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An Interactive Hydrologic Model for Semi-arid Watersheds

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Abdelaziz Aslouni

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Dr. John B. Gerrish, P.E.

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AN INTERACTIVE MODEL FOR
SEMI ARID WATERSHEDS

By

Abdelaziz Aslouni

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ABSTRACT

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Semi-Arid Watershed Model (SAWM) was developed using an object-oriented interactive software. In the model, rainfall is partitioned to four components of the hydrologic cycle, namely, a river, the atmosphere, a shallow aquifer, and a deep aquifer.

SAWM estimates water yield, evapotranspiration, soil loss, and aquifer recharge - both flows and accumulations. Theoretical step-function storms of 30 days' duration and six uniform intensities (5 through 50 mm/day) were used to calibrate SAMW against a secondary reference model, previously validated.

When realistic rainfall and weather were applied, SAWM overestimated the annual ET by 6%, water yield by 38%, and sediment yield by 120%. Discrepancies are related to SAWM's oversimplification of the soil and shallow aquifer. Interactively improving and tuning SAWM can be readily done for a particular watershed using real data.

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Chapter 1

INTRODUCTION

Water is a limiting factor for biosystems in arid and semi-arid regions. Human conditions in many areas are becoming degraded due to overpopulation and the continual abuse of water resources. Agricultural, industrial and urban areas are encroaching on lands that once were rangelands or deserts. Surface water and groundwater are unable to keep up with the continual growth in needs. Water quality is declining because of the contamination of aquifers by waste water. The conventional approach that takes water resources for granted is no longer acceptable. It is urgent to address water management problems in a holistic manner, understanding how all components of the hydrological cycle interact.

Computerized modeling techniques are rapidly becoming an integral tool in water management and planning due to the availability of appropriate technology and the cost effectiveness of computerized simulations compared to field experimentation. Hydrological modeling (at the scale of a watershed) allows one to better understand each system component and to make predictions according to the response of the system to inquiries. Methods at the scale of a single watershed

command the attention of local authorities and citizens who are immediately affected by water management policy.

This study is intended to evaluate the impact of management scenarios on both surface and groundwater resources within a watershed by quantifying the major components of the hydrologic balance including surface runoff, return flow, impoundment storage, plant uptake, consumptive use, and depletion of groundwater by pumping wells. Scenarios are limited to arid and semi-arid regions in developing countries where the technology is at a low level and data are scarce. Typically, rivers are ungaged and potential users are novices with computers.

This study has three main objectives. The first objective is to make a continuous lumped-parameter descriptive model of the hydrological cycle at the scale of a rural watershed using an object-oriented software (STELLA II, High Performances Systems, Inc. 1990-1994). The second objective is to keep this model simple, user-friendly, educational and adaptable to developing countries' conditions. The third objective is to link surface water and groundwater by considering flow interconnections in the water budget in order to predict the effects of management decisions. The fourth objective is to validate this lumped-parameter model against a secondary reference - i.e., a validated distributed model such as WMS, SWRRB, SWAT or MODFLOW.

Chapter 2

LITERATURE REVIEW

Prior to the development of modeling and simulation techniques, classical hydrological methods relied mostly on observed values, pencil and paper. Despite the simplification of procedures. the task was tedious and time-consuming. People who used models tended to be highly trained in relevant areas and possessed an appreciation for problem-solving in general. Use of complex models as management tools has grown as the power of computers has increased and particularly as microcomputers have become powerful, inexpensive and easier to use.

Computer simulation in hydrology started to be common since the development of the Stanford Watershed Model (Crawford and Linsley, 1966). In the 1960's the challenge was to make a program that would simulate many continuous years of streamflow, that would be fast enough, and that would be physically based to allow the hydrologist to extrapolate beyond the range of the validating data.

In recent years, mathematical modeling of water resources has become possible due to the computer technology and the substantial level of funding in this relatively new area. The modeling is driven by the public's concern for environmental quality and by the increasing severity of water resource management problems worldwide.

In early 1980's, the Office of Technology Assessment (OTA) of the US Congress found that mathematical modeling of water resources was very useful to managers and decision makers (Friedman et al., 1980). One recognizes, however, that many organizational, financial and institutional barriers are to be surpassed before development of modeling can occur. Institutional constraints include lack of information about available models, lack of training in model use and interpretation, lack of communication between modelers and decision makers, and lack of general support services. Development and use of complex models, require highly qualified personnel as well as adequate budgetary support for computer facilities, collecting and processing data. According to OTA, most federal agencies have no comprehensive strategy for developing and using models due to the newness and technical complexity of such work.

The role of models in managing water resources expanded after many regions had noticed decreased availability of water from major aquifers (e.g Ogallalla), and increased public concern for the quality of its drinking water, lakes and rivers. Models that merely determine water yields at the watershed outlet are inadequate (Friedman, ibid). Models should be perceived as a part of the water quality planning process; they should be comprehensive with the biological and chemical facets in a comprehensive manner.

The watershed models are of different types, depending on the purpose for which they were developed. The most evident division is between water quantity models and water quality models. Water quantity models are concerned with the physical allocation and the prediction of stormwater runoff, expected demands, and water supply shortfalls (Biswas, 1975). Water quality models focus on physical attributes, biological processes, and chemical substances (Ott, 1976). Simulation models are the most common type of model in water resource planning. They are usually descriptive in explaining the causal connection between policy and model parameters. However, despite their flexibility and ability to compress or expand the time scale, models may lead the planner to non-feasible solutions because they use trial and error to assess the response of selected outputs to the input variables.

A simulation may be either time-sequenced or event-sequenced (Goodman, 1983). The time-sequenced form uses a fixed time interval to examine the watershed at regular time intervals. The event-sequenced simulations model events only as they happen, by simply recording the time they occurred. The time-sequenced type is more appropriate for watershed simulations because of the structure of water resource data.

The watershed models can be classified also according to other criteria such as process description, scale, and technique of solution (Singh, 1995). The processes are dependent on the watershed characteristics, the resulting models can be described as lumped or distributed, deterministic or stochastic or mixed. Lumped-parameter models are expressed only by differential equations, without considering the spatial variability of processes, the boundary conditions or the watershed geometry. The lumped-parameter approach considers the whole catchment as a single entity and maps the input rainfall excess to an output hydrograph. Typical of this type of model is the Universal Soil Loss Equation (USLE, Wishmeier and Smith, 1978). On the other hand, distributed models consider spatial variability, boundary conditions and watershed characteristics. Distributed models divide the catchment into a number of smaller areas (which could be square elements or subcatchments), which are assumed to be internally uniform with respect to the hydrologic parameters. Hydrology is simulated within each of these small areas and the output routed to the outlet. Examples of distributed models include AGNPS (Agricultural Non-Point Source Pollution, Young et al., 1987), and SWRRB (A Basin Scale Simulation Model for Soil and Water Resources Management, Williams et al., 1985). Considerable time and effort are required to collect data, run the models and interpret results. Integration with GIS (Geographic Informatin System) can eliminate many of the data-entry

problems. Several models have been integrated with GIS including AGNPS, GRASS GIS (Srinivasan and Engel,1994), and SPUR and ERDAS (Sasowsky and Gardner, 1991).

The description of the process can be either deterministic, probabilistic (stochastic) or mixed (Singh, 1988). Deterministic models treat the relationships among the elements of the system to provide results as the mean of different parameters values based on physical laws and empirical information. Stochastic models rely on assumptions about the system, including uncertainty in both inputs and relationships. Stochastic models require large amounts of data to determine the probability distribution and to validate the model. Mixed models have some components stochastic and some deterministic.

The time-scale classification is critical in watershed modeling and can be defined as a combination of two time-intervals (Diskin and Simon, 1979). One interval is used for input and internal computations. The other interval is used for the output and calibration of the model.

The spatial scale can be used to classify models into small-watershed (100km^2 or less), medium-sized watershed (100 to 1000km^2) and large watershed (More than 1000km^2). However , this classification may not be meaningful, depending on the heterogeneity of the soils and the land use characteristics.

The technique used for modeling is driven by the need to solve a particular problem . Data availability determines both the model size

and the accuracy needed. Some simple models rely only on locally available data; others may rely on remote sensing and GIS capabilities to satisfy their needs in data. The cost of the first type of models is cheap because data are at hand, but the second type is costly at present due to technological and expertise overheads.

The previous generation of models(e.g. SWRRB, AGNPS, etc..) needed much hydrological and meteorological records for their calibration. They used curve fitting to calibrate their parameters, but were always error-prone because they did not include critical data, such as topography, soil type and changes in vegetation. Physically-based models can overcome these anomalies if their parameters are physically significant (Abott et al., 1986). However, even with the improvement of computer software, simulation models are always subject to errors, because they are involved in either exploring the implications of making certain assumptions about the nature of the real world system, or predicting the behavior of the real world system under a set of naturally-occurring circumstances (Beven, 1989). Both assumptions and predictions are essential in model building, but their impact on results may vary from acceptable to completely surprising outcomes.

The experience with many complex models showed that the results depend more on the understanding of the hydrologic processes rather than the sophistication of methods used. A lumped-parameter model based on a good hydrological knowledge of the system may provide better outputs in ungaged areas than a mathematically and technologically sophisticated approach. Beven (1989) pointed out that increased model complexity does not necessarily mean better accuracy. This is confirmed by Wilcox et al.(1990) in their comparison of two very different hydrology models designed to predict runoff from ungaged rural catchments. They found that the improved and complex Green and Ampt model is not noticeably more accurate than the simple Soil Conservation Service curve number method. On some catchments, the simple model was more accurate than the complex one. The SCS method is found in many actual models because it is simple, trustworthy, and widely recognized. Sorooshian and Michaud (1994) compared the accuracy of simulations of rainfall-runoff forecasting of a complex distributed model (KINEROS) developed by Woolhiser et al.(1990) and a simple distributed model based on the SCS method. Sorooshian and Michaud conclude that for a semi-arid watershed the two models are similar in accuracy.

Today, four federal agencies are widely recognized for their leadership and activity in water resources modeling: The U.S. Army Corps of Engineers, U.S. Department of Agriculture, U.S. Environmental Protection Agency, and U.S. Geological Survey. All are developing and using their own models.

Army Corps of Engineers' Hydrologic Engineering Center (HEC): HEC provides assistance in applying mathematical models to hydrological planning, design and operation problems. This includes developing and maintaining many computer models, teaching of techniques and model use in formal training courses, and assisting Corps of Engineers officers in applying models and techniques (Fledman, 1981).

The HEC's areas of technical expertise are in hydrologic engineering, related computer applications and analytical techniques used in water resources planning. The areas include: Precipitation-runoff processes, water resources systems, frequency and risk analysis, fluvial hydraulics, urban hydrology, water resources planning, real-time water control, hydropower, and water supply. The main HEC goal in software development is to provide efficient tools to a diverse group of managers and planners. The codes are written in FORTRAN77 for this purpose.

The rainfall-runoff model called HEC-1(Hydrologic Engineering Center, Army Corps of Engineers, 1990) is very widely used. It is a distributed parameter, physically based, single event model. The model components are simple mathematical relationships derived from the kinematic wave approach (Hjelmfelt, 1986) to represent meteorologic, hydrologic and hydraulic processes. Hydrographs and flood waves can be described as either dynamic or

kinematic. Kinematic waves are determined by the weight of the fluid flowing in response to gravity. Dynamic waves are determined by mass, inertial forces, and pressure. The kinematic procedure uses both momentum and continuity principles with solution by finite differences. The fundamental laws that govern and describe fluid flow are described by the momentum and continuity equations (Chow, 1959).

$$dy/dx + v/g\, dv/dx + 1/g\, dv/dt = So - Sf \tag{2.1}$$

$$dA/dt + dQ/dx = q \tag{2.2}$$

where:

y = depth (ft);
v = velocity (ft/s);
x = longitudinal distance (ft);
t=time in sec);
g = gravitational acceleration (ft/sec2);
So = ground slope (ft/ft);
Sf = friction slope (ft/ft);
Q = flow rate (cfs);
A = flow area (ft2);
and q = discharge per unit length (cfs/ft).

Equations 1 and 2 have been approximated respectively by Manning's equation and the Continuity equation:

$$V = (1.486 / n) R^{2/3} So^{1/2} \tag{2.3}$$

$$Q = VA \tag{2.4}$$

where:

A = average area (ft2);
R = hydraulic radius (ft);
V = velocity(ft/sec);
n = Manning's coefficient;
So = ground slope (ft/ft);
and Q = flow rate (ft3/sec).

Volume and time distribution of runoff are controlled through three parameters: Manning's surface roughness coefficient, initial moisture loss, and constant rate of infiltration during overland flow. HEC-1 was mainly designed for flood event studies because flood protection was the Corps' major responsibility. It is not limited to any watershed or river basin size and has been used on complex sub-basins provided that they are in a converging treelike form. Even though HEC-1 is a distributed-parameter model, it assumes that precipitation and infiltration are uniform. within the sub-basin (unit area). This lumped-parameter characteristic is common to many other models, but can be solved in HEC-1 by making the simulation building blocks small enough to capture the desired variability.

HEC-1 has benefitted from the support of the U.S. Army Corps of Engineers to evolve from a small rainfall-runoff program to an integrated software package including, Data Storage System to pass data from one analysis program to another, and Geographic Information System technology to capture the spatial process of watersheds. However, because HEC-1 was mainly designed for flood event studies, it does not recover precipitation losses, such as infiltration, interception, and detention storage.

The U. S. Army Engineer Experiment Station and Brigham Young University have developed a computer program that combines surface water and groundwater. The surface water module is a two dimensional, depth-averaged, free surface, finite element program and is a part of the TABS-MD numerical modeling system (Thomas and Mc Anally, 1991). The groundwater module consists of a flow and transport model (3DFEMFT) model (Yeh, 1991) and a 3-D finite element mesh graphical user interface (GeoSolid) to view the results.

The U.S. Department of Agriculture had its Agricultural Research Service worked for eleven years on a special model: SPUR-91 (Simulation of Production and Utilization of Rangelands Carlson and Thurow, 1992). SPUR-91 is physically based, integrating climate, hydrology, plant, animal and economics in a complex system. The hydrology and plant submodels are influenced by the climate submodel, while they interact with the animal module, the economic part depends on the animal and plant models. The most critical outputs of SPUR-91 are water yield and plant production.

SPUR uses the curve number method to simulate overland flow and to determine how much water will infiltrate. It is a complete hydrology model in that the major components of rangeland water budgets are simulated: overland flow, subsurface flow, soil water, and evapotranspiration. The curve number method, as a runoff prediction tool, is widely used as a part of models because it is simple, does not require calibration, and the Curve Number can be easily obtained from land use and soils maps. A major limitation of the curve number method however is that rainfall intensity and duration are not considered, only total volume.

SPUR is one of several models which simulate the surface and root zone. These models include spatially detailed, single-event models such as ANSWERS (Beasley et al., 1980) and AGNPS (Young et al., 1987), and continuous time models such as HSPF (Johansen et al., 1984) and SWRRB (Arnold et al., 1990). Weather data is generated stochastically by CLIGEN (Nicks and Lane, 1989) which was originally developed to simulate weather for SPUR. The weather elements generated on daily time step are: precipitation amount, maximum intensity, duration, temperature maximum, temperature minimum, dew point, solar radiation, wind speed and wind direction.

The hydrology submodel in SPUR is based on daily water balance, and is similar to SWRRB (Williams et al., 1985) with some adaptations for rangeland conditions:

The water budget equation is:

$$SW = Swo + P - Q - ET - PL - QR \qquad (2.5)$$

where:

SW = Current soil water content;

Swo = Initial (current day - 1) soil water contenet;
P = Precipitation;
Q = Surface runoff;
ET = Evapotranspiration;
PL = Percolation loss below the root zone to groundwater storage;
and QR = Return flow.

Runoff is estimated using the Soil Conservation curve number method (USDA, Soil Conservation Service, 1985). Daily curve number is computed based on soil water storage (Williams and LaSeur, 1976). Water storage is modified because plants can extract moisture at soil water tensions down to -5.0 MPa under rangeland conditions instead of -1.5MPa under cropping conditions (Carlson and Thurow, 1992). The rest of the hydrology submodel and subroutines are similar to those of SWRRB. Unlike SWRRB, however, the interaction between vegetation, soil and climatic variables is well-developed and detailed in SPUR to accommodate a diversity of rangelands and to better simulate the hydrologic process. SPUR is a complicated but powerful tool for assessing various management practices because it combines hydrology, climate, ecology and economy.

A model called Simulation for Water Resources in Rural Basins (SWRRB) was designed to predict the effect of management decisions on water and sediment with reasonable accuracy for ungaged rural basins (William et al., 1985). SWRRB is chosen as a secondary reference model against which my lumped-parameter Semi-Arid

Watershed Model (SAWM, hereinafter) is to be validated. The reasons why SWRRB is chosen are: (a) adaptable for semi-arid watersheds which are ungaged; (b) simple enough to cope with developing countries' technology and computer literacy; (c) and cost effectiveness because it is free of charge for educational and governmental uses.

SWRRB operates on daily time step for up to 100 years. The major processes of the model are surface runoff, percolation, return flow, evapotranspiration, transmission losses, pond and reservoir storage, sedimentation, and crop growth.

The hydrology model is based on the water balance equation.

$$SW = SWo + \Sigma\ (Ri - Qi - Eti - Pi - Qri) \quad \text{(mm)} \qquad (2.6)$$

where: SW is the soil water content minus the 15-bar non-removable water content; t is time in days; R is daily amount of precipitation; Q is runoff; ET is evapotranspiration; P is percolation, and Qr is return flow.

The model requires daily rainfall, maximum and minimum temperatures, and solar radiation as input. In addition, it is capable of working on different soil classes and divides the soil profiles into as many as ten layers. Surface runoff is estimated using a modification of the SCS curve number method (U.S. Department of Agriculture (USDA) Soil and Conservation Service, 1972). It uses a procedure similar to its predecessor, the CREAMS model (Knisel, 1980; Williams and Nicks, 1982). The runoff is predicted separately for each sub-area and routed to obtain the total runoff for the basin.

The SCS curve number equation for predicting surface runoff is:

$$Q = (P - 0.2\ S)^2 / (P + 0.8\ S) \qquad P > 0.2\ S \qquad (2.7)$$

where:

Q is daily runoff (mm);
P is daily rainfall (mm);
and S is a storage index related to curve number by:

$$S = 25400 / (CN - 254) \qquad (2.8)$$

The curve number CN is dimensionless and varies non linearly from condition 1 (dry) at wilting point to condition 3 (wet) at field capacity, and approaches 100 at saturation

Peak runoff rate is based on the Rational Method

$$Qp = \rho\ r\ A / 360 \qquad (2.9)$$

where:

Qp is peak runoff rate in m^3/s;
ρ is runoff coefficient equal to ratio of runoff volume to percolation;
r is rainfall intensity in mm/h;
and A is drainage area in ha.

The percolation component of SWRRB uses a storage routing technique to predict flow through each soil layer in the root zone. Upward flow and downward flow are allowed from the layer where field capacity is exceeded to the less saturated layer. However, due to gravity forces and low rate of recharge, downward flows are more likely to occur than upward flows.

Lateral subsurface flow is simulated when the storage in any layer is more than field capacity after percolation. It is calculated simultaneously with percolation. The flow is dictated by the hydraulic conductivity of the media as well as by the topography and geology of the subsoil. According to Sloan and Moore (1984), subsurface flow is likely to be significant in watersheds with soils having high hydraulic conductivities and an impermeable layer at shallow depths that can support a perched water table.

The evapotranspiration component of SWRRB is critical for semi-arid watersheds. It is based on the concepts of Richie's model (Richie, 1972). Potential evaporation is computed using the equation (Priestley and Taylor, 1972):

$$Eo = 1.28\ (ho)\ (\lambda) \qquad (2.10)$$

where:

Eo is the potential evaporation rate in mm/d ;
ho is the net solar radiation in ly ;
and λ is a psychrometric constant.

$$ho = RA\ (1 - AB)\ /\ 58.3 \qquad (2.11)$$

where:

RA is the daily solar radiation in ly
and AB the albedo.

Soil and plant evaporation are computed separately. Potential soil evaporation is estimated by the equation (Richardson and Richie, 1973)

$$Eso = Eo \exp (-0.4\ LAI) \tag{2.12}$$

where:

Eso is the potential evapotation rate at the soil surface in mm/d;
and LAI is the leaf area index defined as the area of plant leaves relative to the surface soil area.

LAI is difficult to measure on semi-arid rangelands because plants grow randomly. However, Weltz (1987) reported "LAI maximum is equal to 3 for shrub clusters and equal to 2 for herbaceous vegetation on a range site near Alice, Texas."

Transmission losses are included in SWRRB water budget, primarily in semi-arid watersheds where alluvial channels abstract a big part of the streamflow (Lane, 1982). The portion of the flood wave that is lost from the system can be estimated in SWRRB by the method suggested by the SCS Hydrology Handbook (USDA, 1983) based on the channel's width, length, depth, and flow duration.

Ponds and reservoirs are also simulated to manage excess water whenever this may happen. Required inputs are capacity and surface area.

The main weather variables in SWRRB are precipitation, air temperature and solar radiation. Precipitation and temperature data if not available, can be generated using the first-order Markov chain method developed by Nicks (1974). The method uses probability to estimate daily rain given the previous day was either dry or wet. Daily maximum and minimum air temperature and solar radiation are generated from a normal distribution corrected for wet-dry probability state. The probabilites of wet or dry day following a dry or wet day are associated with a random number (0-1). If the random number is less than or equal to the wet-dry probability, precipitation occurs on that day.

Sediment yield is estimated for each sub-basin with the Modified Universal Soil Loss Equation (MUSLE) (Williams and Berndt, 1977). The equation requires varied data about the watershed, such as surface runoff, peak flow, soil erodibility factor, crop management factor, slope and length of basin. Complimentary data can be provided from the SCS Soil-5 database and by Wischmeier and Smith (1978).

For estimated nutrients, such as nitrogen and phosphorous, SWRRB uses a modification of the method used in the EPIC model (Williams et al., ibid, 1984).

Transport of pesticides by runoff or percolation is also part of the model, which comes from its predecessor GLEAMS (Leonard et al., 1987). The model's scope is extended to the EPIC crop model

(Williams et al ibid, 1987) to follow the growth of crops and simulate their needs in water and monitor their content in biomass and pesticides. Even the effect of land management on ponds and lakes is predicted in SWRRB.

Despite its lack of accuracy in water partitioning to the different components of the system watershed and the weakness of its groundwater component, SWRRB uses a broad analysis approach to predict the effect of management decisions on water and sediment yields.

The study of the hydrologic cycle would not be complete without understanding and incorporating the exchanges of water between ground and surface supplies. Many streams and lakes are fed primarily by groundwaters. Excess stormwater is also used to recharge groundwater and compensate depletion caused by increasing needs.

Groundwater is the water below the land surface that saturates the pore spaces in the subsurface media. It begins as infiltration from precipitation on the ground, and from streams, lakes and reservoirs. Water flows downward through the zone of aeration by gravity. This percolation leaves a film of water on the soil grains known as soil moisture. The amount of water in the profile depends on climatic, soil conditions, and depth of the aeration zone.

Groundwater dynamics are dictated by Darcy's law which provides the underlying theory for groundwater flow and is relevant to such concerns as groundwater drawdown, rate of flow from a well, and speed of movement through an aquifer. The basic principle defining the flow of groundwater is:

$$v=K*h/s \tag{2.13}$$

where:

v is the velocity of the flow (L/T);
K is the saturated hydraulic conductivity (L/T);
s is the distance through which the head h is dissipated (L).

The subsurface is divided into two regions, the unsaturated zone and the saturated zone (Figure 1). The unsaturated zone is the upper portion that contains air and water in the pores. It contains the root zone where plants can obtain water and nutrients. It is also separated from the saturated zone by the water table where the pressure is equal to the atmospheric pressure. The saturated zone is the subsurface zone where all voids and pores are filled with groundwater. The flow of water is so slow that is noticeable only on a long term.

The saturated zone can contain two types of aquifers, confined and/or unconfined (Figure 2). The unconfined zone is immediately beneath the unsaturated zone and topped by the water table. The confined aquifer is below the unconfined zone where pressure is higher due to the weight of overlying layers. Aquifers are permeable geologic strata that hold and convey groundwater. Most are large enough to be considered as huge storage reservoirs.

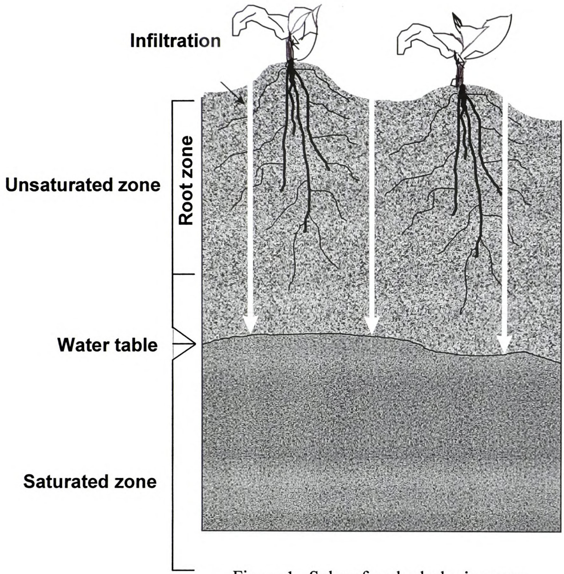

Figure 1. Subsurface hydrologic zones.

