSS-SECTIONAL FLOW IN SATURATED-UNSATURATED ANISOTROPIC, HETEROGENEOUS POROUS MEDIA.

completion date: OCT. 1980
last update date: FEB. 1981

MODEL CHARACTERISTICS

aquifer conditions: -WATER TABLE -ANISOTROPIC -HETEROGENEOUS -CHANGING AQUIFER CONDITIONS IN TIME

flow conditions: -STEADY -UNSTEADY -SATURATED -UNSATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -FREE SURFACE -INFILTRATION -WELLS -CONSTANT PUMPAGE -SEEPAGE

fluid conditions: -HOMOGENEOUS

model processes: -PRECIPITATION -INFILTRATION -PONDING

other model characteristics: -ENGLISH UNITS

equations solved: -DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER BOTTOMS -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -POROSITY -SPECIFIC WEIGHT -SOIL PROPERTIES

boundary values: -HEADS OR PRESSURES -FLUXES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -VISCOSITY.

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -VELOCITIES -INPUT VALUES

GEOMETRY OF MODEL--

shape of cell: -SQUARE. -RECTANGULAR -ISOPARAMETRIC QUADRILATERAL -TRIANGULAR

spatial characteristics:
< saturated zone > -2D VERTICAL
<unsaturated zone> -2D VERTICAL

grid orientation and sizing: -CROSS SECTIONAL OR VERTICAL VIEW

number of nodes: -VARIABLE

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT -SOLVING FOR VELOCITY FIELD AT NODAL POINTS.

equation solving technique: -CRANK NICHOLSON -INCLUDED ARE 6 NUMERICAL SOLUTION SCHEMES

error criteria: -WATER BALANCE OVER MODEL

COMPUTERS USED---

make and model: VAX 11/780

PROGRAM INFORMATION--

no. of statements: 3000

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; PROGRAM CODE AND DOCUMENTATION PUBLISHED IN REF. #1

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: < $100

MODEL EVALUATION---

USABILITY
- -preprocessor: NO
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REMARKS--

01 FEMWATER IS AN EXTENSIVELY MODIFIED AND EXPANDED VERSION OF A FINITE-ELEMENT GALERKIN MODEL DEVELOPED BY REEVES AND DUGUID, 1975

02 FECWATER IS A SLIGHTLY MODIFIED VERSION OF FEMWATER.

03 THE MODEL IS EVALUATED IN: THOMAS, S.D., B. ROSS, J.W. MERCER. 1982. A SUMMARY OF REPOSITORY SITING MODELS. NUREG/CR-2782, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

REFERENCES---

01 YEH, G.T. AND D.S. WARD. 1980. FEMWATER: A FINITE-ELEMENT MODEL OF WATER FLOW THROUGH SATURATED-UNSATURATED POROUS MEDIA. ORNL-5567, OAK RIDGE NATIONAL LAB., OAK RIDGE, TN 37830.

02 REEVES, M. AND J.O. DUGUID. 1975. WATER MOVEMENT THROUGH SATURATED-UNSATURATED POROUS MEDIA: A FINITE-ELEMENT GALERKIN MODEL. ORNL-4927, OAK RIDGE NATIONAL LAB., OAK RIDGE, TN 37830.

03 YEH, G.T. AND R.H. STRAND. 1982. FECWATER: USER'S MANUAL OF A FINITE-ELEMENT CODE FOR SIMULATING WATER FLOW THROUGH SATURATED-UNSATURATED POROUS MEDIA. ORNL/TM-7316, OAK RIDGE NATIONAL LAB., OAK RIDGE, TN 37830.

04 YEH, G.T. 1982. TRAINING COURSE NO. 1: THE IMPLEMENTATION OF FEMWATER (ORNL-5567) COMPUTER PROGRAM. NUREG/CR-2705. U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

IGWMC key= 3372

MODEL TEAM--

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MODEL IDENTIFICATION--

model name: **AQUIFLOW**

model purpose: A TWO-DIMENSIONAL FINITE ELEMENT MODEL TO SIMULATE TRANSIENT FLOW IN HORIZONTAL, ANISOTROPIC, HETEROGENEOUS AQUIFERS UNDER CONFINED, LEAKY OR UNCONFINED CONDITIONS.

completion date: 1983
last update date: 1984

MODEL CHARACTERISTICS---

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -ANISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS (CONFINED -UNCONFINED)

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

other model characteristics: -METRIC UNITS

equations solved: -TWO-DIMENSIONAL TRANSIENT FLOW EQUATION

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -HYDRAULIC RESISTANCE IN CONFINING LAYER

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -LEAKAGE RATES -VARIABLE, AUTOMATIC ADJUSTING TIMESTEPS

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -FLUXES

GEOMETRY OF MODEL--

shape of cell: -TRIANGULAR -ISOPARAMETRIC QUADRILATERAL

spatial characteristics: < saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

number of nodes: -VARIABLE

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT -ORTHOGONAL WEIGHING FUNCTIONS

equation solving technique: -GAUSS-SEIDEL OR POINT SUCCESSIVE OVER RELAXATION -GAUSS ELIMINATION

COMPUTERS USED---

make and model: IBM 370/3033

PROGRAM INFORMATION--

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: <$100

MODEL EVALUATION--

USABILITY	RELIABILITY
-preprocessor: NO	-peer reviewed
-postprocessor: GENERIC	-theory: UNKNOWN
-user's instructions: YES	-coding: UNKNOWN
-sample problems: YES	-verified: YES
-hardware dependency: NO	-field validation: LIMITED
-support: YES	-model users: UNKNOWN

REFERENCES--

01 YEH, G.T. 1983. SOLUTION OF GROUNDWATER FLOW EQUATIONS USING AN ORTHOGONAL FINITE-ELEMENT SCHEME. ESD-2231, CONF-8309160-1 /DE84000690, OAK RIDGE NATIONAL LAB., OAK RIDGE, TN.

02 YEH, G.T. AND C.W. FRANCIS. 1984. AQUIFLOW: AN ORTHOGONAL FINITE ELEMENT APPROACH TO MODELING AQUIFER WATER FLOW. OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TN.

IGWMC key= 3373

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MODEL IDENTIFICATION

model name: FEWA

model purpose: A TWO-DIMENSIONAL FINITE ELEMENT MODEL TO SIMULATE TRANSIENT VERTICALLY AVERAGED FLOW IN CONFINED, LEAKY CONFINED, OR WATER TABLE AQUIFERS.

completion date: NOV 1983
last update date: NOV 1983

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -STORAGE IN CONFINING LAYER -DELAYED YIELD FROM STORAGE -ISOTROPIC -ANISOTROPIC -HOMOGENEOUS -HETEROGENEOUS -CHANGING AQUIFER CONDITIONS IN SPACE (CONFINED/UNCONFINED)

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

surface flow characteristics: -TIME VARIABILITY OF SURFACE WATER STAGE -LAKES -RIVERS

fluid conditions: -HOMOGENEOUS

other model characteristics: -METRIC UNITS

equations solved: -TWO-DIMENSIONAL VERTICALLY AVERAGED FLOW EQUATION; DARCY'S LAW AND CONTINUITY.

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN CONFINING LAYER -HYDRAULIC RESISTANCE IN RIVER BED AND LAKE BED

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -VELOCITIES

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR -TRIANGULAR -ISOPARAMETRIC QUADRILATERAL

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

number of nodes: -VARIABLE

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS-SEIDEL OR POINT SUCCESSIVE OVER RELAXATION -GAUSS ELIMINATION

COMPUTERS USED---

make and model: VAX 11/780

PROGRAM INFORMATION--

no. of statements: 1650
language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: < $100

MODEL EVALUATION---

USABILITY
- -preprocessor: NO
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: FEW

REFERENCES---

01 YEH, G.T. AND D.D. HUFF. 1983. FEWA: A FINITE ELEMENT MODEL OF WATER FLOW THROUGH AQUIFERS. ORNL-5976, OAK RIDGE NATIONAL LAB., OAK RIDGE, TN.

IGWMC key= 3376

MODEL TEAM

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MODEL IDENTIFICATION

model name: **FEMA**

model purpose: A TWO-DIMENSIONAL FINITE ELEMENT MODEL TO SIMULATE SOLUTE TRANSPORT INCLUDING RADIOACTIVE DECAY, SORPTION, AND BIOLOGICAL AND CHEMICAL DEGRADATION. THIS MODEL SOLVES ONLY SOLUTE TRANSPORT EQUATION AND VELOCITY FIELD HAS TO BE GENERATED BY A FLOW MODEL.

completion date: 1984
last update date: 1984

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -ANISOTROPIC -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONCENTRATIONS -CONSTANT SOLUTE FLUX -SOLUTE SOURCE

fluid conditions: -HOMOGENEOUS

model processes: -DISPERSION -DIFFUSION -ADSORPTION -DECAY -ADVECTION

other model characteristics: -METRIC UNITS

equations solved: -NONCONSERVATIVE SOLUTE TRANSPORT EQUATION

MODEL INPUT--

areal values: -POROSITY -DISPERSIVITY -DECAY RATE -INITIAL QUALITY

boundary values: -CONCENTRATIONS -SOLUTE FLUXES -SOLUTE SOURCES AND SINKS

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -COMPRESSIBILITY OF MEDIUM -VELOCITY FIELD.

