THE DEVELOPMENT OF A PROCESS MODEL FOR DETERMINING GROUNDWATER ACCESSIONS.

BY

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A thesis submitted in partial fulfillment of the requirements
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ABSTRACT

The derivation of a computer based process model designed to predict recharge to groundwater using daily data on rainfall and potential evapotransporation is described. Methods of deriving daily potential evapotranspiration from commonly read meterological data are given. An account of the hydrogeology of the Sherwood Borefield and the development of a computer based model used to successfully model the Sherwood Borefield groundwater system is presented to provide a background for evaluation of the recharge process model developed.

A sensitivity study of the daily timestep process model is presented. The daily model is shown to successfully model recharges previously established for the Sherwood Borefield.

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1. INTRODUCTION

Many water resource projects require an adequate knowledge of the variation of recharge to groundwater. This may be knowledge of historical rates of recharge, or a predicted set of future recharges under assumed hydrologic conditions. In recent years there has been increasing usage of computer based process models to predict the required recharge rates.

Process models of a catchment response seek to describe the influence of transport processes in partitioning precipitation between the various water stores within the system. A process model is based on an understanding of the hydrologic processes within a catchment, which depend on the principles of energy exchange and mass transport. The algorithms used to describe the hydrologic processes must necessarily be a simplification of reality, and usually consist of a series of flux equations linked by continuity to represent the respective transport processes.

Since 1960 a considerable amount of literature has been published describing various modelling techniques applicable to the rainfall - runoff process. However little work has been documented of the validity of applying such models to the prediction of groundwater recharge.

This thesis describes the derivation of a model intended to predict recharge to groundwater, using daily data on rainfall and potential evapotranspiration. The derived model is evaluated by comparing the monthly predictions with the monthly recharge rates previously used for successful calibration of a finite element model of the Sherwood Borefield groundwater system near Kempsey.

The model was based on a daily timestep to match the usually available data. Pluviometer data are scarce in Australia and mostly of short duration. Data for daily rainfalls are available at many sites, and are often of long duration. Direct measurements of data related to daily potential evapotranspiration, such as Class A pan evaporation, are scarce. Methods of deriving such data from commonly read meterological data are described.

An account of the hydrogeology of the Sherwood Borefield, and the development of a computer based model used to successfully model the Sherwood Borefield groundwater system is presented to provide a background for evaluation of the recharge process model.

2. CLIMATIC DATA

2.1 Introduction

The model developed requires as inputs precipitation and potential evapotranspiration. Daily records of rainfall for the Kempsey Meterological Station (No.59017) were available but no direct estimate of evapotranspiration such as pan evaporation has been recorded.

The potential evapotranspiration was therefore calculated from other daily meterological readings taken at the Kempsey Station. These measurements included wet and dry bulb temperatures, windspeed, and cloud cover. For each of these meteorological variables two readings per day at 9 a.m. and 3 p.m. had been taken.

The data was aquired in the form of printed sheets and entered into a data base. Forty missing records were estimated using both adjacent values and monthly averages for guidance. The processing ability of the data base package was then used to produce a file containing records of the year, month, and day, as well as daily averages of the wet and dry bulb temperatures, windspeed, cloud cover, and total daily rainfall.

A program (Appendix C : Program Listing - Calculation of Model Data) was written based on the relationships developed below to calculate daily values of rainfall and potential evapotranspiration (both in mm). These values were stored as a computer file(Day.dat) to be used by the model developed. A listing of this file is given in Appendix E: Data Listing - Model Input Data.

2.2 Estimation of Potential Evapotranspiration

2.2.1. <u>The Process of Evapotranspiration</u>

Evapotranspiration is the combined evaporation from all surfaces and the transpiration of plants. The rate of evapotranspiration from a partially wet surface is greatly affected by the nature of the ground, so potential evapotranspiration is defined as the rate when the water supply is unlimited.

The rate of potential evapotranspiration depends on the evaporative power of the air. This is determined by temperature, wind, humidity and radiation. To understand how evapotranspiration depends on these factors we must examine the processes involved.

Evaporation is a diffusive process, partly turbulent, and partly molecular. The turbulent process is the dominant mechanism, except in the thin layer near the evaporating surface. According to the theory of turbulence, the upward flow of water vapour is equal to the product of the vertical gradient of vapour pressure and the rate of mixing. The latter does not depend upon the wind speed at any particular height, but upon the rate of change of the wind speed with height. Thus, any method of estimating potential evapotranspiration that employs wind speed at one height must rely upon a relatively crude measurement of turbulence.

Advection is the exchange of energy, moisture, or momentum as a result of horizontal heterogeneity. If the area upwind of an irrigated field is hot and dry, then the sensible heat will be transfered to the irrigated field, and its evapotranspiration rate will be increased. On the other hand if the advected air is colder than the vegetation then the evapotranspiration rate will be relatively low. Advection has a major effect in arid and semi-arid climates.

Advected energy processes can be divided into the 'clothesline effect' and the 'oasis effect'. When warm air blows through a small plot with little or no guard area, a very severe horizontal heat transfer occurs, called the clothesline effect. Inside a large field the vertical energy transfer from the air above to the crop is called the oasis effect.

The most important internal condition affecting transpiration is the state of the stomata: their number,distribution, structural features, and how open they happen to be. External conditions affecting transpiration include temperature, relative humidity, air movements, atmospheric pressure, light, and water supply.

Potential evapotranspiration serves as an estimate of the upper limit of the actual transpiration from a crop and evaporation from the soil surface. Generally evapotranspiration will fall short of this limit because of various factors such as stomatal resistance of a water-stressed plant, variation in water extraction rates with moisture content, plant maturity, and the density of ground cover.

2.2.2. Prediction of Evapotranspiration From Climatic Data

Evapotranspiration may be considered as a response to two climatic 'inputs'; (i) insolation , (ii) water supply from precipitation. The radiation balance is the dominating factor in energy exchanges at the surface if considered over a wide enough area, but locally energy is re-distributed by wind and water.

Possible methods of predicting evapotranspiration from climatic data are:

1) Empirical methods. These are based on the correlation of measured evapotranspiration data with climatic data. In spite of their limitations they may be necessary for areas where climatic data needed for better methods are lacking.

2) Micrometeorological methods. These involve profile measurements and turbulent transfer theory. They are essentially methods for intensive research and not for broad scale applications.

3) The 'aerodynamic' method. This has been used widely for the calculation of evaporation from oceans and large lakes and has the form $E = (e_s - e_a) \times f(u)$, where $f(u)$ is a function of windspeed at some reference height; e_s and e_a are vapour pressures at the (water) surface and in the air at the reference level.

4) The energy balance method. This apportions net radiation as the main source of energy to provide for heating of the air and latent heat of evaporation so that $E = (R - G)/L(1 + B)$, where R is net radiation, G is ground heat flux, L the latent heat of vaporisation and B (the Bowen ratio) is the ratio of sensible heat flux to latent heat flux. In certain circumstances the Bowen ratio can be estimated, or it can be evaluated from the profiles of temperature and humidity.

5) The 'combination' method. This overcomes most of the difficulties inherent in the application of either the aerodynamic method or the energy balance method for broad climatological applications, by eliminating the need to assign a value for B, to measure or estimate e_s, and to establish an accurate formulation of $f(u)$.

6) Direct measurement of evaporation by physical measurement of water lost from evaporation pans, lysimeters, soil samples, lakes or catchments. Of these only pans are generally included in climatological observing networks.

2.2.3. The Combination Method for Evaluating Potential Evapotranspiration

The best known formulation is by Penman (Penman, 1948) and is a combination of the aerodynamic and energy budget approaches:

$$E = [s / (s+g)] \times [Rn - G] + [g / (s+g)] \times Ea$$

where

E = Potential evaporation from a uniform well-watered surface (mm/day)

s = Rate of increase of saturation vapour pressure with air temperature ($mb/^{o}c$)

g = Psychrometric constant (0.66 $mb/^{o}c$ at 1000 mb and 20 ^{o}c)

Rn = Net solar radiation (mm/day)

G = Ground heat flux (usually assumed = 0 mm/day)

Ea = Advected energy (mm/day)

The equation has been widely used and shown to give reasonably accurate results under a wide range of conditions.

Methods of deriving the various terms are detailed in the sections that follow.

2.2.3.1. Calculation of s/(s + g) and g/(s + g)

The term s/(s+g) may be obtained from the following equation (Linsley, et al 1982)

$$s/(s+g) = [\,1 + 0.66\,/\,(0.00815 \times Ta + 0.8912\,)^{7}\,]^{-1}$$

where

Ta = Air temperature (°c)

The other dimensionless ratio in the Penman equation can be computed from :

$$g/(s+g) = 1 - s/(s+g)$$

$g = c_p p/\epsilon\lambda$ is called the psychrometric constant, where c_p is the specific heat of air at constant pressure, p is the air pressure, ϵ is the ratio of the molecular weight of water vapour to that of dry air (= 0.622), and λ is the latent heat of vaporization of water.

The increase of g with atmospheric pressure is sufficient to result in appreciable variation of the two ratios with elevation, but sea-level values are customarily applied without adjustment. Since the ratios define relative weights for two terms which are usually of the same order of magnitude, the resulting error is less than might be expected. (Linsley, et al, 1982).

2.2.3.2. Calculation of the Net Solar Radiation Rn

The Penman equation requires the daily net radiation. The equation of radiative balance for a unit area of a surface can be written as:

Balance	=	Gains	-	Losses

In terms of the net radiation :

Net Radiation	=	Incident short wave radiation + absorbed long wave radiation	-	reflected and transmitted short wave radiation + emitted long wave radiation

Let the average net radiation per unit area of a body be Rn. The incident short wave radiation consists of direct and diffuse radiation from the sun and the atmosphere S_t, plus sunlight reflected from the environment, S_e. The total incident short wave radiation is then $S_t + S_e$ and if the albedo of the body is r_b, the reflected short wave flux is $r_b \times (S_t + S_e)$. Fluxes of long wave radiation to be included in the radiation blance are L_d from the atmosphere, L_e from the environment and $L_b = \sigma T_b^4$, the flux of full radiation at mean surface temperature, where σ is the Stefan-Boltzmann constant. A surface with an emissivity of ϵ will gain $\epsilon \times (L_d + L_e)$ from its surroundings and emit $\epsilon \times L_p$ to its surroundings.

The general equation of radiation balance can now be written :

$$Rn = (1 - r_b) \times (S_t + S_e) + \epsilon \times (L_d + L_e - L_b)$$

All natural materials reflect and transmit solar radiation in the waveband from 0.4 to 3 um. At the short wavelength, high frequency end of the solar spectrum, the radiative behaviour of materials is determined mainly by the presence of pigments absorbing radiation at wavelengths associated with specific electron transitions. For radiation between 1 and 3 um, liquid water is an important constituent of many natural materials, because water has strong absorption bands in this region, and even in the visible spectrum where absorption by water is negligible, the reflection and transmission of light by porous materials is often strongly correlated with their water content. In the long wave spectrum beyond 3um, most natural surfaces behave like full radiators.

The albedo of soils depends mainly on their organic matter content, on water content, particle size and angle of incidence. The albedo ranges from about 10% for soils with a high organic matter content to about 30% for desert sand. Even a very small amount of organic matter can depress the albedo of the soil.

The fraction of radiation transmitted and reflected by a leaf depend on the angle of incidence. Thus the albedo of a canopy depends on its geometry, on the angle of the sun, as well as on the radiative properties of its components. In general, maximum values of albedo r (close to 0.25) are recorded over relatively smooth surfaces such as closely cut lawns. For crops growing to heights of 50 to 100 cm, r is usually between 0.18 and 0.25 when ground cover is complete but values as small as 0.10 have been recorded for forests. (Monteith, 1973).

To simplify analysis we can assume we have a continuous horizontal surface receiving radiation from above and not from below. The net radiation is simply

$Rn = (1-r_b) \times S_t + L_d - \sigma T_b^4$

where r_b is the albedo of the surface, σ the Stefan-Boltzmann constant, and T_b the radiative temperature of the surface (°K). The other terms are defined above.

In the absence of direct measurements of the radiation fluxes several methods can be used to derive an estimate of the net solar radiation using commonly available meterological data. These methods try to account, with varying degrees of complexity, for the various processes described above. The first method descibed below assumes that the variation in net solar radiation can be satisfactorily accounted for by the variation in observed average daily air temperature and daily solar radiation.

Linsley et al (1982) give a formula for net solar radiation Rn based on the daily solar radiation at the earth's surface (Ra) and the air temperature at the surface (Ta). If Rn and Rs are in megajoules and Ta is in degress Celsius then:

$Qn = 0.171Ra + 1.26 \times 10^{-4}Ra(Ta + 17.8)^{1.87} + 2.25 \times 10^{-3}Ra^2 - 1.36 \times 10^{-6}Ra^2(Ta - 7.2)^2 - 1.02$

This equation was derived by correlation analysis of data from the U.S.A.