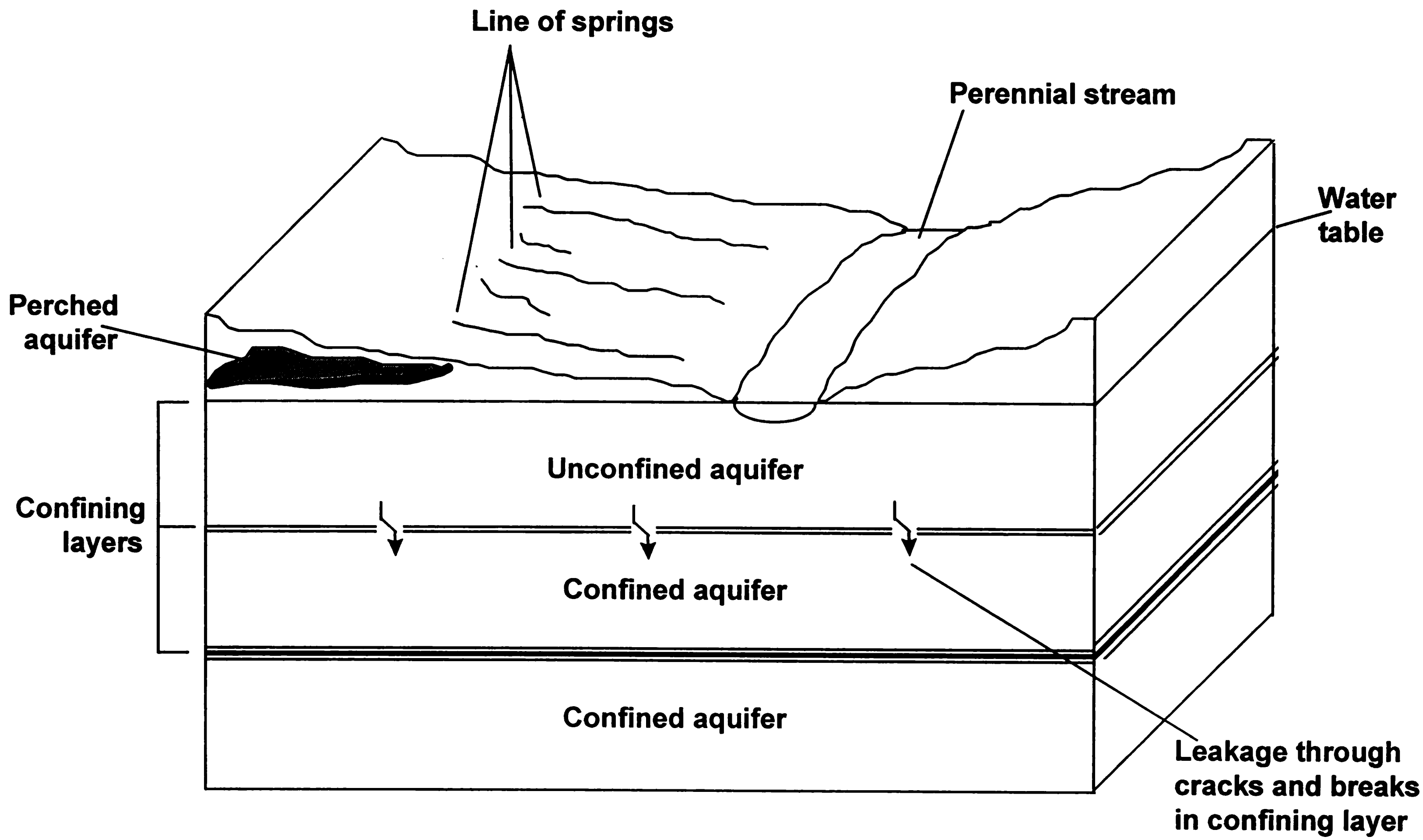

Figure 2. Aquifer types.

Watersheds are complex and dynamic natural systems that display variable behavior temporally and spatially. When a watershed is pertutbed by a storm, its outputs fluctuate for a time before returning to equilibrium (Kort and Kassel, 1993).

Most models that simulate real watershed behavior are hard to understand because they consist of many lines of computer code, which only experienced users can customize. STELLA II (High Performance Systems 1990, 1992) is an object oriented software that uses a dynamic approach to view a system as a collection of individual elements connected in a way so that feedbacks are allowed to operate as observed in reality. STELLA II uses four types of building blocks that may be interconnected to imitate the process modeled. These are stocks, pipelines, converters, and connectors. Stocks are rectangular in shape and act like reservoirs by accumulating flows. Pipelines convey the flow from the source to the stock or from the stock to the sick (end).

Pipelines have controllers which contain equations , logical statements, and numerical relationships that regulate the flow. Converters (circles) are used to convert inputs into outputs. Connectors (arrows) depict the causal linkages among the objects in the model. Sources and sinks are infinite in size and will provide amount of input or accept any amount of output.

STELLA II simplifies model-building via a three-step method: mapping (in which equations that state the logic of simulation are automatically generated); modeling (where the software automatically creates equations); and simulation (where graphs, tables and animation can be viewed).

The tool enables testing of different scenarios and viewpoints in a simple and interactive way; the user can experiment with interconnections and feedback, unburdened by codes and book keeping. The user needs to concentrate on the real-world problem, for example, a place like Morocco where water problems are urgent. The modeling of the hydrologic cycle in a Moroccan watershed seems an ideal application for using STELLA II.

Morocco is a typical semi-arid area where ungaged watersheds are numerous and remote enough to be monitored for data collection. Moroccan geography and climate are similar to those of California. Both have high mountains, bordering oceans to the west, and desert in the south. Their climate is Mediterranean, with seasonal precipitation occurring in the coldest months of the year (October through March) and a hot, dry season for the rest of the year.

Morocco is located in northwest Africa. A 3.500 kilometer coastline on the Mediterranean Sea and Atlantic Ocean bounds the country on the north and west. Algeria is to the east and Mauritania to

the south. The country's area is about 750,000 square kilometers, almost 45 percent of which is in the Sahara region (GATT, 1990).

Four mountain ranges divide the country into three agroecological zones: the fertile agricultural plain in the northwest with 400-1000mm of rain per year; mountains and plateaus in the east with 200-400mm of rain per year; and, deserts in the south with less than 200mm.)

A climatic zoning based on the moisture index has been established (UNESCO, 1979) as

$$I = P / PET \tag{2.14}$$

where:

P is the average annual precipitation, according to Penman's formula;
and PET is the potential evapotranspiration.

Four classes were considered:

a / Hyper-arid zones such as deserts with $I<0.03$

b / Arid zones with $0.2> I>0.03$

c / Semi-arid zones including steppes, prairies, with $0.20<I<0.50$.

d / Sub-humid zones $0.50<I<0.75$

Semi-arid areas have usually one completely dry season, lasting 3 to 4 months. The annual precipitation varies between 200 and 800mm. Storms occur briefly and intensively, causing floods and soil erosion, and cover only small areas aroud the epicenter. Precipitation varies considerably from year to year. In addition, the distribution of rains during the agricultural cycle varies such that the aggregate production levels fluctuate significantly. For example, rainfall in Morocco, in three out of ten years falls by 80-99 percent of the average (Ait kadi, 1989).

Evapotranspiration is high and poorly estimated in the water balance budget. Morocco receives an average annual amount of precipitation of 150 billion cubic meters(Ambrogi, 1985). However, only 20 percent of water is captured, and the remaining 80 percent returns to the atmosphere as evapotranspiration (Ambri, 1986). Aquifer recharge is low because precipitation is low and unevenly distributed on the time scale, so that the soil is seldom saturated.

Moroccan soils are shallow and poor in organic matter. Only 15 percent of the lands have potential agricultural value, with appropriate soils and satisfactory rainfall (GATT, 1990). Due to recurrence of drought, many rural families combine livestock and crop production. They cultivate rangelands which are inappropriate for agriculture due to the steepness and low level of fertility. Therefore, those lands are experiencing permanent soil erosion under the effect of human and animal activities. Modeling ungaged watersheds which are under such conditions would be a useful tool for planners and managers, to better understand interconnections between the components of the hydrologic cycle, and anticipate the consequences of management interventions on the water budget and the ecology of the watershed .

Chapter 3

METHODS

The model suggested in this study is designed to simulate the main components of the hydrologic cycle at the scale of a semi-arid watershed, including the interconnections between surface water and groundwater. The lumped-parameter model is built using STELLA II. STELLA II views the system (watershed) as a collection of individual elements connected in a dynamic network such that realistic feedback mechanisms are allowed to operate. Since the model permits evaluation of the impact of interconnections between groundwater and surface water within the watershed, it can be used to predict the effect of management decisions. The lumped-parameter SAWM is to be validated against the surface, groundwater and sediment submodels of the distributed model, SWRRB.

SAWM is a representation of the mass balance of water within a particular control volume dictated by the watershed's hydrologic and climatic conditions. It represents the law of conservation of mass. Thus, the rate of change of storage of water within an element is "equal" to the difference between its rates of inflow and outflow across the control surface. The water balance is coupled to a simplification of Darcy's momentum law for groundwater flow. Darcy's law defines how quickly water can move between different parts of a porous medium.

The water that is discharged from an aquifer can be approximated with Darcy's law:

$$Q=k*A*dh/dx \tag{3.1}$$

The discharge from an aquifer, thus, is dependent on the cross-sectional area through which the flow occurs (A), the hydraulic conductivity of the material constituting the aquifer (k), and the hydrulic gradient (dh/dx). The value of k is dependent on the properties of the porous medium.

The hydrologic processes represented in the model are shown in the conceptual model(Figure 3). Four submodels or building blocks can be placed in the screen to form the dynamic process being modeled. Figure 3 shows the STELLA II screen on which a simplified hydrological cycle displays its most important components within a watershed. Components are either interconnected between them in the soil or related to other atmospheric components of the cycle.

The four submodels - soil water, river, shallow aquifer and deep aquifer - are detailed below.

1. SOIL WATER:

The model considers soil water as the moisture contained within the soil column from the surface to the lower limit of the root zone. Unlike SWRRB (that divides the soil into ten layers), this model considers the soil as a single block 2 meters deep at a single uniform

moisture. The water content in the profile is the difference between the input (precipitation, irrigation, shallow aquifer return) and the outputs (runoff, lateral flow, evapotranspiration, percolation). To keep the model simple and interactive with the user, the following assumptions are made: (i) the root zone is considered homogeneous; (ii) the water content is uniform in each layer; (iii) the flow is two-dimensional; (iv) water flow from the soil is partitioned according to the priority given to each outflow in the cycle; (v) the hydraulic conductivity used in determining the flow between layers is estimated by an arbitrary coefficient acting as a resistance to the flow; (vi) only removable moisture is computed as part of the water budget. Thus initial soil moisture can be zero.

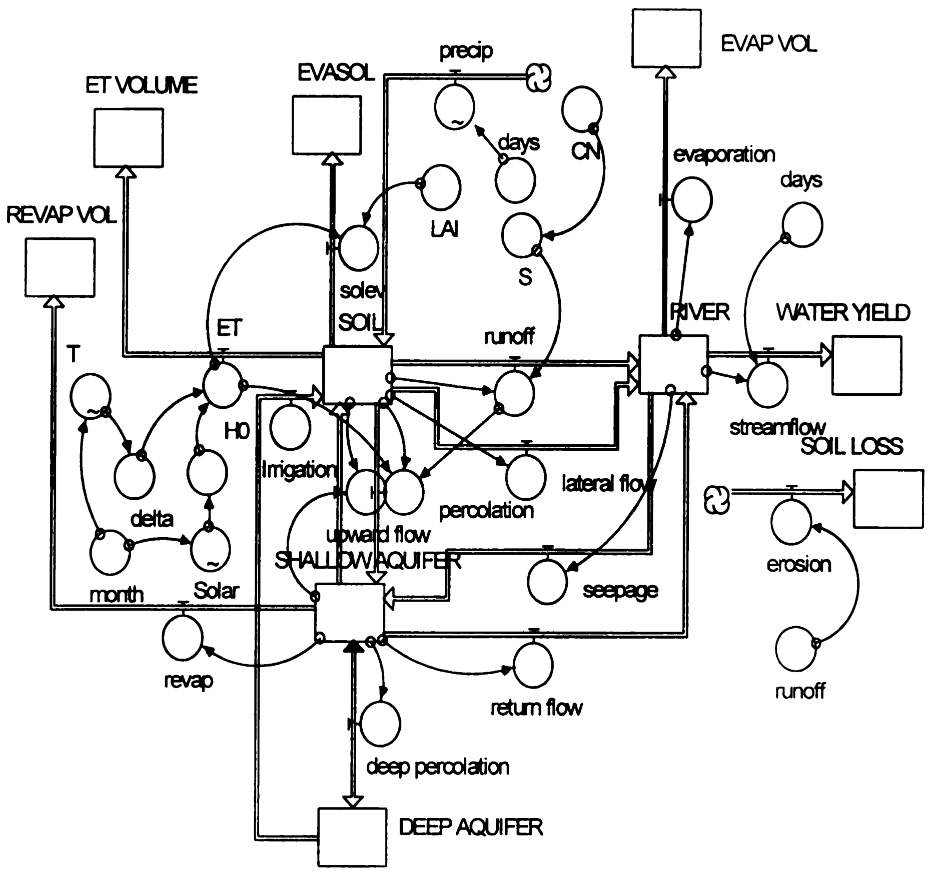

Figure 3. Conceptual model of SAWM using STELLA II.

The excess water from the soil which should flow from the soil to become either surface and/or groundwater recharge is influenced by the time step of the simulation. After a dry period, if it rains heavily for one day, the soil can be quickly saturated due to the intensity and the brevity of the storm - as semi-arid areas are characterized - ; the water surplus can be transformed to runoff and/or percolation. However, if the same rain volume is averaged over an entire month, it may be just enough to return to the atmosphere by evaporation and/or transpiration. Therefore,

computation on a daily basis will always yield more water surplus than computation on a monthly basis.

The water balance equation is:

$$SW=\sum(R-Q-ET-P-QR) \tag{3.2}$$

where:

SW is the increase in soil water content over the duration;
R is the amount of precipitation;
Q is the surface runoff;
ET is the evapotranspiration from the soil profile;
P is the percolation from the soil ;
and QR is the return flow (lateral subsurface flow).

a / Inputs:

Precipitation: Unlike SWRRB , SAWM does not generate rainfall data using the Markov chain method when data are not available. Instead, SAWM can take either daily or monthly rainfall data up to the duration of simulation. The lack of a weather generator in this model is compensated by the ability to simulate multiple rain storms and rapidly analyze the effects.

Irrigation: The Irrigation feature of the model is not used in this study. Eventually it can imitate the real conditions in semi-arid rangelands. When productivity of the shallow aquifer or deep aquifer is sufficient (through the process of recharge), the water table can be exploited efficiently by allocating excessive water to irrigation or human and livestock consumption.

Upward flow: Upward flow from the shallow aquifer is set to a rate determined by the volume of water in the shallow aquifer. The 0.01 factor works in combination with percolation and resistance of the soil to limit the moisture coming from the saturated shallow aquifer. It is added separately from the percolation component to simulate the portion of moisture that leaves the shallow aquifer to the soil profile when the soil is very dry (SOIL<7) and the shallow aquifer is sufficiently saturated (SHALLOW AQUIFER>15) to yield some of its water under the effect of soil sorptivity and capillarity forces.

The equation is:

upward flow =IF((SOIL<7)AND(SHALLOW_AQUIFER>15))

THEN((SHALLOW_AQUIFER-15)*0.01)ELSE(0) (3.3)

Equations 3.3-3.18 can be seen in SAWM's algorithm joined in Appendix A.

b / Outputs:

The model outputs, in order of priority, are: plant transpiration, surface runoff, percolation, lateral flow, and soil evaporation.

Runoff: Surface runoff is an important component of the water budget. It has priority 2 and is computed from the SCS curve number.

$$Q = k*SOIL*(1-S/1000) \quad k=0.12 \tag{3.4}$$

$$\text{and} \quad S=254*(100/CN-1) \tag{3.5}$$

where:

S is a retention parameter;
k is a coefficient to adjust the shape of the runoff curve;
and CN is the average curve number of the watershed.

CN depends mostly on the soil cover and the soil hydrologic group (USDA, 1972; see Appendix B) which provides CN for different groups of soils and type of soil cover.

The coefficient k is adjusted during the model tuning process to provide the best volume of runoff that approximates the one simulated by SWRRB. SAWM was not tuned for peak runoff; but this can be done in the future.

Lateral flow: Lateral subsurface flow in the soil profile (0-2m) occurs not only after the soil is saturated, but also occurs depending on the topography of the site and the difference in pressure between the soil water and the river. The model simplifies the estimate of the lateral flow to a fraction of the excessive moisture of the soil beyond 25mm using IF/THEN reasoning and giving it priority 3.

Lateral flow =IF(SOIL >25) THEN (1.2*(SOIL - 25)/40) ELSE (0) (3.6)

where 25 is the water content of the soil, above which, the excess moisture can freely leave the soil profile as a lateral flow. The coefficients 1.2 and 40 have been adjusted to give a realistic accumulation of the lateral flow over time. They also act as a resistance to the flow to compensate for the Darcy's hydraulic gradient between the soil and the river.

Percolation: Percolation in this model is the downward flow which occurs when field capacity of the soil is exceeded. The excessive moisture flow downward under the combined effect of gravity and suction (negative pressure) from the unsaturated lower zone. Temperatures below 0° Celsius that may prevent flows from occurring are rare under Mediterranean semi-arid conditions. Therefore the model does not consider temperature in the subsurface water flow.

The Percolation equation is:

percolation = IF(SOIL>15) THEN(SOIL-15)*0.05 ELSE(0) (3.7)

where 15 is set as the limit of saturation of the soil, above which the excessive soil moisture can be lost to the shallow aquifer. The coefficient 0.05 is used to adjust the accumulated amount of percolated water (estimated by the area under the percolation curve).

Evapotranspiration: The evapotranspiration component considers only the potential evapotranspiration but not the actual evapotranspiration . The model computes evaporation from soil and plants separately. Potential soil water evaporation is estimated as a function of potential ET and leaf area index (LAI is the area of plant leaves relative to the soil surface area).

PT is computed from the equation of Priestley and Taylor (1972).

PT = 0.5*(1.28*delta*H0)/(delta+0.68) (3.8)

where:

PT is the plant transpiration rate in mm/d;
H0 is the net solar radiation in ly;

and delta is a psychrometric constant.

The value of H0 is calculated with the equation

$$H0 = (0.77/58.3)*Solar \qquad (3.9)$$

where Solar is the daily solar radiation in ly and delta is determined using the equation:

$$delta = 5304*EXP(21.255-(5304/T))/(T)^2 \qquad (3.10)$$

where:

T = 273 + °C
and °C is the soil temperature in degrees Celsius.

PT VOLUME stock is used as a fictitious reservoir to compute the accumulated water lost from the soil by evapotranspiration to the atmosphere.

Soil evaporation: The evaporation from the soil is ranked 5 in priority; however, it is part of the evapotranspiration submodel, even though computed separately. It is a function of the plantl transpiration PT and the leaf area index LAI. Potential soil evaporation is estimated by the equation (Richie and Richardson, 1973):

$$solev = PT*EXP(-0.4*LAI) \qquad (3.11)$$

where:

solev is the potential evaporation at the soil surface;
and LAI is the area of plant leaves relative to the surface soil area, estimated by Weltz (ibid, 1987) as 3 for shrub and clusters.

2. RIVER:

The river body is considered in the model as a reservoir regulated by three inflows and three ouflows. The inflows are surface runoff, subsurface lateral flow, and return flow from the shallow aquifer. The outflows are evaporation and streamflow.

a / Inputs:

Runoff: The amount of surface runoff estimated by the SCS curve number method as the main output from the previous model component, namely SOIL, is supposed to flow laterally to the river without any losses en route to simplify the model. See equations 4 and 5 discussed previously.

Lateral flow: The lateral flow is an outflow from the unsaturated zone of the soil profile. It is estimated as a fraction of the runoff. Its coefficients are adjusted in the tuning process . Equation 6 describe the flow without considering the time delay between surface runoff and subsurface flow.

Return flow: The return flow is the part of the shallow aquifer's saturated water that does not move vertically (upward to the soil profile

or downward to the deep aquifer), but horizontally from the shallow aquifer to the river. This flow may come partially or completely due to the excess recharge of the shallow aquifer by water percolating from the root zone.

The equation estimates the lateral flow as a small fraction of the shallow aquifer.

return flow = IF(SHALLOW_AQUIFER>20) THEN(0.01*(SHALLOW_ AQUIFER -20)ELSE(0).

(3.12)

where 0.01 is set to describe the amount of the return flow as well as the delay vis-à-vis to surface runoff and lateral flow. The value of 20 is the minimum moisture in the

shallow aquifer. Only the excess amount beyond 20 mm can return to the river.

b / Outputs:

Streamflow: The streamflow describes the main output and the only concrete outflow from the system. It is generally more important than the other outputs from the river combined, namely river evaporation and seepage. The streamflow is simulated on a daily basis as a fraction of the total volume of the water in the river.

The equation is:

$$\text{stream flow} = 0.0018 * \text{days} * \text{RIVER} \qquad (3.13)$$

where: 0.0018 is a coefficient of adjustment of volume and “days” causes a realistic delay of the flow over time.

Evaporation: The evaporation from the river is simplified to a fraction of the water in the river that evaporates daily as a fraction of the volume of water in the river.

Temperatures below 0° Celsius that may prevent flows from occurring are so rare under semi-arid conditions that is why the model does not consider temperature in the subsurface water flow.

Evaporation equation is:

$$\text{evaporation} = 0.002 * \text{RIVER} \qquad (3.14)$$

where: 0.003 was adjusted to estimate the average fraction of river water that can be lost by evaporation.

Seepage: Seepage is the flow of water from the river to the shallow aquifer. It occurs to compensate for decrease in pressure of the saturated zone in areas along the river channel where the shallow aquifer may become unsaturated. The model estimates the seepage as a simple fraction of the river. The equation of the seepage is :

$$\text{seepage} = 0.006 * \text{RIVER} \tag{3.15}$$

where: the coefficient 0.006 is tuned estimate the loss from the river to the shallow aquifer in some areas.

3. SHALLOW AQUIFER:

In semi-arid developing countries, the shallow aquifer and the deep aquifer are the most difficult submodels to verify due to the lack of appropriate technologies to monitor water table dynamics and their interconnections with hydrogeologic aquifers. This model simulates primarily the shallow aquifer as a part of the system watershed, but approximates the amount of water lost from the shallow aquifer to the deep aquifer (deep percolation) as part of the total water budget.

The shallow aquifer is considered as reservoir with two inputs (percolation and seepage), and four outputs (return flow, deep percolation, revap and upward flow).

a / Inputs:

Percolation: Percolation is the fraction of water from the rain event which cannot be retained by the soil because it exceeds the field capacity and migrates downward to the shallow aquifer either by gravity or capillary action in the media below.

The equation describing percolation was seen before in (equation 3.7) as output from the SOIL.

b/ Outputs:

Return flow: The return flow is the opposite of seepage. It occurs in areas where the shallow aquifer is saturated and the water table level is higher than the river level. The return flow is approximated as a fraction of the shallow aquifer. Equation (3.11), which was used as input to the river, regulates the return flow as output from the shallow aquifer.

Deep percolation: The deep percolation is particular in this model. It is simulated at the same time as input to the shallow aquifer as well as output from it (biflow). However, water is more likely to flow downward through cracks and breaks in confining layers, than upward from confined aquifer to unconfined aquifer. Except for artesian aquifers). Unlike the percolation that is simulated only during the rain event, the deep percolation is estimated as a fraction of the shallow aquifer that is continuously leaking to the deep aquifer and proportionally to the volume of water in the shallow aquifer storage. The equation below describes this flow lost to the deep aquifer as :

$$\text{deep percolation} = 0.0006*\text{SHALLOW AQUIFER} \qquad (3.16)$$

where the coefficient 0.0006 is chosen to compute the amount of percolated water in the leakage process.

Revap: The revap is added to estimate the proportion of moisture that may evaporate directly from the shallow aquifer to the atmosphere through the soil's existing cracks and fissures under hot arid conditions. This happens frequently during dry seasons in semi-arid areas located in the range of latitudes between 28 and 35 such as Morocco, South California, and North Texas. That is why the amount of revap is approximated as a function of the amount of water in the shallow aquifer as well as the number of days. The amount of water lost by evaporation and revap are counted in the water budget whenever they are not small enough to be negligible. The equation describing this loss is:

revap = 0.0016*SHALLOW AQUIFER (3.17)

where 0.0016 is used to approximate the amount of water lost by revap from the shallow aquifer.

Upward flow: The upward flow simulates the flow from the shallow aquifer to the soil when the soil is dry. The equation stating this process is the same as equation (3.3) simulating the upward flow as an input to the soil.

4. DEEP AQUIFER:

Deep aquifer: The dynamic behavior of the deep aquifer is generally not known. SAWM simulates the deep aquifer as a huge reservoir connected to the shallow aquifer by a "biflow " which allows

the movement of water in two directions. Only the increases from its initial level are simulated to evaluate its productivity . It has been put in the model for use in the future when it can guide management decisions such as irrigation or recharge.

The deep percolation from the shallow aquifer is both input and output for the deep aquifer. Equation (3.16) states the relationship (mentioned above) prioritizing shallow aquifer losses according to the recharge from the deep aquifer.

The stocks (reservoirs) are linked to the end of all output flows to allow the user to monitor the amount of water allocated by the model to each component of the hydrologic cycle.

5.SEDIMENT YIELD:

Unlike SWRRB which uses the Modified Universal Soil Loss Equation (MUSLE by Williams and Berndt, 1977) to compute the sediment for each subbasin, SAWM simplifies the method from a six-parameter formula to a single equation requiring only the values of runoff above a certain threshold where the flow becomes enough to transport soil.

The equation is:

$$\text{erosion} = \text{IF (runoff}<5\text{)THEN (0) ELSE(}0.12*(\text{runoff} - 5))^2\text{)} \tag{3.18}$$

where 5 is the maximum runoff that causes no erosion and 0.12 and the exponent are set to represent the parabolic shape of the soil erosion as a function of runoff.

The technique chosen to validate SAWM against SWRRB is to generate six artificial rainstorms of 30 days duration (30 days is required by SWRRB) and constant intensities of 50, 40, 30, 20, 10, and 5mm per day. These step-function storms (pulses) are simulated on both SAWM and SWRRB while keeping sensitive parameters on both models constant and similar. The Figure 4 shows this theoretical rainstorm pulse and the simulated response of percolation, soil transpiration, streamflow and seepage.

