93 0215

F 1

GROUND-WATER FLOW AND TRANSPORT MODELING FOR BASELINE RISK ASSESSMENT IN FRACTURED MEDIA AT ARID AREA

Eddebbarh, A.A., Groundwater Resources
CH2M HILL

Introduction. A ground-water flow and transport modeling was used as a tool to assist in estimating concentrations of contaminants at various receptors in the future. The modeling consists of a numerical ground-water flow model used in conjunction with a numerical solute transport model. The flow model utilized is the modular three-dimensional finite-difference (MODFLOW) ground-water flow model developed by Michael McDonald and Arlen Harbaugh (USGS, 1988). The model is publicly available, well documented, and extensively used. The transport modeling was performed using the Modular Three-Dimensional Transport (MT3D) model (Zheng, 1990). The computer code uses a modular three-dimensional structure similar to that implemented in MODFLOW. The modular structure makes it possible to simulate advection, dispersion, sink/source mixing, and sorption.

Modeling Objectives. The major objective of the modeling effort was to estimate the relative concentrations of contaminants at different receptors over time for several future exposure scenarios. The scenarios include domestic and industrial wells. In addition, the models were tested to identify the sensitivity of the relative concentrations to input parameters.

Numerical modeling was chosen as the appropriate analytical tool for this task because it has the capability to represent multidimensional flow in a heterogeneous system with less conceptual idealization than is required by other analytical techniques.

Model Conceptualization

Regional Hydrogeologic Characteristics. The climate of the modeled area is semiarid. The mean annual precipitation is approximately 14 inches with about 70 percent of the precipitation occurring between April and November. Mean monthly temperatures range from approximately 70°F in July and August to

32°F in December and January. Mean annual pan evaporation is estimated to be 55 inches.

The modeled area is located within the Denver Basin. This basin is a north-south trending structural depression extending from Wyoming into southern Colorado. As much as 15,000 feet of sediments have been deposited in some parts of the basin. These sediments have been grouped into a number of geologic formations. Of these, three formations are of interest to the modeling effort and of regional importance as aquifers; the Dawson, the Denver, and the Arapahoe Formations. The lateral and vertical extents of the formations do not coincide exactly with the extents of the aquifers because part of the formations do not transmit water. For this modeling effort, seven model layers were identified and cover the extent of the three formations of interest.

Fractures have been identified within the weathered Dawson but appear to be sufficiently interconnected for the ground-water system to function as an equivalent porous medium. Fracture data from both core and borehole geophysical logs were compiled and analyzed. Core logs from 14 ASC boreholes and 26 pre-ASC boreholes were examined and assessed for fracture occurrence, character, and dip angle. Additionally, FMS logs from six ASC boreholes were interpreted for fracture occurrence and orientation.

A three-dimensional ground-water system exists at the site within the seven identified model layers. The principal flow directions are northward and downward.

<u>Model Domain</u>. The extent of the model domain was determined primarily on the basis of the distribution of receptors and the types of ground-water extraction scenarios.

Grid Delineation and Boundary Conditions. Both the MODFLOW and MT3D models were developed as seven-layer models using the same computational grid with 42 rows and 32 columns in the horizontal plane.) describes how the grid was delineated and the boundary conditions used in the steady-state MODFLOW simulations.

Hydraulic Properties. The parameterization of the ground-water flow model required estimation of the transmissivities and vertical leakage. Transmissivity is defined as the product of horizontal hydraulic conductivity and layer thickness. These hydraulic properties were computed based on site characterization data and concepts. This flux was verified by performing mass balances. For each exposure scenario, MODFLOW was run to simulate the pumping stresses in the Dawson, Denver or Arapahoe Aquifers, thus generating the heads used in MT3D.

Model Calibration. During calibration, model parameters and boundary conditions are adjusted to minimize the difference between computed and observed hydraulic conditions.

Most of the computed heads were within 10 feet of the values measured in the field. The maximum elevation difference, 35 feet, occurred in Layer 1. With the exception of Layers 1, 4, and 5, the results for the other layers appear to be randomly distributed about the correlation line. No overall systematic bias appears to be present. Most of the calibrated hydraulic parameters have been altered only minimally from the original estimates. The most altered parameters are the vertical leakages for Layers 5 and 6. For the overall model, the mass balance discrepancy is less than 0.01 percent.