A method of calculating Rs, the daily solar radiation at the top of the atmosphere, is given in Appendix A. However, by the processes detailed above, a large part of the solar radiation reaching the outer limits of the atmosphere is scattered and absorbed in the atmosphere or reflected from clouds and the earth's surface. About half the incident radiation at the outer limits of the atmosphere eventually reaches the earth's surface.

For this reason the method detailed below based on the Angstrom equation, was used to calculate the net radiation Rn at the Sherwood site.

The Angstrom equation as modified by Prescott (1940) has been used by many workers to estimate the total solar radiation falling on a horizontal area of the earth's surface. The equation is:

$$Rh/Rs = a + b(n/N)$$

where Rh is the total radiation per unit time on a horizontal unit area on the earth's surface and Ra is the solar radiation per unit time on a horizontal unit area at the top of the atmosphere. N is the astronomically possible sunshine per unit time and n is the actual bright sunshine per unit time. The constants a and b can be determined by a least squares approach from a series of simultaneous radiation and sunshine measurements. (De Lisle, J.F., 1966, and Doorenbos J. and Pruitt W., 1977)

The Angstrom equation, and equations based on consideration of the variations of radiation with temperature and water content of the air, lead to various emperical equations that can be used to calculate net radiation in the absence of Rn.

One such equation (De Lisle, J.F., 1966) is:

$$Rn = (1-r) \times (C_1 + C_2 \times n/N) \times Rs - \varepsilon \times \sigma \times T^4 \times (C_3 + C_4 \times n/N) \times (C_5 - C_6 \times e)$$

where

r	=	reflection coefficient for surface
n	=	sunshine duration (hr)
N	=	possible sunshine duration (hr)
Ra	=	daily mean solar insolation at the top of the atmosphere (mm/day)
ε	=	surface emissivity
σ	=	Stefan-Boltzmann constant (1.985×10^{-9} mm/day/K^4)
T	=	air temperature (°K)
e	=	water vapour partial pressure (mb)

De Lisle (1966) used measured daily radiation and calculated regression coefficients for C_1 and C_2 for sites throughout New Zealand. For Auckland he found $C_1 = 0.26$ and $C_2 = 0.49$ on an annual basis. He also derived C_1 and C_2 on a seasonal basis for many other sites throughout New Zealand. The variation was less than +/- 0.05 for both constants. These constants were used for the Kempsey site.

After the data required had been derived using these coefficient values an additional reference (Doorenbos J. and Pruitt W. 1977) was discovered. This document quotes values for Australia from 12 - 43° S of C_1=0.26 and C_2=0.50 with the source given as Hounam(1963). Unfortunately no further details are listed, and a search of the literature failed to uncover further details. As the values were so similar the data was not recalculated.

Penman (1963) derived $C_3 = 0.10$, $C_4 = 0.90$, $C_5 = 0.56$, $C_6 = 0.078$ and $\varepsilon = 1.0$. For the conditions at the Sherwood site r can be taken as 0.25. It was found that use of alternative values made little difference in most cases.

Values of the constants have been adapted for use with vapour pressures in millibars, evaporation in mm/day, and energy terms in equivalent evaporation units (mm/day). The equivalent for this conversion is 1 mm/day = 28.59 w/m^2. If measured global radiation is available it may be used with advantage in place of $(1\text{-}r) \times (C_1 + C_2\, n/N) \times Ra$.

The values of the bright sunshine duration (n) were unavailable for the Kempsey data so estimates of cloud cover were used to derive the fraction of cloud cover FC. The value of (1-FC) was used instead of n/N.

The water vapour pressure e at the air temperature can be derived from:

$$e = e_s \times f / 100$$

where f is the relative humidity (as a percentage).

2.2.3.3. Evaluation of Groundheat Flux G

The analysis of heat conduction in soils is complex, partly because steady states are rare when a soil surface is exposed to annual and seasonal cycles of radiation and partly because changes in the water content or compaction of a soil may change its thermal properties profoundly (Monteith, 1973).

A reasonable approximation is to assume that the temperature of the soil-air interface oscillates sinusoidally during a daily cycle with an annual cyclic trend imposed upon this pattern. Measurements indicate that the ground heat flux is small compared to the solar heat flux.

The reversal of heat flux over a 24 hour period indicated by the sinusoidal oscillation of the soil-air interface and the small part that the ground heat flux plays in the total radiation balance lead to the assumption that G was zero for all timesteps.

2.2.3.4. Evaluation of the Advected Energy Ea

The advected energy term Ea can be calculated from(Doorenbos, J. and Pruitt W. 1977):

$Ea = 0.27 \times (e_s - e_a) \times (1.0 + v/100)$

where

E_a is advected energy; (mm/day)

e_s is the saturation vapour pressure; (mb)

e_a is the vapour pressure; (mb)

v is the wind movement 2 m above the surface; (km/day)

The vapour-pressure difference can be computed from (Linsley et al, 1982)

$e_s - e_a = 33.86 \times [(0.00738Ta + 0.8072)^8 - (0.00738Td + 0.8072)^8]$ $\quad$ $Td >= -27°C$

where the vapour pressures are in millibars and the dewpoint Td and air temperature Ta are in degrees celsius.

A common error in the application of this equation is the use of the wet bulb temperature Tw instead of the dewpoint temperature Td.

An alternative method is given by

$(e_s - e_a) = e_s \times (1 - f/100)$

where f is the relative humidity.

A method of obtaining f and e_s from wet and dry bulb temperatures is given in Appendix B.

2.2.4 Calculated Evapotranspiration - Calibration

Initial calculations of daily values of potential evapotranspiration were examined. It appeared that excessively high values were obtained on days for which high average wind speeds were recorded. The recorded pan evaporation values at the nearest meterological station (Taree - Station No.60030) were examined to obtain an idea of the evapotranspiration expected for each month. With these values as a guide the average daily windspeed was adjusted in the following manner.

It was believed that the average daily windspeed calculated from the 9a.m. and 3p.m. values was producing over-estimates of the daily windrun for two reasons. Firstly surface windspeed is usually at a minimum about sunrise and increases to a maximum in the early afternoon(Linsley et al. 1982). Secondly it is likely that with higher windspeeds an observer will tend to record a speed indicative of the gusts rather than the average speed.

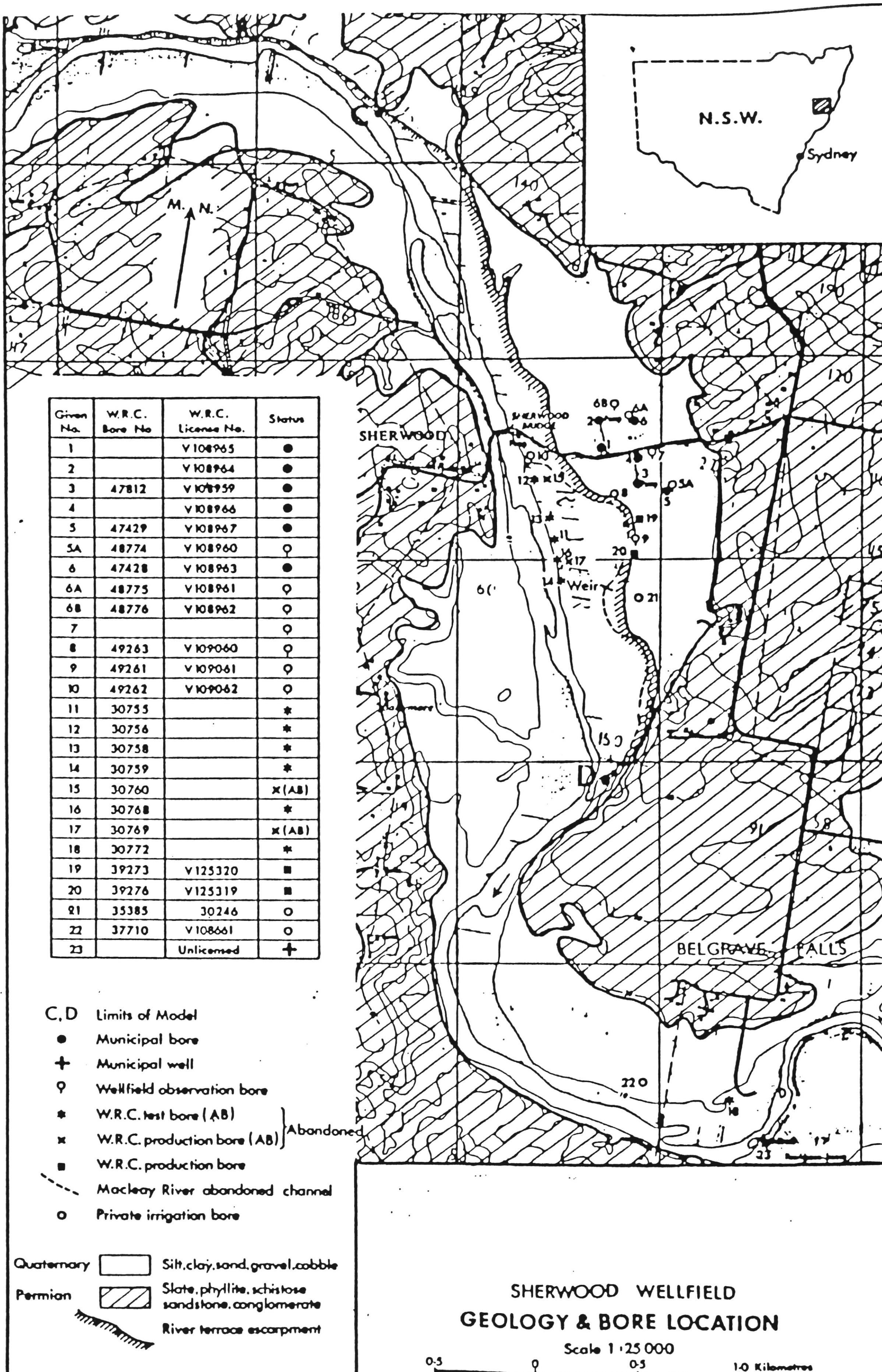
After several calibration runs, comparing the calculated monthly potential evapotranspiration to that recorded at the Taree Station a relationship was developed that produced results that appeared highly realistic. The relationship consisted of multiplying the observed windspeed by 0.75 to account for the typical daily variation in windspeed and then taking the result to the power of 0.95 to account for the over estimation of the higher windspeeds. The use of the power term had virtually no effect on the lower windspeed values.

2.3 Rainfall

Rainfall is measured at the Kempsey Station daily. Rainfall records have been kept since 1882. The mean and median rainfall for Kempsey are 1213 and 1130mm respectively. Monthly statistics presented in Table 2-1 show that most rain falls in summer.

TABLE 2-1 : MONTHLY RAINFALL STATISTICS

	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV	DEC
Mean (mm)	134	153	151	114	93	99	68	66	57	82	87	109
Median (mm)	104	109	128	79	62	58	30	36	36	60	74	83
Mean Raindays	11	11	12	10	8	7	6	6	6	8	9	10



Given No.	W.R.C. Bore No	W.R.C. License No.	Status
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2		V108964	●
3	47812	V108959	●
4		V108966	●
5	47429	V108967	●
5A	48774	V108960	♀
6	47428	V108963	●
6A	48775	V108961	♀
6B	48776	V108962	♀
7			♀
8	49263	V109060	♀
9	49261	V109061	♀
10	49262	V109062	♀
11	30755		*
12	30756		*
13	30758		*
14	30759		*
15	30760		× (AB)
16	30768		*
17	30769		× (AB)
18	30772		*
19	39273	V125320	■
20	39276	V125319	■
21	35385	30246	○
22	37710	V108661	○
23		Unlicensed	+

FIGURE 3-1 SOURCE : MERRICK, N.P. AND BLAIR, A.H. (1986)

3. SHERWOOD BOREFIELD

3.1 Introduction

The following description of the Sherwood Borefield is based closely on the Water Resources Commission Hydrogeological Report No 1986-1 (Merrick N.P., Blair A.H., 1986) with some additional input from two reports by Australian Groundwater Consultants Pty Ltd (Lower Macleay Water Supply Completion Report 1985, and Lower Macleay Water Supply Sherwood Borefield Safe Yield Review, 1978).