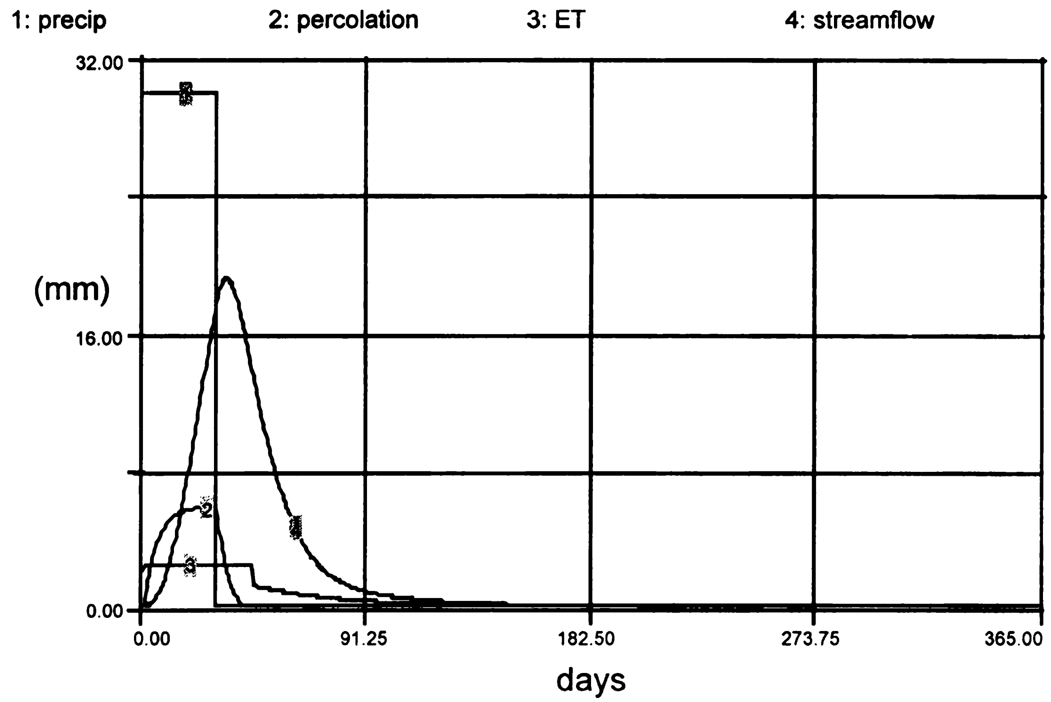

Figure 4. The pulse-rainstorm of 900mm and the response of other components.

The other graphs from SAWM are compared to those of SWRRB and tuned, one at a time, so that they match reasonably. The tuning process is tedious and time- consuming because areas under the graphs are computed by hand, approximating the area as a sum of multiple trapezoids:

$$\text{Area}=((H+h)/2)*w \qquad (3.19)$$

where H and h are the heights and w is the width of each trapezoid.

The list of tuned parameters and their values are listed in Table 1.

Table 1. Tuned parameters, their values and their sensitivities..

Component	Coefficient	Eqn No.	Value used	Sensiti-vity
upward flow	multiplier threshold	3.3	0.01 7, 15	low
surface runoff	multiplier	3.4	0.12	high
lateral flow	multiplier threshold	3.6	0.03 25	medium
percolation	multiplier threshold	3.7	0.05 15	high
return flow	multiplier threshold	3.12	0.01 20	medium
streamflow	multiplier	3.13	0.0018	high
evaporation	multiplier	3.14	0.002	low
seepage	multiplier	3.15	0.006	low
deep percolation	multiplier	3.16	0.0006	medium
revap	multiplier	3.17	0.0016	low
sediment yield	multiplier threshold exponent	3.19	0.12 5 2	medium

To cover a wide range of rainfall amounts. the rainstorms tested for the tuning process are respectively 1500, 1200, 900, 600, 300, and 150 mm. These amounts include the range of annual semi-arid rainfall. The main output curves from SAWM and SWRRB at are compared to guide the tuning process are Water Yield, ET, and Sediment Yield. Water Yield and evapotranspiration are in mm in both models, while the soil loss estimate is in kg/ha.

Chapter 4

RESULTS AND DISCUSSION

The graphs that compare the water yield, total evapotranspiration and sediment yield from the two models and for the six rainfall simulations appear in Table 2.

This table also displays the input rain for each model. Results from the tuning process are plotted in Figures 4, 5, and6 to better compare the response of each model to each rainstorm event.

The simulated water yields from SAWM shown in Figure 5 track the water yield from SWRRB fairly for the six storms simulated. The general shape of Figure 5 is not linear, this is probably because the system is completely dry before the 30-day rainfall event begins. The early rain goes into the soil. For small storms (less than 300mm , i.e. 30 days at 10mm per day), no runoff is produced. Thus, no yield.

Figure 6 reveals that the evapotranspiration simulated by SWRRB stays constant above the 300mm storm, while it keeps increasing in SAWM. Figure 6 shows an inherent difference in the two models. The constant ET which SWRRB shows for all large storms is unrealistic and fails to account for prolongation of moist soil conditions following large rainfall events. I tend to trust SAWM model on this difference.

TABLE 2. Summary of the outputs from the tuning simulations.
Numbers are in millimeters except for percentages.

Simulation #	1		2		3		4		5		6	
Storm in (mm)	1500		1200		900		600		300		150	
	SAWM	**SWRRB**	**SAWM**	**SWRRB**	**SAWM**	**SWRRB**	**SAWM**	**SWRRB**	**SAWM**	**SWRRB**	**SAWM**	**SWRRB**
Water Yield	**1208**	**1369**	**940**	**1025**	**675**	**670**	**411**	**318**	**154**	**61**	**41**	**35**
Discrepancy	-12 %		-8 %		1 %		29 %		152 %		17 %	
ET vol	172		156		139		119		94		79	
Evap Vol	39		30		22		13		5		2	
EvaSol	33		32		31		29		23		23	
RevapVol	29		24		18		14		9		2	
Total ETP	**273**	**206**	**242**	**206**	**210**	**206**	**175**	**206**	**131**	**206**	**106**	**119**
Discrepancy	33 %		17 %		2 %		-15 %		-36 %		-11 %	
ETP+WaYield	**1481**	**1575**	**1182**	**1231**	**885**	**876**	**586**	**524**	**285**	**267**	**147**	**154**
Total rain	**1500**	**1553**	**1200**	**1243**	**900**	**933**	**600**	**623**	**300**	**313**	**150**	**158**
Discrepancy	-3 %		-3 %		-4 %		-4 %		-4 %		-5 %	
Soil loss(kg/ha)	**807**	**765**	**672**	**654**	**514**	**470**	**307**	**277**	**0**	**12**	**0**	**0**
Discrepancy	5 %		3 %		9 %		11 %					

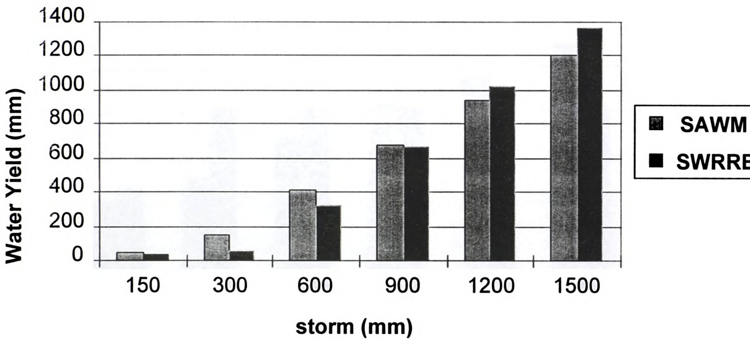

Figure 5. Comparison of water yields from the two models

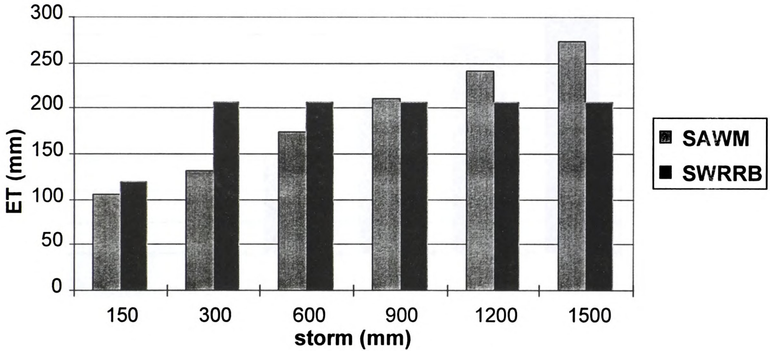

Figure 6. Comparison of evapotranspiration from the two models

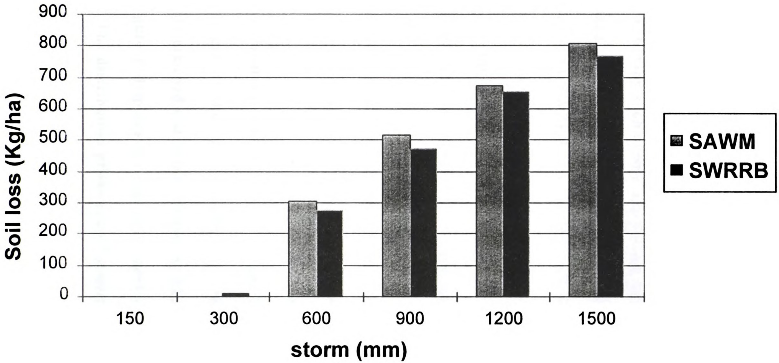

Figure 7. Comparison of soil losses from the two models.

The sediment yield in Figure 7 is registered only above the 300mm storm on both models. The tuned soil loss quantities from the two models are similar for rainstorms of 600mm and more. SAWM consistently yielded more sediment than SWRRB, although differences were small . The small sediment yield from a 300mm event signals problems if many such events occur every few weeks.

Once the sensitive parameters of SAWM were tuned against their counterparts in SWRRB, a realistic simulation was performed for a theoretical watershed. This watershed features many climatic and hydrologic similarities with Moroccan arid regions. The watershed is 538 km^2 in area, located at 31° 37' latitude similar to Morocco. The weather data file used to simulate realistic conditions is taken from a watershed located in Waco, Texas (one of the many locations where SWRRB was validated). The rest of the input data reflects Moroccan conditions, such as soil data, slopes, land use, and may be seen in the SWRRB computer printouts added as Appendix C.

The graphs showing the results of this simulation from the two models are matched and presented here as Figures 8 - 24 and discussed.

Figure 8 displays the one-year input rainfall applied to the two models. The distribution of the runoff generated from these rainfall data is well represented in SAWM as shown in Figure 10, but generates no runoff in SWRRB except for the main storm that occurs around day 300 (between of October and November). This means that SAWM is more

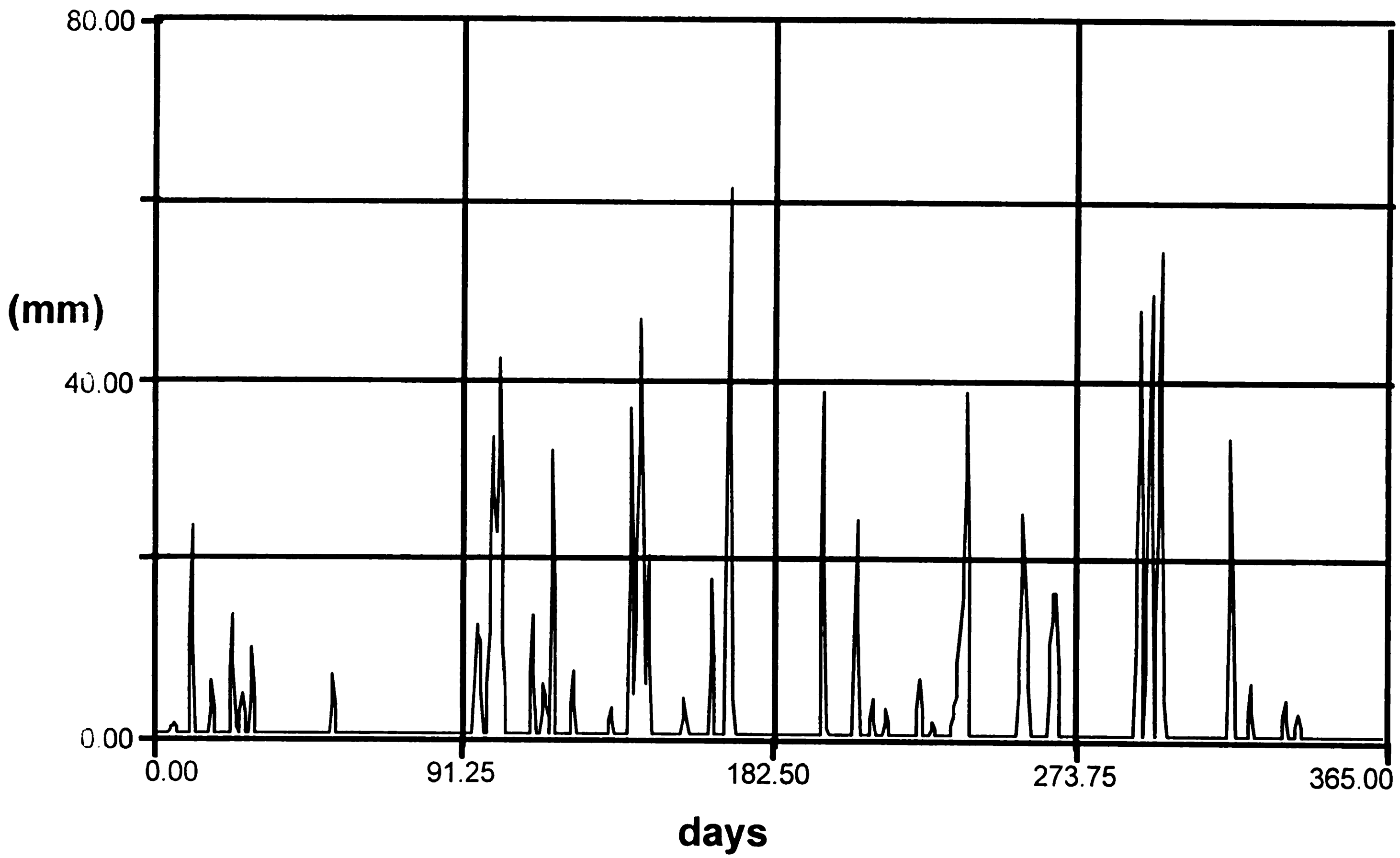

Figure 8. One year rainfall input to SAWM

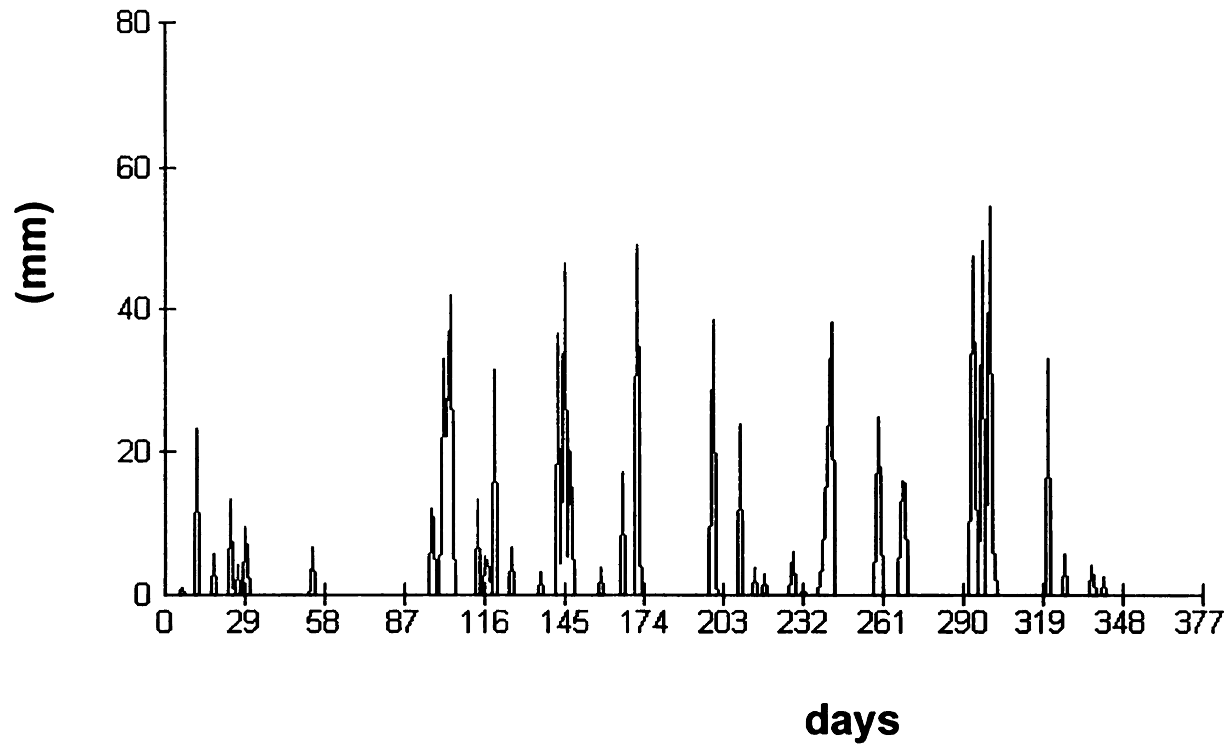

Figure 9. One year rainfall input to SWRRB.

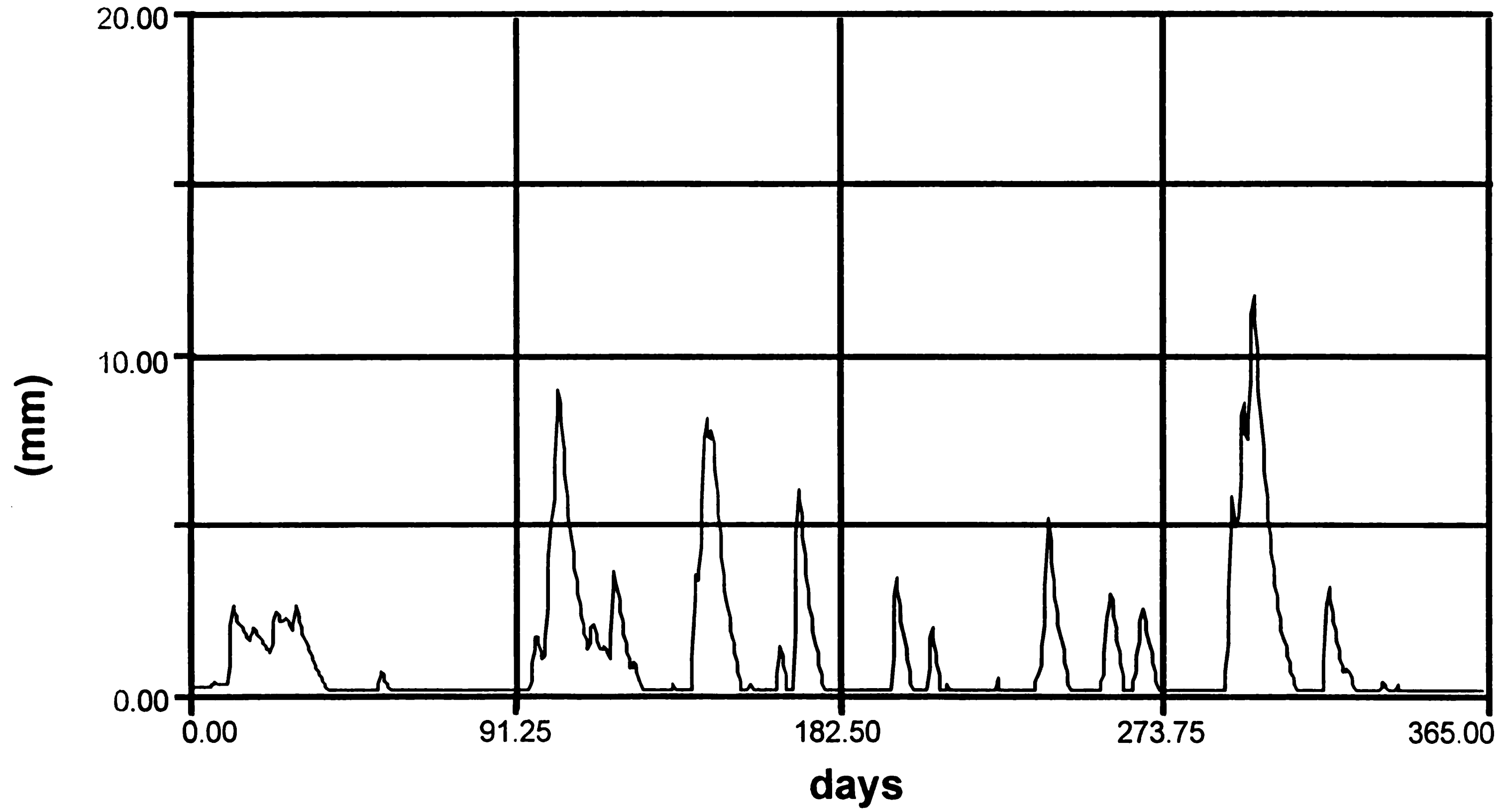

Figure 10. Runoff estimated by SAWM.

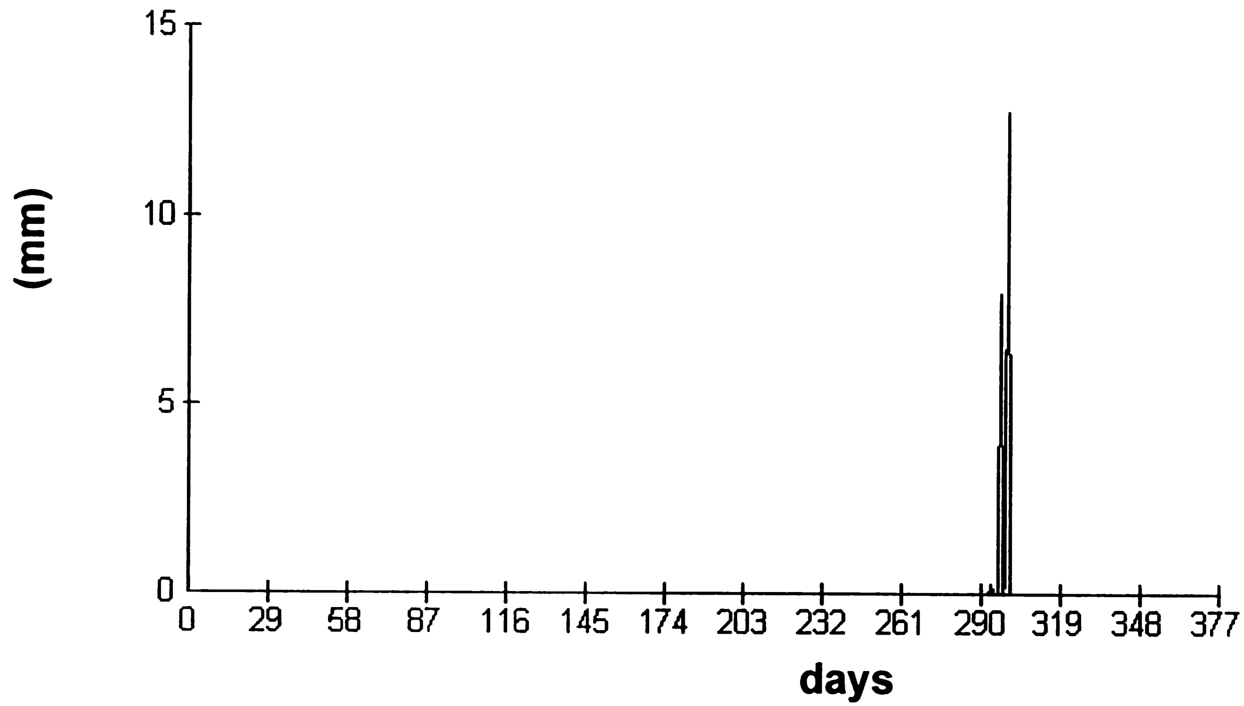

Figure 11. Runoff estimated by SWRRB.

sensitive to low intensity rains than SWRRB. The water yield is conveniently accumulated from the river stream flow as shown in Figure 12, making it easy to read the yearly amount of water transported by the river. However, in SWRRB, this amount is estimated by computing the area under the curve in Figure 13. This estimation is subject to errors due to the irregularity of the curve's shape. The evapotranspiration is also better estimated in SAWM (Figure 14) than in SWRRB (Figure 15) because it can be read directly in SAWM by summing its four components of ET. The unstable curve generated by SWRRB shown in Figure 15 makes it very hard to estimate evapotranspiration, let alone its four components.

The return flow simulated in SAWM (which contributes to the river's water yield, Figure 16) tracks fairly its couterpart in SWRRB (Figure 17), but with less intensity.

SAWM goes below the shallow aquifer and simulates the recharge of the deep aquifer. Figure 18 provides a valuable updated water budget of the deep aquifer by simulating the amount of recharge (or withdrawals to satisfy human and animal needs).

Soil erosion:

The sediment yield resulting from the erosion process is more sensitive to runoff in SAWM (Figure 19) than in SWRRB (Figure 20). However, the threshold set for a minimum runoff to cause soil erosion

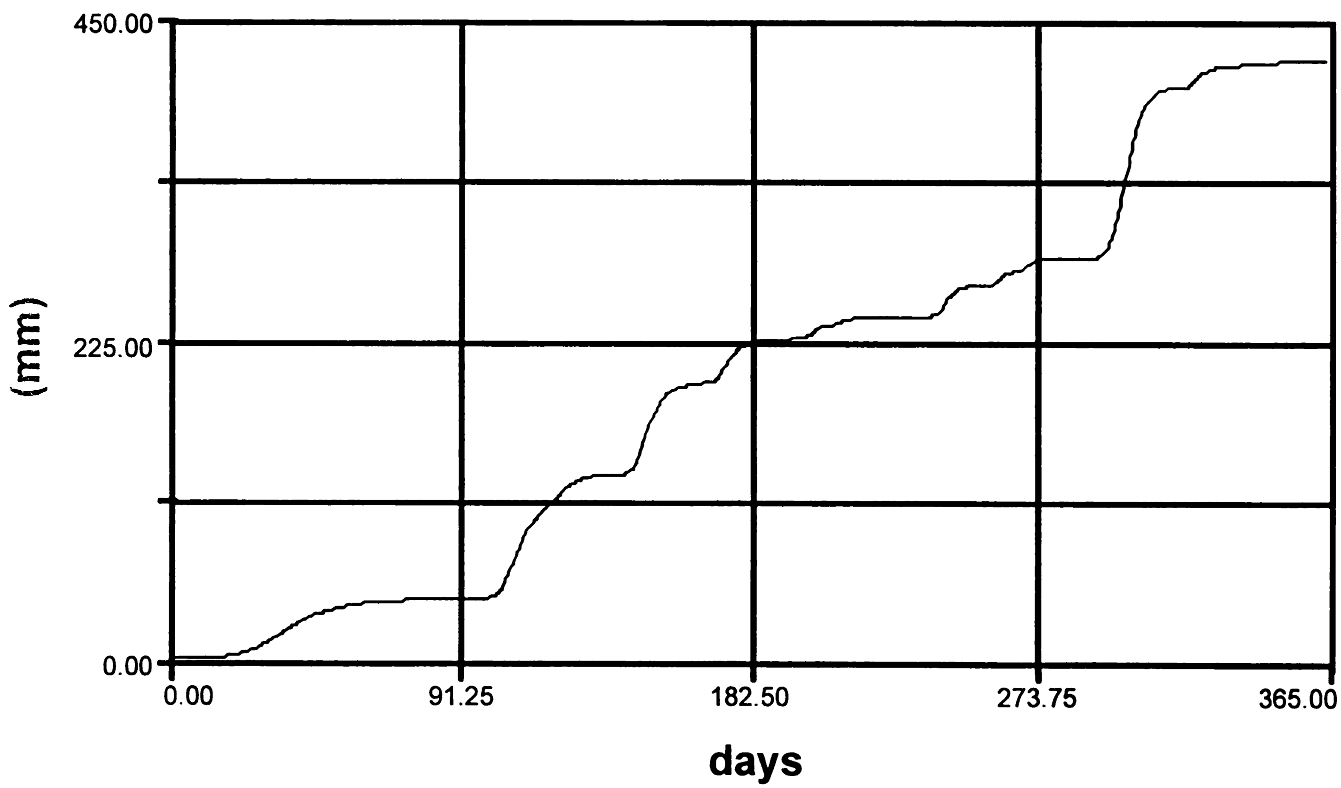

Figure 12. Cumulative water yield estimated by SAWM.