Calibration of the transport model was not performed because of the difficulties associated with defining the source, the numerous chemicals detected, and the uncertainty related to the transport parameters.

Transport Model MT3D is designed to work directly with MODFLOW. This means only a few additional parameters must be estimated. The additional input parameters used in the MT3D transport model relate to advection, dispersion, sorption, sources, and sinks.

Advection. The input parameters for advection include hydraulic conductivity, thickness, and effective porosity for each layer.

Dispersion. The input parameters for dispersion are the longitudinal dispersivity, the ratio of the horizontal transverse to the longitudinal dispersivity, the ratio of the vertical transverse to the longitudinal dispersivity, and molecular diffusion.

Sorption. Sorption is implemented in MT3D through the use of a retardation factor (R). The input parameters for sorption are the partition coefficient, the bulk density, and the type of sorption isotherm.

Sources and Sinks. The remaining input parameters deal with sources and sinks. Source and sink input parameters include the type of boundary conditions, stresses, and concentrations associated with the source areas.

Initial Conditions. For the transport model it was necessary to specify initial solute concentrations. An initial solute concentration of zero was specified everywhere in the seven layers, simulating the conditions prior to any disposal at the landfill. The source area for the Site is defined as the area where waste pits have been delineated and along Unnamed Creek. Each model cell in the source area received contaminated water at a rate calculated by the flow model. This contaminated source water was assigned a constant unitless normalized concentration of 1.

The length of time the source would be present and contributing contaminants to the ground water was estimated using a mixing model approach. Assuming a two order of magnitude reduction in contaminant mass, the source duration was estimated to be 200 years.

Sensitivity Analysis. Sensitivity analysis is the process of studying the sensitivity of parameters by systematically changing one parameter while holding other parameters constant. This is done, even if a model is calibrated, because the calibration may not be unique. Sensitivity analysis of the transport model included systematic variation of dispersivity, effective porosity, and retardation parameters.

Summary of Transport Modeling. The predicted arrival times at a receptor and the relative concentrations are based on conservative assumptions. Therefore, actual arrival times are likely to be higher and relative concentrations lower. Advective transport was simulated using low effective porosities and sorption terms were not considered.

The scenarios with the greatest relative concentrations are the domestic/industrial Scenarios 2 and 3. These scenarios have receptors located closest to the source area in Layers 1 and 2.

The Denver and Arapahoe Aquifers (Layers 6 and 7) are the only aquifers that can sustain municipal pumping. The relative concentrations simulated from municipal wells pumping in these layers and having receptors in these layers were low. Based on a flowpath analysis using MODPATH, contaminants moving purely by advection would reach these aquifers between 700 to 1,100 years. This indicates the relative concentrations simulated at these receptors are due to pure dispersion. The majority of the dispersion is numeric 1. The effects of retardation would increase the travel times even more.

References. McDonald, M.G. and Harbaugh, A. W. *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model*. Techniques of Water Resources Investigation of the USGS. U.S. Government Printing Office. Chapter A1, Book 6. 1988.

Zheng, C. *A Modular Three-Dimensional Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Ground-Water Systems*. S. S. Papadopulos and Associates, Inc. October 17, 1990.

BORDEREAU D'ENTREE DES DONNEES

AGRIS Formulaire 1(Rev. 5)F

agris

001 C F | ANNEE | NUMERO DE SERIE: M A | 9 2 | 3 1 6 — TRN

002 1 / 1 — Numero de bordereau / Nombre total de bordereaux

003 REVISION R | RETRAIT W — Modification de données entrées

004 NOUVEAU [✓ N] | SUBSTITUE C | SUPPRIME D — Statut de l'enregistrement

005 — RN du document affecté

006 TRADUCT. T | GENERIQ. /

007 — RN ou TRN de relation

008 T 0 1 ; P 1 0 ; (PRINCIPALE) (SECONDAIRES) CATEGORIES MATIERES / CODE PAYS (ENTREE REGIONALE) /

TYPE BIBLIOGRAPHIQUE: MONOGRAPH. B | NORME C | DESSIN D | FILM F | CARTE OU ATLAS G | ENREGISTR. SONORE H | [✓ ART. PUBL. EN SERIE J] | BREVET P | RAPPORT R | SUPPORT INFORMATIQ. T /