Sherwood Borefield is located on a high level terrace of the alluvial flats of the Macleay River, about 11 kilometers west of Kempsey, on the North Coast of New South Wales (Figure 3-1). There are six production bores in the borefield, with a further two yet to be commissioned. Water from the borefield contributes substantially to the Kempsey District Water Supply Scheme which serves the towns of Kemsey, Frederickton, Smithtown, Gladstone,Clybucca, South West Rocks and Hat Head, as well as rural properties between Sherwood and South West Rocks.

Associated with the borefield is an artificial recharge scheme which delivers water from the Macleay River to the former river channel abandoned about 35 years ago. After artificial recharge to the abandoned river channel was trialled in November 1977, the scheme became fully operational in the spring of 1979.

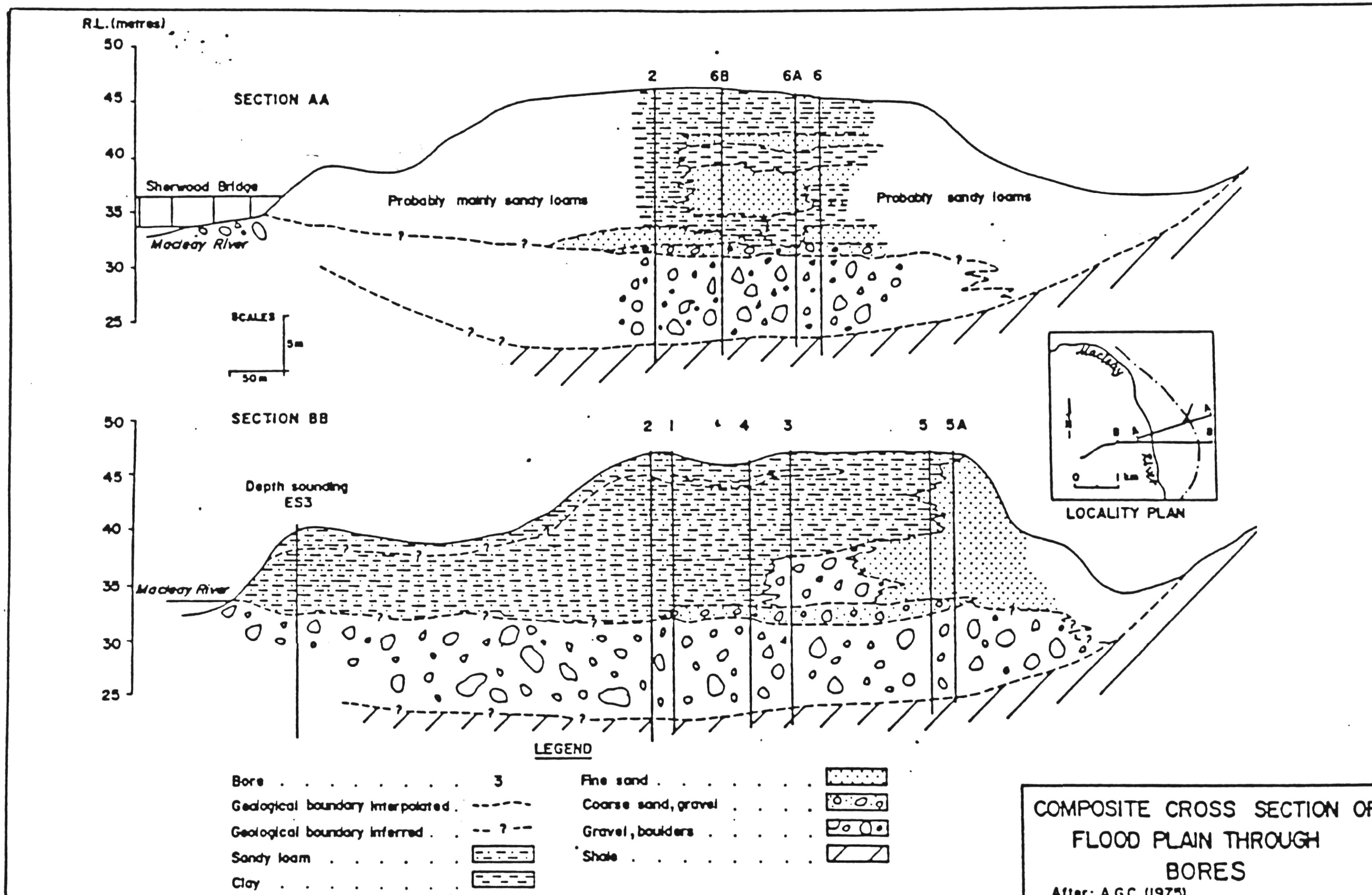

FIGURE 3-2 SOURCE : MERRICK, N.P. AND BLAIR, A.H. (1986)

3.2 Data

Kempsey Shire Council personnel have collected data on a weekly basis on behalf of the Public Works Department. All elevations refer to the Sherwood Datum.

3.2.1. Aquifer Geometry

Figure 3-2 shows in cross-section the configuration of the aquifer (A.G.C., 1975). The section shows low-level and high-level terraces at elevations of about 39 m and 47 m respectively. Alluvial sediments have a maximum thickness of about 24 m. The main gravel aquifer occupying the bottom 8 m of section is generally semi-confined but is less confined to the east.

3.2.2. Aquifer Properties

The hydraulic capability of an aquifer is controlled by two intrinsic properties: hydraulic conductivity (K) and storage coefficient (S). Often, instead of K, the term transmissivity (T) is preferred; this is defined as the product of hydraulic conductivity and the saturated thickness of the aquifer. Storage coefficient is defined as the volume of water which an aquifer releases from storage per unit surface area for a unit change in head.

There have been many estimates of aquifer parameters in the Sherwood borefield based on pumping test analyses. The hydraulic conductivity is in the order of 1000 m/day except beneath the low-level terrace where it is about 100 m/day, and the storage coefficient is in the order of 0.01.

3.2.3. Artificial Recharge

The delivery rate to the recharge channel in each month has been estimated from daily records of the number of hours of operation of the recharge pump. Due to uncertainties in the volumes pumped, and losses other than infiltration, the final infiltration rates were estimated at 60% of the initial delivery estimates. This figure was resolved in the calibration stage of the groundwater model (see Section 4). The last recorded use of the recharge pump was on the 7th March, 1983. At this time the recharge channel was excavated and extended, and subsequently gravity feed was used with no records kept of the volume of water delivered.

3.2.4. Pumpage

The total volume of water extracted from the borefield is metered (in KL units) and recorded at the end of each week. In January 1984, the borefield meter broke down and was not replaced until January 1985. There is also evidence that the meter readings after February 1983 were erroneous. The extraction from each individual bore has been determined either from reported usuage or from weekly records of pump hours at assumed rates.

3.2.5. Hydrographic Record

Water levels in seven observation bores are measured weekly. The hydrographs are characterised by sudden high-amplitude fluctuations which correlate well with rainfall and river level variations. In any one bore, water levels vary by as much as 5 m, while single peaks have a maximum amplitude of 3 m. There are very few definite correlations with borefield extraction, because most of the prominent troughs are merely recessions from high water levels.

4. SHERWOOD BOREFIELD GROUNDWATER MODEL

The following description of the Sherwood Borefield Groundwater Model is based on the Water Resources Commission Hydrogeological Report No 1986-1 (Merrick N.P.,Blair A.H., 1986).

The Public Works Department, on behalf of Kempsey Shire Council, requested that the Water Resources Commission assess the maximum potential withdrawal rate of the borefield under normal conditions, drought conditions, and conditions of higher artificial recharge. The Commission responded by developing a numerical model of the borefield.

The proximity of outcrop and river boundaries to Sherwood Borefield, as well as spatial variability in aquifer properties, led to the use of a numerical model rather than an analytical model.

4.1 Computer Code

A well-documented computer model called AQUIFEM-1 (Townley L.,Wilson J.,1980) was used to model the borefield. It uses the finite element method to solve the groundwater flow equation within each of a number of triangular elements. The solution gives the value of hydraulic head at the corner of each element in response to the boundary conditions and stresses placed on the model.

4.2 Conceptual Model

The Sherwood aquifer is conceptualised as a single semi-confined aquifer, of varying thickness, in hydraulic connection with the Macleay River. The study area is confined on the eastern side by outcrop, considered to be a no-flow boundary. The stretch of river between points C and D on Figure 3-1 defines the Western edge of the modelled area. Subsurface outflow from the system is expected at point D.

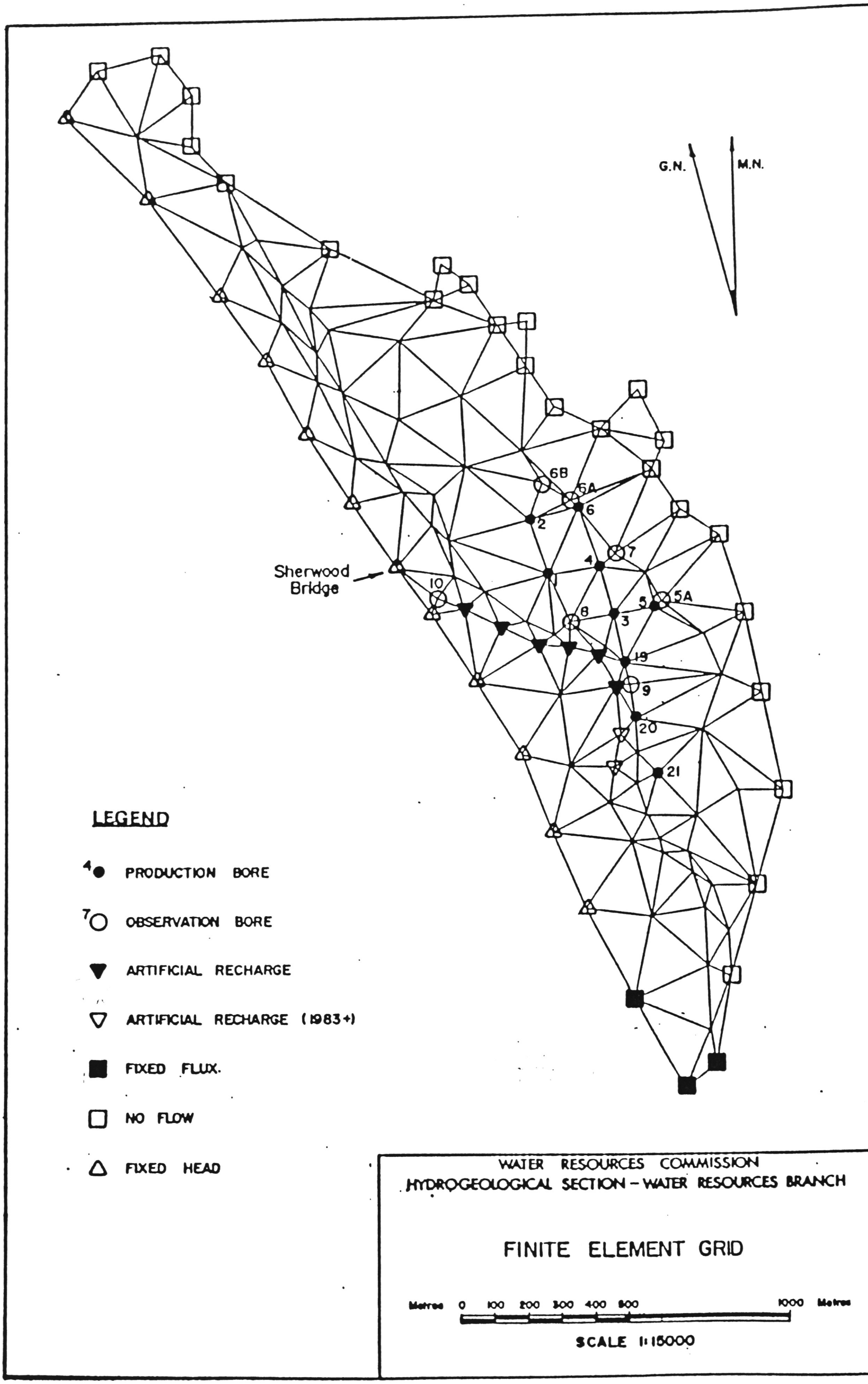

FIGURE 4-1 SOURCE : MERRICK, N.P. AND BLAIR, A.H. (1986)

4.3 Grid Design

The finite element grid for the modelled area, shown in Figure 4-1, covers an area of 200 ha. Nodes have been placed at each of the nine production bores and seven observation bores. The positions of the river, recharge channel and outcrop have been preserved by tracking each boundary with linear segments.

At each node the following parameters were specified:- bottom elevation, aquifer thickness, hydraulic conductivity, storage coefficient. At pumping nodes and artificial recharge nodes, fluxes were specified. Lateral fluxes were specified through two sides at the outflow boundary. Rainfall infiltration was specified for each element, assuming no local spatial variability.