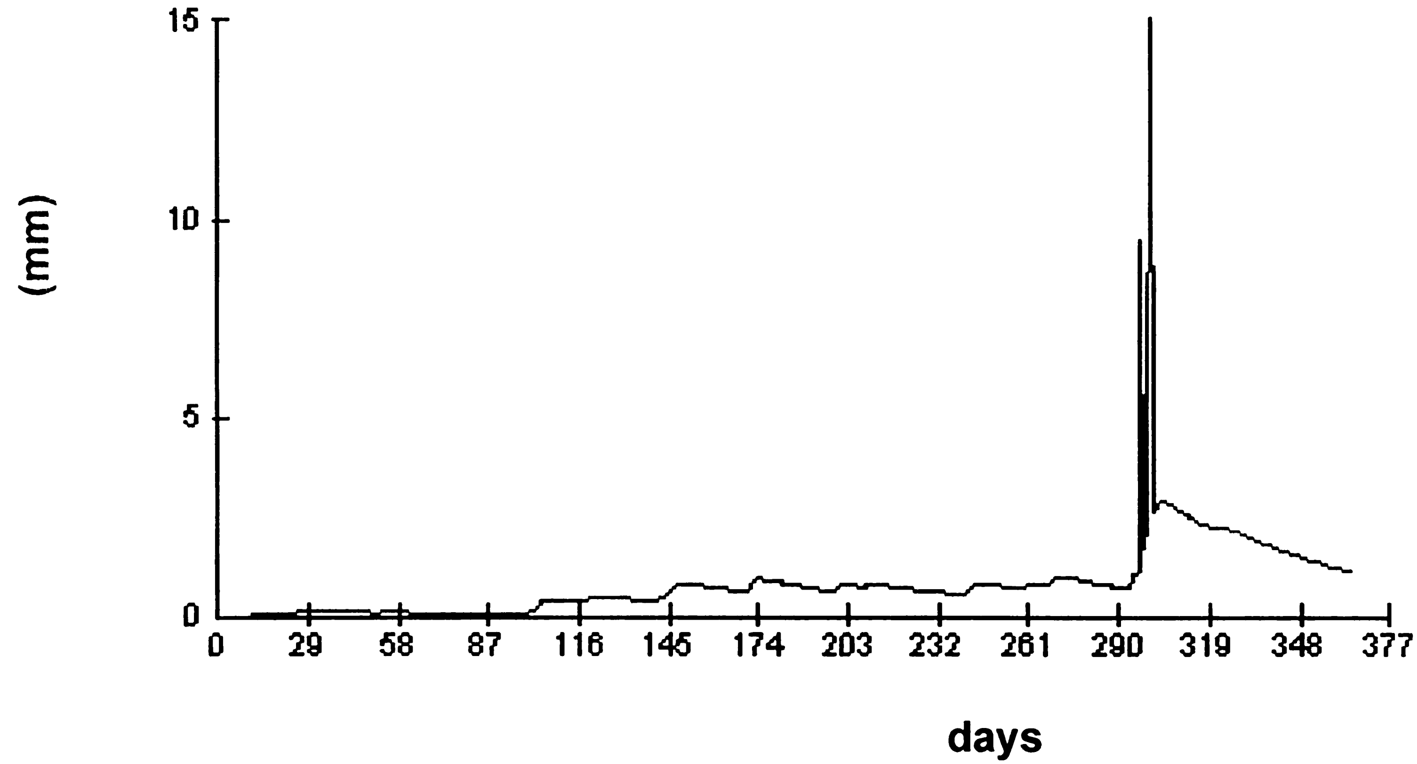

Figure 13. Daily water yield estimated by SWRRB.

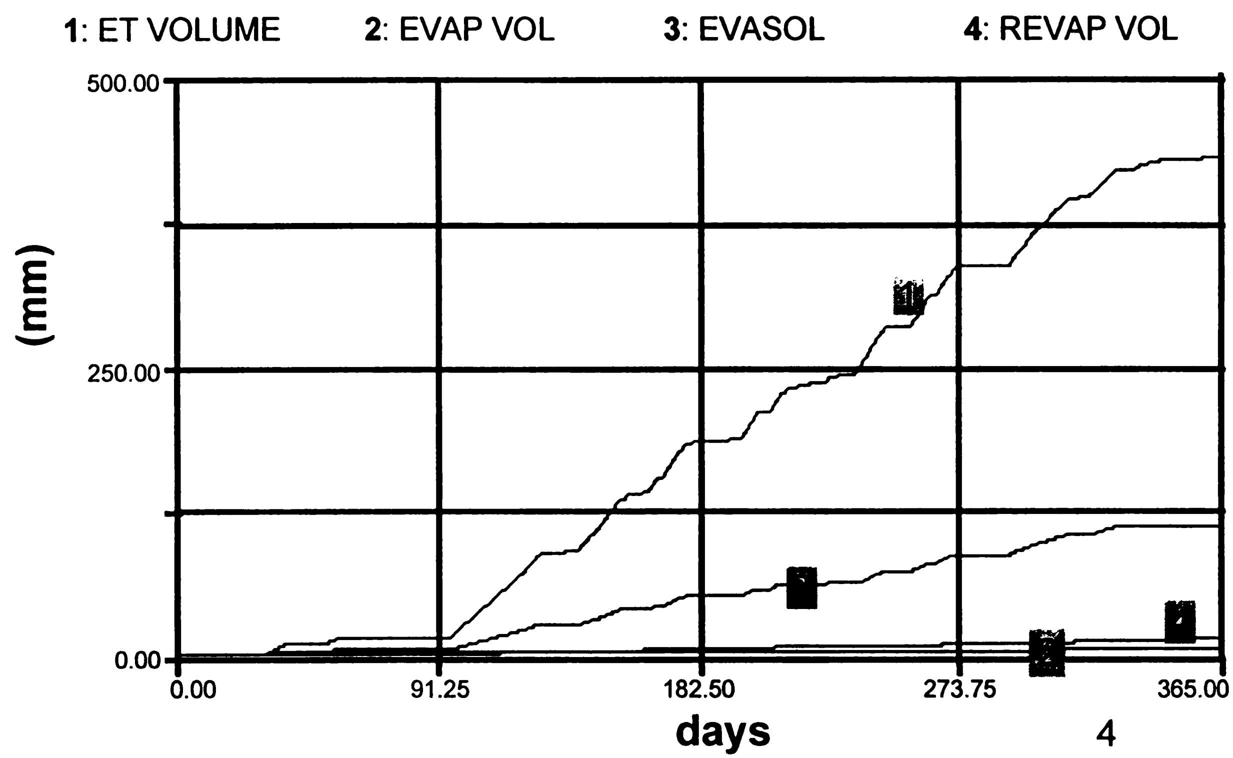

Figure 14. Total ET estimated by SAWM.

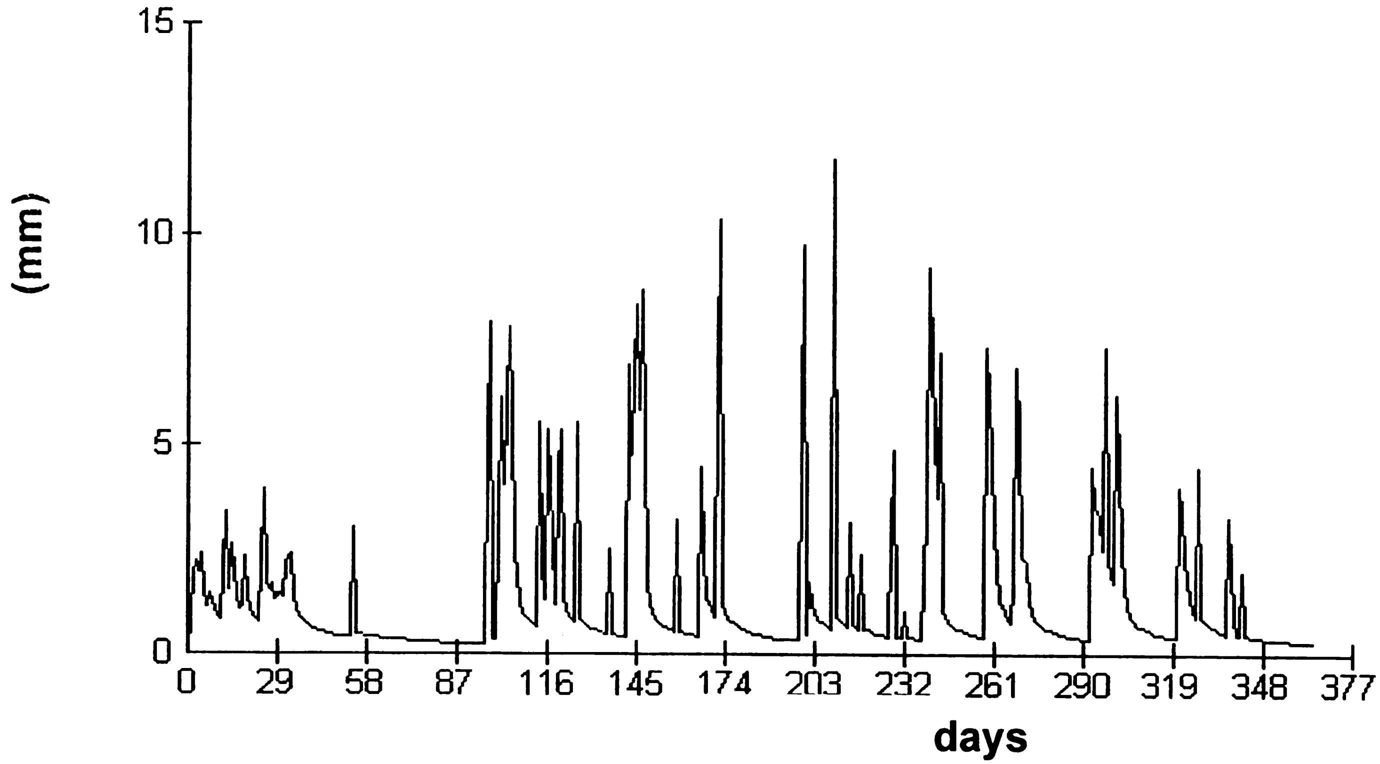

Figure 15. Evapotranspiration estimated by SWRRB.

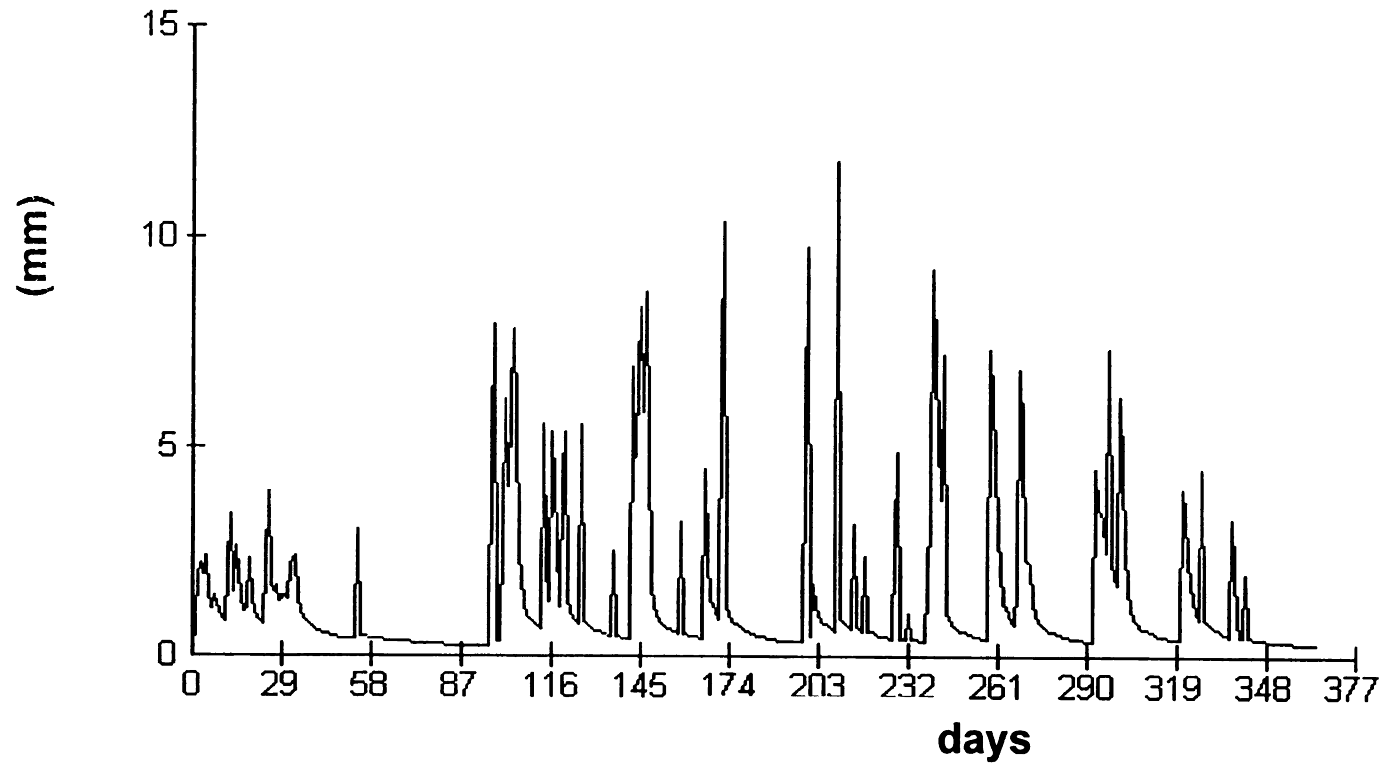

Figure 15. Evapotranspiration estimated by SWRRB.

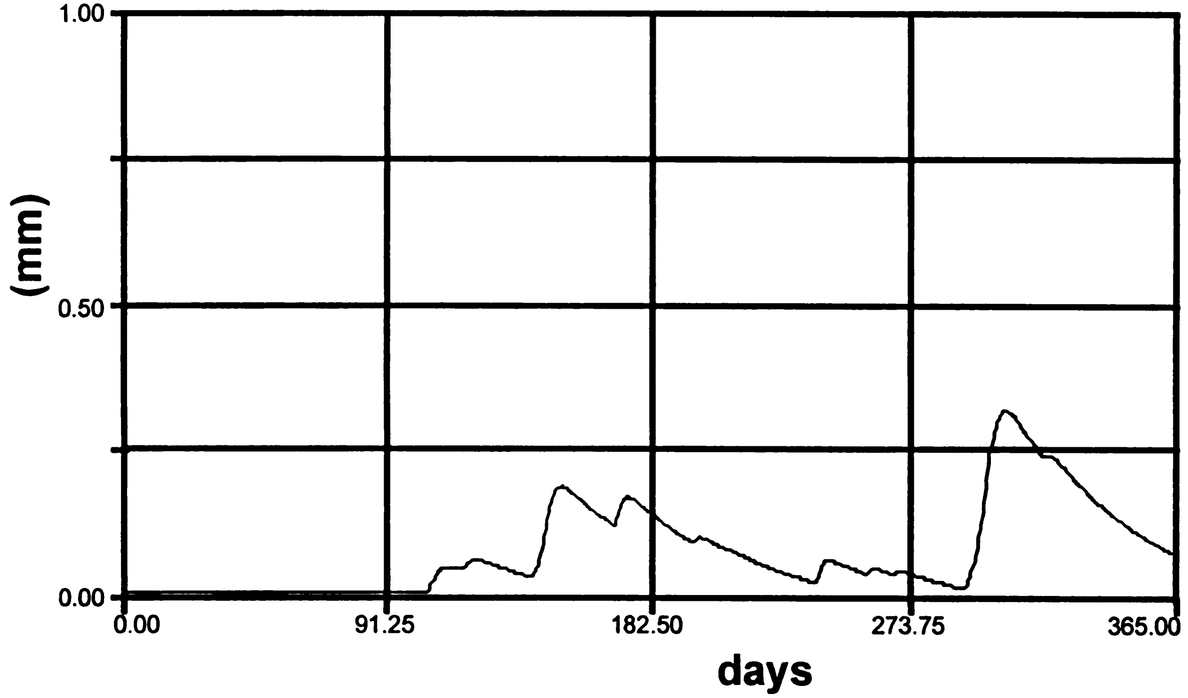

Figure 16. Return flow estimated by SAWM.

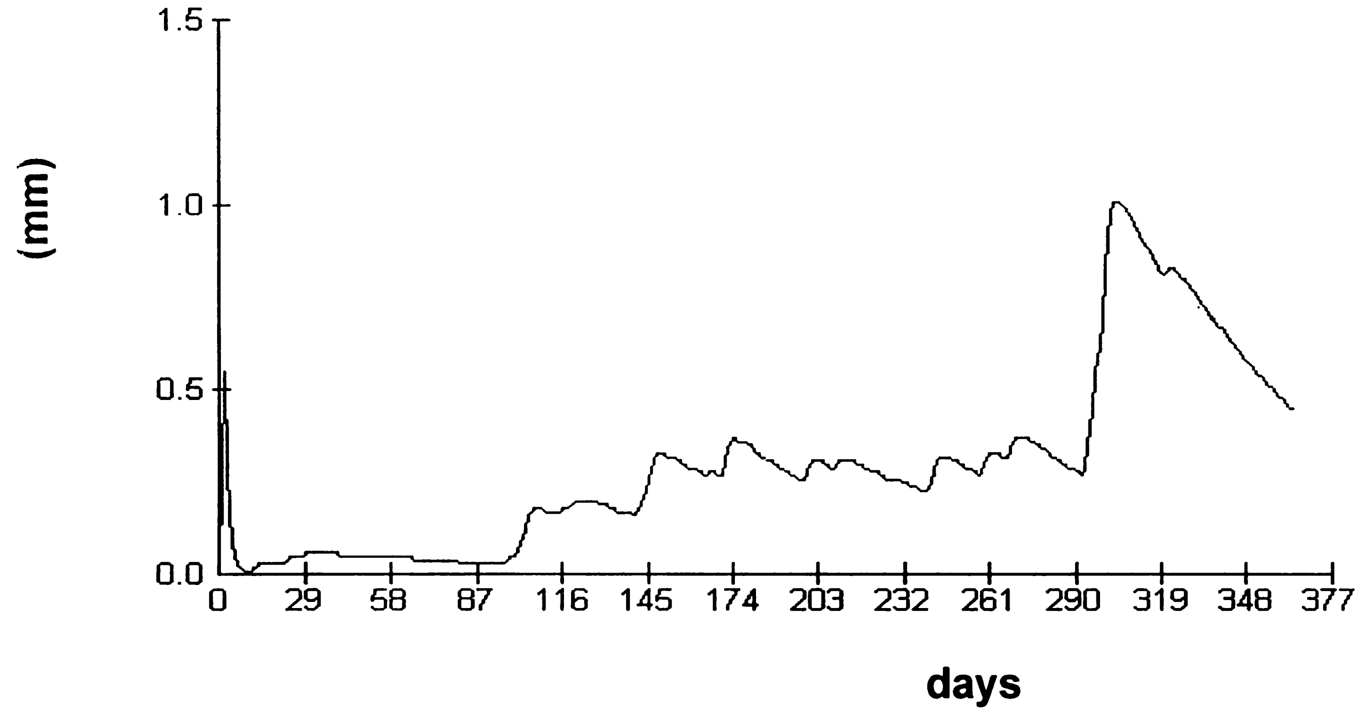

Figure 17. Return flow estimated by SWRRB.

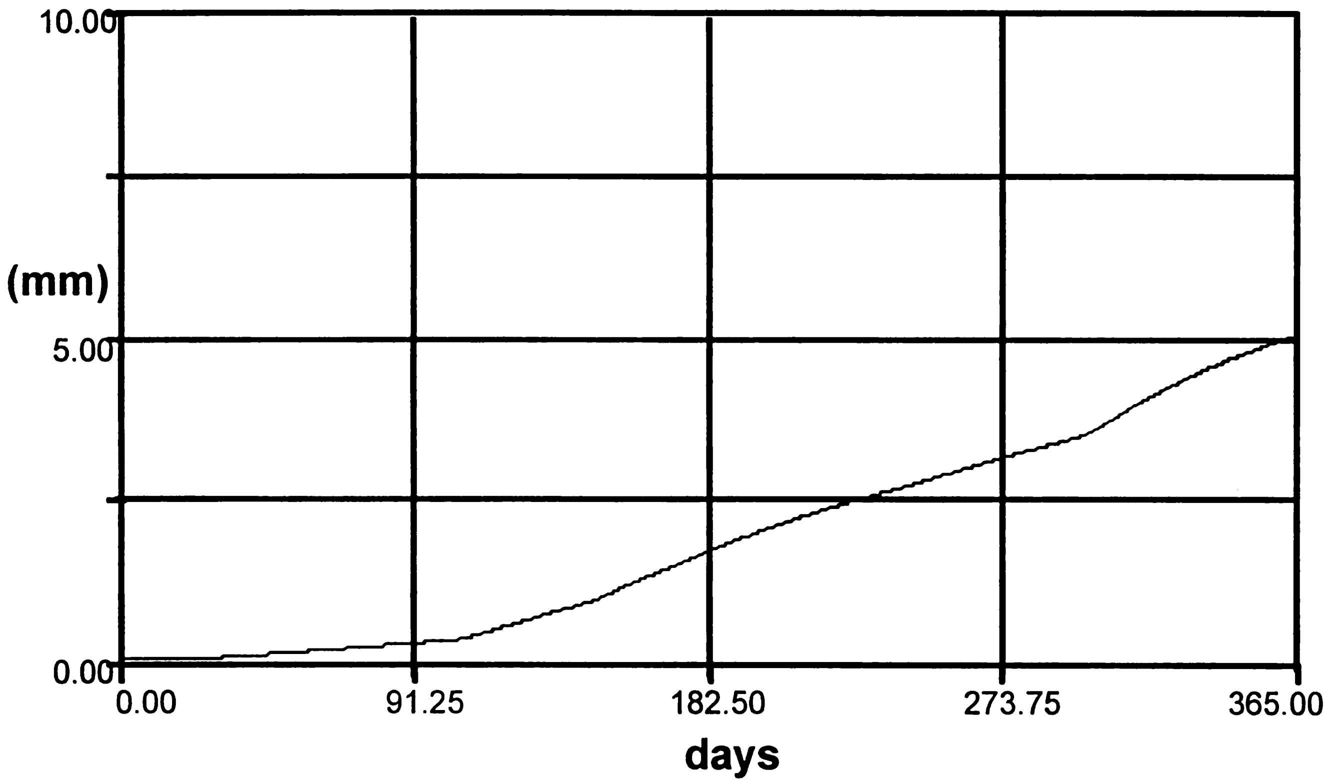

Figure 18. Recharge of the deep aquifer estimated by SAWM.

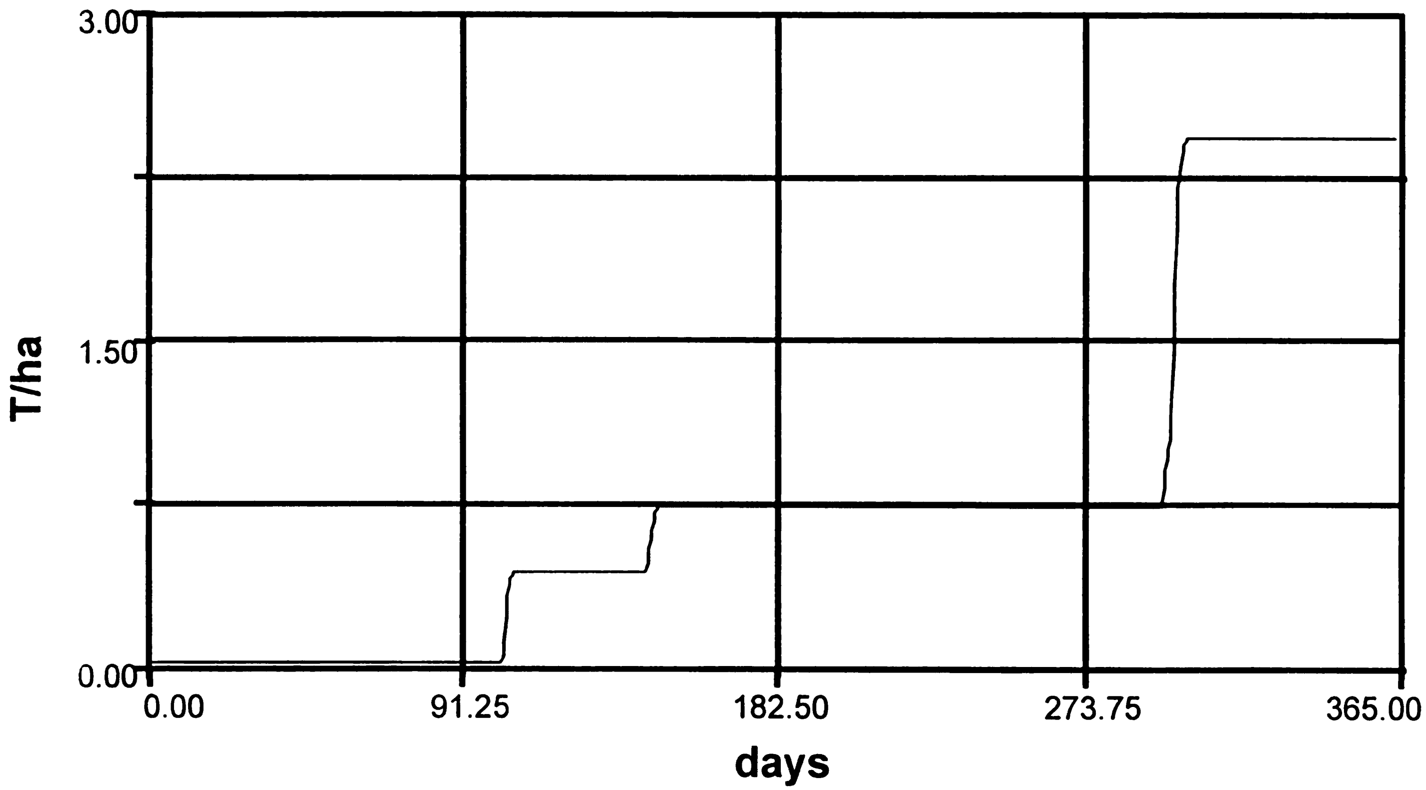

Figure 19. Sediment yield estimated by SAWM.