MODEL OUTPUT---

tables: -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL--

shape of cell: -TRIANGULAR -ISOPARAMETRIC QUADRILATERAL

spatial characteristics: < saturated zone > -2D HORIZONTAL

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS-SEIDEL OR POINT SUCCESSIVE OVER RELAXATION -GAUSS ELIMINATION

COMPUTERS USED---

make and model: VAX 11/780

PROGRAM INFORMATION--

no. of statements: 3200

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN

available code form: -PRINTED LISTING

cost: < $100

MODEL EVALUATION--

USABILITY
- -preprocessor: NO
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: FEW

REMARKS--

01 THE VELOCITY FIELD IS NEEDED FOR INPUT AND CAN BE GENERATED USING MODEL FEWA BY THE SAME AUTHORS (ORNL-5976) 1983.

02 A NEW GEOCHEMICAL MODEL, HYDROGEOCHEM, HAS BEEN DEVELOPED BY INTERFACING FEMA WITH MINEQL (PRESENTED AT ISIS SEMINAR ON SUPERCOMPUTERS IN HYDROLOGY, PURDUE UNIVERSITY, SEPTEMBER 1985).

REFERENCES---

01 YEH, G.T. AND D.D. HUFF. 1985. FEMA: A FINITE ELEMENT MODEL OF MATERIAL TRANSPORT THROUGH AQUIFERS. ORNL-6063, OAK RIDGE NATIONAL LAB, OAK RIDGE, TN.

02 YEH, G.T. 1985. COMPARISONS OF SUCCESIVE ITERATION AND DIRECT METHODS TO SOLVE FINITE ELEMENT EQUATIONS OF AQUIFER CONTAMINANT TRANSPORT. WATER RESOURCES RESEARCH, VOL. 21(3): PP. 272-280.

03 YEH, G.T., K.V. WONG, P.M. CRAIG, AND E.C. DAVIS. 1985. DEVELOPMENT AND APPLICATIONS OF TWO FINITE ELEMENT GROUND-WATER FLOW AND CONTAMINANT TRANSPORT MODELS: FEWA AND FEMA. CONF-8509121--26, OAK RIDGE NATIONAL LAB., OAK RIDGE, TN.

IGWMC key= **3830**

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MODEL IDENTIFICATION

model name: **SUTRA**

model purpose: A FINITE ELEMENT MODEL FOR SIMULATION OF TWO-DIMENSIONAL TRANSIENT SATURATED-UNSATURATED, FLUID DENSITY DEPENDENT GROUND WATER FLOW WITH TRANSPORT OF ENERGY OR TRANSPORT OF A CHEMICALLY REACTIVE SOLUTE

completion date: 1984
last update date: 1984

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -ISOTROPIC -ANISOTROPIC -HOMOGENEOUS -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -UNSATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -NO FLOW -FREE SURFACE -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -TEMPERATURE -HEAT FLUX -SOLUTE FLUX -CONCENTRATION

fluid conditions: -HETEROGENEOUS -TEMPERATURE DEPENDENT -VARIABLE DENSITY

model processes: -CONVECTION -DISPERSION -DIFFUSION -ADSORPTION -REACTIONS -DECAY

other model characteristics: -METRIC UNITS

equations solved: -DARCY'S LAW AND CONTINUITY; -CONVECTIVE-DISPERSIVE TRANSPORT EQUATION FOR NONCONSERVATIVE SINGLE SOLUTE.

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -HYDRAULIC RESISTANCE IN CONFINING LAYER -DISPERSIVITY -THERMAL CONDUCTIVITY -THERMAL CAPACITY -SPECIFIC HEAT -TEMPERATURE -FLUID DENSITY -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -GROUND WATER RECHARGE RATES -HEAT AND SOLUTE FLUXES -CONCENTRATIONS -SOURCES AND SINKS

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -SOIL PROPERTIES -LEAKAGE RATES

MODEL OUTPUT--

tables: -HEADS OR PRESSURES -FLUXES -VELOCITIES -TEMPERATURE -CONCENTRATIONS OF WATER CONSTITUENTS -PUMPAGE RATES -ARTIFICIAL RECHARGE RATES -GROUND WATER RECHARGE RATES

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR -TRIANGULAR -ISOPARAMETRIC QUADRILATERAL

spatial characteristics:

< saturated zone > -2D HORIZONTAL -2D VERTICAL

<unsaturated zone> -2D HORIZONTAL -2D VERTICAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW

number of nodes: -VARIABLE 1000

TECHNIQUES--

basic modeling technique: -FINITE ELEMENT

equation solving technique: -GAUSS-SEIDEL OR POINT SUCCESSIVE OVER RELAXATION -INITIAL LU DECOMPOSITION FOR STEADY-STATE

COMPUTERS USED--

make and model: IBM 3081, PRIME 750, VAX 11/780

PROGRAM INFORMATION---

language: FORTRAN

terms of availability of code and user's manual: PUBLIC DOMAIN

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: < $100

MODEL EVALUATION--

USABILITY
- -preprocessor: YES
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REMARKS---

01 AN EXTENSION OF THE CODE SUTRA IS GIVEN IN REF. #2 IT INCLUDES SORPTION, ION EXCHANGE, AND EQUILIBRIUM CHEMISTRY. THE NONLINEAR COMPONENTS RESULTING FROM THESE CHEMICAL PROCESSES ARE REDUCED INTO TWO TIME-DEPENDENT VARIABLES THAT ESSENTIALLY PLUG INTO A GENERAL FORM OF THE CLASSIC ADVECTION-DISPERSION EQUATION.

REFERENCES--

01 C.I. VOSS. 1984. SUTRA: A FINITE ELEMENT SIMULATION MODEL FOR SATURATED-UNSATURATED FLUID DENSITY-DEPENDENT GROUND WATER FLOW WITH ENERGY TRANSPORT OR CHEMICALLY REACTIVE SINGLE SPECIES SOLUTE TRANSPORT. WATER RESOURCES INVEST. 84-4369, U.S. GEOL. SURVEY, RESTON, VA.

02 LEWIS, F.M. 1984. SORPTION, ION-EXCHANGE, AND EQUILIBRIUM CHEMISTRY IN ADVECTIVE-DISPERSIVE SOLUTE TRANSPORT. DEPARTMENT OF HYDROLOGY AND WATER RESOURCES, UNIVERSITY OF ARIZONA, PHOENIX, AZ

IGWMC key= 3840

MODEL TEAM--

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(SEE REMARKS FOR DISTRIBUTORS)

MODEL IDENTIFICATION--

model name: **SWIFT (SANDIA WASTE ISOLATION FLOW AND TRANSPORT) AND SWIFT-II**

model purpose: A THREE-DIMENSIONAL FINITE-DIFFERENCE MODEL FOR SIMULATION OF COUPLED, TRANSIENT, DENSITY DEPENDENT FLOW AND TRANSPORT OF HEAT, BRINE, TRACERS AND RADIONUCLIDE CHAINS IN POROUS AND FRACTURED CONFINED AQUIFERS

completion date: 1978
last update date: 1981 (RELEASE 4.81)
1986 (SWIFT-II)

MODEL CHARACTERISTICS---

aquifer conditions: -CONFINED -ANISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS -FRACTURES -DUAL POROSITY

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -GROUNDWATER RECHARGE
-WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE
-ENTHALPY INJECTION AND PRODUCTION -RADIONUCLIDE OR BRINE INJECTION AND PRODUCTION -WASTE LEACHATE

fluid conditions: -HETEROGENEOUS -TEMPERATURE DEPENDENT -VARIABLE DENSITY -BRINE -VARIABLE VISCOSITY

model processes: -CONVECTION -CONDUCTION -DISPERSION -DIFFUSION -NONLINEAR ADSORPTION -ION EXCHANGE -DECAY -REACTIONS -BUOYANCY -SALT DISSOLUTION

other model characteristics: -METRIC UNITS

equations solved: -CONSERVATION OF MASS AND ENTHALPY -VARIOUS CONSTITUTIVE RELATIONSHIPS AND STATE EQUATIONS

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -PERMEABILITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD -DISPERSIVITY -THERMAL CONDUCTIVITY -THERMAL CAPACITY -SPECIFIC HEAT -TEMPERATURE -FLUID DENSITY -SPECIFIC WEIGHT -DECAY RATE -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -INITIAL TIME STEP -ERROR CRITERIA -ENTHALPY BOUNDARY CONDITIONS -SOLUTE FLUX AND CONCENTRATION BOUNDARY CONDITION

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -FLUXES -TEMPERATURE -FLUID DENSITY -CONCENTRATIONS OF WATER CONSTITUENTS -POROSITY -VISCOSITY

GEOMETRY OF MODEL--

shape of cell: -ORTHOGONAL

spatial characteristics: < saturated zone > -3D -2D -CLYLINDRICAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW

number of nodes: -VARIABLE ->10,000

TECHNIQUES--

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -LINE SUCCESSIVE OVER RELAXATION OR GAUSSIAN ELIMINATION -IMPLICIT -CRANK NICHOLSON -UPWIND WEIGHTING

COMPUTERS USED--

make and model: CDC 7600

core storage: 400K OCTAL WORDS

PROGRAM INFORMATION---

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN (SEE REMARKS)

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: < $2,000 from ARGONNE NATIONAL LABORATORY

MODEL EVALUATION--

USABILITY
- -preprocessor: NO
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REMARKS---

01 THE SWIFT CODE HAS BEEN BASED ON THE SWIP AND SWIPR CODE (IGWMC KEY 0692), DEVELOPED FOR THE USGS IN 1976 AND UPDATED IN 1979. A NEW VERSION, SWIFT-II, INCORPORATES DUAL POROSITY FOR FRACTURED MEDIA.