The variables which varied with time were:- river levels, pumping, artificial recharge, rainfall infiltration. The chosen time step was one month. This implies that all water levels and all flux rates were monthly averages.

The Macleay River hydrograph was digitised at one-month intervals to provide fixed head values at Sherwood Bridge. River levels at the other river nodes were estimated by assuming a 0.025% gradient.

Artificial recharge volumes were divided equally between the nodes which defined the recharge channel.

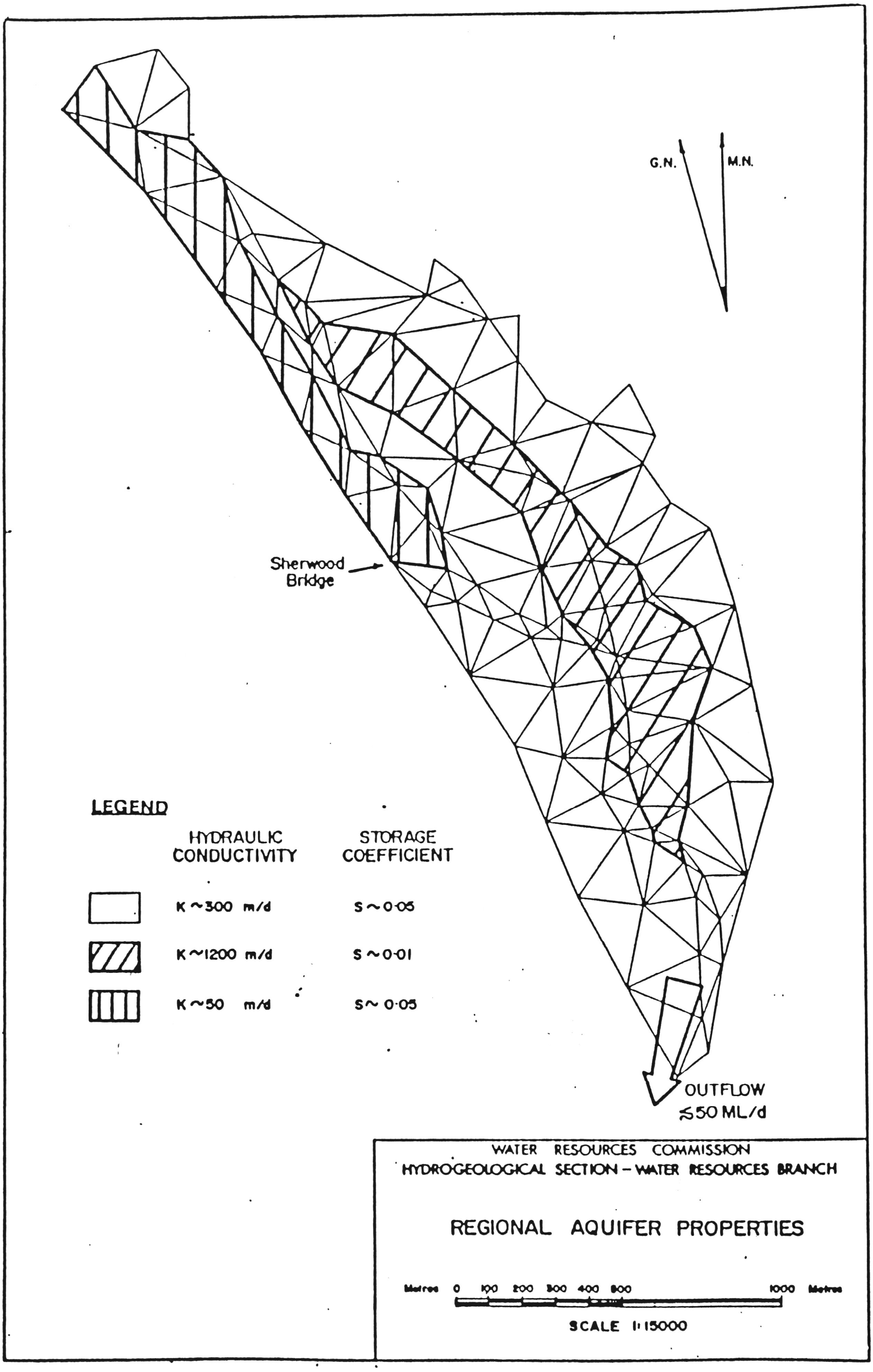

FIGURE 4-2 SOURCE : MERRICK, N.P. AND BLAIR, A.H. (1986)

4.4 Model Calibration

Calibration is the process which aims to match observed water levels with the levels computed by the model, over some representative historical period. This is achieved by adjusting those parameters in the model which are unknown or uncertain, namely:- hydraulic conductivity, storage coefficient, outflow, rainfall infiltration.

Variables considered exact were:- river level, pumpage, bore location. Initially artificial recharge rates were treated as known but it was necessary to reduce the assumed infiltration from 100% to 60%.

The historical period chosen for calibration was April 1978, when hydrographic records commenced, to February 1983, when pumpage figures become unreliable and the artificial recharge operation changed from pumping to gravity feeding.

Figure 4-2 provides a picture of the broad aquifer regions into which the modelled area has been divided. There are three distinct regions. The permeable buried channel ($K \approx 1200$ m/d) passing beneath the borefield is not in direct contact with the river. The hydraulic connection is inhibited by sediments of lower permeability (50-300 m/d), particually in the northern half of the model. The storage coefficient is about 0.01 to 0.05, an insignificant variation over the modelled area. There must be significant outflow (up to 50 ML/d) at the downstream end of the model, in order to sustain groundwater levels at about 3m lower than the river level.

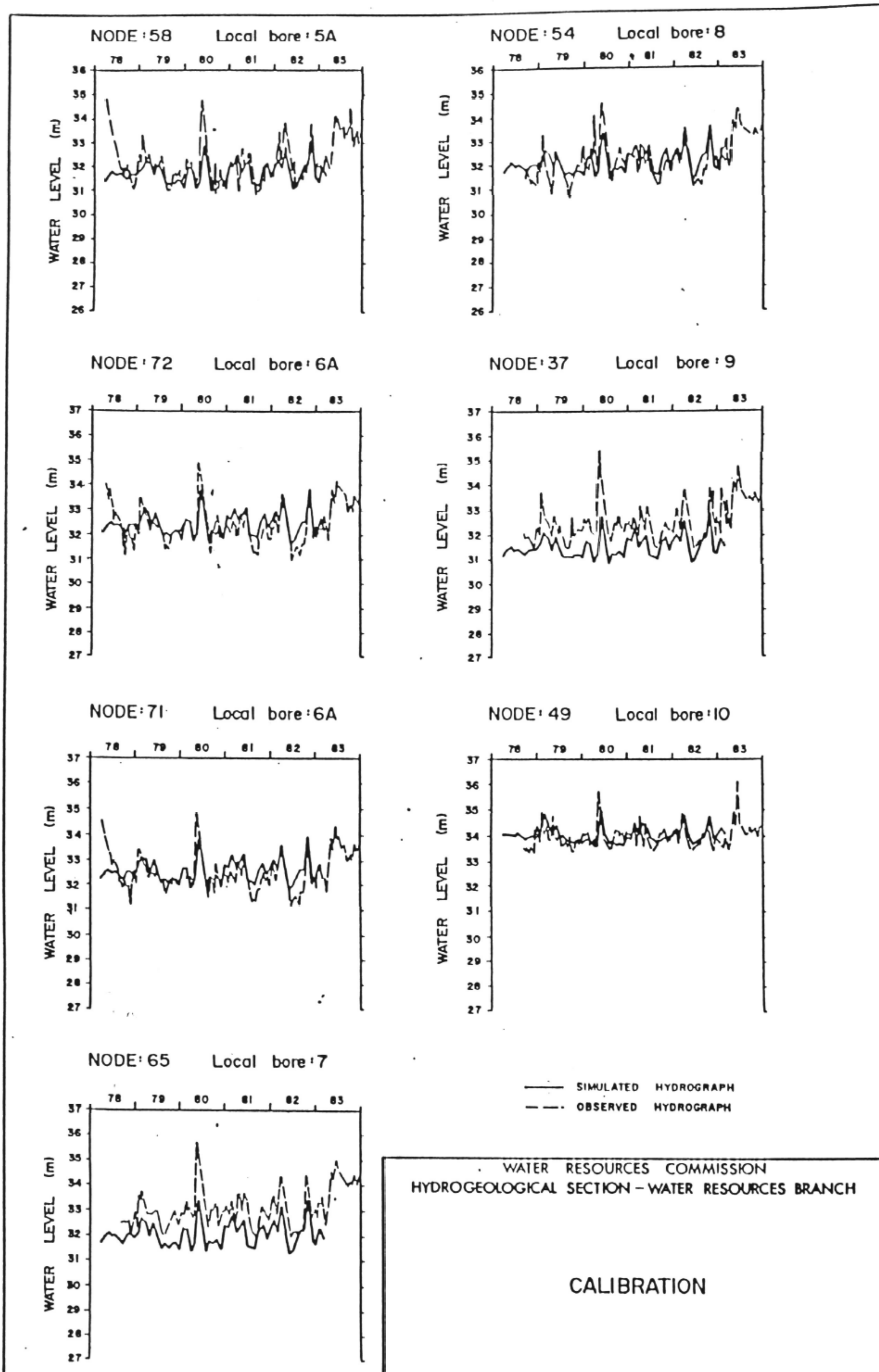

FIGURE 4-3 SOURCE : MERRICK, N.P. AND BLAIR, A.H. (1986)

Rainfall infiltration appeared to be very high. Even with the value of 70% infiltration used observed hydrograph peaks resulting from rainfall events were found to be greater than the simulated peaks. There is no reason to suppose that Sherwood rainfall is any higher than Kempsey rainfall, where the meteorological station is based. The mismatch may be explained by the smoothing effects of monthly averaging in the model, because comparisons are made with observed weekly groundwater levels; or by runoff contributions to the system from the hills to the east, occurring at the same time as rainfall events. Rainfall supplies about 4 ML/d (on average) to the Sherwood aquifer.

As there was no reliable potentiometric map for the area, calibration was achieved by matching observed hydrographs against simulated hydrographs at each of the seven observation bores. The comparison is shown in Figure 4-3 .

The match is as good as could be expected of a numerical model, given the simplicity of the conceptual model and the smoothing effects of the model monthly time steps, especially when compared with the observed weekly hydrographs.

4.5 Model Verification

To assess the reliability of a numerical model it is customary to exclude some of the historical record of water levels from the calibration stage, and reserve it for verification purposes. This process is actually a prediction of behaviour following the calibration period.

The verification period was March 1983 to July 1985. The agreement with observed water levels was very good through to mid-1984, after which the computed levels are a little high in most bores. This discrepancy may have been due to the assumption that artificial recharge was occurring at a constant rate, rather then varying in sympathy with river levels, or to the likelihood that gradual siltation of the channel had decreased infiltration. There is also some uncertainty in the volumes of groundwater pumped during 1983 and 1984, when the borefield meter was inoperative.

4.6 Groundwater Model Conclusions

The numerical model of Sherwood Borefield has revealed that rainfall, river level and artifical recharge all have a significant impact on groundwater levels in the borefield. Historical extraction by pumping has had only a minor effect. Good model calibration is achieved when it is assumed that 70% of monthly rainfall infiltrates to the groundwater system.