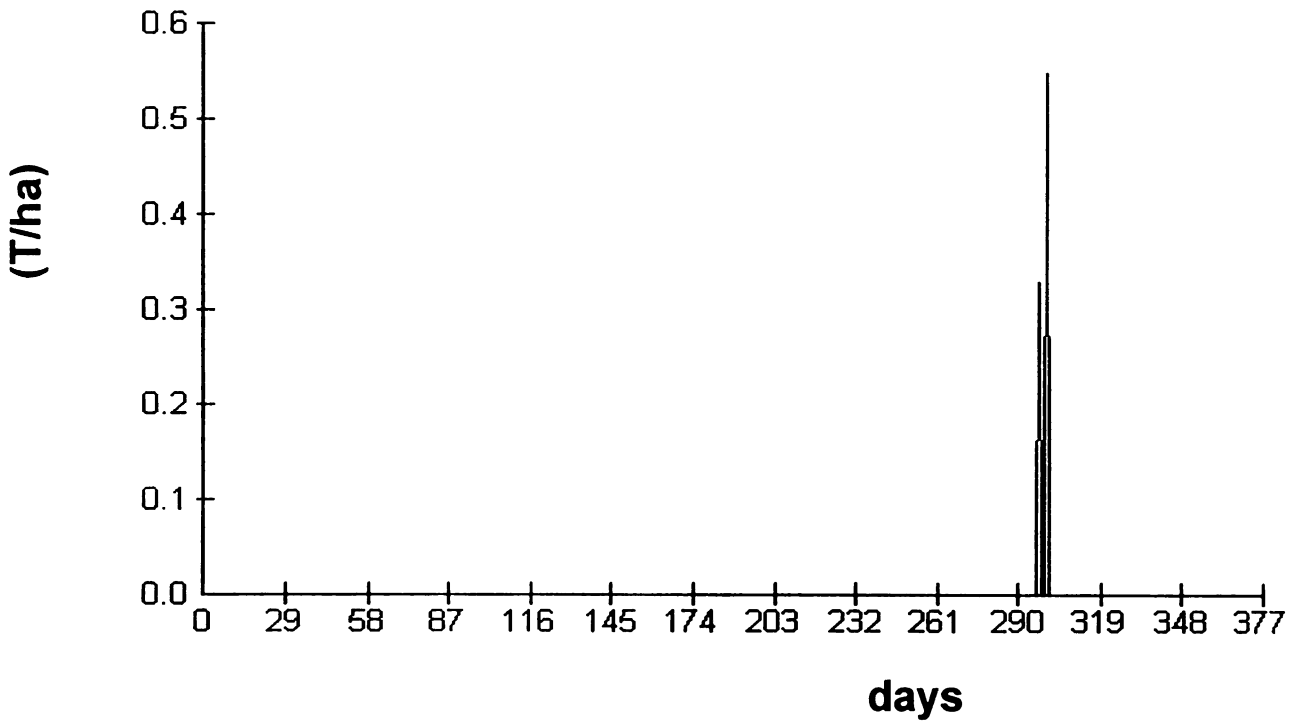

Figure 20. Sediment yield estimated by SWRRB.

and the constancy of the curve number CN during the whole year causes the discrepancy between the sediment yields simulated by each model. Similar discrepancies, however, are frequent when USLE is used to estimate soil loss from watersheds where precipitation is infrequent and low in intensity. Figures 10 and 11 explain some of the discrepancy in sediment yield.

Despite the simplifications in SAWM, the main hydrologic outputs (water yield and evapotranspiration, (Figure 21) show that the evapotranspiration submodel in SAWM is accurate enough to make predictions similar to those of SWRRB. However, the water yield output from SAWM is 38% less than the water yield from SWRRB, even though precipitation is the same for both.

Comparison of precipitation, ET, and water Yield for both models during the tuning process (Table 1), as well as for the realistic situation simulation(Figure 21), shows that SWRRB always is better. This fact explains the difference between the two water yields as well as sediment yields (Figure 22), since soil erosion is function of runoff in SAWM. The weakness in water yield estimation and the time delay can be corrected by introducing gradually more stocks (reservoirs) in the conceptual model to better imitate the soil component of SWRRB (which does a better job of storing excessive moisture and simulates better the slow motion of water through the soil.

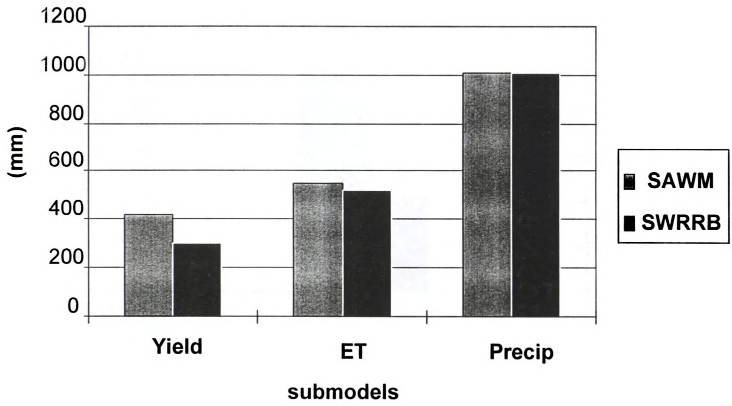

Figure 21. Comparison of water budgets for the two models.

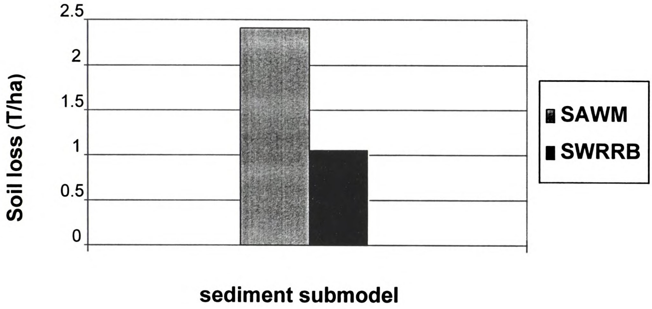

Figure 22. Comparison of soil loss estimated by the two models.

The technique of the tuning process worked well. It was a pleasant surprise that the realistic weather scenario for SAWM emulated SWRRB on the first attempt; no tuning had to be done for the stochastic input rainfall.

Unlike SWRRB which was designed by a multidisciplinary team to be used by professionals, SAWM is simple enough to be used by people with no Mathematics or hydrology background. The user can communicate interactively with the model from conception to execution. The process can be explained to other people interested in the problem modeled. Even when soil and weather data are available as input files in SWRRB, the remaining of inputs require at least 20 minutes to enter. The output file is printed on tens of pages of numbers, hardly comprehensible to the common user. The graphical outputs, however, are only ten in numbers but their areas are difficult to translate to numbers without accumulating errors. On the other hand, outputs from SAWM are clear as graphs. The single screen summary of outputs (Figure 23) is clear to users who are interested only in the results.

Considering these advantage of convenience, the results provided by SAWM are encouraging. Because SAWM is interactive, fast, and user- friendly, the user is encouraged to try multiple scenarios before deciding on the appropriate one.

As public domain software, SWRRB is free-of-charge for students and governmental agencies. However, it was corrupted when I

APPROXIMATE REPARTITION OF RAINFALL
OVER THE WATERSHED
(mm)

TOTAL RAIN	**1,008.2**

TOTAL EVAPOTRANSPIRATION

ET VOLUME	430.5
EVAP VOL	3.7
EVASOL	110.7
REVAP VOL	13.3

WATER YIELD

WATER YIELD	419.1
DEEP AQUIFER	5.0
RIVER	0.1
SOIL	0.1
SHALLOW AQUIF...	26.9

SOIL LOSS IN (T/Ha)

SOIL LOSS	2.33

Figure 23. Main outputs from simulating real conditions and their values.

downloaded it from the EPA web and caused me considerable time and inconvenience. SWRRB also lacks flexibility because it does not accept storm durations of less than 30.

A positive thing about SWRRB is its large view of the watershed's hydrology. Soils, land use, and water bodies (reservoirs and ponds) are detailed and considered as important components of the model to make predictions of the impact of management decisions on the watershed. These features are so important that they should be considered for a future version SAWM. so that it can be used as a convenient tool in watershed management and planning.

SAWM was reasonable in that it handled large storms as well as SWRRB. This means that it might be applicable in humid or sub-humid conditions. The evidence is scant, however, since entirely differnt soils would be involved, as well as cropping practices.

Chapter 5

CONCLUSIONS

SAWM describes fairly well the hydrologic cycle within a semi-arid watershed. It has also a flexible and interactive approach in describing the interconnections between surface water and groundwater. It permits simulating different scenarios and allowing immediate analysis and interpretation. SAWM is therefore useful in predicting the effect of management decisions on water balance and sedimentation of watersheds. The simulation of the deep aquifer is encouraging because allows consideration of both surface and groundwater in management decisions. The validation of SAWM against SWRRB is satisfactory, given the simplicity of the equations stating the relationships between different components and given the convenience in running simulations.

Chapter 6

RECOMMENDATIONS

Modeling the hydrologic cycle using STELLA II has proven to be and interesting exercise that needs to be considered in the curriculum of both Civil Engineering and Agriculture Engineering to stimulate curiosity and interest of undergraduate students.

Graduate students interested in soil and water issues can improve SAWM by better simulating the soil component as multiple stocks (reservoirs) interconnected in a fashion so that they can mimic the soil in retaining moisture and delaying its motion.

The improved SAWM can be validated against a better secondary reference model than SWRRM; such as SWAT (improved SWRRB with GIS capabilities). This will allow SAWM to be extended and consider the interconnections between the ecological, economical and social as a an integrated and useful tool of planning and management of watersheds.

APPENDIX A

APPENDIX A - SAWM ALGORITHM

```
DEEP_AQUIFER(t) = DEEP_AQUIFER(t - dt) + (deep_percolation - Irrigation) * dt
INIT DEEP_AQUIFER = 0
INFLOWS:
  deep_percolation = SHALLOW_AQUIFER*0.00060
OUTFLOWS:
  Irrigation = 0
ET_VOLUME(t) = ET_VOLUME(t - dt) + (PT) * dt
INIT ET_VOLUME = 0
INFLOWS:
  PT = 0.5*(1.28*delta*H0)/(delta+0.68)
EVAP_VOL(t) = EVAP_VOL(t - dt) + (evaporation) * dt
INIT EVAP_VOL = 0
INFLOWS:
  evaporation = 0.002*RIVER
EVASOL(t) = EVASOL(t - dt) + (solev) * dt
INIT EVASOL = 0
INFLOWS:
  solev = PT*EXP(-0.4*LAI)
REVAP_VOL(t) = REVAP_VOL(t - dt) + (revap) * dt
INIT REVAP_VOL = 0
INFLOWS:
  revap = 0.0016*SHALLOW_AQUIFER
RIVER(t) = RIVER(t - dt) + (lateral_flow + runoff + return_flow - evaporation - seepage - streamflow) *
dt
INIT RIVER = 0
INFLOWS:
  lateral_flow = IF(SOIL>25)THEN(1.2*(SOIL-25)/40)ELSE(0)
  runoff = 0.12*SOIL*(1-S/1000)
  return_flow = IF(SHALLOW_AQUIFER>20)THEN(   0.01*(SHALLOW_AQUIFER-20) )ELSE
OUTFLOWS:
  evaporation = 0.002*RIVER
  seepage = 0.006*RIVER
  streamflow = 0.0018*days*RIVER
SHALLOW_AQUIFER(t) = SHALLOW_AQUIFER(t - dt) + (percolation + seepage - upward_flow -
revap - deep_percolation - return_flow) * dt
INIT SHALLOW_AQUIFER = 0
INFLOWS:
  percolation = IF(SOIL>15)THEN(SOIL-15)*.05
    ELSE(0) + PT*0+runoff*0
  seepage = 0.006*RIVER
OUTFLOWS:
  upward_flow =
  IF((SOIL<7)AND(SHALLOW_AQUIFER>15))THEN((SHALLOW_AQUIFER-15)*.01)ELSE(0)
  revap = 0.0016*SHALLOW_AQUIFER
  deep_percolation = SHALLOW_AQUIFER*0.00060
```

⊘ C = GRAPH(month)
(0.00, 0.00), (1.08, 9.00), (2.17, 12.5), (3.25, 13.2), (4.33, 19.2), (5.42, 28.0), (6.50, 27.0), (7.58, 29.0), (8.67, 29.0), (9.75, 25.0), (10.8, 21.0), (11.9, 14.0), (13.0, 10.0)

⊘ Solar = GRAPH(month)
(0.00, 0.00), (1.00, 250), (2.00, 320), (3.00, 427), (4.00, 488), (5.00, 562), (6.00, 651), (7.00, 613), (8.00, 593), (9.00, 503), (10.0, 403), (11.0, 306), (12.0, 245)

```
    return_flow = IF(SHALLOW_AQUIFER>20)THEN(  0.01*(SHALLOW_AQUIFER-20) )ELSE
SOIL(t) = SOIL(t - dt) + (precip + upward_flow + Irrigation - PT - percolation - runoff - lateral_flow -
solev) * dt
INIT SOIL = 1
INFLOWS:
    precip = GRAPH(days)
    (0.00, 0.00), (1.00, 0.00), (2.01, 0.00), (3.01, 0.00), (4.01, 0.67), (5.01, 1.13), (6.02, 0.00),
    (7.02, 0.00), (8.02, 0.00), (9.02, 0.00), (10.0, 23.1), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00),
    (14.0, 0.00), (15.0, 0.00), (16.0, 5.90), (17.0, 0.00), (18.0, 0.00), (19.1, 0.00), (20.1, 0.00),
    (21.1, 0.00), (22.1, 13.4), (23.1, 1.76), (24.1, 0.01), (25.1, 4.31), (26.1, 0.00), (27.1, 0.00),
    (28.1, 9.65), (29.1, 0.00), (30.1, 0.00), (31.1, 0.00), (32.1, 0.00), (33.1, 0.00), (34.1, 0.00),
    (35.1, 0.00), (36.1, 0.00), (37.1, 0.00), (38.1, 0.00), (39.1, 0.00), (40.1, 0.01), (41.1, 0.00),
    (42.1, 0.00), (43.1, 0.00), (44.1, 0.00), (45.1, 0.00), (46.1, 0.00), (47.1, 0.00), (48.1, 0.00),
    (49.1, 0.00), (50.1, 0.00), (51.1, 0.00), (52.1, 6.64)...
    upward_flow =
    IF((SOIL<7)AND(SHALLOW_AQUIFER>15))THEN((SHALLOW_AQUIFER-15)*.01)ELSE(0)
    Irrigation = 0
OUTFLOWS:
    PT = 0.5*(1.28*delta*H0)/(delta+0.68)
    percolation = IF(SOIL>15)THEN(SOIL-15)*.05
     ELSE(0) + PT*0+runoff*0
    runoff = 0.12*SOIL*(1-S/1000)
    lateral_flow = IF(SOIL>25)THEN(1.2*(SOIL-25)/40)ELSE(0)
    solev = PT*EXP(-0.4*LAI)
SOIL_LOSS(t) = SOIL_LOSS(t - dt) + (erosion) * dt
INIT SOIL_LOSS = 0
INFLOWS:
    erosion = IF(runoff<5)THEN(0)ELSE((0.12*(runoff-5))^2)
TOTAL_RAIN(t) = TOTAL_RAIN(t - dt) + (ACCUMULATOR) * dt
INIT TOTAL_RAIN = 0
INFLOWS:
    ACCUMULATOR = precip
WATER_YIELD(t) = WATER_YIELD(t - dt) + (streamflow) * dt
INIT WATER_YIELD = 0
INFLOWS:
    streamflow = 0.0018*days*RIVER
CN = 70
days = COUNTER(1,366)
delta = 5304*EXP(21.255-5304/(C+273))/(C+273)^2
H0 = (0.77/58.3)*Solar
LAI = 3
month = INT(COUNTER(1,366)/30)
S = 254*((100/CN)-1)
```

APPENDIX B

APPENDIX B - USDA SOIL DATA

Land use	Cover: Treatment or practice	Cover: Hydrologic condition	Hydrologic soil group: A	B	C	D
Fallow	Straight row	----	77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
	"	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	"	Good	65	65	82	86
	Contoured and terraced	Poor	66	74	80	82
	"	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
	"	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	"	Good	61	73	81	84
	Contoured and terraced	Poor	61	72	79	82
	"	Good	59	70	78	81
Close-seeded legumes[1] or rotation meadow	Straight row	Poor	66	77	85	89
	"	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	"	Good	55	69	78	83
	Contoured and terraced	Poor	63	73	80	83
	"	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	"	Fair	25	59	75	83
	"	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		----	59	74	82	86
Roads (dirt)[2]		----	72	82	87	89
(hard surface)[2]		----	74	84	90	92

[1] Close-drilled or broadcast.
[2] Including right-of-way.

Taken from USDA (1972).

Runoff curve numbers for hydrologic soil-cover complexes in Puerto Rico.
(Antecedent moisture condition II, and $I_a = 0.2\,S$).

Cover and condition	Hydrologic soil group A	B	C	D
Fallow	77	86	91	93
Grass (bunch grass or poor stand of sod)	51	70	80	84
Coffee (no ground cover, no terraces)	48	68	79	83
Coffee (with ground cover and terraces)	22	52	68	75
Minor crops (garden or truck crops)	45	66	77	83
Tropical kudzu	19	50	67	74
Sugarcane (trash burned; straight-row)	43	65	77	82
Sugarcane (trash mulch; straight-row)	45	66	77	83
Sugarcane (in holes; on contour)	24	53	69	76
Sugarcane (in furrows; on contour)	32	58	72	79

Runoff curve numbers for hydrologic soil-cover complexes of a typical watershed in Contra Costa County, California. (Antecedent moisture condition II, and $I_a = 0.2\,S$).

Cover	Condition	Hydrologic soil group A	B	C	D
Scrub (native brush)	----	25-30	41-46	57-63	66
Grass-oak (native oaks with understory of forbs and annual grasses)	Good	29-33	43-48	59-65	67
Irrigated pasture	Good	32-37	46-51	62-68	70
Orchard (winter period with understory of cover crop)	Good	37-41	50-55	64-69	71
Range (annual grass)	Fair	46-49	57-60	68-72	74
Small grain (contoured)	Good	61-64	69-71	76-80	81
Truck crops (straight-row)	Good	67-69	74-76	80-83	84
Urban areas:					
Low density (15 to 18 percent impervious surfaces)		69-71	75-78	82-84	86
Medium density (21 to 27 percent impervious surfaces)		71-73	77-80	84-86	88
High density (50 to 75 percent impervious surfaces)		73-75	79-82	86-88	90

APPENDIX C

APPENDIX C - SWRRB COMPUTER PRINTOUT

```
1
  SWRRBWQ 08/02/91 IBM PC  VERSION 1.0

      MOROCCO /  Reference File
       NO YRS =    1
       BASIN AREA =   538.200 KM**2
       AVE A RAINFALL/AVE A FOR GAGE
         SUBBASIN
            1    1.00
            2    1.00
            3    1.00
            4    1.00
       BASEFLOW FACTOR =      .250
       BASIN LAG TIME =   30.00 D
       GENERATOR CYCLES =   99
       WATER STATS =  1
       SEDIMENT STATS =  1


       GENERATOR SEEDS
                3  32 483  17
               45  66 657  13
              681  66 717  73
              215  33 243  60
              295  37 830   0
               17   0 776  66
              409  50 678  12
              340  43 393  14
              440   4 774  68

       CENTROID COORDINATES OF SUB AREAS(KM)
       9.30   12.30   22.10   12.30

       CENTROID COORDINATES OF SUB AREAS(KM)
      28.20   19.90   24.20   11.00

       TP-40 RAINFALL AMOUNTS (10 YR FREQ) FOR DUR
            0.5 H =  56.00 MM
            6H=108.00 MM

       NO YRS RECORD MAX.5H RAIN=  8.0

       LATITUDE= 35.10 DEG
```

GROUNDWATER DATA

INITIAL GROUNDWATER HEIGHT = 1.00000 M
INITIAL GROUNDWATER FLOW = .00000 MM
ALPHA FACTOR = .60000
SPECIFIC YIELD = .00300
GROUNDWATER DELAY = 60.00000 DAYS

1

SWRRBWQ 08/02/91 IBM PC VERSION 1.0

MOROCCO / Reference File
CLIMATE DATA

RAINFALL DATA USED IN THIS RUN ARE:
SIMULATED SINGLE RAINGAGE

TEMPERATURE DATA USED IN THIS RUN ARE;
SIMULATED SINGLE TEMP FOR ENTIRE BASIN

-MO RAIN PROB--		-MO STATS FOR DAILY RAIN-		
W/D	W/W	MEAN	ST DV	SKW CF
.148	.397	6.860	9.910	2.360
.210	.424	7.370	9.400	2.250
.166	.417	7.620	9.650	2.010
.203	.414	12.190	16.760	2.190
.188	.429	15.750	21.840	2.260
.138	.416	11.680	14.990	2.100
.072	.344	8.130	12.450	2.790
.111	.389	9.910	14.480	3.770
.138	.455	13.970	16.510	1.970
.123	.337	13.720	17.020	1.860
.142	.425	10.410	14.220	3.120
.133	.414	8.130	10.670	2.250