02 RELATED TO THE SWIFT CODE AND BASED ALSO ON SWIP AND SWIPR IS THE SWENT CODE, DEVELOPED AT OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE

03 SWIFT CODE IS AVAILABLE FROM NATIONAL ENERGY SOFTWARE CENTER, ARGONNE NATIONAL LABORATORY, ARGONNE, IL 60439, ACCESS NR NESC #973. SWIFT: WASTE-ISOLATION FLOW AND TRANSPORT MODEL. MAG TAPE ANL/NESC-973 U.S. SALES ONLY. PRICE INCLUDES DOCUMENTATION. TAPES CAN BE PREPARED IN MOST RECORDING MODES FOR ONE-HALF INCH TAPE. SPECIFY RECORDING MODE DESIRED.

04 IT IS ALSO DISTRIBUTED BY NTIS, NAT. TECHN. INFORMATION CENTER, U.S. DEPT. OF COMMERCE, 5285 PORT ROYAL RD., SPRINGFIELD, VA, 22161. CALL NTIS COMPUTER PRODUCTS IF YOU HAVE QUESTIONS. PRICE CODE: CP T99.

05 SWIFT II IS AVAILABLE THROUGH THE NATIONAL ENERGY SOFTWARE CENTER AND FROM GEOTRANS, INC., 250 EXCHANGE PLACE, SUITE A, HERNDON, VA 22070.

06 A VERSION OF SWIFT HAS BEEN PREPARED FOR THE ATOMIC ENERGY OF CANADA, INC. (SEE REF. #4).

REFERENCES--

01 DILLON, R.T., ET. AL. 1978. RISK METHODOLOGY FOR GEOLOGIC DISPOSAL OF RADIOACTIVE WASTE: THE SANDIA WASTE ISOLATION FLOW AND TRANSPORT (SWIFT) MODEL. SAND 78-1267/NUREG-CR-0424, SANDIA NATIONAL LABORATORIES, ALBUQUERQUE, NEW MEXICO.

02 FINLEY, N.C. AND M. REEVES. 1981. SWIFT SELF-TEACHING CURRICULUM. SAND 81-0410/NUREG-CR-1968, SANDIA NATIONAL LABORATORIES, ALBUQUERQUE, NEW MEXICO.

03 REEVES, M. AND R.M CRANWELL. 1981. USER'S MANUAL FOR THE SANDIA WASTE-ISOLATION FLOW AND TRANSPORT MODEL (SWIFT) RELEASE 4.81. SAND 81-2516/NUREG-CR-2324, SANDIA NATIONAL LABORATORIES, ALBUQUERQUE, NEW MEXICO.

04 INTERA ENVIRONMENTAL CONSULTANTS, INC. 1982. AN OVERVIEW OF THE INTERA SIMULATORS, SWIFT-AECL/PTC AND SWIFT-AECL/SSP, FOR WASTE INJECTION, FLOW AND TRANSPORT. WHITESHELL NUCLEAR RESEARCH ESTABLISHMENT, PINAWA, MANITOBA ROE 1LO, CANADA

05 WARD, D., ET AL. 1986. SWIFT-II: THEORY AND IMPLEMENTATION. NUREG/CR-3328, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

06 WARD, D., ET AL. 1986. SWIFT-II: DATA INPUT. NUREG/CR-3162, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

07 WARD, D., ET AL. 1986. SWIFT-II: SELF TEACH CURRICULUM. NUREG/CR-3925. U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, D.C.

IGWMC key= 3868

MODEL TEAM

author name(s): DESAI, C.S.

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CONTACT ADDRESS

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MODEL IDENTIFICATION

model name: **MAST-2D**

model purpose: A FINITE ELEMENT MODEL TO SIMULATE COUPLED TRANSIENT SEEPAGE AND MASS TRANSPORT IN SATURATED POROUS MEDIA.

completion date: UNKNOWN
last update date: UNKNOWN

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -ISOTROPIC -HETEROGENEOUS

flow conditions: -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -FREE SURFACE -WELLS -CONSTANT PUMPAGE

fluid conditions: -HOMOGENEOUS

model processes: -CONVECTION -DISPERSION -DIFFUSION

equations solved: -COUPLED FLOW AND MASS TRANSPORT

MODEL INPUT

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -DISPERSIVITY -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES

others: -TIME STEP SEQUENCE -VELOCITIES -ELEMENT CONNECTIVITY

MODEL OUTPUT--

tables: -HEADS OR PRESSURES -VELOCITIES -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL---

shape of cell: -ISOPARAMETRIC QUADRILATERAL

spatial characteristics:
< saturated zone > -2D VERTICAL

grid orientation and sizing: -CROSS SECTIONAL OR VERTICAL VIEW

number of nodes: -RANGES FROM 100 TO 1000

TECHNIQUES--

basic modeling technique: -FINITE ELEMENT

equation solving technique: -CRANK NICOLSON

COMPUTERS USED--

PROGRAM INFORMATION---

language: FORTRAN IV

terms of availability of code and user's manual: PROPRIETARY, LEASE

available code form: -MAGNETIC TAPE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION---

USABILITY
- -preprocessor: NO
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: UNKNOWN

IGWMC key= 3870

MODEL TEAM

author name(s): JORGENSEN, D.G., H. GRUBB, C.H. BAKER, JR. (1)
G.E. HILMES (2) AND E.D. JENKINS (3)

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(2) KANSAS STATE BOARD OF AGRICULTURE
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MODEL IDENTIFICATION

model name: GWMD3

model purpose: AN AXISYMMETRIC FINITE DIFFERENCE MODEL TO CALCULATE DRAWDOWN DUE TO A PROPOSED WELL, AT ALL EXISTING WELLS IN THE SECTION OF THE PROPOSED WELL AND IN THE ADJACENT 8 SECTIONS AND TO COMPARE DRAWDOWNS WITH ALLOWABLE LIMITS; INCLUDES AN OPTIONAL PROGRAM TO EVALUATE ALLOWABLE DEPLETION FOR ONE OR MORE TOWNSHIPS

completion date: 1982
last update date: 1982

MODEL CHARACTERISTICS

aquifer conditions: -WATER TABLE -ISOTROPIC -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -WELLS -CONSTANT PUMPAGE -INFINITE EXTENT

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS

equations solved: -DUPUIT-FORCHEIMER ASSUMPTION FOR RADIAL, TRANSIENT FLOW; DARCY'S LAW AND CONTINUITY

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD

boundary values: -PUMPAGE RATES

others: -GRID INTERVALS -TIME STEP SEQUENCE

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -FLUXES -DEPLETION -APPROPRIATION

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics: < saturated zone > -CYLINDRICAL OR RADIAL

grid orientation and sizing: -AXIAL SYMMETRY

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -THOMAS-ALGORITHM

error criteria: -SUM HEAD CHANGE OVER MODEL BETWEEN ITERATIONS

COMPUTERS USED---

make and model: HARRIS S 125

PROGRAM INFORMATION--

language: FORTRAN 66

terms of availability of code and user's manual: PUBLIC DOMAIN; USER'S INSTRUCTIONS AND PROGRAM CODE PUBLISHED IN REFERENCE #1.

available code form: -PRINTED LISTING

cost: < $100

MODEL EVALUATION---

USABILITY
- -preprocessor: NO
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: LIMITED
- -model users: UNKNOWN

REMARKS---

01 THE MODEL USES THE AUTOMATED WATER-RIGHTS FILE TO EVALUATE WELL-SPACING AND DEPLETION REQUIREMENTS AND TO CALCULATE THE DRAWDOWN IN ALL NEARBY WELLS.

REFERENCES---

01 JORGENSEN, D.G., H.F. GRUBB, C.H. BAKER, JR., G.E. HILMES, AND E.D. JENKINS. 1982. A NUMERICAL MODEL TO EVALUATE PROPOSED GROUND-WATER ALLOCATIONS IN SOUTHWEST KANSAS. WATER-RESOURC. INVESTIG. 82-4095, U.S. GEOLOGICAL SURVEY, LAWRENCE, KANSAS.

IGWMC key= 3881

MODEL TEAM

author name(s): TRACY, J.V.