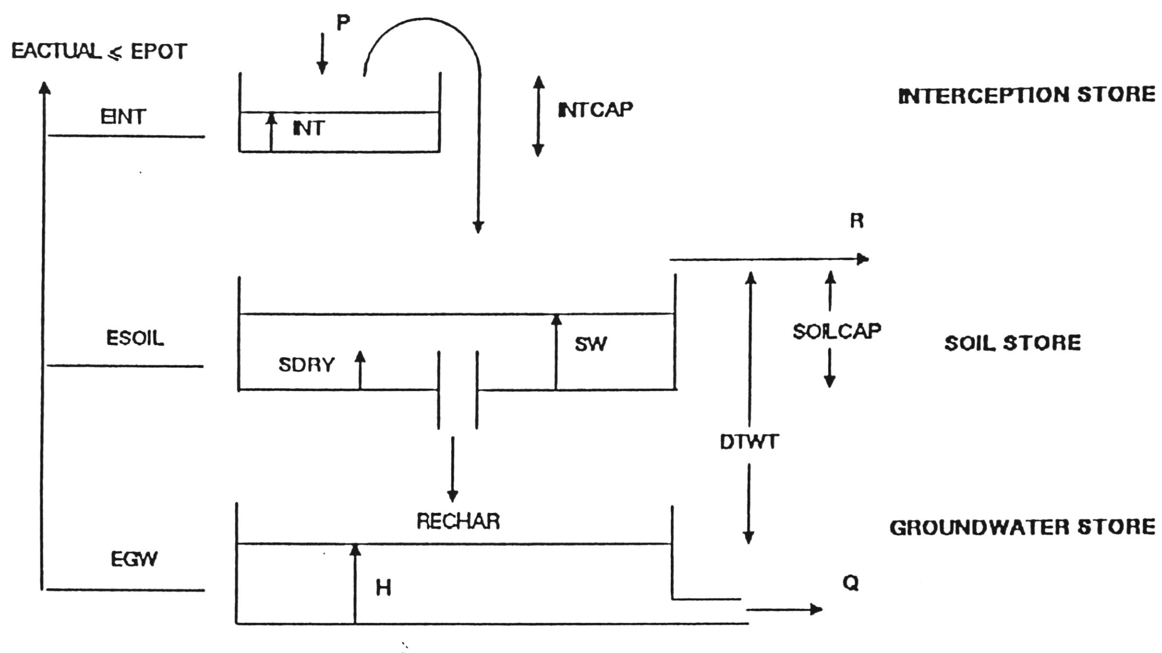

FIGURE 5 – 1 : DAILY MODEL

5 MODEL DEVELOPMENT

5.1 Introduction

The model developed below is based upon hydrologic processes. The principles of energy exchange and mass transport were used as the building blocks of a physically based model of the catchment. However to model the physical processes occurring in fine detail would require a complex model that would be rendered less exact by the imprecise data available for the various model parameters and variables. This lack of precise data occurs due to both the difficulties of measurement in the field, and the need to assign a single value to parameters and variables that in fact represent processes occurring over a wide area.

The model developed was therefore kept relatively simple and consists of three conceptual stores. The overall structure of the model is illustrated in Figure 5-1. The meaning of the symbols used and the development of the various algorithms used to calculate the flow of water through the model are described below.

5.2 Interception Store

The interception store submodel is developed below. It consists of a single conceptual store. Precipitation P is routed through the store. The contents of the store are adjusted for evapotranspiration at the end of the time step and the potential evapotranspiration is decreased to allow for evapotranspiration that has taken place from the store.

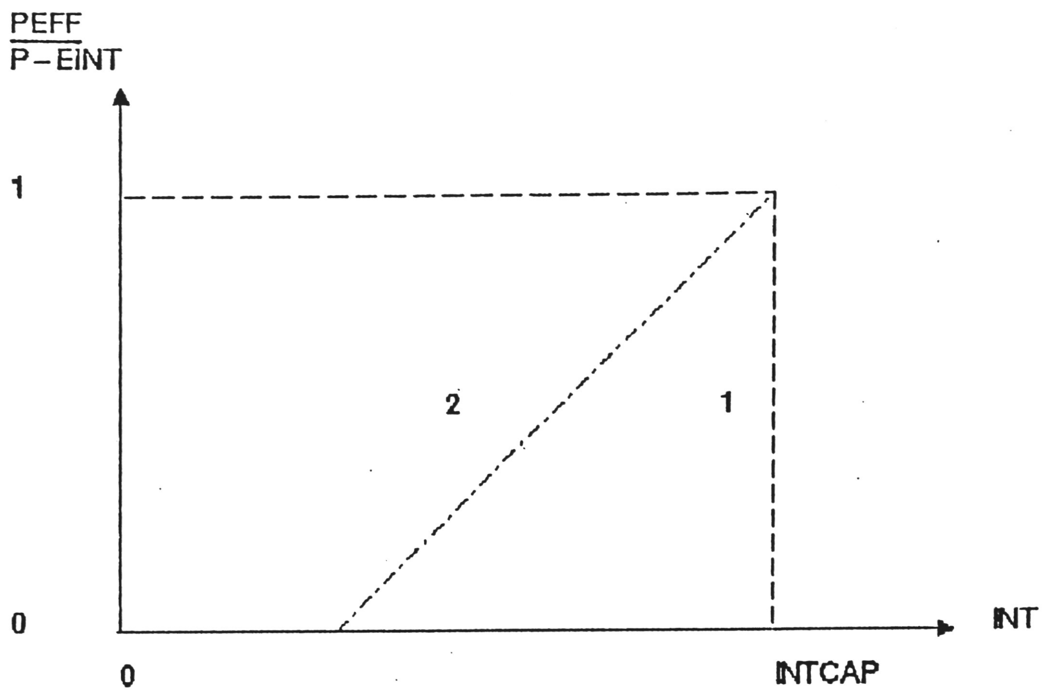

FIGURE 5 - 2 : INTERCEPTION STORE

The following variable names are used in this submodel:

INTCAP	=	Interception storage capacity
INT	=	Content of interception store
EINT	=	Evapotranspiration from the interception store
EPOT	=	Potential evapotranspiration
P	=	Precipitation
PEFF	=	Effective precipitation reaching the soil store

At the start of rainfall with dry vegetation INT = 0 and PEFF = 0. By the end of the storm if the interception store is full INT = INTCAP and PEFF = P - EINT. This allows the end points to be fixed on the graph shown in Figure 5-2. Most daily models (Boughton, 1966 etc) use the relationship indicated by line 1 which corresponds to a process where no effective precipitation flows from the store until it is completely full. For an individual rainfall event this is not what is usually observed and line 2 is likely to more closely represent the actual process.

The process indicated by line 2 in Figure 5-2 is a reasonable approximation to the actual process for a single simple storm event. It is less likely to be a reasonably close approximation for a daily timestep model. A storm event may last for a greater or a shorter period than one day. While INT may equal INTCAP at times throughout this period the actual relationship of PEFF to P, EINT, INT and INTCAP will be the result of summing the effect of a number of events occurring within the daily timestep.

If a typical storm pattern existed for a particular site it may be possible to derive an accurate relationship. In view of the effort and data required for such a procedure it woud be simpler and more accurate to use a smaller timestep that would more accurately model each event. Thus for a daily model line 1 is a reasonable approximation. To more accurately model the actual processes a shorter timestep should be used.

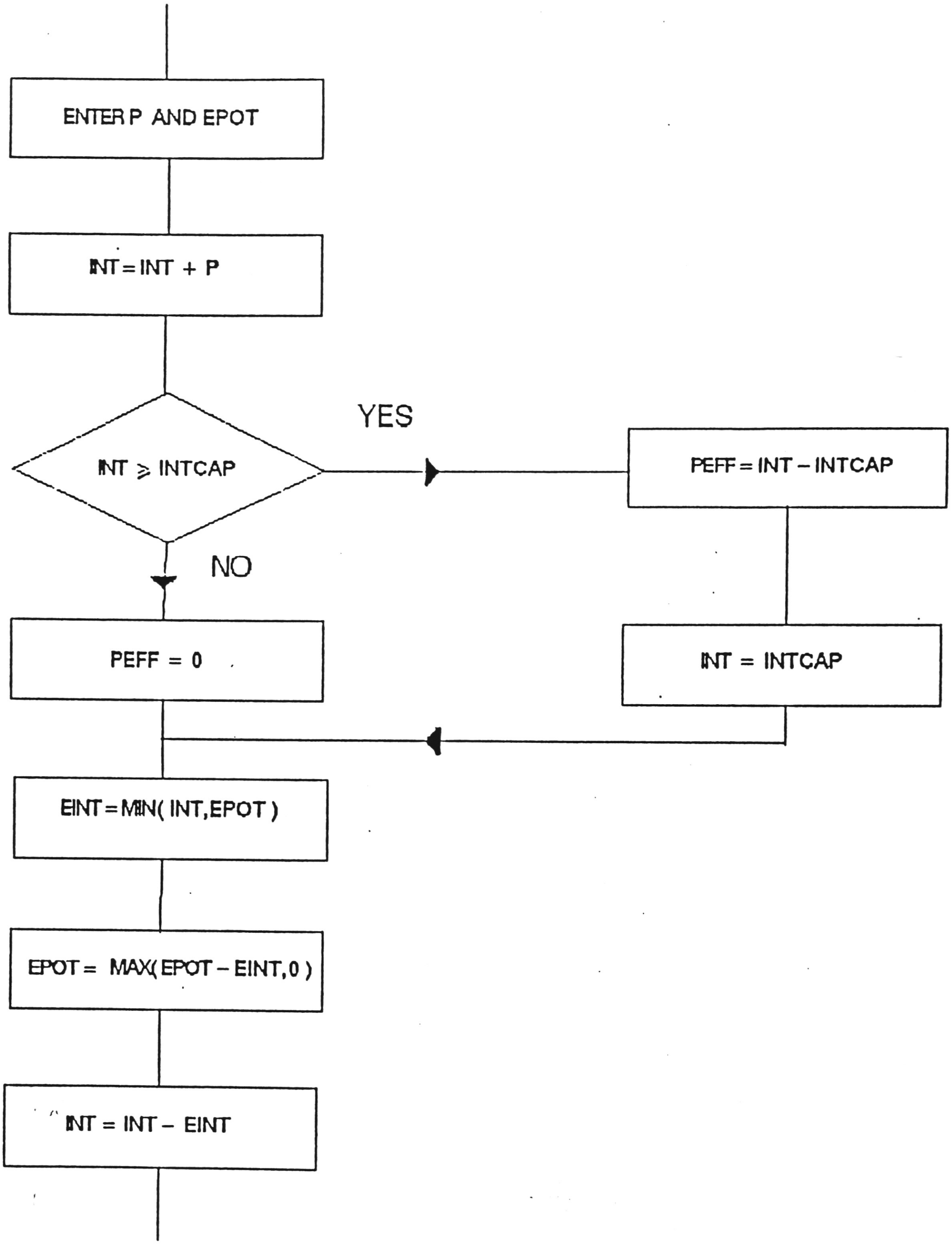

FIGURE 5 – 3 : INTERCEPTION STORE FLOW CHART

The values of EPOT and P are read in from the data file for the model. The values in this file were obtained from meteorological readings (see Section 2). The values of INT, EINT and PEFF at the end of each timestep are calculated by the model. The value of INTCAP, the interception store capacity, was estimated. The site is predominantly grassland. The interception store capacity is the storage component filled by initial wetting by precipitation falling on the vegetal cover and other objects.

No definitive study exists on the interception store capacity of various vegetation types. Local variations and difficulties in measurements meant that estimates were used. A value of 2 mm was adopted after a lengthy search through the available literature.

The interception store submodel developed using the above relationships is described by the flow chart given in Figure 5-3. The terms MIN and MAX used on this, and subsequent flow charts are used to indicate that the minimum, or maximum value of the bracketed terms should be used.

5.3 Soil Store

The soil store consists of a single conceptual store. The following variable names are used in this submodel:

PEFF	=	Effective precipitation reaching the soil store
ESOIL	=	Evapotranspiration from the soil store
EPOT	=	Potential evapotranspiration
SOILCAP	=	Soil store capacity
SW	=	Contents of soil store
R	=	Runoff
INFIL	=	Infiltration
INFMAX	=	Maximum infiltration per day
INFPOT	=	Potential infiltration
SDRY	=	Wilting point
EMAX	=	Maximum evapotranspiration loss possible at field capacity
GCONST	=	Recession constant
RECHAR	=	Water percolating to the groundwater store

Representative physical properties of a number of soil types are given in Table 5-1. From the values presented INFMAX may be estimated directly. SOILCAP and SDRY may be estimated from the values of FC and WP if the rooting depth of the vegetation is known.

Table 5-1 : Representative Physical Properties of Soil

SOIL TEXTURE	INFILTRATION INFMAX (mm/day)	FIELD CAPACITY FC (%)	WILTING POINT WP (%)	APPARENT SPECIFIC GRAVITY As
sandy	1200 (600-6000)	6 (6-12)	4 (2-6)	1.65 (1.55-1.80)
sandy loam	600 (300-1800)	14 (10-18)	6 (4-8)	1.50 (1.40-1.60)
loam	300 (190-480)	22 (18-26)	10 (8-12)	1.40 (1.35-1.50)
clay loam	190 (60-360)	27 (23-31)	13 (11-15)	1.35 (1.30-1.40)
silty clay	60 (7-120)	31 (27-35)	15 (13-17)	1.30 (1.30-1.40)
clay	12 (2-24)	35 (31-39)	17 (15-19)	1.25 (1.20-1.30)

Note :

1. Normal ranges shown in parenthesis.
2. Moisture content = FC / 100 or WP / 100 X As X D where D = rooting depth.
3. The above figures have been assembled from a variety of sources.