	R5MX	TMX	TMN	RA	CVT	RAIN	DAYP	ALPH
JAN	10.67	14.60	3.20	250.00	.17	41.91	6.11	.34
FEB	17.02	16.60	5.00	320.00	.12	57.10	7.75	.35
MAR	17.53	20.60	8.20	427.00	.15	52.35	6.87	.42
APR	23.88	25.20	13.20	488.00	.09	94.09	7.72	.37
MAY	40.13	29.30	17.70	562.00	.06	120.94	7.68	.32
JUN	22.86	33.60	21.90	651.00	.06	66.97	5.73	.51
JUL	50.80	35.60	23.70	613.00	.04	24.93	3.07	.66
AUG	29.21	35.90	23.50	593.00	.08	47.23	4.77	.58
SEP	31.75	32.30	19.90	503.00	.06	84.68	6.06	.40
OCT	36.83	27.30	14.20	403.00	.08	66.56	4.85	.35
NOV	8.89	20.10	7.40	306.00	.11	61.85	5.94	.33

```
     DEC    12.19     16.00     4.30   245.00       .15    46.62      5.73       .25
     YR     25.15     25.59    13.52   446.75       .10   765.23     72.28       .41
1
    SWRRBWQ 08/02/91 IBM PC  VERSION 1.0

        MOROCCO /  Reference File

    CROP DATA


 SUBBASIN  1

  CROP 1                        CROP 2                         CROP 3
  NUMBER OF CROPS =  3
  PLANTING DATE =  1/ 1         PLANTING DATE =  0/ 0          PLANTING DATE =  0/ 0
  CURVE NO PLANTING = 50.0      CURVE NO PLANTING =    .0      CURVE NO PLANTING =    .0
  HARVEST DATE =  6/15          HARVEST DATE =  0/ 0           HARVEST DATE =  0/ 0
  CURVE NO HARVEST = 50.0       CURVE NO HARVEST =    .0       CURVE NO HARVEST =    .0
  TILLAGE OPER =    1           TILLAGE OPER =    0            TILLAGE OPER =    0
  POT HEAT UNITS=1083. C        POT HEAT UNITS=6998. C         POT HEAT UNITS=6998. C
  BIOMASS CONV. =    30.00      BIOMASS CONV. =    30.00       BIOMASS CONV. =    30.00
  WATER STRESS FAC =     .01    WATER STRESS FAC =     .01     WATER STRESS FAC =     .01
  HARVEST INDEX =      .25      HARVEST INDEX =      .25       HARVEST INDEX =      .25
  LEG (1=NO,2=YES) 1            LEG (1=NO,2=YES) 1             LEG (1=NO, 2=YES) 1
  AVE C FACTOR =      .00       AVE C FACTOR =      .00        AVE C FACTOR =      .00

                                  FERTILIZER
 CROP 1                          CROP 2                   CROP 3
 APP. DATE        N        P     DATE        N        P     DATE        N        P
              (KG/HA)  (KG/HA)           (KG/HA)  (KG/HA)           (KG/HA)  (KG/HA)

   1   0/ 0      .00      .00    0/ 0      .00      .00    0/ 0      .00      .00
   2   0/ 0      .00      .00    0/ 0      .00      .00    0/ 0      .00      .00
   3   0/ 0      .00      .00    0/ 0      .00      .00    0/ 0      .00      .00
   4   0/ 0      .00      .00    0/ 0      .00      .00    0/ 0      .00      .00
   5   0/ 0      .00      .00    0/ 0      .00      .00    0/ 0      .00      .00

                                  PESTICIDE
              APPLIED  PEST              APPLIED PEST              APPLIED PEST
   (KG/HA)    (KG/HA)   NO.              (KG/HA)  NO.                       NO.

       0/ 0      .00     0       0/ 0      .00    0       0/ 0      .00    0
       0/ 0      .00     0       0/ 0      .00    0       0/ 0      .00    0
       0/ 0      .00     0       0/ 0      .00    0       0/ 0      .00    0
       0/ 0      .00     0       0/ 0      .00    0       0/ 0      .00    0
```

```
     DEC     12.19     16.00      4.30   245.00         .15     46.62      5.73        .25
     YR      25.15     25.59     13.52   446.75         .10    765.23     72.28        .41
1
    SWRRBWQ 08/02/91 IBM PC  VERSION 1.0

        MOROCCO /  Reference File

    CROP DATA


 SUBBASIN  1

  CROP 1                        CROP 2                         CROP 3
  NUMBER OF CROPS =  3
  PLANTING DATE =  1/ 1         PLANTING DATE =  0/ 0          PLANTING DATE =  0/ 0
  CURVE NO PLANTING = 50.0      CURVE NO PLANTING =    .0      CURVE NO PLANTING =    .0
  HARVEST DATE =  6/15          HARVEST DATE =  0/ 0           HARVEST DATE =  0/ 0
  CURVE NO HARVEST = 50.0       CURVE NO HARVEST =    .0       CURVE NO HARVEST =    .0
  TILLAGE OPER =    1           TILLAGE OPER =    0            TILLAGE OPER =    0
  POT HEAT UNITS=1083. C        POT HEAT UNITS=6998. C         POT HEAT UNITS=6998. C
  BIOMASS CONV. =     30.00     BIOMASS CONV. =     30.00      BIOMASS CONV. =     30.00
  WATER STRESS FAC =      .01   WATER STRESS FAC =      .01    WATER STRESS FAC =      .01
  HARVEST INDEX =       .25     HARVEST INDEX =       .25      HARVEST INDEX =       .25
  LEG (1=NO,2=YES) 1            LEG (1=NO,2=YES) 1             LEG (1=NO, 2=YES) 1
  AVE C FACTOR =       .00      AVE C FACTOR =       .00       AVE C FACTOR =       .00

                                  FERTILIZER
 CROP 1                          CROP 2                      CROP 3
 APP. DATE         N        P     DATE        N        P     DATE         N        P
                (KG/HA)  (KG/HA)           (KG/HA)  (KG/HA)            (KG/HA)  (KG/HA)

   1   0/ 0       .00      .00   0/ 0       .00      .00    0/ 0        .00      .00
   2   0/ 0       .00      .00   0/ 0       .00      .00    0/ 0        .00      .00
   3   0/ 0       .00      .00   0/ 0       .00      .00    0/ 0        .00      .00
   4   0/ 0       .00      .00   0/ 0       .00      .00    0/ 0        .00      .00
   5   0/ 0       .00      .00   0/ 0       .00      .00    0/ 0        .00      .00

                                   PESTICIDE
                APPLIED  PEST              APPLIED PEST                APPLIED PEST
    (KG/HA)     (KG/HA)   NO.              (KG/HA)  NO.                         NO.

       0/ 0       .00     0      0/ 0       .00     0       0/ 0        .00    0
       0/ 0       .00     0      0/ 0       .00     0       0/ 0        .00    0
       0/ 0       .00     0      0/ 0       .00     0       0/ 0        .00    0
       0/ 0       .00     0      0/ 0       .00     0       0/ 0        .00    0
```

```
      0/ 0       .00      0       0/ 0       .00     0       0/ 0       .00     0

                                          IRRIGATION
             APPLIED                             APPLIED                             APPLIED
              (MM)                                (MM)                                (MM)

      0/ 0       .00              0/ 0       .00             0/ 0       .00
      0/ 0       .00              0/ 0       .00             0/ 0       .00
      0/ 0       .00              0/ 0       .00             0/ 0       .00
      0/ 0       .00              0/ 0       .00             0/ 0       .00
      0/ 0       .00              0/ 0       .00             0/ 0       .00
1
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       MOROCCO /  Reference File
   CROP DATA


 SUBBASIN  2

  CROP 1                        CROP 2                       CROP 3
  NUMBER OF CROPS =  3
  PLANTING DATE =  1/ 1         PLANTING DATE =  0/ 0        PLANTING DATE =  0/ 0
  CURVE NO PLANTING = 50.0      CURVE NO PLANTING =    .0    CURVE NO PLANTING =    .0
  HARVEST DATE =  6/15          HARVEST DATE =  0/ 0         HARVEST DATE =  0/ 0
  CURVE NO HARVEST = 50.0       CURVE NO HARVEST =    .0     CURVE NO HARVEST =    .0
  TILLAGE OPER =    2           TILLAGE OPER =    3          TILLAGE OPER =    0
  POT HEAT UNITS=1083. C        POT HEAT UNITS=6998. C       POT HEAT UNITS=6998. C
  BIOMASS CONV. =    30.00      BIOMASS CONV. =    30.00     BIOMASS CONV. =    30.00
  WATER STRESS FAC =     .01    WATER STRESS FAC =     .01   WATER STRESS FAC =     .01
  HARVEST INDEX =      .25      HARVEST INDEX =      .25     HARVEST INDEX =      .25
  LEG (1=NO,2=YES) 1            LEG (1=NO,2=YES) 1           LEG (1=NO, 2=YES) 1
  AVE C FACTOR =       .00      AVE C FACTOR =       .00     AVE C FACTOR =       .00

                                        FERTILIZER
 CROP 1                                CROP 2                         CROP 3
 APP. DATE        N        P           DATE        N        P        DATE        N         P
               (KG/HA)  (KG/HA)                 (KG/HA)  (KG/HA)              (KG/HA)   (KG/HA)

   1  0/ 0       .00      .00       0/ 0       .00      .00       0/ 0       .00       .00
   2  0/ 0       .00      .00       0/ 0       .00      .00       0/ 0       .00       .00
   3  0/ 0       .00      .00       0/ 0       .00      .00       0/ 0       .00       .00
   4  0/ 0       .00      .00       0/ 0       .00      .00       0/ 0       .00       .00
   5  0/ 0       .00      .00       0/ 0       .00      .00       0/ 0       .00       .00
```

```
                                      PESTICIDE
               APPLIED   PEST                APPLIED PEST                    APPLIED PEST
   (KG/HA)     (KG/HA)    NO.                (KG/HA)  NO.                             NO.

      0/ 0        .00      0      0/ 0         .00     0       0/ 0         .00     0
      0/ 0        .00      0      0/ 0         .00     0       0/ 0         .00     0
      0/ 0        .00      0      0/ 0         .00     0       0/ 0         .00     0
      0/ 0        .00      0      0/ 0         .00     0       0/ 0         .00     0
      0/ 0        .00      0      0/ 0         .00     0       0/ 0         .00     0

                                      IRRIGATION
               APPLIED                       APPLIED                         APPLIED
                 (MM)                          (MM)                            (MM)

      0/ 0        .00             0/ 0         .00             0/ 0         .00
      0/ 0        .00             0/ 0         .00             0/ 0         .00
      0/ 0        .00             0/ 0         .00             0/ 0         .00
      0/ 0        .00             0/ 0         .00             0/ 0         .00
      0/ 0        .00             0/ 0         .00             0/ 0         .00
1
  SWRRBWQ 08/02/91 IBM PC  VERSION 1.0

      MOROCCO /  Reference File

      CROP DATA

 SUBBASIN  3

  CROP 1                      CROP 2                      CROP 3
  NUMBER OF CROPS =  1
  PLANTING DATE =  1/ 1       PLANTING DATE =  0/ 0       PLANTING DATE =  0/ 0
  CURVE NO PLANTING = 50.0    CURVE NO PLANTING =    .0   CURVE NO PLANTING =    .0
  HARVEST DATE =  6/15        HARVEST DATE =  0/ 0        HARVEST DATE =  0/ 0
  CURVE NO HARVEST = 50.0     CURVE NO HARVEST =    .0    CURVE NO HARVEST =    .0
  TILLAGE OPER =     3        TILLAGE OPER =     0        TILLAGE OPER =     0
  POT HEAT UNITS=1083. C      POT HEAT UNITS=   0. C      POT HEAT UNITS=   0. C
  BIOMASS CONV. =    35.00    BIOMASS CONV. =       .00   BIOMASS CONV. =       .00
  WATER STRESS FAC =     .01  WATER STRESS FAC =     .00  WATER STRESS FAC =     .00
  HARVEST INDEX =      .42    HARVEST INDEX =       .00   HARVEST INDEX =       .00
  LEG (1=NO,2=YES) 1          LEG (1=NO,2=YES) 0          LEG (1=NO, 2=YES) 0
  AVE C FACTOR =      .03     AVE C FACTOR =       .00    AVE C FACTOR =       .00

                                   FERTILIZER
 CROP 1                         CROP 2                  CROP 3
```

```
APP. DATE        N        P      DATE       N        P      DATE       N        P
              (KG/HA)  (KG/HA)           (KG/HA)  (KG/HA)           (KG/HA)  (KG/HA)

  1   0/ 0      .00      .00     0/ 0      .00      .00     0/ 0      .00      .00
  2   0/ 0      .00      .00     0/ 0      .00      .00     0/ 0      .00      .00
  3   0/ 0      .00      .00     0/ 0      .00      .00     0/ 0      .00      .00
  4   0/ 0      .00      .00     0/ 0      .00      .00     0/ 0      .00      .00
  5   0/ 0      .00      .00     0/ 0      .00      .00     0/ 0      .00      .00

                                  PESTICIDE
               APPLIED  PEST              APPLIED PEST               APPLIED PEST
     (KG/HA)   (KG/HA)   NO.              (KG/HA)  NO.                        NO.

      0/ 0      .00      0       0/ 0      .00     0        0/ 0      .00     0
      0/ 0      .00      0       0/ 0      .00     0        0/ 0      .00     0
      0/ 0      .00      0       0/ 0      .00     0        0/ 0      .00     0
      0/ 0      .00      0       0/ 0      .00     0        0/ 0      .00     0
      0/ 0      .00      0       0/ 0      .00     0        0/ 0      .00     0

                                  IRRIGATION
               APPLIED                    APPLIED                    APPLIED
                (MM)                       (MM)                       (MM)

      0/ 0      .00              0/ 0      .00              0/ 0      .00
      0/ 0      .00              0/ 0      .00              0/ 0      .00
      0/ 0      .00              0/ 0      .00              0/ 0      .00
      0/ 0      .00              0/ 0      .00              0/ 0      .00
      0/ 0      .00              0/ 0      .00              0/ 0      .00
1
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       MOROCCO /  Reference File

       CROP DATA


 SUBBASIN   4

  CROP 1                       CROP 2                      CROP 3
  NUMBER OF CROPS =  1
  PLANTING DATE =  1/ 1        PLANTING DATE =  0/ 0       PLANTING DATE =  0/ 0
  CURVE NO PLANTING = 50.0     CURVE NO PLANTING =   .0    CURVE NO PLANTING =   .0
  HARVEST DATE =  6/15         HARVEST DATE =  0/ 0        HARVEST DATE =  0/ 0
  CURVE NO HARVEST = 50.0      CURVE NO HARVEST =   .0     CURVE NO HARVEST =   .0
  TILLAGE OPER =    4          TILLAGE OPER =    0         TILLAGE OPER =    0
```

POT HEAT UNITS=	1083. C	POT HEAT UNITS=	0. C	POT HEAT UNITS=	0. C
BIOMASS CONV. =	30.00	BIOMASS CONV. =	.00	BIOMASS CONV. =	.00
WATER STRESS FAC =	.01	WATER STRESS FAC =	.00	WATER STRESS FAC =	.00
HARVEST INDEX =	.25	HARVEST INDEX =	.00	HARVEST INDEX =	.00
LEG (1=NO,2=YES)	1	LEG (1=NO,2=YES)	0	LEG (1=NO, 2=YES)	0
AVE C FACTOR =	.00	AVE C FACTOR =	.00	AVE C FACTOR =	.00

FERTILIZER

CROP 1				CROP 2			CROP 3		
APP.	DATE	N (KG/HA)	P (KG/HA)	DATE	N (KG/HA)	P (KG/HA)	DATE	N (KG/HA)	P (KG/HA)
1	0/ 0	.00	.00	0/ 0	.00	.00	0/ 0	.00	.00
2	0/ 0	.00	.00	0/ 0	.00	.00	0/ 0	.00	.00
3	0/ 0	.00	.00	0/ 0	.00	.00	0/ 0	.00	.00
4	0/ 0	.00	.00	0/ 0	.00	.00	0/ 0	.00	.00
5	0/ 0	.00	.00	0/ 0	.00	.00	0/ 0	.00	.00

PESTICIDE

(KG/HA)	APPLIED (KG/HA)	PEST NO.		APPLIED (KG/HA)	PEST NO.		APPLIED	PEST NO.
0/ 0	.00	0	0/ 0	.00	0	0/ 0	.00	0
0/ 0	.00	0	0/ 0	.00	0	0/ 0	.00	0
0/ 0	.00	0	0/ 0	.00	0	0/ 0	.00	0
0/ 0	.00	0	0/ 0	.00	0	0/ 0	.00	0
0/ 0	.00	0	0/ 0	.00	0	0/ 0	.00	0

IRRIGATION

	APPLIED (MM)		APPLIED (MM)		APPLIED (MM)
0/ 0	.00	0/ 0	.00	0/ 0	.00
0/ 0	.00	0/ 0	.00	0/ 0	.00
0/ 0	.00	0/ 0	.00	0/ 0	.00
0/ 0	.00	0/ 0	.00	0/ 0	.00
0/ 0	.00	0/ 0	.00	0/ 0	.00

IRRIGATION DATA

SUBBASINS	IRRIGATE (1=YES,0=NO)	WATER STRESS	RUNOFF RATIO (1 minus fraction that runs off)
1	0	.00	.00

```
       2              0                 .00                 .00
       3              0                 .00                 .00
       4              0                 .00                 .00
1
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       MOROCCO /  Reference File

       SUB-BASIN DATA


        SUB-BASIN AREA/BASIN AREA
              .250      .250      .250

        POND CATCHMENT AREA FRACTION
     .000      .000      .000      .000

        POND SURFACE AREA(HA)
      .00       .00       .00       .00

        MAX POND STORAGE(MM)
       .0        .0        .0        .0

        INTIAL POND STORAGE(MM)
       .0        .0        .0        .0

        INITIAL SED CONC IN PONDS(PPM)
       0.        0.        0.        0.

        NORMAL SED CONC IN PONDS(PPM)
       0.        0.        0.        0.

        SAT CONDUCTIVITY FOR POND BOTTOMS(MM/H)
      .00       .00       .00       .00

        RESERVOIR CATCHMENT AREA FRACTION
     .000      .000      .000      .000

        RESERVOIR SURFACE AREA AT EMERGENCY SPILLWAY(HA)
      .00       .00       .00       .00

        RESERVOIR STORAGE AT EMERGENCY SPILLWAY(MM)
       .0        .0        .0        .0

        RESERVOIR SURFACE AREA AT PRINCIPAL SPILLWAY(HA)
```

```
   .00       .00       .00       .00

     RESERVOIR STORAGE AT PRINCIPAL SPILLWAY(MM)
    .0        .0        .0        .0

     INITIAL RESERVOIR STORAGE(MM)
    .0        .0        .0        .0

     AVE RESERVOIR RELEASE RATES(M**3/S/KM**2)
.00000    .00000    .00000    .00000

     INITIAL SED CONC IN RESERVOIRS(PPM)
    0.        0.        0.        0.

     NORMAL SED CONC IN RESERVOIRS(PPM)
    0.        0.        0.        0.

     SAT CONDUCTIVITY OF RESERVOIR BOTTOMS (MM/H)
   .00       .00       .00       .00

     2 COND CN
  70.0      70.0      70.0      70.0

     SOIL ALBEDO
   .15       .15       .15       .15

     WATER CONTENT OF SNOW COVER (MM)
    .0        .0        .0        .0

     MAIN CHANNEL LENGTH (KM)
 14.20     11.70      6.80     27.10     41.20

     CHANNEL SLOPE(M/M)
 .0040     .0040     .0080     .0110     .0020

     AVERAGE MAIN CHANNEL WIDTH (M)
  9.00     11.00     11.00     13.00

     HYDR COND OF CHANNEL ALLUVIUM(MM/H)
 10.00     10.00     10.00     10.00

     CHANNEL N VALUE
  .050      .050      .050      .050      .050

     OVERLAND FLOW N VALUE
```

```
 .050      .050      .050      .050      .050

   TIME OF CONCENTRATION FOR SUB-BASINS(H)
 4.22      3.51      1.68      5.80     13.17

   RET FLO SED CONC (PPM)
 750.      750.      750.      750.

   RET FLO TRAVEL TIME(D)
 .000      .000      .000      .000

   SLOPE LENGTH(M)
  55.       55.       50.      100.      100.

   SLOPE STEEPNESS(M/M)
.0800     .0900     .0800     .0100     .0150

   EROSION CONTROL PRACTICE FACTORS(P)
 1.00      1.00      1.00      1.00


   SLOPE LENGTH AND STEEPNESS FACTORS(LS)
 1.42      1.70      1.35       .15


           ROUTING DATA -- SUB-BASIN TO BASIN OUTLET

   AVE CHANNEL WIDTH(M)
10.00      9.00     11.00       .00

   AVE CHANNEL DEPTH(M)
 2.00      2.00      2.50       .00

   CHANNEL SLOPE(M/M)
  .01       .01       .01       .00

   CHANNEL LENGTH(KM)
27.10     12.30      2.10       .00

   CHANNEL N VALUE
  .05       .05       .05       .05

   HYDR COND OF CHANNEL ALLUVIUM(MM/H)
10.00     10.00     10.00     10.00
```

USLE SOIL FACTOR K FOR CHANNEL

.310	.310	.310	.310

USLE SOIL FACTOR C FOR CHANNEL

1.000	1.000	1.000	1.000

PESTICIDE DATA

TOTAL NO OF PESTICIDES SIMULATED = 0

PEST	KOC	WASH OFF FRAC.	---HALF LIFE--- ON FOLIAGE	IN SOIL	APPL. EFF	WATER SOLU.

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MOROCCO / Reference File

SOILS DATA

ST NO	LAYER DEPTH (MM)	POROSITY (MM/MM)	15 BAR SW (MM/MM)	.3 BAR SW (MM/MM)	AVAIL W ST (MM)	INITIAL W ST (MM)	SAT COND (MM/H)	INITIAL NO3 (G/T)	ORG CARBON (%)
SUBBASIN 1			RAMMEL						
1	10.0	.43	.10	.27	1.70	.54	33.02	1.50	2.62
2	152.4	.43	.10	.27	24.21	7.67	33.02	10.68	2.62
3	838.2	.25	.03	.20	116.59	36.92	33.02	68.58	1.32
4	990.6	.25	.07	.20	19.81	6.27	33.02	15.24	1.13
TOTALS					162.3	51.4			
SUBBASIN 2			RAMMEL						
1	10.0	.43	.10	.27	1.70	.54	33.02	1.50	2.62
2	152.4	.43	.10	.27	24.21	7.67	33.02	10.68	2.62
3	838.2	.25	.03	.20	116.59	36.92	33.02	68.58	1.32
4	990.6	.25	.07	.20	19.81	6.27	33.02	15.24	1.13
TOTALS					162.3	51.4			
SUBBASIN 3			RAMMEL						
1	10.0	.43	.10	.27	1.70	.54	33.02	1.50	2.62
2	152.4	.43	.10	.27	24.21	7.67	33.02	10.68	2.62
3	838.2	.25	.03	.20	116.59	36.92	33.02	68.58	1.32
4	990.6	.25	.07	.20	19.81	6.27	33.02	15.24	1.13
TOTALS					162.3	51.4			

SUBBASIN	4		PORT						
1	10.0	.46	.07	.26	1.90	.60	12.00	1.42	.50
2	280.0	.46	.13	.32	51.30	16.25	12.00	19.17	.50
3	560.0	.46	.22	.41	53.20	16.85	12.00	19.88	.38
4	860.0	.45	.26	.44	54.00	17.10	12.00	21.75	.28
5	1270.0	.45	.24	.42	73.80	23.37	12.00	29.73	.19
6	1500.0	.45	.24	.42	41.40	13.11	12.00	16.67	.15
7	1828.0	.45	.24	.42	59.04	18.70	12.00	23.78	.11
TOTALS					334.6	106.0			

INITIAL COMPOSITE ST = 65.0 MM

1

SOIL SURFACE LAYER

SUB-BASIN	CLAY	SILT	SAND	K	ORG N (G/M3)	ORG P (G/M3)	SOLUBLE P (G/M3)
1	.16	.51	.33	.37	.00	.00	.00
2	.16	.51	.33	.37	.00	.00	.00
3	.16	.51	.33	.37	.00	.00	.00
4	.12	.72	.16	.31	.00	.00	.00

SEDIMENT SIZE DISTRIBUTION SIZE(MM)

SUB-BASIN	SAND .20	SILT .01	CLAY .002	SM AG .03	L AG .50
1	.800	.100	.100	.000	.000
2	.800	.100	.100	.000	.000
3	.800	.100	.100	.000	.000
4	.400	.300	.300	.000	.000

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MOROCCO / Reference File

GW HT	R	SURQ	SUB SURQ	WATER YIELD	PERCO LATE	ET	SED YIELD	SW	ORGANIC N	ORGANIC P	SURQ NO3	SOL P	CROP NO3	SSQ NO3	PERC NO3	RES. VOL	GW FLOW

	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(T/HA)	(MM)					--------(KG/HA)--------			(MM)	(MM)
(M)																	
1	.00	.00	.00	.00	.00	1.89	.00	63.15	.00	.00	.00	.00	.00	.00	.00	.00	.55
2	.00	.00	.00	.00	.00	2.24	.00	60.91	.00	.00	.00	.00	.00	.00	.00	.00	.30
3	.00	.00	.00	.00	.00	1.97	.00	58.93	.00	.00	.00	.00	.00	.00	.00	.00	.17
4	.00	.00	.00	.00	.00	2.42	.00	56.51	.00	.00	.00	.00	.00	.00	.00	.00	.09
5	.67	.00	.00	.00	.42	1.56	.00	55.21	.00	.00	.00	.00	.00	.00	.23	.00	.05
6	1.13	.00	.00	.01	.49	1.17	.00	54.68	.00	.00	.00	.00	.00	.00	.26	.01	.03
7	.00	.00	.00	.01	.00	1.46	.00	53.21	.00	.00	.00	.00	.00	.00	.00	.01	.02
8	.00	.00	.00	.01	.00	1.12	.00	52.10	.00	.00	.00	.00	.00	.00	.00	.01	.01
9	.00	.00	.00	.01	.00	.94	.00	51.15	.00	.00	.00	.00	.00	.00	.00	.01	.01
10	.00	.00	.00	.01	.00	.83	.00	50.33	.00	.00	.00	.00	.00	.00	.00	.01	.01
11	23.13	.00	.00	.04	3.69	2.03	.00	67.74	.00	.00	.00	.00	.00	.00	2.12	.04	.02
12	.00	.00	.00	.06	.00	3.44	.00	64.30	.00	.00	.00	.00	.00	.00	.00	.06	.02
13	.00	.00	.00	.06	.00	1.56	.00	62.74	.00	.00	.00	.00	.00	.00	.00	.06	.03
14	.00	.00	.00	.07	.00	2.62	.00	60.12	.00	.00	.00	.00	.00	.00	.00	.07	.03
15	.00	.00	.00	.07	.00	1.41	.00	58.71	.00	.00	.00	.00	.00	.00	.00	.07	.03
16	.00	.00	.00	.07	.00	1.09	.00	57.62	.00	.00	.00	.00	.00	.00	.00	.07	.03
17	5.90	.00	.00	.08	1.14	1.20	.00	61.17	.00	.00	.00	.00	.00	.00	.61	.08	.03
18	.00	.00	.00	.08	.00	2.34	.00	58.83	.00	.00	.00	.00	.00	.00	.00	.08	.03
19	.00	.00	.00	.08	.00	1.37	.00	57.47	.00	.00	.00	.00	.00	.00	.00	.08	.03
20	.00	.00	.00	.08	.00	1.08	.00	56.39	.00	.00	.00	.00	.00	.00	.00	.08	.03
21	.00	.00	.00	.08	.00	.92	.00	55.48	.00	.00	.00	.00	.00	.00	.00	.08	.03
22	.00	.00	.00	.08	.00	.81	.00	54.66	.00	.00	.00	.00	.00	.00	.00	.08	.03
23	13.36	.00	.00	.10	2.35	2.17	.00	63.50	.00	.00	.00	.00	.00	.00	1.30	.10	.04
24	1.76	.00	.00	.11	.52	3.95	.00	60.79	.00	.00	.00	.00	.00	.00	.27	.11	.05
25	.01	.00	.00	.11	.01	1.76	.00	59.03	.00	.00	.00	.00	.00	.00	.00	.11	.05
26	4.31	.00	.00	.12	.89	1.56	.00	60.90	.00	.00	.00	.00	.00	.00	.47	.12	.05
27	.00	.00	.00	.13	.00	1.70	.00	59.20	.00	.00	.00	.00	.00	.00	.00	.13	.05
28	.00	.00	.00	.13	.00	1.33	.00	57.87	.00	.00	.00	.00	.00	.00	.00	.13	.05
29	9.65	.00	.00	.14	1.75	1.47	.00	64.31	.00	.00	.00	.00	.00	.00	.94	.14	.06
30	.00	.00	.00	.15	.00	1.41	.00	62.90	.00	.00	.00	.00	.00	.00	.00	.15	.06
31	.00	.00	.00	.15	.00	2.19	.00	60.70	.00	.00	.00	.00	.00	.00	.00	.15	.06
1	59.92	.00	.00	2.05	11.25	53.00	.00	60.70	.00	.00	.00	.00	.00	.00	6.20	.00	2.04
.06																	
32	.00	.00	.00	.15	.00	2.31	.00	58.39	.00	.00	.00	.00	.00	.00	.00	.15	.06
33	.00	.00	.00	.15	.00	2.38	.00	56.01	.00	.00	.00	.00	.00	.00	.00	.15	.06
34	.00	.00	.00	.15	.00	1.38	.00	54.63	.00	.00	.00	.00	.00	.00	.00	.15	.06
35	.00	.00	.00	.14	.00	1.08	.00	53.55	.00	.00	.00	.00	.00	.00	.00	.14	.06
36	.00	.00	.00	.14	.00	.92	.00	52.64	.00	.00	.00	.00	.00	.00	.00	.14	.06
37	.00	.00	.00	.14	.00	.81	.00	51.82	.00	.00	.00	.00	.00	.00	.00	.14	.06
38	.00	.00	.00	.14	.00	.74	.00	51.09	.00	.00	.00	.00	.00	.00	.00	.14	.06
39	.00	.00	.00	.14	.00	.68	.00	50.41	.00	.00	.00	.00	.00	.00	.00	.14	.06
40	.00	.00	.00	.13	.00	.63	.00	49.78	.00	.00	.00	.00	.00	.00	.00	.13	.06
41	.01	.00	.00	.13	.01	.61	.00	49.17	.00	.00	.00	.00	.00	.00	.00	.13	.05