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CONTACT ADDRESS

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MODEL IDENTIFICATION

model name: **GALERKIN FINITE ELEMENT FLOW MODEL**

model purpose: A FINITE ELEMENT MODEL FOR SIMULATION OF TWO-DIMENSIONAL, TRANSIENT FLOW IN A ISOTROPIC, HETEROGENEOUS, CONFINED OR WATERTABLE AQUIFER IN CONTACT WITH A STREAM. THE MODEL INCLUDES THE CALCULATION OF THE SURFACE WATER BALANCE.

completion date: 1977
last update date: 1977

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -ISOTROPIC -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE

surface flow characteristics: -TIME VARIABILITY OF SURFACE WATER STAGE -WATER BALANCE OF SURFACE WATER INCLUDED -RIVERS

fluid conditions: -HOMOGENEOUS

model processes: -PRECIPITATION -EVAPOTRANSPIRATION -STREAM-AQUIFER INTERACTION -IRRIGATION other model characteristics: -ENGLISH UNITS -CONSISTENT UNITS

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -PERMEABILITY -TRANSMISSIVITY -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN RIVER BED AND LAKE BED

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

others: -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -STREAM DATA -SOIL CAPACITY

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -WATER BALANCE

plotted graphics:
<time series> -HEADS
<areal maps > -HEADS

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR -TRIANGULAR -ISOPARAMETRIC QUADRILATERAL

spatial characteristics:
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW

number of nodes: -RANGES FROM 100 TO 1000

TECHNIQUES---

basic modeling technique: -FINITE ELEMENT -ITERATIVE -UPSTREAM TO DOWNSTREAM METHOD FOR STREAMFLOW

equation solving technique: -DIRECT SOLVER: FORWARD AND BACKWARD SUBSTITUTION

COMPUTERS USED---

make and model: AMDAHL

PROGRAM INFORMATION--

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; CODE AND USER'S INSTRUCTIONS PUBLISHED IN REF #1

cost: < $100

MODEL EVALUATION---

USABILITY
- -preprocessor: NO
- -postprocessor: NO
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: FEW

REMARKS--

01 AN EARLY VERSION IS DESCRIBED IN REFERENCE #2.

02 THE MODEL SIMULATES RATES OF STREAMFLOW STARTING WITH INPUT STREAMFLOW AT THE UPPERMOST STREAM NODE AND WORKING DOWNSTREAM CALCULATING THE FLOW FOR EACH RIVER REACH ON THE BASIS OF INCOMING FLOW AND THE GAIN OR LOSS TO THE AQUIFER THROUGHOUT THE LENGTH OF THE REACH.

REFERENCES---

01 DUNLAP, L.E., R.J. LINDGREN, AND J.E. CARR. 1984. PROJECTED EFFECTS OF GROUND-WATER WITHDRAWALS IN THE ARKANSAS RIVER VALLEY, 1980-99, HAMILTON AND KEASAY COUNTIES, SOUTHWESTERN KANSAS, WRI 84-4082, U.S. GEOLOGICAL SURVEY, LAWRENCE, KANSAS, 68P.

02 BOLKE, E.L. AND J.J. VACCARD. 1981. DIGITAL - MODEL SIMULATION OF THE HYDROLOGIC FLOW SYSTEM, WITH EMPHASIS ON GROUND WATER, IN THE SPOKANE VALLEY, WASHINGTON AND IDAHO. WATER RESOURCE INVEST. 80-1300, U.S. GEOLOG. SURVEY, TACOMA, WA.

IGWMC key= 3940

MODEL TEAM

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MODEL IDENTIFICATION

model name: RESSQ

model purpose: A SEMI-ANALYTICAL MODEL TO CALCULATE 2-DIMENSIONAL CONTAMINANT TRANSPORT BY ADVECTION AND ADSORPTION IN A HOMOGENEOUS, ISOTROPIC CONFINED AQUIFER OF UNIFORM THICKNESS WHEN REGIONAL FLOW, SOURCES AND SINKS CREATE A STEADY STATE FLOW FIELD.

completion date: 1983
last update date: 1983

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -ISOTROPIC -HOMOGENEOUS

flow conditions: -STEADY -SATURATED -LAMINAR

boundary conditions: -GROUNDWATER RECHARGE -WELLS

surface flow characteristics: -PONDS

fluid conditions: -HOMOGENEOUS

model processes: -ADSORPTION -ADVECTION

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -DARCY'S LAW AND CONTINUITY; COMPLEX VELOCITY POTENTIAL AND STREAM FUNCTION

MODEL INPUT--

areal values: -THICKNESS OF AQUIFER -POROSITY

boundary values: -PUMPAGE OR INJECTION RATES

others: -PORE WATER VELOCITY -DIRECTION OF REGIONAL FLOW -ADSORPTION CAPACITY OF SOIL -INJECTION CONCENTRATION

MODEL OUTPUT--

tables: -CONCENTRATIONS OF WATER CONSTITUENTS -STREAMLINES -CONTAMINANT FRONTS

GEOMETRY OF MODEL--

spatial characteristics: < saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

TECHNIQUES--

basic modeling technique: SEMI-ANALYTIC

COMPUTERS USED--

make and model: VAX-11/780, IBM-PC/XT/AT

core storage: 256K

PROGRAM INFORMATION---

no. of statements: 1200

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; -USER'S MANUAL AND CODE PUBLISHED IN REF. #1.

available code form: MAGNETIC TAPE -PRINTED LISTING

cost: $150

MODEL EVALUATION--

USABILITY	RELIABILITY
-preprocessor: NO	-peer reviewed
-postprocessor: YES	-theory: YES
-user's instructions: YES	-coding: YES
-sample problems: YES	-verified: YES
-hardware dependency: NO	-field validation: YES
-support: YES	-model users: MANY

REMARKS--

01 IBM-PC VERSION AVAILABLE FROM IGWMC.

02 DEDICATED POSTPROCESSOR FOR RESSQ DEVELOPED BY IGWMC.

REFERENCES--

01 JAVANDEL, I., C. DOUGHTY AND C.F. TSANG, 1984. GROUNDWATER TRANSPORT: HANDBOOK OF MATHEMATICAL MODELS. WATER RESOURCES MONOGR. 10, AM. GEOPHYS. UNION, WASHINGTON, D.C. 228 P.

02 KEELY, J.F. AND C.F. TSANG. 1983. VELOCITY PLOTS AND CAPTURE ZONES OF PUMPING CENTERS FOR GROUNDWATER INVESTIGATIONS. GROUNDWATER 21(6): 701-714.

03 JAVANDEL, I. AND C.F. TSANG. 1986. CAPTURE-ZONE TYPE CURVES: A TOOL FOR AQUIFER CLEANUP. GROUND WATER 24(5):616-625.

IGWMC key= 3980

MODEL TEAM

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MODEL IDENTIFICATION

model name: **MODFLOW**

model purpose: A MODULAR THREE-DIMENSIONAL FINITE-DIFFERENCE GROUND-WATER MODEL TO SIMULATE TRANSIENT FLOW IN ANISOTROPIC, HETEROGENEOUS, LAYERED AQUIFER SYSTEMS.

completion date: JUN 1983
last update date: MAY 1984

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -STORAGE IN CONFINING LAYER -DELAYED YIELD FROM STORAGE -ANISOTROPIC -HETEROGENEOUS -MANY OVERLYING AQUIFERS -CHANGING AQUIFER CONDITIONS IN TIME (CONFINED-UNCONFINED) -CHANGING AQUIFER CONDITIONS IN SPACE (CONFINED-UNCONFINED)

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CHANGING HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -HEAD DEPENDENT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -DRAINAGE

surface flow characteristics: -TIME VARIABILITY OF SURFACE WATER STAGE -SPRINGS -LAKES -RIVERS -PONDS

fluid conditions: -HOMOGENEOUS

model processes: -EVAPOTRANSPIRATION

other model characteristics: -METRIC UNITS -WATER BALANCE

equations solved: -DARCY'S LAW AND CONTINUITY IN THREE-DIMENSIONS

MODEL INPUT--

areal values: -ELEVATION OF LAND SURFACE -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD -HYDRAULIC RESISTANCE IN CONFINING LAYER -HYDRAULIC RESISTANCE IN RIVER BED

boundary values: -HEADS OR PRESSURES -FLUXES -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS -ERROR CRITERIA -LEAKAGE RATES

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -ALL INPUT -FLUXES

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics: < saturated zone > -2D HORIZONTAL -2D VERTICAL -3D

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -THREE-DIMENSIONAL

number of nodes: -VARIABLE 10,000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -LINE SUCCESSIVE OVER RELAXATION -STRONGLY IMPLICIT PROCEDURE -SLICE SUCCESSIVE OVER RELAXATION

COMPUTERS USED---

make and model: IBM PC/XT/AT, VAX 11/780

core storage: 512K

PROGRAM INFORMATION--

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; USER INSTRUCTIONS AND PROG. CODE PUBLISHED IN REF #1.

available code form: MAGNETIC TAPE -PRINTED LISTING

cost: $120 from IGWMC

MODEL EVALUATION--

USABILITY
- -preprocessor: YES
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REMARKS--