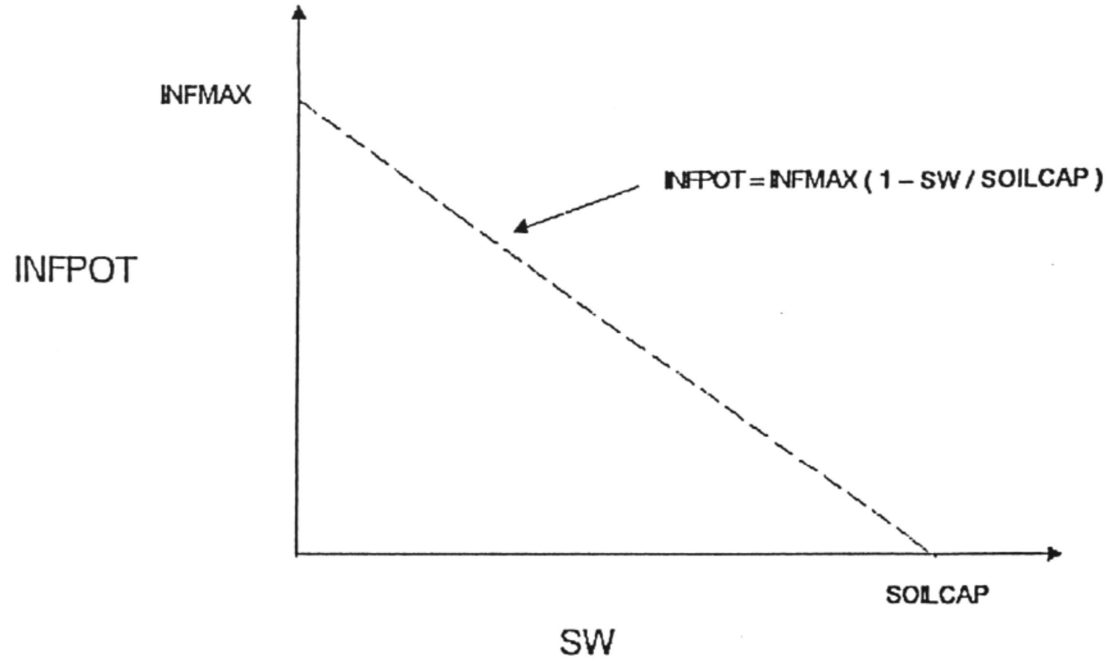

FIGURE 5 – 4 : POTENTIAL INFILTRATION FUNCTION

If the daily effective rainfall exceeds the infiltration rate throughout the day then the relationship between R, PEFF and INFIL will be given by:

$$R = PEFF - INFIL$$

More usually the effective precipitation rate will vary throughout the day and may be discontinuous. In the periods between rainfall water held in the topsoil layer in excess of field capacity will continue to drain into the subsoil. When the rainfall recommences there is a lag in the restart of runoff until the drained amount is refilled in the topsoil layer. This storage of water in the topsoil layer tends to balance minor fluctuations in the rainfall pattern providing a relatively continuous infiltration rate throughout the day. (Boughton, M.E., 1966).

Thus this assumption will be resonably correct when the rainfall rate is continuous throughout the day. When the daily rainfall is small the rate is likely to vary throughout the day. In such a case the apparent value of the daily infiltration rate will be reduced.

Observation indicates that the infiltration rate is much higher when the catchment is dry before rain than when the catchment is wet. Observation also shows that infiltration rate decreases throughout a storm. Equations, such as inverse exponential functions, have been proposed to describe the rate of change. These observations can be accounted for in the model by an infiltration function which varies the infiltration rate inversely with the contents of the soil water store. Such a function is described by the graph in Figure 5-4. A quantity up to the potential infiltration is added to the soil store, and any excess becomes runoff.

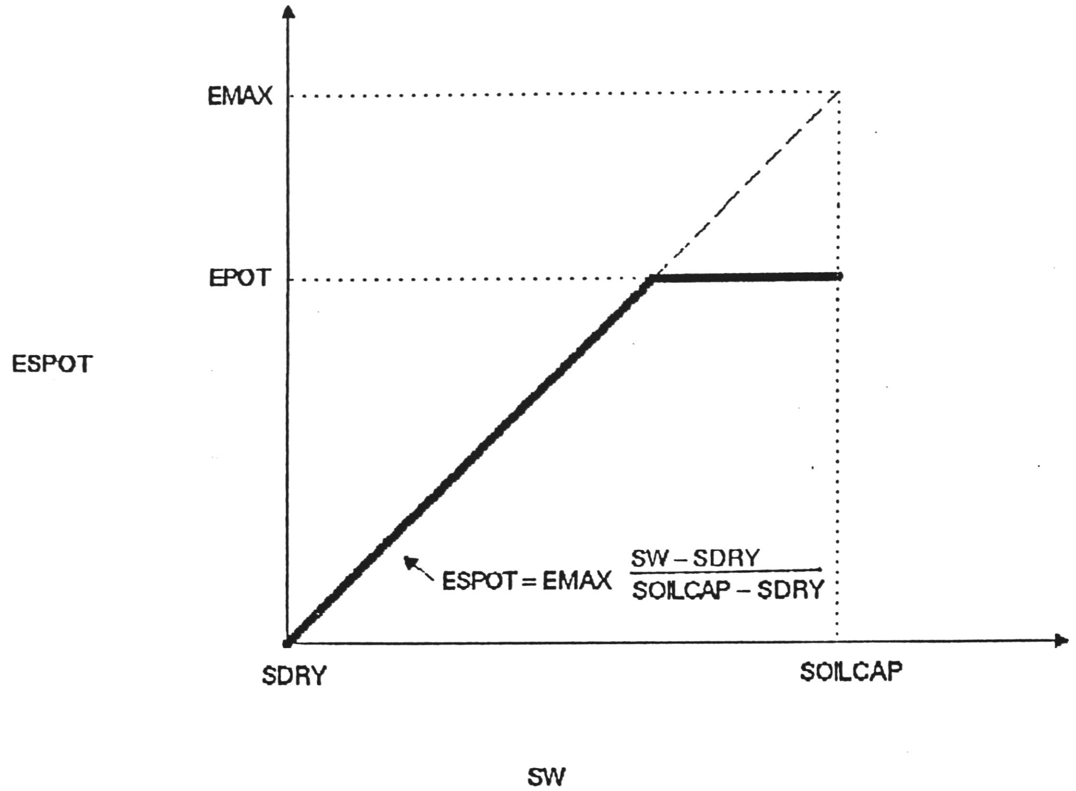

FIGURE 5 – 5 : POTENTIAL SOIL EVAPOTRANSPIRATION FUNCTION

Evapotranspiration up to the remaining potential EPOT is lost from the soil store in each daily period. The rate at which a plant uses water under given meteorological conditions and when soil moisture is freely available is termed the potential transpiration rate. This has been widely studied but, in hydrological studies of water lost from a natural catchment, it is necessary to be able to calculate the transpiration rate at very low soil moisture levels as the catchment dries out. (Boughton, 1966). It has been shown that the ratio of actual to potential transpiration rate is not a single value depending only on the soil moisture level but the ratio also depends on the prevailing potential rate (Denmead and Shaw, 1962, Slatyer, 1967).

Transpiration can continue at the potential rate while the soil moisture is reduced almost to the wilting point if the prevailing potential transpiration rate is low. When the prevailing rate is high the actual transpiration rate is reduced below the potential rate when the soil moisture level is only a small amount less than field capacity. The relationship used in the model based on the above behaviour is illustrated in Figure 5-5.

The parameter EMAX indicates the maximum evapotranspiration loss possible at field capacity for that particular soil and crop. Data is available which relates the maximum possible evapotranspiration for a crop (with soil moisture at field capacity) to measured climatic parameters (e.g. pan evaporation). This would allow an estimate of EMAX to be made. It should be noted that here EPOT is the potential evapotranspiration remaining after interception store requirements have been met and not that which would be indicated by climatic measurements.

The recharge that can take place to groundwater (RECHAR) will be determined by the infiltration characteristics of the soil layers. These will be determined by the soil characteristics and the degree of saturation of the soil. Within the model the degree of saturation above the wilting point is indicated by (SW - SDRY).

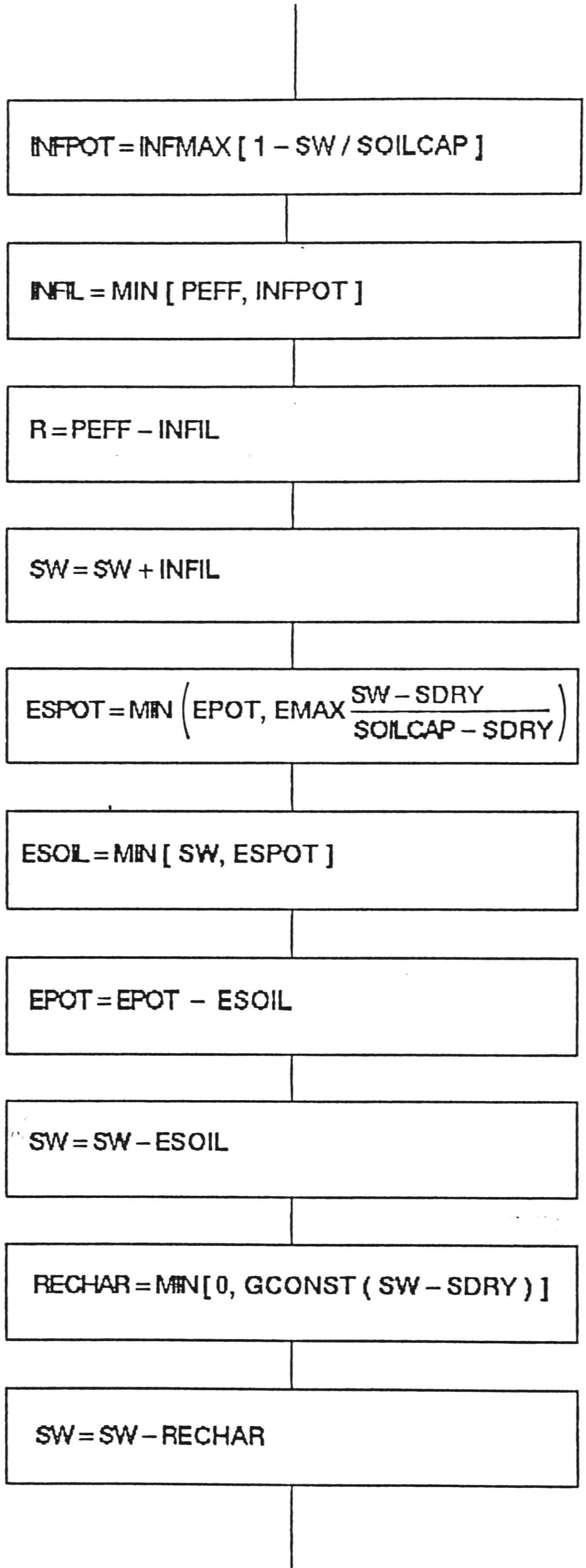

FIGURE 5 – 6 : SOIL STORE SUBROUTINE

For saturated flow Darcy's law states:

$$v = -K_{sat}\,dH/dZ$$

where v is the velocity of flow, K_{sat} is the saturated hydraulic conductivity, and dH/dZ is the hydraulic gradient.

For unsaturated flow, as will be most often the case for the model we have:

$$v = -K(\theta)dH/dZ$$

where $K(\theta)$ is the unsaturated hydraulic conductivity.

$K(\theta)$ varies with the degree of saturation θ but will always be less than or equal to K_{sat}. Typically a 10% reduction in θ from saturation will lead to about a 50% reduction in $K(\theta)$. For vertical infiltration dH/dZ will be less than or equal to 1 for drainage within the soil store. This implies $v \leqslant$ Ksat. For sand loam, using the median value, we have $v \leqslant 600$ mm/day.

The modelling of water movement in unsaturated soils is still an inexact science and would be very difficult in this instance due to the need to firstly measure the various soil parameters required, and secondly to use a single lumped value of these parameters to account for the behavior of soilwater flow over a wide area. The relationship used was therefore simplified to:

RECHAR = GCONST x (SW - SDRY)

It should be possible, given sufficient data, to determine the value of GCONST from the analysis of groundwater bore recession records. For the present study GCONST was set during the sensitivity study described in Section 6.

The soil store submodel developed using the above relationships is described by the flow chart given in Figure 5-6.

6.4 Groundwater Store

For the Sherwood borefield the model does not need the capability to model evapotranspiration from the watertable as the watertable is too deep for significant capillary evapotranspiration to occur from the groundwater. For the sake of completeness a method of accounting for watertable evapotranspiration has been included and is detailed below.

The groundwater model described consists of a single conceptual store. However for many studies the groundwater system may be modelled by a more detailed numerical computer model consisting of a number of cells. Many of the relationships developed below could be readily incorporated into such a model.