NIVEAU BIBLIOGR.: [✓ ANALYTIQUE A] | MONOGRAPH. M | [✓ PUBL. EN SERIE S] | COLLECTIF C /

INDICATEUR BIBLIOGRAPHIQUE: [✓ REUNION K] | DICTIONNAIRE L | DONNEES NUMERIQUES N | THESE OU DISSERTATION U | LEGISLATION W | BIBLIOGRAPH. Z | CARTE(S) INCLUSE(S) Y | RESUME E | NON CONVENTION. V | SYNTHESE BIBLIOGR. R

1

009 A NIVEAU

Utiliser un bordereau pour chaque niveau bibliographique A, M ou C, cerclé en 008, en partant du niveau le plus spécifique (c'est-à dire la gauche) et reporter le code correspondant en 009. Pour le niveau bibliographique S, utiliser la section 2 du bordereau. Pour les descripteurs AGROVOC, les termes d'indexation du vocabulaire local et les résumés utiliser les sections 3 à 5 au verso.

		Eti-quette	Données (à dactylographier)
Auteur (s) Personne physique (Affiliation (s))		100	Eddebarh, A.A.;
Collectivité(s) auteur(s)		110	
Titre universitaire		111	
Titre anglais	Titre principal	200	Ground-water flow and transport modeling for baseline risk assessment in fractured media at
	Eléments secondaires	201	arid area
Réunion	Nom	210	Hydrogeologie des Milieux Discontinus sous Climats Arides
	Lieu	211	Marrakech (Maroc)
	Date	213	22-25 Avr 1992
Titre original (Translit.)	Titre principal	230	Modelisation de l'ecoulement et du transport de l'eau souterraine pour la determination du risque dans les milieux
	Eléments secondaires	231	fracturés des zones arides
Edition (N°)		250	
No Rapport/brevet		300	
Nos. secondaires		310	
ISBN/IPC		320	
Adresse bibliographique	Lieu de publication	401	
	Editeur	402	
	Date de publication	403	
Collation		500	
Langue (s) du texte		600	(En)
Notes		610	2 ref.

2

009 S NIVEAU

Titre de publication en série	Titre principal	230	Rev. de la Fac. des Sc. de Marrakech - Semlalia (Maroc)
	Eléments secondaires	231	
ISSN		320	
Date de publication		403	(1992)
Collation		500	No special p. 107-110
Notes		610	

GIL 33/F 5.85 20.M - R3483

Sections 3 à 5 au verso

3 009 9 / EN 009 9 / ES 009 9 / [✓ FR]

Code de langue des descripteurs (cocher obligatoirement celui qui convient)

	Étiquette	Données (à dactylographier)
Descripteurs AGROVOC pour l'index mondial dans Agrindex	800	EAU SOUTERRAINE; MODELE DE SIMULATION; POLLUANT; CIRCULATION DE L'EAU; ECOULEMENT DE FLUIDE; (Séparer les descripteurs par un point virgule (;) et un espace. Faire précéder les propositions de nouveaux descripteurs par un point d'interrogation (?))
Autres descripteurs AGROVOC		/ (Laisser un espace après la barre oblique (/))
Commentaires sur les descripteurs existants ou proposés	810	

4 009 9 /

Code de langue des termes d'indexation

Termes d'indexation du vocabulaire local	820	

5 009 X / FR

Code de langue du résumé

Langue du résumé en clair	850	
Résumé	860	La modelisation de l'ecoulement et du transport de l'eau souterraine a pour objectif d'estimer les concentrations des contaminants dans differents recepteurs, et d'identifier la sensitivité des concentrations relatives aux parametres ~~[illegible]~~ d'alimentation.

FIN **النهاية**

8

مشاهد **VUES**