01 THE CODE IS AVAILABLE FROM THE U.S.G.S. ON TAPE. CONTACT MICHAEL MCDONALD (SEE CONTACT ADDRESS). THE DOCUMENTATION (PAPER COPY $69.75, MICROFICHE $3.50) IS AVAILABLE FROM:
OPEN-FILE SERVICE SECTION
BRANCH OF DISTRIBUTION
U.S. GEOLOGICAL SURVEY
BOX 25425, FEDERAL CENTER
DENVER, CO 80225

02 THE DOCUMENTATION IS ALSO AVAILABLE FROM:
SCIENTIFIC PUBLICATIONS CO.
P.O. BOX 23041
WASHINGTON D.C. 20026-3041
PHONE: 703/522-4601
(PAPER COPY OF REPT. $39)

03 WAGNER, HEINDEL, AND NOYES INC. HAS IMPLEMENTED THIS THREE-DIMENSIONAL, FINITE-DIFFERENCE GROUND-WATER FLOW MODEL ON A HEWLETT-PACKARD MICROCOMPUTER (SERIES 200). THOSE INTERESTED IN THE MODEL MODIFICATION NECESSARY FOR MICROCOMPUTER USE AS DEVELOPED HERE MAY CONTACT JEFFREY E. NOYES, GEOLOGIST, WAGNER, AND NOYES, INC., 285 NORTH ST., BURLINGTON, VERMONT 05401 (802-658-0820).

04 MAINFRAME AND IBM PC VERSION AVAILABLE FROM IGWMC.

05 POSTPROCESSORS AVAILABLE FROM SCIENTIFIC PUBLICATIONS CO. GEOTRANS, INC., HERNDON, VA.; AND DPMS, INC., KIRKLAND, WA

REFERENCES--

01 McDONALD, M.G. AND A.W. HARBAUGH. 1983. A MODULAR THREE-DIMENSIONAL FINITE-DIFFERENCE GROUND-WATER MODEL. OPEN-FILE REPORT 83-875, U.S. GEOLOGICAL SURVEY, RESTON, VA.

IGWMC key= 4070

MODEL TEAM

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DESERT RESEARCH INSTITUTE
UNIVERSITY OF NEVADA SYSTEM
RENO, NEVADA

CONTACT ADDRESS

contact person: KOLTERMAN, C.R.

address: WATER RESOURCES CENTER
DESERT RESEARCH INSTITUTE
UNIVERSITY OF NEVADA SYSTEM
RENO, NEVADA

MODEL IDENTIFICATION

model name: **GWUSER/CONJUN**

model purpose: A COMBINED SIMULATION-OPTIMIZATION MODEL TO DETERMINE OPTIMAL PUMPING LOCATIONS AND RATES FOR CONFINED AQUIFER WITH OR WITHOUT ARTIFICIAL RECHARGE OR FOR CONJUNCTIVE USE OF AQUIFER-STREAM SYSTEM. THE MODEL USES A FINITE DIFFERENCE SIMULATOR.

completion date: NOV 1983
last update date: NOV 1983

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -ISOTROPIC -ANISOTROPIC -HOMOGENEOUS -HETEROGENEOUS

flow conditions: -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -GROUNDWATER RECHARGE -UNKNOWN WELL DISCHARGE

surface flow characteristics: -TIME VARIABILITY OF SURFACE WATER STAGE -WATER BALANCE OF SURFACE WATER INCLUDED -RIVERS

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS -METRIC UNITS -OPTIMIZATION -CONJUNCTIVE USE -MANAGEMENT DECISIONS -WATER BALANCE equations solved: -DARCY'S LAW -CONTINUITY (GROUNDWATER AND SURFACE WATER) -OBJECT FUNCTIONS: 1. MAXIMIZATION HYDRAULIC HEAD 2. MAXIMIZATION TOTAL WATER SUPPLY 3. MINIMIZATION AUGMENTATION AND RECHARGE 4. MAXIMIZATION SUPPLY WHILE MINIMIZING WATER TRANSFER

MODEL INPUT--

areal values: -THICKNESS OF AQUIFER -ELEVATION OF SURFACE WATER BOTTOMS -TRANSMISSIVITY -STORAGE COEFFICIENT -HYDRAULIC RESISTANCE IN RIVER BED AND LAKE BED

boundary values: -HEADS OR PRESSURES -FLUXES -GROUND WATER RECHARGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -OBJECTIVES -CONSTRAINTS

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -PUMPAGE RATES -WATER BALANCES

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics: < saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

number of nodes: -RANGES FROM 10 TO 1000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE -LINEARING PROGRAMMING

equation solving technique: -PRIMAL SIMPLEX METHOD

COMPUTERS USED---

make and model: CDC CYBER 730

core storage: 262K

other requirements: XMP LINEAR PROGRAMMING PACKAGE (SEE REMARK #1)

PROGRAM INFORMATION--

language: FORTRAN IV

available code form: PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION---

USABILITY
- -preprocessor: UNKNOWN
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: UNKNOWN

REMARKS--

01 THE MODELS GWUSER FOR AQUIFER ALONE AND CONJUN FOR AQUIFER STREAM SYSTEMS PREPARE THE DATA INPUT (OBJECTIVE FUNCTIONS, CONSTRAINTS) FOR THE XMP PACKAGE (EXPERIMENTAL MATHEMATICAL PROGRAM). THE USED XMP PROGRAM RESIDES ON A CDC CYBER 730 COMPUTER. (SEE REF. #2)

REFERENCES---

01 KOLTERMAN, C.R. 1983. AN LP EMBEDDED SIMULATION MODEL FOR CONJUNCTIVE USE MANAGEMENT OPTIMIZATION. PUBL. 41091, WATER RESOURCES CENTER, DESERT RESEARCH INSTITUTE, UNIVERSITY OF NEVADA SYST., RENO, NEVADA, 134 P.

02 MARSTEN, R. 1981. THE DESIGN OF THE XMP LINEAR PROGRAMMING LIBRARY. ACM TRANSACTIONS ON MATHEMATICAL SOFTWARE. VOL. 7(4), P. 481-497.

IGWMC key= 4270

MODEL TEAM

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MODEL IDENTIFICATION

model name: TRACR3D

model purpose: A THREE-DIMENSIONAL FINITE-DIFFERENCE MODEL OF TRANSIENT TWO-PHASE FLOW AND MULTICOMPONENT TRANSPORT IN DEFORMABLE, HETEROGENEOUS, REACTIVE POROUS/FRACTURED MEDIA.

completion date: MAY 1984
last update date: MAY 1984

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -ISOTROPIC -ANISOTROPIC -HOMOGENEOUS -HETEROGENEOUS -DISCRETE FRACTURES -AQUIFER SYSTEM DEFORMATION

flow conditions: -STEADY -UNSTEADY -SATURATED -UNSATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -CHANGING FLUX -NO FLOW

fluid conditions: -HOMOGENEOUS

model processes: -DISPERSION -DIFFUSION -ADSORPTION -DECAY -ADVECTION

MODEL INPUT

areal values: -PERMEABILITY -POROSITY -STORAGE COEFFICIENT -DIFFUSIVITY -DISPERSIVITY -FLUID DENSITY -DECAY RATE

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -SOIL PROPERTIES

MODEL OUTPUT--

tables: -HEADS OR PRESSURES -FLUXES -VELOCITIES -PERMEABILITY -STORAGE COEFFICIENT -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR

spatial characteristics:
< saturated zone > -3D -CYLINDRICAL OR RADIAL, CARTESIAN

TECHNIQUES--

basic modeling technique: -FINITE DIFFERENCE

COMPUTERS USED--

make and model: CDC 7600, CRAY-1, VAX, CRAY-XMP

PROGRAM INFORMATION--

language: FORTRAN 77

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: NO
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: FEW

REFERENCES--

01 TRAVIS, B. 1984. TRACR3D: A MODEL OF FLOW AND TRANSPORT IN POROUS/FRACTURED MEDIA, LA-9667-MS. LOS ALAMOS NATIONAL LABORATORY, LOS ALAMOS, NM.

IGWMC key= 6022

MODEL TEAM

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MODEL IDENTIFICATION

model name: THWELLS

model purpose: TO CALCULATE HEAD DRAWDOWN OR BUILDUP CAUSED BY MULTIPLE WELLS IN AN ISOTROPIC, HOMOGENEOUS, NONLEAKY, CONFINED AQUIFER.

completion date: NOV 1982
last update date: JAN 1987

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -ISOTROPIC -HOMOGENEOUS

flow conditions: -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -VARIABLE PUMPAGE -BOUNDARY CONDITION IMAGE WELLS

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -THEIS EQUATION

MODEL INPUT

areal values: -TRANSMISSIVITY -STORAGE COEFFICIENT

boundary values: -PUMPAGE RATES

others: -GRID INTERVALS

MODEL OUTPUT

tables: -HEADS OR PRESSURES

GEOMETRY OF MODEL

shape of cell: -NONE
< saturated zone > -2D HORIZONTAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW

number of nodes: -RANGES FROM 100 TO 1000

TECHNIQUES

basic modeling technique: -ANALYTICAL METHOD

COMPUTERS USED

make and model: IBM PC/XT/AT

core storage: 256K

PROGRAM INFORMATION

no. of statements: 1000

language: MICROSOFT BASIC

available code form: PRINTED LISTING -DISKETTE

cost: $50 from IGWMC

MODEL EVALUATION

USABILITY
- -preprocessor: YES
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REFERENCES---

01 VAN DER HEIJDE, P.K.M. 1987. THWELLS, A BASIC PROGRAM TO CALCULATE HEAD DRAWDOWN OR BUILDUP CAUSED BY MULTIPLE WELLS IN AN ISOTROPIC, HETEROGENEOUS, NONLEAKY, CONFINED AQUIFER. IGWMC-PLUTO 6022, HOLCOMB RESEARCH INSTITUTE, BUTLER UNIVERSITY, INDIANAPOLIS, INDIANA.