The following variable names are used in the groundwater submodel :

S	= Storage coefficient
H	= Elevation of watertable above arbitary reference level
RECHAR	= Water percolating to the groundwater store
DTWT	= Depth to watertable
D1	= Depth at which maximum capillary evapotranspiration starts
D2	= Depth at which capillary evapotranspiration stops
EGW	= Evapotranspiration from the groundwater store
EPOT	= Potential evapotranspiration
Q	= Outflow from the groundwater store
BFCONST	= Recession constant

The volume of water contained in the groundwater store above an arbitary reference level is given by S x H.

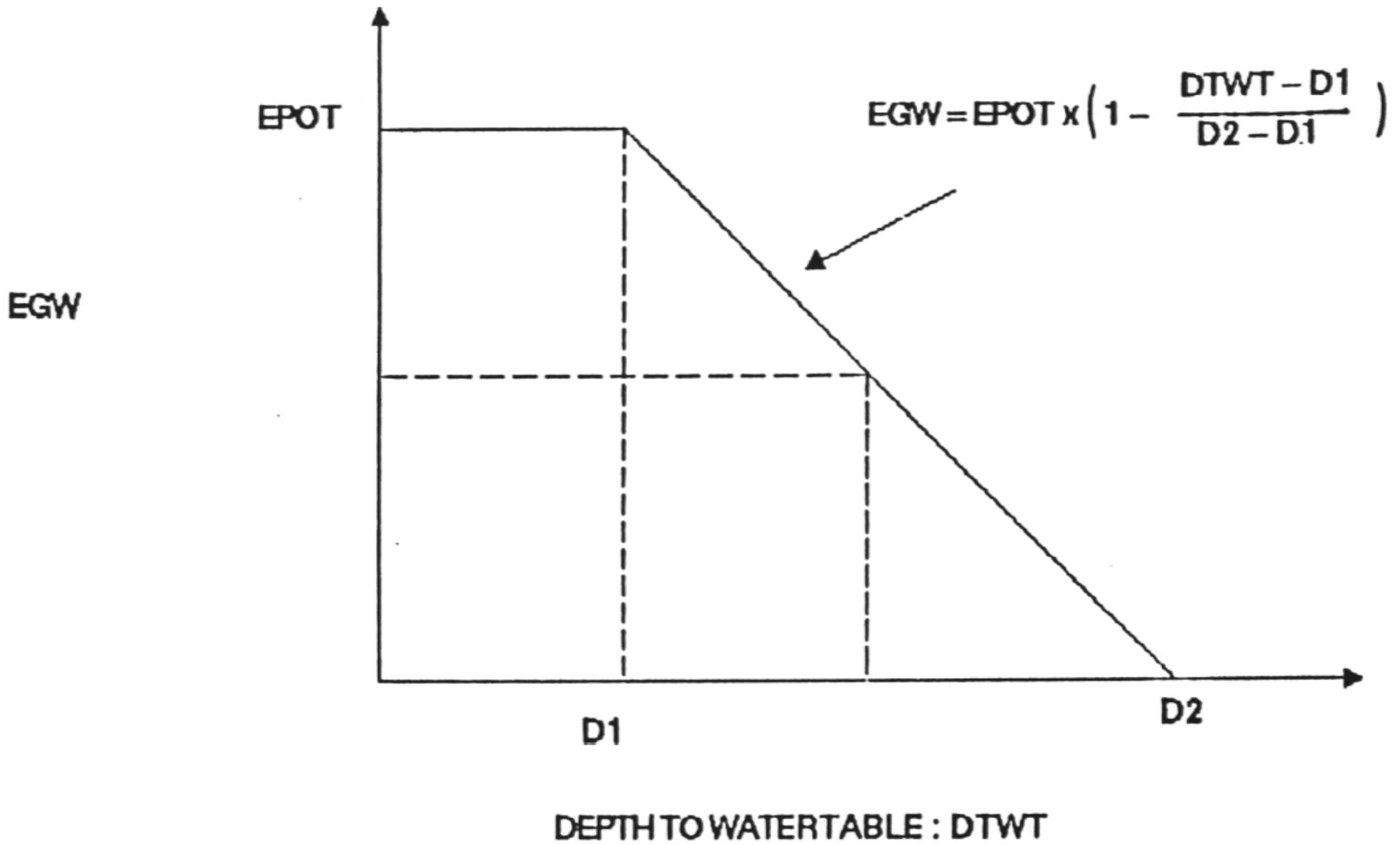

FIGURE 5 – 7 : GROUNDWATER EVAPOTRANSPIRATION FUNCTION

Where the watertable is close to the surface, groundwater may be discharged by direct evaporation or by transpiration from the capillary fringe. Plants deriving their water from groundwater, called phreatophytes, often have root systems extending to depths of 12m or more (Linsley et al., 1982).

A relationship describing watertable evaporation as a function of depth below the natural surface is presented in graphical form in Figure 5-7. This relationship has been used in a number of other studies.

To permit evaluation of the effects of various management measures on the flow and salinity regime of Barr Creek in Northern Victoria (Rural Water Commission of Victoria, 1985), a computer model was developed in which the three components of creek flow (groundwater inflow, irrigation runoff, and rainfall runoff) were computed separately.

A relationship describing watertable evaporation as a function of depth below the natural surface was presented in the graphical form without explanation or references. The same relationship was used irrespective of the time of the year, with a limiting value equal to the open water evaporation rate. The curve used was similar to that given in Figure 5-7, except a gentle curve was used instead of the straight line section from D1 to D2. The value of D1 used was approximately 0.5 m and D2 was approximately 2.6 m.

Prickett and Lonnquist (1968) describe a computer routine which models evapotranspiration. The relationship is similar to that given in Figure 5-7. They quote an example from the Punjab region of West Pakistan described by Greenman et al (1967) where this relationship was successfully used. For this region the evapotranspiration rate equaled the recharge rate of 0.39 mm/day when the depth to water was 1 m.

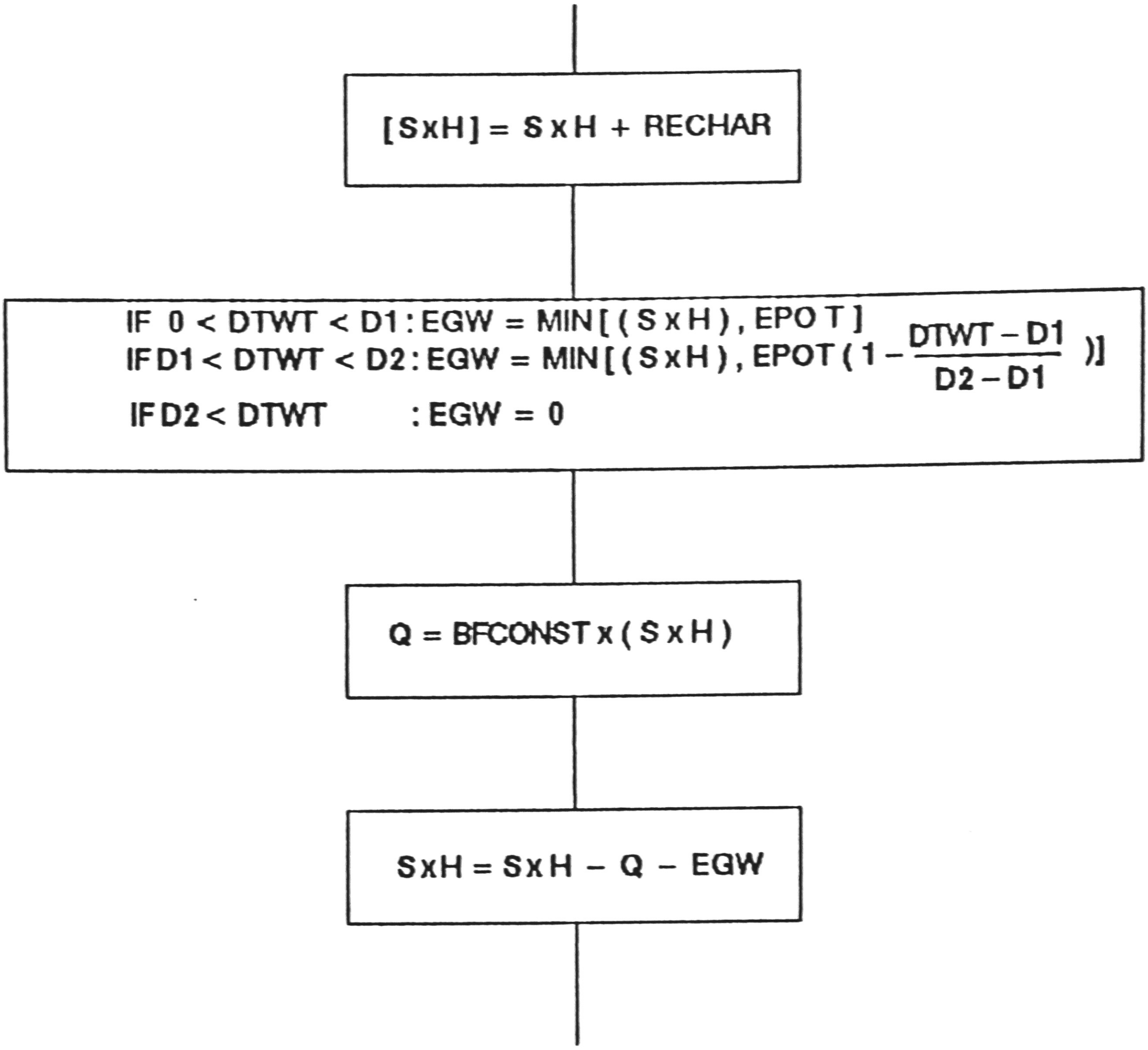

FIGURE 5 – 8 : GROUNDWATER STORE SUBROUTINE

It should be noted that these relationships describe only evaporation from the watertable, and their use alone is only appropraiate when only shallow rooted grasses and crops are present. Where significant numbers of phreatophytes are present the model would need to be modified to include evapotranspiration by the phreatophytes. Where there is more than one type of vegetation (e.g. deep-rooted trees and shrubs with shallow-rooted grasses or crops) , the usual procedure is to estimate the evaporation from each as proportional to its cover, as estimated from aerial photography or by ground surveys. This glosses over some conceptual difficulties in terms of the depth of the soil water store which is available to each type of vegetation, but is probably adequate at this overall level of modelling (Chapman T.G., 1985).

The equation describing the groundwater evaporation can be derived as follows :

$$\frac{DTWT - D1}{EGW - EPOT} = \frac{D2 - D1}{-EPOT}$$

$$\Rightarrow \quad EGW - EPOT = \frac{(DTWT - D1) \times (-EPOT)}{(D2 - D1)}$$

$$\Rightarrow \quad EGW = EPOT - EPOT \times \frac{(DTWT - D1)}{(D2 - D1)}$$

$$\Rightarrow \quad EGW = EPOT(1 - [(DTWT - D1) / (D2 - D1)]$$

For many catchments discharge from the groundwater system into streams takes place. Such a discharge is accounted for by Q, the outflow from the groundwater store. The value of the recession constant BFCONST could be estimated from studies of bore recession records.

The submodel developed based on the above relationships is described in Figure 5-8.

6. MODEL RESULTS

6.1 Introduction

The developed model was used to predict monthly recharge rates to the groundwater system. The model results were calculated on a daily basis which were then summed to obtain the monthly values. The first six months of data from January 1978 to June 1978 were used to 'warm up' the model. It was found that initial store values had no effect upon the model results after the first six months and they were initially set to half of their maximum values.

The model calculated the rates of recharge to rainfall for each month. As discussed in Section 4 successful calibration of the Sherwood Borefield Groundwater Model was obtained when it was assumed that this ratio was 0.70. The aim of the daily process model calibration was therefore to achieve on a monthly basis a mean ratio value of 0.70.

The model had the capability of calculating the mean and standard deviation of the monthly ratio value for the calibration period of July 1978 until the end of December 1981. These values are printed in the table of results for each model run. The initial block of data in these tables covering the warm up period from January 1978 until June 1978 was not used in the calculation of the mean and standard deviation for the monthly ratio values.

6.2 Sensitivity Study

In order to gain an appreciation of the effect that each model parameter had upon the monthly recharge to rainfall ratio a sensitivity study was undertaken. A number of computer runs were undertaken for this study. The results of these model runs are given in Tables 6.1 to 6.13.