42	.00	.00	.00	.13	.00	.56	.00	48.61	.00	.00	.00	.00	.00	.00	.00	.13	.05
43	.00	.00	.00	.13	.00	.54	.00	48.07	.00	.00	.00	.00	.00	.00	.00	.13	.05
44	.00	.00	.00	.12	.00	.51	.00	47.56	.00	.00	.00	.00	.00	.00	.00	.12	.05
45	.00	.00	.00	.12	.00	.49	.00	47.07	.00	.00	.00	.00	.00	.00	.00	.12	.05
46	.00	.00	.00	.12	.00	.47	.00	46.59	.00	.00	.00	.00	.00	.00	.00	.12	.05
47	.00	.00	.00	.12	.00	.46	.00	46.13	.00	.00	.00	.00	.00	.00	.00	.12	.05
48	.00	.00	.00	.12	.00	.44	.00	45.69	.00	.00	.00	.00	.00	.00	.00	.12	.05
49	.00	.00	.00	.11	.00	.43	.00	45.26	.00	.00	.00	.00	.00	.00	.00	.11	.05
50	.00	.00	.00	.11	.00	.42	.00	44.84	.00	.00	.00	.00	.00	.00	.00	.11	.05
51	.00	.00	.00	.11	.00	.41	.00	44.44	.00	.00	.00	.00	.00	.00	.00	.11	.05
52	.58	.00	.00	.11	.40	.46	.00	44.15	.00	.00	.00	.00	.00	.00	.21	.11	.05
53	6.64	.00	.00	.12	1.15	3.06	.00	46.58	.00	.00	.00	.00	.00	.01	.61	.12	.05
54	.00	.00	.00	.12	.00	.52	.00	46.06	.00	.00	.00	.00	.00	.00	.00	.12	.05
55	.00	.00	.00	.13	.00	.50	.00	45.57	.00	.00	.00	.00	.00	.00	.00	.13	.05
56	.00	.00	.00	.12	.00	.48	.00	45.09	.00	.00	.00	.00	.00	.00	.00	.12	.05
57	.00	.00	.00	.12	.00	.46	.00	44.63	.00	.00	.00	.00	.00	.00	.00	.12	.05
58	.00	.00	.00	.12	.00	.45	.00	44.18	.00	.00	.00	.00	.00	.00	.00	.12	.05
59	.00	.00	.00	.12	.00	.43	.00	43.75	.00	.00	.00	.00	.00	.00	.00	.12	.05
2	7.23	.00	.00	3.58	1.56	22.61	.00	43.75	.00	.00	.00	.00	.00	.01	.82	.00	3.57
.05																	
60	.00	.00	.00	.12	.00	.42	.00	43.33	.00	.00	.00	.00	.00	.00	.00	.12	.05
61	.00	.00	.00	.12	.00	.41	.00	42.93	.00	.00	.00	.00	.00	.00	.00	.12	.05
62	.00	.00	.00	.11	.00	.40	.00	42.53	.00	.00	.00	.00	.00	.00	.00	.11	.05
63	.00	.00	.00	.11	.00	.39	.00	42.14	.00	.00	.00	.00	.00	.00	.00	.11	.05
64	.00	.00	.00	.11	.00	.38	.00	41.76	.00	.00	.00	.00	.00	.00	.00	.11	.05
65	.00	.00	.00	.11	.00	.37	.00	41.39	.00	.00	.00	.00	.00	.00	.00	.11	.05
66	.00	.00	.00	.11	.00	.36	.00	41.03	.00	.00	.00	.00	.00	.00	.00	.11	.04
67	.00	.00	.00	.11	.00	.36	.00	40.67	.00	.00	.00	.00	.00	.00	.00	.11	.04
68	.00	.00	.00	.10	.00	.35	.00	40.32	.00	.00	.00	.00	.00	.00	.00	.10	.04
69	.00	.00	.00	.10	.00	.34	.00	39.98	.00	.00	.00	.00	.00	.00	.00	.10	.04
70	.00	.00	.00	.10	.00	.34	.00	39.64	.00	.00	.00	.00	.00	.00	.00	.10	.04
71	.00	.00	.00	.10	.00	.33	.00	39.32	.00	.00	.00	.00	.00	.00	.00	.10	.04
72	.00	.00	.00	.10	.00	.32	.00	38.99	.00	.00	.00	.00	.00	.00	.00	.10	.04
73	.00	.00	.00	.10	.00	.32	.00	38.67	.00	.00	.00	.00	.00	.00	.00	.10	.04
74	.00	.00	.00	.09	.00	.31	.00	38.36	.00	.00	.00	.00	.00	.00	.00	.09	.04
75	.00	.00	.00	.09	.00	.31	.00	38.05	.00	.00	.00	.00	.00	.00	.00	.09	.04
76	.00	.00	.00	.09	.00	.30	.00	37.74	.00	.00	.00	.00	.00	.00	.00	.09	.04
77	.00	.00	.00	.09	.00	.30	.00	37.44	.00	.00	.00	.00	.00	.00	.00	.09	.04
78	.00	.00	.00	.09	.00	.30	.00	37.15	.00	.00	.00	.00	.00	.00	.00	.09	.04
79	.00	.00	.00	.09	.00	.29	.00	36.86	.00	.00	.00	.00	.00	.00	.00	.09	.04
80	.00	.00	.00	.09	.00	.29	.00	36.57	.00	.00	.00	.00	.00	.00	.00	.08	.04
81	.00	.00	.00	.08	.00	.28	.00	36.29	.00	.00	.00	.00	.00	.00	.00	.08	.03
82	.00	.00	.00	.08	.00	.28	.00	36.01	.00	.00	.00	.00	.00	.00	.00	.08	.03
83	.00	.00	.00	.08	.00	.28	.00	35.73	.00	.00	.00	.00	.00	.00	.00	.08	.03
84	.00	.00	.00	.08	.00	.27	.00	35.46	.00	.00	.00	.00	.00	.00	.00	.08	.03

85	.00	.00	.00	.08	.00	.27	.00	35.18	.00	.00	.00	.00	.00	.00	.00	.08	.03
86	.00	.00	.00	.08	.00	.27	.00	34.92	.00	.00	.00	.00	.00	.00	.00	.08	.03
87	.00	.00	.00	.08	.00	.26	.00	34.65	.00	.00	.00	.00	.00	.00	.00	.08	.03
88	.00	.00	.00	.07	.00	.26	.00	34.39	.00	.00	.00	.00	.00	.00	.00	.07	.03
89	.00	.00	.00	.07	.00	.26	.00	34.13	.00	.00	.00	.00	.00	.00	.00	.07	.03
90	.00	.00	.00	.07	.00	.26	.00	33.88	.00	.00	.00	.00	.00	.00	.00	.07	.03
3	.00	.00	.00	2.90	.00	9.88	.00	33.88	.00	.00	.00	.00	.00	.00	.00	.00	2.89
.03																	
91	.00	.00	.00	.07	.00	.25	.00	33.62	.00	.00	.00	.00	.00	.00	.00	.07	.03
92	.00	.00	.00	.07	.00	.25	.00	33.37	.00	.00	.00	.00	.00	.00	.00	.07	.03
93	.00	.00	.00	.07	.00	.25	.00	33.12	.00	.00	.00	.00	.00	.00	.00	.07	.03
94	.00	.00	.00	.07	.00	.25	.00	32.88	.00	.00	.00	.00	.00	.00	.00	.07	.03
95	.00	.00	.00	.07	.00	.24	.00	32.63	.00	.00	.00	.00	.00	.00	.00	.07	.03
96	12.04	.00	.00	.08	1.90	5.09	.00	37.69	.00	.00	.00	.00	.00	.00	.99	.08	.03
97	10.29	.00	.00	.10	1.76	7.94	.00	38.29	.00	.00	.00	.00	.00	.00	.94	.10	.04
98	.00	.00	.00	.11	.00	.38	.00	37.91	.00	.00	.00	.00	.00	.00	.00	.11	.05
99	.00	.00	.00	.11	.00	.37	.00	37.54	.00	.00	.00	.00	.00	.00	.00	.11	.05
100	11.41	.00	.00	.13	1.85	3.11	.00	44.00	.00	.00	.00	.00	.00	.00	.98	.13	.05
101	33.15	.00	.00	.18	5.62	6.14	.00	65.40	.00	.00	.00	.00	.00	.03	3.16	.18	.07
102	22.45	.00	.00	.24	4.03	4.09	.00	79.69	.00	.00	.00	.00	.00	.06	2.17	.23	.10
103	42.18	.00	.01	.33	7.95	7.83	.00	105.93	.00	.00	.00	.00	.00	.25	4.53	.32	.13
104	10.24	.00	.01	.39	1.93	5.80	.00	108.35	.00	.00	.00	.00	.00	.17	.94	.38	.16
105	.00	.00	.01	.42	.05	2.50	.00	105.79	.00	.00	.00	.00	.00	.02	.02	.41	.17
106	.00	.00	.01	.43	.00	1.90	.00	103.90	.00	.00	.00	.00	.00	.00	.00	.42	.18
107	.00	.00	.01	.43	.00	1.28	.00	102.62	.00	.00	.00	.00	.00	.00	.00	.43	.18
108	.00	.00	.01	.43	.00	1.03	.00	101.59	.00	.00	.00	.00	.00	.00	.00	.42	.18
109	.00	.00	.01	.43	.00	.89	.00	100.70	.00	.00	.00	.00	.00	.00	.00	.42	.18
110	.00	.00	.01	.42	.00	.79	.00	99.91	.00	.00	.00	.00	.00	.00	.00	.42	.17
111	.00	.00	.01	.42	.00	.72	.00	99.19	.00	.00	.00	.00	.00	.00	.00	.41	.17
112	.00	.00	.01	.41	.00	.67	.00	98.52	.00	.00	.00	.00	.00	.00	.00	.40	.17
113	13.40	.00	.01	.42	2.36	5.55	.00	103.98	.00	.00	.00	.00	.00	.04	1.15	.41	.17
114	.00	.00	.01	.43	.00	2.20	.00	101.78	.00	.00	.00	.00	.00	.00	.00	.42	.17
115	.00	.00	.01	.42	.00	1.35	.00	100.43	.00	.00	.00	.00	.00	.00	.00	.42	.17
116	5.42	.00	.01	.43	1.12	5.38	.00	99.35	.00	.00	.00	.00	.00	.00	.53	.42	.18
117	3.48	.00	.01	.43	.61	2.80	.00	99.43	.00	.00	.00	.00	.00	.00	.29	.42	.18
118	.01	.00	.01	.43	.01	1.22	.00	98.21	.00	.00	.00	.00	.00	.00	.00	.42	.18
119	31.55	.00	.01	.47	5.55	4.42	.00	119.67	.00	.00	.00	.00	.00	.19	1.90	.46	.19
120	.06	.00	.01	.49	.11	5.38	.00	114.15	.00	.00	.00	.00	.00	.06	.04	.48	.20
4	195.66	.00	.16	8.93	34.85	80.04	.00	114.15	.00	.00	.00	.00	.00	.84	17.63	.00	8.76
.20																	
121	.00	.00	.01	.50	.00	1.37	.00	112.78	.00	.00	.00	.00	.00	.00	.00	.48	.20
122	.00	.00	.01	.49	.00	1.08	.00	111.70	.00	.00	.00	.00	.00	.00	.00	.48	.20
123	.00	.00	.01	.49	.00	.92	.00	110.78	.00	.00	.00	.00	.00	.00	.00	.48	.20
124	.00	.00	.01	.48	.00	.81	.00	109.97	.00	.00	.00	.00	.00	.00	.00	.47	.20
125	6.92	.00	.01	.49	1.34	5.54	.00	109.99	.00	.00	.00	.00	.00	.01	.13	.48	.20

126	.00	.00	.01	.49	.00	.88	.00	109.11	.00	.00	.00	.00	.00	.00	.00	.48	.20
127	.00	.00	.01	.48	.00	.79	.00	108.33	.00	.00	.00	.00	.00	.00	.00	.47	.20
128	.00	.00	.01	.47	.00	.72	.00	107.61	.00	.00	.00	.00	.00	.00	.00	.47	.19
129	.00	.00	.01	.47	.00	.67	.00	106.94	.00	.00	.00	.00	.00	.00	.00	.46	.19
130	.00	.00	.01	.46	.00	.62	.00	106.32	.00	.00	.00	.00	.00	.00	.00	.45	.19
131	.00	.00	.01	.45	.00	.59	.00	105.73	.00	.00	.00	.00	.00	.00	.00	.44	.19
132	.00	.00	.01	.45	.00	.56	.00	105.17	.00	.00	.00	.00	.00	.00	.00	.44	.18
133	.00	.00	.01	.44	.00	.53	.00	104.64	.00	.00	.00	.00	.00	.00	.00	.43	.18
134	.00	.00	.01	.43	.00	.51	.00	104.13	.00	.00	.00	.00	.00	.00	.00	.42	.18
135	.00	.00	.01	.42	.00	.49	.00	103.64	.00	.00	.00	.00	.00	.00	.00	.42	.17
136	3.12	.00	.01	.42	.72	2.50	.00	103.54	.00	.00	.00	.00	.00	.01	.07	.41	.17
137	.00	.00	.01	.42	.00	.49	.00	103.04	.00	.00	.00	.00	.00	.00	.00	.41	.17
138	.00	.00	.01	.41	.00	.48	.00	102.56	.00	.00	.00	.00	.00	.00	.00	.41	.17
139	.00	.00	.01	.41	.00	.46	.00	102.10	.00	.00	.00	.00	.00	.00	.00	.40	.17
140	.00	.00	.01	.40	.00	.45	.00	101.66	.00	.00	.00	.00	.00	.00	.00	.39	.16
141	.00	.00	.01	.39	.00	.43	.00	101.23	.00	.00	.00	.00	.00	.00	.00	.39	.16
142	36.61	.00	.01	.45	7.30	6.94	.00	123.44	.00	.00	.00	.00	.00	.15	1.13	.44	.18
143	4.36	.00	.01	.48	1.07	4.77	.00	121.89	.00	.00	.00	.00	.00	.04	.26	.47	.19
144	21.55	.00	.02	.54	4.84	6.77	.00	131.62	.00	.00	.00	.00	.00	.09	.72	.52	.21
145	46.52	.00	.03	.66	11.43	8.37	.00	157.89	.00	.00	.00	.00	.00	.22	2.32	.62	.26
146	5.52	.00	.04	.73	1.54	5.85	.00	155.82	.00	.00	.00	.00	.00	.04	.24	.69	.29
147	19.92	.00	.05	.80	4.55	8.71	.00	162.06	.00	.00	.00	.00	.00	.10	.87	.75	.31
148	.00	.00	.05	.83	.15	1.73	.00	160.09	.00	.00	.00	.00	.00	.02	.05	.78	.33
149	.00	.00	.05	.85	.07	1.22	.00	158.76	.00	.00	.00	.00	.00	.01	.02	.79	.33
150	.00	.00	.05	.84	.07	1.00	.00	157.67	.00	.00	.00	.00	.00	.01	.02	.79	.33
151	.00	.00	.05	.84	.06	.87	.00	156.73	.00	.00	.00	.00	.00	.00	.02	.79	.33
5	144.53	.00	.54	16.48	33.14	67.14	.00	156.73	.00	.00	.00	.00	.00	.69	5.86	.00	15.93
.33																	
152	.00	.00	.05	.83	.06	.78	.00	155.89	.00	.00	.00	.00	.00	.00	.02	.78	.32
153	.00	.00	.05	.82	.00	.71	.00	155.18	.00	.00	.00	.00	.00	.00	.00	.77	.32
154	.00	.00	.04	.80	.00	.66	.00	154.52	.00	.00	.00	.00	.00	.00	.00	.76	.32
155	.00	.00	.04	.79	.00	.62	.00	153.90	.00	.00	.00	.00	.00	.00	.00	.75	.31
156	.00	.00	.04	.78	.00	.58	.00	153.32	.00	.00	.00	.00	.00	.00	.00	.73	.31
157	.00	.00	.04	.76	.00	.55	.00	152.77	.00	.00	.00	.00	.00	.00	.00	.72	.30
158	4.02	.00	.04	.76	.77	3.21	.00	152.80	.00	.00	.00	.00	.00	.00	.11	.72	.30
159	.00	.00	.04	.75	.01	.56	.00	152.22	.00	.00	.00	.00	.00	.00	.00	.71	.29
160	.00	.00	.04	.73	.00	.54	.00	151.69	.00	.00	.00	.00	.00	.00	.00	.70	.29
161	.00	.00	.04	.72	.00	.51	.00	151.17	.00	.00	.00	.00	.00	.00	.00	.69	.29
162	.00	.00	.03	.71	.00	.49	.00	150.68	.00	.00	.00	.00	.00	.00	.00	.68	.28
163	.00	.00	.03	.70	.00	.47	.00	150.21	.00	.00	.00	.00	.00	.00	.00	.67	.28
164	.00	.00	.03	.69	.00	.46	.00	149.75	.00	.00	.00	.00	.00	.00	.00	.65	.27
165	.00	.00	.03	.68	.00	.44	.00	149.31	.00	.00	.00	.00	.00	.00	.00	.64	.27
166	17.30	.00	.03	.69	3.55	4.51	.00	158.49	.00	.00	.00	.00	.00	.01	.51	.66	.28
167	.00	.00	.03	.69	.06	2.45	.00	155.98	.00	.00	.00	.00	.00	.00	.02	.66	.28
168	.00	.00	.03	.69	.02	1.39	.00	154.57	.00	.00	.00	.00	.00	.00	.01	.66	.28

169	.00	.00	.03	.68	.00	1.08	.00	153.49	.00	.00	.00	.00	.00	.00	.00	.66	.27
170	.00	.00	.03	.67	.00	.92	.00	152.57	.00	.00	.00	.00	.00	.00	.00	.65	.27
171	61.35	.00	.05	.80	14.78	6.78	.00	191.64	.00	.00	.00	.00	.00	.14	3.33	.75	.31
172	8.40	.00	.07	.89	3.34	10.37	.00	185.64	.00	.00	.00	.00	.00	.16	.94	.82	.34
173	.00	.00	.07	.93	.76	1.23	.00	183.55	.00	.00	.00	.00	.00	.05	.12	.86	.36
174	.00	.00	.07	.95	.08	1.00	.00	182.40	.00	.00	.00	.00	.00	.03	.03	.88	.37
175	.00	.00	.07	.95	.08	.87	.00	181.42	.00	.00	.00	.00	.00	.02	.03	.88	.37
176	.00	.00	.07	.94	.08	.78	.00	180.55	.00	.00	.00	.00	.00	.01	.03	.87	.36
177	.00	.00	.07	.93	.07	.71	.00	179.77	.00	.00	.00	.00	.00	.00	.03	.87	.36
178	.00	.00	.06	.92	.00	.66	.00	179.10	.00	.00	.00	.00	.00	.00	.00	.85	.36
179	.00	.00	.06	.90	.00	.62	.00	178.49	.00	.00	.00	.00	.00	.00	.00	.84	.35
180	.00	.00	.06	.89	.00	.58	.00	177.91	.00	.00	.00	.00	.00	.00	.00	.83	.35
181	.00	.00	.06	.87	.00	.55	.00	177.35	.00	.00	.00	.00	.00	.00	.00	.82	.34
6	91.06	.00	1.41	23.92	23.66	45.11	.01	177.35	.00	.00	.00	.00	.00	.41	5.17	.00	22.51
.34																	
182	.00	.00	.06	.86	.00	.53	.00	176.83	.00	.00	.00	.00	.00	.00	.00	.80	.33
183	.00	.00	.05	.84	.00	.50	.00	176.32	.00	.00	.00	.00	.00	.00	.00	.79	.33
184	.00	.00	.05	.83	.00	.48	.00	175.84	.00	.00	.00	.00	.00	.00	.00	.78	.32
185	.00	.00	.05	.81	.00	.47	.00	175.37	.00	.00	.00	.00	.00	.00	.00	.76	.32
186	.00	.00	.05	.80	.00	.45	.00	174.92	.00	.00	.00	.00	.00	.00	.00	.75	.31
187	.00	.00	.05	.79	.00	.44	.00	174.49	.00	.00	.00	.00	.00	.00	.00	.74	.31
188	.00	.00	.05	.77	.00	.42	.00	174.06	.00	.00	.00	.00	.00	.00	.00	.73	.30
189	.00	.00	.04	.76	.00	.41	.00	173.65	.00	.00	.00	.00	.00	.00	.00	.71	.30
190	.00	.00	.04	.75	.00	.40	.00	173.25	.00	.00	.00	.00	.00	.00	.00	.70	.29
191	.00	.00	.04	.73	.00	.39	.00	172.86	.00	.00	.00	.00	.00	.00	.00	.69	.29
192	.00	.00	.04	.72	.00	.38	.00	172.48	.00	.00	.00	.00	.00	.00	.00	.68	.28
193	.00	.00	.04	.71	.00	.37	.00	172.10	.00	.00	.00	.00	.00	.00	.00	.67	.28
194	.00	.00	.04	.69	.00	.36	.00	171.74	.00	.00	.00	.00	.00	.00	.00	.66	.27
195	.00	.00	.04	.68	.00	.36	.00	171.38	.00	.00	.00	.00	.00	.00	.00	.65	.27
196	.00	.00	.04	.67	.00	.35	.00	171.03	.00	.00	.00	.00	.00	.00	.00	.64	.26
197	.00	.00	.03	.66	.00	.34	.00	170.69	.00	.00	.00	.00	.00	.00	.00	.63	.26
198	.00	.00	.03	.65	.00	.34	.00	170.35	.00	.00	.00	.00	.00	.00	.00	.61	.26
199	38.45	.00	.05	.73	10.45	9.77	.00	188.07	.00	.00	.00	.00	.00	.07	2.30	.68	.28
200	1.63	.00	.05	.77	1.21	.51	.00	187.85	.00	.00	.00	.00	.00	.05	.28	.72	.30
201	.00	.00	.05	.79	.12	1.74	.00	185.89	.00	.00	.00	.00	.00	.04	.03	.74	.31
202	.00	.00	.05	.80	.08	1.22	.00	184.54	.00	.00	.00	.00	.00	.02	.03	.74	.31
203	.00	.00	.05	.79	.08	1.00	.00	183.43	.00	.00	.00	.00	.00	.02	.03	.74	.31
204	.00	.00	.05	.79	.08	.87	.00	182.48	.00	.00	.00	.00	.00	.01	.03	.74	.31
205	.00	.00	.05	.78	.05	.78	.00	181.66	.00	.00	.00	.00	.00	.00	.02	.73	.30
206	.00	.00	.05	.76	.00	.71	.00	180.95	.00	.00	.00	.00	.00	.00	.00	.72	.30
207	.00	.00	.05	.75	.00	.66	.00	180.29	.00	.00	.00	.00	.00	.00	.00	.71	.29
208	.00	.00	.04	.74	.00	.62	.00	179.67	.00	.00	.00	.00	.00	.00	.00	.69	.29
209	23.93	.00	.06	.79	6.25	11.81	.00	185.12	.00	.00	.00	.00	.00	.05	1.25	.73	.30
210	.00	.00	.06	.80	.31	.97	.00	183.77	.00	.00	.00	.00	.00	.02	.03	.75	.31
211	.00	.00	.06	.81	.08	.85	.00	182.80	.00	.00	.00	.00	.00	.02	.03	.75	.31

212	.00	.00	.05	.80	.08	.76	.00	181.95	.00	.00	.00	.00	.00	.01	.03	.75	.31
7	64.00	.00	1.45	23.62	18.77	39.28	.01	181.95	.00	.00	.00	.00	.00	.30	4.06	.00	22.17
.31																	
213	.00	.00	.05	.79	.07	.70	.00	181.17	.00	.00	.00	.00	.00	.00	.03	.74	.31
214	3.98	.00	.05	.79	1.02	3.19	.00	180.95	.00	.00	.00	.00	.00	.00	.19	.74	.31
215	.00	.00	.05	.78	.05	.71	.00	180.19	.00	.00	.00	.00	.00	.00	.01	.73	.31
216	.00	.00	.05	.77	.00	.66	.00	179.53	.00	.00	.00	.00	.00	.00	.00	.72	.30
217	.00	.00	.05	.76	.00	.61	.00	178.92	.00	.00	.00	.00	.00	.00	.00	.71	.30
218	3.04	.00	.05	.76	.95	2.43	.00	178.54	.00	.00	.00	.00	.00	.00	.16	.71	.30
219	.00	.00	.04	.75	.03	.61	.00	177.90	.00	.00	.00	.00	.00	.00	.01	.70	.29
220	.00	.00	.04	.74	.00	.58	.00	177.32	.00	.00	.00	.00	.00	.00	.00	.69	.29
221	.00	.00	.04	.72	.00	.55	.00	176.77	.00	.00	.00	.00	.00	.00	.00	.68	.28
222	.00	.00	.04	.71	.00	.52	.00	176.24	.00	.00	.00	.00	.00	.00	.00	.67	.28
223	.00	.00	.04	.70	.00	.50	.00	175.74	.00	.00	.00	.00	.00	.00	.00	.66	.28
224	.00	.00	.04	.69	.00	.48	.00	175.26	.00	.00	.00	.00	.00	.00	.00	.65	.27
225	.00	.00	.04	.68	.00	.47	.00	174.79	.00	.00	.00	.00	.00	.00	.00	.64	.27
226	.00	.00	.04	.67	.00	.45	.00	174.34	.00	.00	.00	.00	.00	.00	.00	.63	.26
227	.00	.00	.03	.65	.00	.44	.00	173.91	.00	.00	.00	.00	.00	.00	.00	.62	.26
228	6.13	.00	.03	.66	1.71	4.91	.00	173.42	.00	.00	.00	.00	.00	.00	.27	.62	.26
229	.00	.00	.03	.65	.04	.46	.00	172.91	.00	.00	.00	.00	.00	.00	.01	.62	.26
230	.00	.00	.03	.64	.00	.45	.00	172.47	.00	.00	.00	.00	.00	.00	.00	.61	.26
231	.00	.00	.03	.64	.00	.43	.00	172.03	.00	.00	.00	.00	.00	.00	.00	.61	.25
232	1.33	.00	.03	.63	.56	1.06	.00	171.74	.00	.00	.00	.00	.00	.00	.05	.60	.25
233	.00	.00	.03	.62	.00	.43	.00	171.31	.00	.00	.00	.00	.00	.00	.00	.59	.25
234	.00	.00	.03	.61	.00	.41	.00	170.90	.00	.00	.00	.00	.00	.00	.00	.59	.24
235	.00	.00	.03	.60	.00	.40	.00	170.50	.00	.00	.00	.00	.00	.00	.00	.58	.24
236	.00	.00	.03	.59	.00	.39	.00	170.10	.00	.00	.00	.00	.00	.00	.00	.57	.24
237	.00	.00	.02	.58	.00	.38	.00	169.72	.00	.00	.00	.00	.00	.00	.00	.56	.23
238	2.24	.00	.02	.58	.60	1.79	.00	169.56	.00	.00	.00	.00	.00	.00	.06	.55	.23
239	4.39	.00	.02	.58	1.09	3.52	.00	169.35	.00	.00	.00	.00	.00	.00	.13	.56	.23
240	11.54	.00	.02	.59	2.26	9.24	.00	169.39	.00	.00	.00	.00	.00	.00	.31	.57	.24
241	19.06	.00	.02	.62	3.76	6.98	.00	177.64	.00	.00	.00	.00	.00	.01	.53	.60	.25
242	38.29	.00	.06	.74	9.91	3.78	.00	201.26	.00	.00	.00	.00	.00	.16	2.11	.69	.29
243	.00	.00	.07	.81	1.38	7.25	.00	192.19	.00	.00	.00	.00	.00	.08	.34	.74	.31
8	90.02	.00	1.15	21.10	23.44	54.78	.01	192.19	.00	.00	.00	.00	.00	.27	4.20	.00	19.95
.31																	
244	.00	.00	.07	.83	.18	1.10	.00	190.77	.00	.00	.00	.00	.00	.04	.06	.76	.32
245	.00	.00	.07	.84	.12	.93	.00	189.62	.00	.00	.00	.00	.00	.03	.05	.77	.32
246	.01	.00	.07	.84	.12	.83	.00	188.62	.00	.00	.00	.00	.00	.02	.05	.77	.32
247	.00	.00	.07	.83	.11	.74	.00	187.74	.00	.00	.00	.00	.00	.01	.04	.76	.32
248	.00	.00	.07	.82	.10	.68	.00	186.95	.00	.00	.00	.00	.00	.00	.04	.76	.31
249	.00	.00	.07	.81	.07	.64	.00	186.24	.00	.00	.00	.00	.00	.00	.03	.75	.31
250	.00	.00	.06	.80	.00	.60	.00	185.65	.00	.00	.00	.00	.00	.00	.00	.74	.31
251	.00	.00	.06	.79	.00	.57	.00	185.08	.00	.00	.00	.00	.00	.00	.00	.72	.30
252	.00	.00	.06	.77	.00	.54	.00	184.54	.00	.00	.00	.00	.00	.00	.00	.71	.30