IGWMC key= 6062

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MODEL IDENTIFICATION

model name: RADIAL

model purpose: A FINITE DIFFERENCE MODEL FOR THE DETERMINATION OF HEADS DUE TO RADIAL FLOW TOWARDS A WELL AND SIMULATION OF FLOW IN VICINITY OF THE WELL.

completion date: 1979
last update date: 1979

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -STORAGE IN CONFINING LAYER -DELAYED YIELD FROM STORAGE -ISOTROPIC -ANISOTROPIC -HOMOGENEOUS -HETEROGENEOUS -MANY OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -HEAD DEPENDENT FLUX -NO FLOW -SEEPAGE SURFACE -MOVABLE EXTERNAL BOUNDARY -INFILTRATION -WELLS -WELL CHARACTERISTICS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS -METRIC UNITS -CALIBRATION

equations solved: -DARCY'S LAW AND CONTINUITY IN R-Z PLANE

MODEL INPUT--

areal values: -ELEVATION OF AQUIFER TOPS -ELEVATION OF AQUIFER BOTTOMS -HEADS OR PRESSURES -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -SPECIFIC YIELD

boundary values: -PRECIPITATION RATES -EVAPOTRANSPIRATION RATES -PUMPAGE RATES

others: -GRID INTERVALS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -WELL CHARACTERISTICS

MODEL OUTPUT---

-HEADS -FLUXES

GEOMETRY OF MODEL--

shape of cell: -CYLINDRICAL -LOGARITHMIC
< saturated zone > -CYLINDRICAL OR RADIAL

grid orientation and sizing: -AXIAL SYMMETRY -VARIABLE SIZE GRID

number of nodes: -RANGES FROM 100 TO 1000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -GAUSS ELIMINATION

COMPUTERS USED---

make and model: D.G. NOVA 210, IBM-PC/XT/AT

core storage: 64K FOR 200 NODES

PROGRAM INFORMATION--

no. of statements: 100

language: FORTRAN IV,BASIC

terms of availability of code and user's manual: PUBLIC DOMAIN; CONTACT IGWMC

cost: $35 from IGWMC

MODEL EVALUATION--

USABILITY	RELIABILITY
-preprocessor: YES	-peer reviewed
-postprocessor: NO	-theory: YES
-user's instructions: YES	-coding: YES
-sample problems: YES	-verified: YES
-hardware dependency: NO	-field validation: YES
-support: YES	-model users: MANY

REMARKS--

01 IBM-PC VERSION AVAILABLE FROM IGWMC

REFERENCES--

01 RUSHTON, K.R. AND S.C. REDSHAW. 1979. SEEPAGE AND GROUNDWATER FLOW. WILEY, CHICHESTER, UNITED KINGDOM 332 PP.

02 RUSHTON, K.R. AND Y.K. CHAN. 1977. NUMERICAL PUMPING TEST ANALYSIS IN UNCONFINED AQUIFERS. J. IRR. AND DRGE. DIV., ASCE, VOL. 103.

03 RUSHTON, K.R. AND Y.K. CHAN. 1976. PUMPING TEST ANALYSIS WHEN PARAMETERS VARY WITH DEPTH. GROUNDWATER, VOL. 14(2) PP. 82-87.

04 RUSHTON, K.R. 1978. ESTIMATING TRANSMISSIVITY AND STORAGE COEFFICIENT FROM ABSTRACTION WELL DATA. GROUNDWATER, VOL. 16, PP. 81-85.

05 STRELTSOVA, T.D. AND K.R. RUSHTON. 1973. WATER TABLE DRAWDOWN DUE TO A PUMPED WELL IN AN UNCONFINED AQUIFER. WATER RESOURCES RESEARCH, VOL. 9(1), PP. 236-242.

IGWMC key= **6120**

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MODEL IDENTIFICATION

model name: **AT123D**

model purpose: AN ANALYTICAL 1, 2, OR 3-D SIMULATION OF SOLUTE TRANSPORT IN A HOMOGENEOUS, ANISOTROPIC AQUIFER, WITH DECAY AND RETARDATION FROM A VARIETY OF SOURCES.

completion date: MAR 1981
last update date: MAR 1981

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -ISOTROPIC -ANISOTROPIC -HOMOGENEOUS

flow conditions: -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -POINT SOURCE -LINE SOURCE -AREA SOURCE -VOLUME SOURCE.

fluid conditions: -HETEROGENEOUS -CONTAMINANTS, POLLUTANTS, LEACHATE -SULFATES -NITROGEN -RADIOACTIVE -TEMPERATURE DEPENDENT

model processes: -CONDUCTION -DISPERSION -DIFFUSION -ADSORPTION -ION EXCHANGE -DECAY -VOLATILIZATION

other model characteristics: -METRIC UNITS

equations solved: -CONVECTIVE-DISPERSIVE TRANSPORT EQUATION WITH RETARDATION, RADIOACTIVE DECAY, AND HEAT EXCHANGE BETWEEN WATER AND ROCK MATRIX.

MODEL INPUT--

areal values: -PERMEABILITY -POROSITY -DISPERSIVITY -SPECIFIC WEIGHT -DECAY RATE

others: -INSTANTANEOUS, CONTINUOUS AND FINITE DURATION SOURCE RELEASE -SOURCE LOCATION -DISTRIBUTION COEFFICIENT -VELOCITY FIELD

MODEL OUTPUT---

tables: -CONCENTRATIONS OF WATER CONSTITUENTS -RADIATION

GEOMETRY OF MODEL--

< saturated zone > -1D HORIZONTAL -2D HORIZONTAL -2D VERTICAL -3D

grid orientation and sizing: -CROSS SECTIONAL OR VERTICAL VIEW -

TECHNIQUES---

basic modeling technique: -ANALYTICAL METHOD

COMPUTERS USED---

make and model: IBM-PC/XT/AT

core storage: 256K

PROGRAM INFORMATION--

no. of statements: 700

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; CONTACT IGWMC

cost: $95 from IGWMC

MODEL EVALUATION--

USABILITY
- -preprocessor: DEDICATED
- -postprocessor: GENERIC
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: LIMITED
- -model users: MANY

REFERENCES---

01 YEH, G.T. 1981. AT 123D: ANALYTICAL TRANSIENT ONE-, TWO-, OR THREE-DIMENSIONAL SIMULATION OF WASTE TRANSPORT IN THE AQUIFER SYSTEM. ORNL-5602, OAK RIDGE NATIONAL LAB, OAK RIDGE, TN.

02 GENERAL SOFTWARE CORP. 1984. AT123D EXECUTION USING THE DATA MANAGEMENT SUPPORTING SYSTEMS AT123DIN AND AT123DOUT. USERS GUIDE (DRAFT). WASHINGTON, DC: ENVIRONMENTAL PROTECTION AGENCY. CONTRACT 68023970.

IGWMC key= **6220**

MODEL TEAM

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MODEL IDENTIFICATION

model name: **ONE-D**

model purpose: ANALYTICAL SOLUTIONS FOR CONVECTIVE-DISPERSIVE TRANSPORT OF A SOLUTE WITH LINEAR ADSORPTION IN A STEADY-STATE FLOW FIELD IN A SEMI-INFINITE ISOTROPIC, HOMOGENEOUS AQUIFER

completion date: 1982
last update date: 1982

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -ISOTROPIC -HOMOGENEOUS

flow conditions: -STEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT FLUX -FIRST AND SECOND TYPE BOUNDARY CONDITION FOR SOLUTE -SEMI INFINITE EXTENT

fluid conditions: -HOMOGENEOUS

model processes: -CONVECTION -DISPERSION -DIFFUSION -ADSORPTION

other model characteristics: -METRIC UNITS

equations solved: -ONE-DIMENSIONAL CONVECTIVE-DISPERSIVE TRANSPORT EQUATION WITH LINEAR ADSORPION

MODEL INPUT--
areal values: -POROSITY -DISPERSIVITY -INITIAL QUALITY

boundary values:

others: -RETARDATION COEFFICIENT -VELOCITY -CONCENTRATION BOUNDARY CONDITION

MODEL OUTPUT---
tables: -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL--
shape of cell: -NONE
< saturated zone > -1D HORIZONTAL -1D VERTICAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW

TECHNIQUES---
basic modeling technique: -ANALYTICAL METHOD

COMPUTERS USED---
make and model: IBM-PC/XT/AT

PROGRAM INFORMATION--
no. of statements: 100

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; CONTACT IGWMC

user's manual: PROGRAM LISTED IN REF. #1

available code form: PRINTED LISTING

COST: $95 FROM IGWMC

MODEL EVALUATION

USABILITY	RELIABILITY
-preprocessor: NO	-peer reviewed
-postprocessor: NO	-theory: YES
-user's instructions: YES	-coding: YES
-sample problems: YES	-verified: YES
-hardware dependency: NO	-field validation: YES
-support: YES	-model users: MANY

REFERENCES

01 VAN GENUCHTEN, M.TH. AND W.J. ALVES. 1982. ANALYTICAL SOLUTIONS OF THE ONE-DIMENSIONAL CONVECTIVE-DISPERSIVE SOLUTE TRANSPORT EQUATION. TECHN. BULL. NO. 1661, U.S. DEPT OF AGRICULTURE, RIVERSIDE, CA. 151 P.