253	.00	.00	.06	.76	.00	.51	.00	184.03	.00	.00	.00	.00	.00	.00	.00	.70	.29
254	.00	.00	.06	.75	.00	.49	.00	183.53	.00	.00	.00	.00	.00	.00	.00	.69	.29
255	.00	.00	.05	.73	.00	.48	.00	183.06	.00	.00	.00	.00	.00	.00	.00	.68	.28
256	.00	.00	.05	.72	.00	.46	.00	182.60	.00	.00	.00	.00	.00	.00	.00	.67	.28
257	.00	.00	.05	.71	.00	.44	.00	182.16	.00	.00	.00	.00	.00	.00	.00	.66	.27
258	9.27	.00	.05	.71	2.69	7.37	.00	181.35	.00	.00	.00	.00	.00	.00	.46	.67	.28
259	24.73	.00	.06	.77	6.80	6.20	.00	192.74	.00	.00	.00	.00	.00	.03	1.24	.72	.30
260	11.41	.00	.07	.83	3.35	4.81	.00	195.63	.00	.00	.00	.00	.00	.05	.66	.76	.32
261	.00	.00	.07	.86	.22	3.01	.00	192.24	.00	.00	.00	.00	.00	.03	.04	.78	.33
262	.00	.00	.07	.86	.11	2.13	.00	189.91	.00	.00	.00	.00	.00	.02	.04	.79	.33
263	.00	.00	.07	.86	.11	1.33	.00	188.43	.00	.00	.00	.00	.00	.02	.04	.79	.33
264	.00	.00	.07	.85	.10	1.06	.00	187.25	.00	.00	.00	.00	.00	.01	.04	.78	.33
265	.00	.00	.07	.84	.10	.90	.00	186.24	.00	.00	.00	.00	.00	.00	.04	.77	.32
266	.00	.00	.07	.83	.03	.80	.00	185.41	.00	.00	.00	.00	.00	.00	.01	.76	.32
267	10.46	.00	.07	.84	2.79	1.73	.00	191.30	.00	.00	.00	.00	.00	.01	.45	.77	.32
268	15.91	.00	.08	.89	4.56	6.85	.00	195.26	.00	.00	.00	.00	.00	.05	.87	.81	.34
269	15.52	.00	.10	.96	5.39	5.37	.00	199.25	.00	.00	.00	.00	.00	.09	1.14	.86	.36
270	.01	.00	.11	1.00	.98	2.33	.00	195.72	.00	.00	.00	.00	.00	.05	.16	.89	.37
271	.01	.00	.11	1.01	.12	2.21	.00	193.29	.00	.00	.00	.00	.00	.03	.04	.90	.37
272	.00	.00	.11	1.00	.11	1.34	.00	191.77	.00	.00	.00	.00	.00	.02	.04	.90	.37
273	.00	.00	.10	1.00	.11	1.06	.00	190.57	.00	.00	.00	.00	.00	.01	.04	.89	.37
9	87.33	.00	2.14	25.11	28.26	57.51	.02	190.57	.00	.00	.00	.00	.00	.54	5.61	.00	22.97
.37																	
274	.00	.00	.10	.98	.10	.91	.00	189.56	.00	.00	.00	.00	.00	.00	.04	.88	.37
275	.00	.00	.10	.97	.06	.81	.00	188.69	.00	.00	.00	.00	.00	.00	.02	.87	.36
276	.00	.00	.09	.95	.00	.73	.00	187.96	.00	.00	.00	.00	.00	.00	.00	.86	.36
277	.00	.00	.09	.94	.00	.67	.00	187.28	.00	.00	.00	.00	.00	.00	.00	.85	.35
278	.00	.00	.09	.92	.00	.63	.00	186.65	.00	.00	.00	.00	.00	.00	.00	.83	.35
279	.00	.00	.09	.90	.00	.59	.00	186.06	.00	.00	.00	.00	.00	.00	.00	.82	.34
280	.00	.00	.08	.89	.00	.56	.00	185.50	.00	.00	.00	.00	.00	.00	.00	.81	.34
281	.00	.00	.08	.87	.00	.53	.00	184.96	.00	.00	.00	.00	.00	.00	.00	.79	.33
282	.00	.00	.08	.86	.00	.51	.00	184.45	.00	.00	.00	.00	.00	.00	.00	.78	.32
283	.00	.00	.07	.84	.00	.49	.00	183.96	.00	.00	.00	.00	.00	.00	.00	.77	.32
284	.00	.00	.07	.83	.00	.47	.00	183.49	.00	.00	.00	.00	.00	.00	.00	.75	.31
285	.00	.00	.07	.81	.00	.46	.00	183.03	.00	.00	.00	.00	.00	.00	.00	.74	.31
286	.00	.00	.07	.80	.00	.44	.00	182.59	.00	.00	.00	.00	.00	.00	.00	.73	.30
287	.00	.00	.07	.78	.00	.43	.00	182.16	.00	.00	.00	.00	.00	.00	.00	.72	.30
288	.00	.00	.06	.77	.00	.42	.00	181.75	.00	.00	.00	.00	.00	.00	.00	.70	.29
289	.00	.00	.06	.75	.00	.40	.00	181.34	.00	.00	.00	.00	.00	.00	.00	.69	.29
290	.00	.00	.06	.74	.00	.39	.00	180.95	.00	.00	.00	.00	.00	.00	.00	.68	.28
291	.00	.00	.06	.73	.00	.38	.00	180.57	.00	.00	.00	.00	.00	.00	.00	.67	.28
292	.00	.00	.06	.71	.00	.38	.00	180.19	.00	.00	.00	.00	.00	.00	.00	.66	.27
293	20.81	.00	.06	.75	5.70	4.50	.00	190.69	.00	.00	.00	.00	.00	.01	.86	.69	.29
294	47.49	.30	.11	1.07	19.69	3.60	.00	212.99	.00	.00	.00	.00	.00	.24	4.46	.85	.35
295	.00	.00	.14	1.09	3.31	3.34	.00	205.50	.00	.00	.00	.00	.00	.16	.61	.95	.40

296	15.10	.00	.17	1.23	7.30	2.53	.00	209.51	.00	.00	.00	.00	.00	.17	1.23	1.06	.44
297	49.57	8.00	.25	9.44	28.35	7.36	.33	213.02	.18	.00	.10	.00	.00	.35	5.84	1.32	.55
298	.00	.00	.27	1.76	5.36	2.40	.00	204.41	.00	.00	.00	.00	.00	.16	.97	1.49	.62
299	25.24	.37	.32	2.30	12.66	1.92	.00	212.98	.00	.00	.00	.00	.00	.20	1.65	1.66	.69
300	54.37	12.79	.39	15.00	31.38	1.75	.55	219.01	.30	.01	.16	.00	.00	.32	4.92	1.98	.82
301	8.12	.01	.44	2.65	10.95	6.20	.00	208.20	.00	.00	.00	.00	.00	.22	1.50	2.22	.92
302	.00	.00	.44	2.79	3.01	2.72	.00	201.87	.00	.00	.00	.00	.00	.10	.44	2.35	.98
303	.00	.00	.44	2.85	1.52	1.64	.00	198.47	.00	.00	.00	.00	.00	.06	.18	2.42	1.01
304	.00	.00	.43	2.86	.37	1.19	.00	196.76	.00	.00	.00	.00	.00	.04	.08	2.44	1.01
10	220.69	21.47	4.90	59.84	129.76	49.35	.92	196.76	.48	.01	.27	.01	.00	2.05	22.81	.00	34.01
1.01																	
305	.00	.00	.42	2.85	.29	.98	.00	195.39	.00	.00	.00	.00	.00	.03	.06	2.43	1.01
306	.00	.00	.41	2.82	.25	.86	.00	194.23	.00	.00	.00	.00	.00	.02	.05	2.41	1.00
307	.00	.00	.39	2.78	.21	.77	.00	193.22	.00	.00	.00	.00	.00	.01	.03	2.39	.99
308	.00	.00	.38	2.73	.15	.70	.00	192.36	.00	.00	.00	.00	.00	.00	.02	2.35	.98
309	.00	.00	.37	2.69	.04	.65	.00	191.67	.00	.00	.00	.00	.00	.00	.00	2.32	.97
310	.00	.00	.36	2.64	.00	.61	.00	191.06	.00	.00	.00	.00	.00	.00	.00	2.28	.95
311	.00	.00	.34	2.59	.00	.58	.00	190.48	.00	.00	.00	.00	.00	.00	.00	2.25	.94
312	.00	.00	.33	2.54	.00	.55	.00	189.93	.00	.00	.00	.00	.00	.00	.00	2.21	.92
313	.00	.00	.32	2.50	.00	.52	.00	189.41	.00	.00	.00	.00	.00	.00	.00	2.18	.91
314	.00	.00	.31	2.45	.00	.50	.00	188.91	.00	.00	.00	.00	.00	.00	.00	2.14	.89
315	.00	.00	.30	2.41	.00	.48	.00	188.43	.00	.00	.00	.00	.00	.00	.00	2.10	.88
316	.00	.00	.29	2.36	.00	.46	.00	187.96	.00	.00	.00	.00	.00	.00	.00	2.07	.86
317	.00	.00	.28	2.32	.00	.45	.00	187.51	.00	.00	.00	.00	.00	.00	.00	2.04	.85
318	.00	.00	.27	2.27	.00	.43	.00	187.08	.00	.00	.00	.00	.00	.00	.00	2.00	.83
319	.00	.00	.26	2.23	.00	.42	.00	186.66	.00	.00	.00	.00	.00	.00	.00	1.97	.82
320	.00	.00	.25	2.19	.00	.41	.00	186.25	.00	.00	.00	.00	.00	.00	.00	1.94	.81
321	33.25	.00	.27	2.25	9.87	3.98	.00	205.01	.00	.00	.00	.00	.00	.04	.49	1.98	.82
322	.00	.00	.27	2.26	1.02	3.51	.00	200.18	.00	.00	.00	.00	.00	.03	.06	1.99	.83
323	.00	.00	.26	2.25	.20	2.31	.00	197.54	.00	.00	.00	.00	.00	.02	.03	1.99	.83
324	.00	.00	.26	2.23	.20	1.36	.00	195.89	.00	.00	.00	.00	.00	.02	.03	1.97	.82
325	.00	.00	.25	2.20	.19	1.07	.00	194.58	.00	.00	.00	.00	.00	.01	.03	1.95	.81
326	.00	.00	.24	2.17	.18	.91	.00	193.46	.00	.00	.00	.00	.00	.01	.03	1.92	.80
327	5.78	.00	.24	2.15	1.82	4.50	.00	192.91	.00	.00	.00	.00	.00	.01	.08	1.91	.80
328	.00	.00	.23	2.12	.14	.96	.00	191.80	.00	.00	.00	.00	.00	.00	.01	1.89	.79
329	.00	.00	.22	2.09	.01	.84	.00	190.95	.00	.00	.00	.00	.00	.00	.00	1.86	.78
330	.00	.00	.21	2.05	.00	.76	.00	190.19	.00	.00	.00	.00	.00	.00	.00	1.84	.77
331	.00	.00	.21	2.01	.00	.70	.00	189.49	.00	.00	.00	.00	.00	.00	.00	1.81	.75
332	.00	.00	.20	1.98	.00	.65	.00	188.85	.00	.00	.00	.00	.00	.00	.00	1.78	.74
333	.00	.00	.19	1.94	.00	.61	.00	188.24	.00	.00	.00	.00	.00	.00	.00	1.75	.73
334	.00	.00	.19	1.91	.00	.57	.00	187.66	.00	.00	.00	.00	.00	.00	.00	1.72	.72
11	39.04	.00	8.53	69.97	14.56	32.13	.06	187.66	.00	.00	.00	.00	.00	.19	.91	.00	61.45
.72																	
335	.00	.00	.18	1.87	.00	.55	.00	187.12	.00	.00	.00	.00	.00	.00	.00	1.69	.71
336	.00	.00	.18	1.84	.00	.52	.00	186.60	.00	.00	.00	.00	.00	.00	.00	1.67	.69

337	4.14	.00	.17	1.82	1.20	3.31	.00	186.23	.00	.00	.00	.00	.00	.00	.05	1.65	.69
338	.42	.00	.16	1.79	.42	.95	.00	185.27	.00	.00	.00	.00	.00	.00	.01	1.63	.68
339	.00	.00	.16	1.76	.00	.51	.00	184.76	.00	.00	.00	.00	.00	.00	.00	1.61	.67
340	.00	.00	.15	1.73	.00	.49	.00	184.27	.00	.00	.00	.00	.00	.00	.00	1.58	.66
341	2.50	.00	.15	1.71	.75	2.00	.00	183.98	.00	.00	.00	.00	.00	.00	.02	1.56	.65
342	.00	.00	.14	1.68	.01	.49	.00	183.48	.00	.00	.00	.00	.00	.00	.00	1.54	.64
343	.00	.00	.14	1.66	.00	.47	.00	183.01	.00	.00	.00	.00	.00	.00	.00	1.52	.63
344	.00	.00	.14	1.63	.00	.46	.00	182.55	.00	.00	.00	.00	.00	.00	.00	1.49	.62
345	.00	.00	.13	1.60	.00	.44	.00	182.11	.00	.00	.00	.00	.00	.00	.00	1.47	.61
346	.00	.00	.13	1.57	.00	.43	.00	181.68	.00	.00	.00	.00	.00	.00	.00	1.44	.60
347	.00	.00	.12	1.54	.00	.42	.00	181.27	.00	.00	.00	.00	.00	.00	.00	1.42	.59
348	.00	.00	.12	1.52	.00	.40	.00	180.86	.00	.00	.00	.00	.00	.00	.00	1.40	.58
349	.00	.00	.11	1.49	.00	.39	.00	180.47	.00	.00	.00	.00	.00	.00	.00	1.37	.57
350	.00	.00	.11	1.46	.00	.38	.00	180.08	.00	.00	.00	.00	.00	.00	.00	1.35	.56
351	.00	.00	.11	1.44	.00	.38	.00	179.71	.00	.00	.00	.00	.00	.00	.00	1.33	.55
352	.00	.00	.10	1.41	.00	.37	.00	179.34	.00	.00	.00	.00	.00	.00	.00	1.31	.54
353	.00	.00	.10	1.39	.00	.36	.00	178.98	.00	.00	.00	.00	.00	.00	.00	1.29	.54
354	.00	.00	.10	1.36	.00	.35	.00	178.63	.00	.00	.00	.00	.00	.00	.00	1.26	.53
355	.00	.00	.09	1.34	.00	.35	.00	178.28	.00	.00	.00	.00	.00	.00	.00	1.24	.52
356	.00	.00	.09	1.31	.00	.34	.00	177.94	.00	.00	.00	.00	.00	.00	.00	1.22	.51
357	.00	.00	.09	1.29	.00	.33	.00	177.61	.00	.00	.00	.00	.00	.00	.00	1.20	.50
358	.00	.00	.08	1.27	.00	.33	.00	177.29	.00	.00	.00	.00	.00	.00	.00	1.18	.49
359	.00	.00	.08	1.25	.00	.32	.00	176.97	.00	.00	.00	.00	.00	.00	.00	1.16	.48
360	.00	.00	.08	1.22	.00	.32	.00	176.65	.00	.00	.00	.00	.00	.00	.00	1.14	.48
361	.00	.00	.08	1.20	.00	.31	.00	176.34	.00	.00	.00	.00	.00	.00	.00	1.13	.47
362	.00	.00	.07	1.18	.00	.31	.00	176.03	.00	.00	.00	.00	.00	.00	.00	1.11	.46
363	.00	.00	.07	1.16	.00	.30	.00	175.73	.00	.00	.00	.00	.00	.00	.00	1.09	.45
364	.00	.00	.07	1.14	.00	.30	.00	175.43	.00	.00	.00	.00	.00	.00	.00	1.07	.45
365	.00	.00	.07	1.12	.00	.29	.00	175.14	.00	.00	.00	.00	.00	.00	.00	1.05	.44
12	7.06	.00	3.58	45.76	2.38	17.16	.03	175.14	.00	.00	.00	.00	.00	.00	.08	.00	42.18
.44																	
701006.51		21.47	23.87	303.25	321.62	527.99	1.06	175.14	.48	.01	.27	.01	.00	5.3073.35		.00258.44	
.44																	

1

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[illegible] Reference File

FINAL VALUES

SUB-BASIN SOIL WATER FOR LAYER NO
NO

+

	1	2	3	4	5	6	7
1	.0	.0	110.2	19.8			
2	.0	.0	110.2	19.8			
3	.0	.0	110.2	19.8			
4	.0	29.1	53.2	54.0	73.8	41.4	59.0

	TOTAL SOIL WATER
1	130.0
2	130.0
3	130.1
4	310.5

FINAL COMPOSITE ST = 175.1 MM
MIN INDIVIDUAL WATER ST = .0 MM

FINAL CONTENTS

	-----PONDS-----		---RESERVOIRS---	
SUB-BASIN NO	WATER VOL (MM)	SED CONC (PPM)	WATER VOL (MM)	SED CONC (PPM)
1	.0	.0	.0	.0
2	.0	.0	.0	.0
3	.0	.0	.0	.0
4	.0	.0	.0	.0

FINAL COMPOSITE POND ST = .00 MM
FINAL COMPOSITE RESERVOIR ST = .00 MM

IRRIGATION - AVE. ANNUAL

SUB-BASIN NO.	NO.OF APPLICATIONS	VOLUME APPLIED(MM)
1	0	.000
2	0	.000
3	0	.000
4	0	.000

SOIL WATER BALANCE = .378036E-02 MM

POND BALANCE
Q = .000000E+00 MM Y [illegible]000000E+00 T/HA

RESERVOIR BALANCE

Q = .000000E+00 MM Y = .000000E+00 T/HA

1

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SUB-BASIN STATISTICS

AVE ANNUAL VALUES

SUB-BASIN NO	RAIN (MM)	SUR Q (MM)	SUB SUR Q (MM)	Y (T/HA)	TOTAL BIOMASS(KG/HA) CROP 1	CROP 2	CROP 3
1	1006.5	15.6	11.2	3.6	.0	.0	.0
2	1006.5	15.7	11.4	.2	.0	.0	.0
3	1006.5	15.8	11.4	.2	.0		
4	1006.5	38.7	69.4	.5	.0		

AVE MONTHLY BASIN VALUES

MO	R (MM)	SNOW FALL (MM)	SUR Q (MM)	SUB SUR Q (MM)	WATER YIELD (MM)	ET (MM)	Y (T/HA)
1	59.92	.00	.00	.00	2.05	53.00	.00
2	7.48	.00	.00	.00	3.70	23.42	.00
3	.00	.00	.00	.00	2.90	9.88	.00
4	195.66	.00	.00	.16	8.93	80.04	.00
5	144.33	.00	.00	.54	16.48	67.14	.00
6	91.06	.00	.00	1.41	23.92	45.11	.01
7	64.00	.00	.00	1.45	23.62	39.28	.01
8	90.02	.00	.00	1.15	21.10	54.78	.01
9	87.33	.00	.00	2.14	25.11	57.51	.02
10	220.69	.00	21.47	4.90	59.84	49.35	.92
11	39.04	.00	.00	8.53	69.97	32.13	.06
12	7.06	.00	.00	3.58	45.76	17.16	.03

BASIN STATISTICS

CN- MEAN = 43.534 MAX = 87.761 MIN = 30.727

PRED PK FLOW
MEAN = 20.834 M**3/S ST DEV = 23.293 M**3/S
NO PKS = 4

```
          MAX =      46.828 M**3/S

     PRED MO WATER YLD
          MEAN =   25.27 MM
          ST DEV =   22.34 MM

 AVE ANNUAL BASIN STRESS DAYS
           WATER STRESS DAYS =     1.00
           TEMPERATURE STRESS DAYS =    31.13
           NITROGEN STRESS DAYS =      .10
           PHOSPHORUS STRESS DAYS =    99.00
1
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         AVE ANNUAL BASIN VALUES

          PRECIP =   1006.5 MM
          SNOW FALL =     .00 MM
          SNOW MELT =      .00 MM
          PRED SURFACE Q =    21.47 MM
          SUB-SUR Q =   23.87 MM
          GROUNDWATER Q =   258.44 MM
          PRED H20 YLD =   303.25 MM
          DEEP PERC =  321.62 MM
          ET =    528.0 MM
          TRANS LOSSES =      .53 MM
          TOTAL SUB-BASIN SED YLD =     1.114 T/HA
          BASIN SED YLD =    1.060 T/HA
          POND BUDGET
               EVAPORATION =     .000 MM
               SEEPAGE =     .000 MM
               RAINFALL ON POOL =    .000 MM
               INFLOW
                    Q =     .000 MM
                    Y =     .000 T/HA
               OUTFLOW
                    Q =     .000 MM
                    Y =     .000 T/HA
          RESERVOIR BUDGET
               EVAPORATION =     .000 MM
               SEEPAGE =     .000 MM
               RAINFALL ON POOL =     .000 MM
               INFLOW
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              Q =      .000 MM
              Y =      .000 T/HA
         OUTFLOW
              Q =      .000 MM
              Y =      .000 T/HA
     YIELD LOSS FROM PONDS
          Q =     .000 MM
          Y =     .000 T/HA
     YIELD LOSS FROM RESERVOIRS
          Q =     .000 MM
          Y =     .000 T/HA
1
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           AVE ANNUAL BASIN VALUES


     NUTRIENTS
          ORGANIC N =       .479 (KG/HA)
          ORGANIC P =       .008 (KG/HA)
          NO3 YIELD (SQ) =       .266 (KG/HA)
          NO3 YIELD (SSQ) =     5.303 (KG/HA)
          SOL P YIELD =      .005 (KG/HA)
          NO3 LEACHED =     73.347 (KG/HA)
          N UPTAKE =      .000 (KG/HA)
          P UPTAKE =     .000 (KG/HA)
          ACTIVE TO LABILE P FLOW =       .000 (KG/HA)
          ACTIVE TO STABLE P FLOW =       .000 (KG/HA)
          N FERTILIZER APPLIED =     .000 (KG/HA)
          P FERTILIZER APPLIED =     .000 (KG/HA)
          N FIXATION =      .000 (KG/HA)
          DENITRIFICATION =      .000 (KG/HA)
          HUMUS MIN ON ACTIVE ORG N =       .000 (KG/HA)
          ACTIVE TO STABLE ORG N =       .000 (KG/HA)
          HUMUS MIN ON ACTIVE ORG P =      .000 (KG/HA)
          MIN FROM FRESH ORG N =      .000 (KG/HA)
          MIN FROM FRESH ORG P =      .000 (KG/HA)
1


   MOROCCO /  Reference File

     MONTHLY AND ANNUAL WATER STATISTICS
```

MONTHLY STATISTICS

	PRED	OBS	ERR
1	2.05	1.35	.70
2	3.58	1.42	2.16
3	2.90	2.95	-.05
4	8.93	3.81	5.12
5	16.48	2.08	14.40
6	23.92	.91	23.01
7	23.62	.05	23.57
8	21.10	.00	21.10
9	25.11	2.84	22.27
10	59.84	.64	59.20
11	69.97	.66	69.31
12	45.76	.96	44.80
70	303.25	17.67	1616.20

MEAN MEAS =	.147250E+01	R**2 =	.220
MEAN PRED =	.252710E+02	REG SLOPE =	-.025
STD DEV MEAS =	.120709E+01	SUM ER**2 =	.125813E+05
STD DEV PRED =	.223412E+02	NUM OBS =	12

	J	F	M	A	M	J	J	A	S	O	N	D
PRED	2.05	3.58	2.90	8.93	16.48	23.92	23.62	21.10	25.11	59.84	69.97	45.76
OBS	1.35	1.42	2.95	3.81	2.08	.91	.05	.00	2.84	.64	.66	.96

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MOROCCO / Reference File

MONTHLY AND ANNUAL SEDIMENT STATISTICS
MONTHLY STATISTICS

	PRED	OBS	ERR
1	.00	.02	-.02
2	.00	.02	-.02
3	.00	.05	-.05
4	.00	.24	-.24
5	.00	.04	-.04

6	.01	.01	.00
7	.01	.00	.01
8	.01	.00	.01
9	.02	.26	-.24
10	.92	.01	.91
11	.06	.01	.05
12	.03	.01	.02
70	1.06	.67	58.15

```
MEAN MEAS     =     .558333E-01     R**2       =     .028
MEAN PRED     =     .883006E-01     REG SLOPE  =    -.059
STD DEV MEAS  =     .919939E-01     SUM ER**2  =     .947619E+00
STD DEV PRED  =     .261674E+00     NUM OBS    =   12
```

	J	F	M	A	M	J	J	A	S	O	N	D
PRED	.00	.00	.00	.00	.00	.01	.01	.01	.02	.92	.06	.03
OBS	.02	.02	.05	.24	.04	.01	.00	.00	.26	.01	.01	.01

```
BEGINNING TIME:    .67
ENDING    TIME: 19:26:49.57
----------------------------
TOTAL RUN TIME:        8.90
```

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REFERENCES

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