IGWMC key= **6305**

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MODEL IDENTIFICATION

model name: **AQUIFER4**

model purpose: A RADIAL FINITE DIFFERENCE MODEL TO SIMULATE TRANSIENT THREE-DIMENSIONAL GROUNDWATER FLOW IN A LEAKY-CONFINED AQUIFER.

last update date: MAR 1984

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -LEAKY -ISOTROPIC -HOMOGENEOUS -HETEROGENEOUS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -WELLS -WELL CHARACTERISTICS -CONSTANT PUMPAGE -VARIABLE PUMPAGE

fluid conditions: -HOMOGENEOUS

other model characteristics: -ENGLISH UNITS

MODEL INPUT

areal values: -ELEVATION OF AQUIFER TOPS -THICKNESS OF AQUIFER -PERMEABILITY -TRANSMISSIVITY -STORAGE COEFFICIENT -HYDRAULIC RESISTANCE IN CONFINING LAYER

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -TIME STEP SEQUENCE -INITIAL TIME STEP -LEAKAGE RATES

MODEL OUTPUT--

tables: -HEADS OR PRESSURES -DRAWDOWNS

GEOMETRY OF MODEL---

shape of cell: -CYLINDRICAL
< saturated zone > -3D -CYLINDRICAL OR RADIAL

grid orientation and sizing: -AXIAL SYMMETRY

TECHNIQUES--

basic modeling technique: -FINITE DIFFERENCE

equation solving technique: -LINE SUCCESSIVE OVER RELAXATION -ALTERNATING DIRECTION

COMPUTERS USED--

make and model: TRS-80-I/III/IV, IBM PC/XT/AT, APPLE-II, CP/M-80 COMPUTERS

core storage: 64K

PROGRAM INFORMATION---

language: MICROSOFT BASIC

available code form: DISKETTE -PRINTED LISTING

cost: UNKNOWN

MODEL EVALUATION--

USABILITY
- -preprocessor: DEDICATED
- -postprocessor: UNKNOWN
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: NO
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: UNKNOWN
  - -coding: UNKNOWN
- -verified: YES
- -field validation: UNKNOWN
- -model users: UNKNOWN

REMARKS--

01 A PRE-PROCESSOR SETUP4 ENABLES THE USER TO PREPARE INPUT DATA FILES FOR THE SIMULATION MODEL.

02 THE MODEL HAS A RESTART OPTION USING RESULTS OF PREVIOUS SIMULATIONS.

IGWMC key= **6340**

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MODEL IDENTIFICATION

model name: **VERTPAK-1**

model purpose: A PACKAGE OF ANALYTICAL SOLUTIONS ASSEMBLED TO ASSIST IN VERIFICATION OF NUMERICAL CODES USED TO SIMULATE FLUID FLOW, ROCK DEFORMATION, AND SOLUTE TRANSPORT IN FRACTURED AND UNFRACTURED POROUS MEDIA.

completion date: AUG 1982
last update date: AUG 1982

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -ISOTROPIC -HOMOGENEOUS -DISCRETE FRACTURES -DUAL POROSITY FRACTURE SYSTEM -AQUIFER SYSTEM DEFORMATION -AQUIFER COMPACTION

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -WELLS -CONSTANT PUMPAGE -SEMI-INFINITE AQUIFER

fluid conditions: -HOMOGENEOUS

model processes: -CONVECTION -CONDUCTION -DISPERSION -DIFFUSION -DECAY -RETARDATION -ADVECTION

other model characteristics: -METRIC UNITS

MODEL INPUT--

areal values: -THICKNESS OF AQUIFER -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -DISPERSIVITY -THERMAL CONDUCTIVITY -THERMAL CAPACITY -SPECIFIC HEAT -FLUID DENSITY -SPECIFIC WEIGHT -DECAY RATE -INITIAL QUALITY

boundary values: -HEADS OR PRESSURES -FLUXES -PUMPAGE RATES

others: -SOLUTE FLUX -TEMPERATURES

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -FLUXES -VELOCITIES -TEMPERATURE -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL--

shape of cell: -NONE

< saturated zone > -1D HORIZONTAL -1D VERTICAL -2D HORIZONTAL -2D VERTICAL -CYLINDRICAL OR RADIAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -CROSS SECTIONAL OR VERTICAL VIEW -AXIAL SYMMETRY

TECHNIQUES---

basic modeling technique: -ANALYTICAL METHOD

COMPUTERS USED---

make and model: CYBER 176

core storage: 22K

PROGRAM INFORMATION--

no. of statements: 3900

language: FORTRAN IV

terms of availability of code and user's manual: PUBLIC DOMAIN; -CODE AND USER'S MANUAL PUBLISHED IN REF. #1.

available code form: MAGNETIC TAPE -PRINTED LISTING

cost: < $100

MODEL EVALUATION--

USABILITY	RELIABILITY
-preprocessor: NO	-peer reviewed
-postprocessor: NO	-theory: YES
-user's instructions: YES	-coding: UNKNOWN
-sample problems: YES	-verified: YES
-hardware dependency: NO	-field validation: YES
-support: YES	-model users: UNKNOWN

REMARKS---

01 VERTPAK-1 CONTAINS THE FOLLOWING ANALYTICAL SOLUTIONS:

BAREN: A ANALYTICAL SOLUTION DEVELOPED BY BARENBLATT, ZHELTOV AND KOCHINA (1960) FOR DESCRIBING TRANSIENT FLOW TO A WELL PENETRATING A (DOUBLE POROSITY) CONFINED AQUIFER.

GIBMAC: AN ANALYTICAL SOLUTION DEVELOPED BY MCNAMEE AND GIBSON (1960) FOR DESCRIBING CONSOLIDATION OF A SEMI-INFINITE SOIL MEDIUM SUBJECT TO A STRIP (PLANE STRAIN) OR CYLINDRICAL (AXISYMMETRIC) LOADING.

GRINRH: AN ANALYTICAL SOLUTION DEVELOPED BY GRINGARTEN (1971) FOR DESCRIBING TRANSIENT FLOW TO A PARTIALLY PENETRATING WELL IN A CONFINED AQUIFER CONTAINING A SINGLE HORIZONTAL FRACTURE.

GRINRV: AN ANALYTICAL SOLUTION DEVELOPED BY GRINGARTEN, RAMEY AND RAGHAVAN (1974) FOR DESCRIBING TRANSIENT FLOW TO A FULLY PENETRATING WELL IN A CONFINED AQUIFER CONTAINING A SINGLE VERTICAL FRACTURE.

HART: AN ANALYTICAL SOLUTION GIVEN BY NOWACKI (1962) AND IMPLEMENTED BY HART (1981) FOR DESCRIBING THE ELASTIC BEHAVIOR OF AN INFINITE SOLID SUBJECT TO A LINE HEAT SOURCE.

LESTER: AN ANALYTICAL SOLUTION PRESENTED BY LESTER, JANSEN AND BURKHOLDER (1975) FOR DESCRIBING ONE-DIMENSIONAL TRANSPORT OF RADIONUCLIDE CHAINS THROUGH AN ADSORBING MEDIUM.

STRELT: AN ANALYTICAL SOLUTION PRESENTED BY STRELTSOVA-ADAMS (1978) FOR DESCRIBING TRANSIENT FLOW TO A FULLY PENETRATING WELL IN A (DOUBLE POROSITY) CONFINED AQUIFER.

TANG: AN ANALYTICAL SOLUTION DEVELOPED BY TANG, FRIND AND SUDICKY (1981) FOR DESCRIBING SOLUTE TRANSPORT IN A POROUS MEDIUM CONTAINING A SINGLE FRACTURE.

REFERENCES--

01 INTERA ENVIRONMENTAL CONSULTANTS 1983. VERTPAK-1: PACKAGE OF ANALYTICAL SOLUTIONS FOR CODE VERIFICATION. ONWI-451, OFF. OF NUCLEAR WASTE ISOLATION, BATTELLE, COLUMBUS, OHIO.

IGWMC key= **6350**

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MODEL IDENTIFICATION

model name: **35 MICROCOMPUTER PROGRAMS**

model purpose: A SERIES OF ANALYTICAL AND SIMPLE NUMERICAL PROGRAMS TO ANALYZE FLOW AND TRANSPORT OF SOLUTES AND HEAT IN CONFINED, LEAKY OR WATER TABLE AQUIFERS WITH SIMPLE GEOMETRY.

completion date: APR 1984
last update date: MAR 1985

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -WATER TABLE -LEAKY -ISOTROPIC -HOMOGENEOUS -HETEROGENEOUS -TWO OVERLYING AQUIFERS

flow conditions: -STEADY -UNSTEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -GROUNDWATER RECHARGE -WELLS -CONSTANT PUMPAGE -POLLUTION SOURCES/SINKS

fluid conditions: -HOMOGENEOUS

model processes: -CONDUCTION -DISPERSION -ADVECTION -RETARDATION

other model characteristics: -ENGLISH UNITS

MODEL INPUT--

areal values: -THICKNESS OF AQUIFER -PERMEABILITY -TRANSMISSIVITY -POROSITY -STORAGE COEFFICIENT -SPECIFIC YIELD -DISPERSIVITY -THERMAL CONDUCTIVITY -TEMPERATURE -INITIAL QUALITY

boundary values: -FLUXES -PUMPAGE RATES -GROUND WATER RECHARGE RATES

MODEL OUTPUT---

tables: -HEADS OR PRESSURES -TEMPERATURE -CONCENTRATIONS OF WATER CONSTITUENTS -DRAWDOWNS

GEOMETRY OF MODEL--

shape of cell: -SQUARE -RECTANGULAR -NONE

< saturated zone > -1D HORIZONTAL -2D HORIZONTAL -3D -CYLINDRICAL OR RADIAL

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -AXIAL SYMMETRY

number of nodes: -RANGES FROM 100 TO 1000

TECHNIQUES---

basic modeling technique: -FINITE DIFFERENCE -ANALYTICAL METHOD

equation solving technique: -ITERATIVE ALTERNATING DIRECTION -IMPLICIT -RANDOM WALK

COMPUTERS USED---

make and model: IBM PC/XT/AT, TRS 80-III

core storage: 64K

PROGRAM INFORMATION--

language: MICROSOFT BASIC

terms of availability of code and user's manual: PUBLIC DOMAIN; TRS-80 VERSION FROM W.C. WALTON, OTHER VERSIONS FROM IGWMC

available code form: DISKETTE -PRINTED LISTING

cost: $70 from IGWMC

MODEL EVALUATION--

USABILITY	RELIABILITY
-preprocessor: DEDICATED	-peer reviewed
-postprocessor: NO	-theory: YES
-user's instructions: YES	-coding: YES
-sample problems: YES	-verified: YES
-hardware dependency: NO	-field validation: YES
-support: YES	-model users: MANY

REFERENCES--

01 WALTON, W.C. 1984. 35 BASIC GROUNDWATER MODEL PROGRAMS FOR DESKTOP MICROCOMPUTERS. GWMI 84-06/4, INTERNATIONAL GROUND WATER MODELING CENTER, HOLCOMB RESEARCH INSTITUTE, BUTLER UNIVERSITY, INDIANAPOLIS, IN 46208.

IGWMC key= 6380

MODEL TEAM

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MODEL IDENTIFICATION

model name: SOLUTE

model purpose: A PACKAGE OF 8 ANALYTICAL MODELS FOR SOLUTE TRANSPORT SIMULATION IN GROUNDWATER. THE PACKAGE ALSO INCLUDES PROGRAMS FOR UNIT CONVERSION AND ERROR FUNCTION CALCULATION.

completion date: JAN 1985
last update date: JAN 1985

MODEL CHARACTERISTICS

aquifer conditions: -CONFINED -ISOTROPIC -HOMOGENEOUS

flow conditions: -STEADY -SATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX

fluid conditions: -HOMOGENEOUS

model processes: -DISPERSION -ADSORPTION -DECAY -ADVECTION

other model characteristics: -ENGLISH UNITS -METRIC UNITS

equations solved: -ADVECTION-DISPERSION EQUATION

MODEL INPUT--

areal values: -POROSITY -DISPERSIVITY -DECAY RATE

boundary values: -HEADS OR PRESSURES -FLUXES

others: -GRID INTERVALS -NUMBER OF NODES OR CELLS -NODE LOCATIONS OR COORDINATES -TIME STEP SEQUENCE -INITIAL TIME STEP -NUMBER OF TIME INCREMENTS

MODEL OUTPUT--

tables: -AQUIFER GEOMETRY -VELOCITIES -DISPERSIVITY

plotted graphics:
<areal maps > -CONCENTRATIONS

GEOMETRY OF MODEL--

shape of cell: -RECTANGULAR -LINEAR

< saturated zone > -1D HORIZONTAL -2D HORIZONTAL -3D

grid orientation and sizing: -PLAN OR HORIZONTAL VIEW -AXIAL SYMMETRY

number of nodes: -RANGES FROM 10 TO 100

TECHNIQUES--

basic modeling technique: -ANALYTICAL METHOD

COMPUTERS USED--

make and model: IBM-PC/XT/AT

core storage: 64K

PROGRAM INFORMATION--

language: MICROSOFT BASIC

terms of availability of code and user's manual: PUBLIC DOMAIN; AVAILABLE FROM IGWMC

available code form: DISKETTE

cost: $70

MODEL EVALUATION--

USABILITY
- -preprocessor: YES
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: YES
- -model users: MANY

REFERENCES---

01 BELJIN, M.S.. 1985. A PROGRAM PACKAGE OF ANALYTICAL MODELS FOR SOLUTE TRANSPORT IN GROUNDWATER "SOLUTE". BAS15, INTERNATIONAL GROUND WATER MODELING CENTER, HOLCOMB RES. INST., BUTLER UNIV., INDIANAPOLIS, INDIANA, 163 P.

IGWMC key= **6390**

MODEL TEAM

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MODEL IDENTIFICATION

model name: **MOUSE**

model purpose: A SET OF FOUR LINKED ANALYTICAL MODELS FOR TRACKING THE MOVEMENT AND FATE OF A SOLUBLE CHEMICAL IN SATURATED AND UNSATURATED ZONES.

completion date: SEP 1983
last update date: MAY 1987

MODEL CHARACTERISTICS

aquifer conditions: -WATER TABLE -ISOTROPIC -HOMOGENEOUS (SOIL)

flow conditions: -STEADY -SATURATED -UNSATURATED -LAMINAR

boundary conditions: -CONSTANT HEADS OR PRESSURES -CONSTANT FLUX -NO FLOW -INFILTRATION -GROUNDWATER RECHARGE

fluid conditions: -HOMOGENEOUS

model processes: -ADSORPTION -ION EXCHANGE -DECAY -REACTIONS -BIODEGRADATION -ADVECTION

MODEL OUTPUT

tables: -CONCENTRATIONS OF WATER CONSTITUENTS

GEOMETRY OF MODEL--

< saturated zone > -2D VERTICAL

<unsaturated zone> -1D VERTICAL

grid orientation and sizing: -CROSS SECTIONAL OR VERTICAL VIEW

TECHNIQUES--

Basic Modeling Technique: -ANALYTICAL METHOD

COMPUTERS USED---

make and model: IBM PC/XT/AT

core storage: 256K

mass storage: 1-DISK DRIVE

peripherals: COLOR GRAPHIC ADAPTER CARD

other requirements: OPTIONAL 8087 COPROCESSOR, OPTIONAL PRINTER

PROGRAM INFORMATION--

language: PASCAL

terms of availability of code and user's manual: COMPILED VERSION ONLY. SOURCE CODE AVAILABLE FOR INSPECTION

available code form: DISKETTE

cost: UNKNOWN

MODEL EVALUATION---

USABILITY
- -preprocessor: YES
- -postprocessor: YES
- -user's instructions: YES
- -sample problems: YES
- -hardware dependency: YES
- -support: YES

RELIABILITY
- -peer reviewed
  - -theory: YES
  - -coding: YES
- -verified: YES
- -field validation: LIMITED
- -model users: FEW

REMARKS---

01 THE MOUSE PROGRAM INCLUDES THE USE OF COLOR AND GRAPHIC DISPLAYS. IT HAS INTERACTIVE DATA ENTRY AND EDITING THROUGH THE USE OF FULL SCREEN EDITING FACILITIES.

02 THE PROGRAM CONTAINS FOUR LINKED SUBMODELS:

1. GENERATE SYNTHETIC DAILY CLIMATE PATTERNS BASED ON HISTORICAL MONTHLY CLIMATE STATISTICS

2. CALCULATE MOISTURE CONTENT AND FLUXES IN THE UNSATURATED ZONE

3. SIMULATE DEGRADATION AND MOVEMENT OF CHEMICALS WITHIN THE UNSATURATED ZONE

4. SIMULATE THE WATER MOVEMENT AND SOLUTE MOVEMENT AND DEGRADATION IN A VERTICAL TWO-DIMENSIONAL CROSS SECTION OF AN UNCONFINED AQUIFER

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