TABLE 6-1 : SENSITIVITY STUDY RUN 1 - REFERENCE CASE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
2.00	.50	105.00	600.00	10.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	72.80	46.34	.00	112.50	169.96	.65
1978	2	43.88	21.76	.00	63.40	155.74	.69
1978	3	174.69	51.31	125.73	379.10	130.25	.46
1978	4	22.34	19.30	.00	78.80	113.40	.28
1978	5	19.74	18.06	.00	37.80	70.93	.52
1978	6	36.34	21.25	.00	66.60	46.76	.55
1978	7	.89	8.38	.00	8.20	77.45	.11
1978	8	3.07	7.13	.00	10.20	105.40	.30
1978	9	21.46	18.77	.00	42.00	147.24	.51
1978	10	59.49	33.17	.00	89.40	161.08	.67
1978	11	43.94	35.06	.00	79.20	157.69	.55
1978	12	118.87	46.69	12.80	187.60	172.06	.63
1979	1	111.89	47.71	42.48	193.00	181.44	.58
1979	2	15.47	22.15	.00	33.70	133.96	.46
1979	3	74.54	41.16	.00	117.10	144.77	.64
1979	4	51.73	24.51	.00	80.00	97.71	.65
1979	5	99.57	21.78	6.05	117.20	75.06	.85
1979	6	56.45	8.98	11.86	77.10	51.73	.73
1979	7	10.10	10.42	.00	23.40	54.99	.43
1979	8	4.98	4.38	.00	1.40	99.54	3.56
1979	9	9.31	11.31	.00	20.70	131.26	.45
1979	10	26.55	28.52	.00	55.10	172.67	.48
1979	11	62.75	45.40	.00	107.60	160.61	.58
1979	12	20.88	20.95	.00	41.80	215.27	.50
1980	1	74.62	32.16	23.61	134.80	182.40	.55
1980	2	33.33	28.90	.00	49.60	159.22	.67
1980	3	25.91	17.60	.00	45.30	159.99	.57
1980	4	6.64	15.55	.00	22.20	123.71	.30
1980	5	196.51	32.46	196.13	425.50	67.35	.46
1980	6	59.06	12.27	.00	70.00	68.33	.84
1980	7	13.25	9.10	.00	22.50	69.60	.59
1980	8	.26	4.40	.00	4.30	99.91	.06
1980	9	1.00	2.60	.00	3.60	164.85	.28
1980	10	16.86	21.04	.00	37.90	166.68	.44
1980	11	11.43	12.57	.00	24.00	216.35	.48
1980	12	102.57	31.24	34.20	196.50	182.54	.52
1981	1	52.80	20.55	.00	17.80	202.14	2.97
1981	2	96.84	64.09	.00	177.80	137.26	.54
1981	3	10.96	14.86	.00	35.10	186.68	.31
1981	4	121.39	25.05	72.36	202.00	96.58	.60
1981	5	62.60	29.43	74.07	169.10	68.74	.37
1981	6	.32	5.14	.00	6.70	57.44	.05
1981	7	12.11	9.08	.00	21.20	69.23	.57
1981	8	2.19	5.39	.00	7.60	145.89	.29
1981	9	33.33	17.04	.00	50.60	155.19	.66
1981	10	73.71	37.29	.00	110.70	168.21	.67
1981	11	95.24	28.96	.40	135.00	164.83	.71
1981	12	69.60	48.20	.00	118.60	174.43	.59

RATIO: MEAN= .64 STANDARD DEVIATION= .62

TABLE 6-2 : SENSITIVITY STUDY RUN 2 - LOW INTCAP VALUE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
1.00	.50	105.00	600.00	10.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	78.83	39.76	.00	112.50	169.96	.70
1978	2	45.68	20.06	.00	63.40	155.74	.72
1978	3	179.41	43.94	127.97	379.10	130.25	.47
1978	4	26.15	15.67	.00	78.80	113.40	.33
1978	5	22.55	15.25	.00	37.80	70.93	.60
1978	6	38.60	18.83	.00	66.60	46.76	.58
1978	7	2.86	5.98	.00	8.20	77.45	.35
1978	8	4.54	5.72	.00	10.20	105.40	.44
1978	9	23.24	16.42	.00	42.00	147.24	.55
1978	10	63.42	29.50	.00	89.40	161.08	.71
1978	11	49.56	29.69	.00	79.20	157.69	.63
1978	12	122.28	41.67	14.40	187.60	172.06	.65
1979	1	115.67	42.40	43.81	193.00	181.44	.60
1979	2	18.87	18.75	.00	33.70	133.96	.56
1979	3	80.14	35.57	.00	117.10	144.77	.68
1979	4	53.97	22.28	.00	80.00	97.71	.67
1979	5	99.85	20.62	6.70	117.20	75.06	.85
1979	6	56.08	8.85	12.36	77.10	51.73	.73
1979	7	11.57	8.91	.00	23.40	54.99	.49
1979	8	5.06	4.32	.00	1.40	99.54	3.61
1979	9	11.07	9.53	.00	20.70	131.26	.53
1979	10	31.67	23.37	.00	55.10	172.67	.57
1979	11	68.94	39.37	.00	107.60	160.61	.64
1979	12	24.75	17.10	.00	41.80	215.27	.59
1980	1	77.48	27.85	24.61	134.80	182.40	.57
1980	2	37.70	24.60	.00	49.60	159.22	.76
1980	3	27.78	15.75	.00	45.30	159.99	.61
1980	4	9.85	12.34	.00	22.20	123.71	.44
1980	5	197.14	30.76	197.17	425.50	67.35	.46
1980	6	59.18	12.26	.00	70.00	68.33	.85
1980	7	14.13	8.23	.00	22.50	69.60	.63
1980	8	1.10	3.54	.00	4.30	99.91	.26
1980	9	1.72	1.89	.00	3.60	164.85	.48
1980	10	21.57	16.33	.00	37.90	166.68	.57
1980	11	13.01	11.00	.00	24.00	216.35	.54
1980	12	105.00	28.31	35.20	196.50	182.54	.53
1981	1	55.43	17.50	.00	17.60	202.14	3.11
1981	2	104.35	56.15	.00	177.80	187.26	.59
1981	3	14.00	11.57	.00	35.10	186.68	.40
1981	4	122.12	23.81	73.43	202.00	96.58	.60
1981	5	65.09	26.13	74.84	169.10	68.74	.38
1981	6	1.22	4.33	.00	6.70	57.44	.18
1981	7	13.31	7.89	.00	21.20	69.23	.63
1981	8	3.54	4.01	.00	7.60	145.89	.47
1981	9	34.53	15.90	.00	50.60	155.19	.68
1981	10	76.75	34.32	.00	110.70	168.21	.69
1981	11	96.88	25.99	1.40	135.00	164.83	.72
1981	12	75.63	41.54	.00	118.60	174.43	.64

RATIO: MEAN= .71 STANDARD DEVIATION= .61

TABLE 6-3 : SENSITIVITY STUDY RUN 3 - HIGH INTCAP VALUE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
3.00	.50	105.00	600.00	10.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	69.48	50.17	.00	112.50	169.96	.62
1978	2	43.82	21.81	.00	63.40	155.74	.69
1978	3	171.10	55.86	124.83	379.10	130.25	.45
1978	4	18.34	23.12	.00	78.80	113.40	.23
1978	5	17.51	20.29	.00	37.80	70.93	.46
1978	6	34.97	22.62	.00	66.60	46.76	.53
1978	7	.17	9.10	.00	8.20	77.45	.02
1978	8	1.53	8.67	.00	10.20	105.40	.15
1978	9	20.46	20.04	.00	42.00	147.24	.49
1978	10	56.79	35.87	.00	89.40	161.08	.64
1978	11	41.28	37.72	.00	79.20	157.69	.52
1978	12	117.14	49.88	11.29	187.60	172.06	.62
1979	1	110.47	50.48	41.28	193.00	181.44	.57
1979	2	14.00	23.56	.00	33.70	133.96	.42
1979	3	72.13	43.58	.00	117.10	144.77	.62
1979	4	50.84	25.29	.00	80.00	97.71	.64
1979	5	99.45	22.65	5.55	117.20	75.06	.85
1979	6	56.81	9.12	11.36	77.10	51.73	.74
1979	7	8.85	11.15	.00	23.40	54.99	.38
1979	8	4.81	4.98	.00	1.40	99.54	3.43
1979	9	8.43	12.16	.00	20.70	131.26	.41
1979	10	23.19	31.96	.00	55.10	172.67	.42
1979	11	58.84	49.13	.00	107.60	160.61	.55
1979	12	18.01	23.80	.00	41.80	215.27	.43
1980	1	72.88	35.33	22.61	134.80	182.40	.54
1980	2	30.47	31.73	.00	49.60	159.22	.61
1980	3	25.05	18.45	.00	45.30	159.99	.55
1980	4	5.91	16.29	.00	22.20	123.71	.27
1980	5	194.28	34.73	196.08	425.50	67.35	.46
1980	6	57.84	13.52	.00	70.00	68.33	.83
1980	7	11.42	10.94	.00	22.50	69.60	.51
1980	8	.24	4.40	.00	4.30	99.91	.06
1980	9	.29	3.31	.00	3.60	164.85	.08
1980	10	13.44	24.46	.00	37.90	166.68	.35
1980	11	10.00	14.00	.00	24.00	216.35	.42
1980	12	101.33	32.98	33.20	196.50	182.54	.52
1981	1	50.45	23.31	.00	17.80	202.14	2.83
1981	2	91.61	69.49	.00	177.80	137.26	.52
1981	3	9.95	16.02	.00	35.10	186.68	.28
1981	4	121.15	25.55	71.79	202.00	96.58	.60
1981	5	60.96	31.56	73.57	169.10	68.74	.36
1981	6	.05	5.42	.00	6.70	57.44	.01
1981	7	10.85	10.35	.00	21.20	69.23	.51
1981	8	1.37	6.23	.00	7.60	145.89	.18
1981	9	32.61	17.76	.00	50.60	155.19	.64
1981	10	71.12	39.80	.00	110.70	168.21	.64
1981	11	94.17	30.43	.00	135.00	164.63	.70
1981	12	67.42	50.84	.00	118.60	174.43	.57

RATIO: MEAN= .59 STANDARD DEVIATION= .61

TABLE 6-4 : SENSITIVITY STUDY RUN 4 - LOW GCONST VALUE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
2.00	.25	105.00	600.00	10.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	55.55	58.36	.00	112.50	169.96	.49
1978	2	41.43	31.11	.00	63.40	155.74	.65
1978	3	117.18	61.62	170.99	379.10	130.25	.31
1978	4	19.26	24.71	.00	78.80	113.40	.24
1978	5	15.59	22.17	.00	37.80	70.93	.41
1978	6	31.89	25.30	.00	66.60	46.76	.48
1978	7	1.16	8.86	.00	8.20	77.45	.14
1978	8	2.39	7.81	.00	10.20	105.40	.23
1978	9	15.51	22.43	.00	42.00	147.24	.37
1978	10	49.73	45.15	.00	89.40	161.08	.56
1978	11	34.93	44.11	.00	79.20	157.69	.44
1978	12	76.72	54.79	32.72	187.60	172.06	.41
1979	1	89.78	67.18	57.94	193.00	181.44	.47
1979	2	17.36	29.50	.00	33.70	133.96	.52
1979	3	58.25	54.79	2.74	117.10	144.77	.50
1979	4	36.28	30.41	.00	80.00	97.71	.45
1979	5	86.16	39.55	13.85	117.20	75.06	.74
1979	6	47.97	15.84	12.66	77.10	51.73	.62
1979	7	6.98	11.29	.00	23.40	54.99	.30
1979	8	6.00	6.55	.00	1.40	99.54	4.28
1979	9	6.90	13.08	.00	20.70	131.26	.33
1979	10	20.44	34.22	.00	55.10	172.67	.37
1979	11	52.23	57.67	.00	107.60	160.61	.49
1979	12	16.34	25.67	.00	41.80	215.27	.39
1980	1	61.66	42.93	23.78	134.80	182.40	.46
1980	2	26.96	35.34	.00	49.60	159.22	.54
1980	3	20.75	22.84	.00	45.30	159.99	.46
1980	4	5.29	16.82	.00	22.20	123.71	.24
1980	5	122.51	41.85	259.84	425.50	67.35	.29
1980	6	52.13	20.41	.00	70.00	68.33	.74
1980	7	10.52	10.83	.00	22.50	69.60	.47
1980	8	1.16	5.23	.00	4.30	99.91	.27
1980	9	.78	2.82	.00	3.60	164.85	.22
1980	10	13.04	24.73	.00	37.90	166.68	.34
1980	11	9.01	15.21	.00	24.00	216.35	.38
1980	12	75.47	40.47	34.25	196.50	182.54	.38
1981	1	47.19	31.59	.05	17.60	202.14	2.65
1981	2	78.93	80.39	.00	177.80	137.26	.44
1981	3	7.02	16.06	.00	35.10	186.68	.20
1981	4	89.66	33.85	95.33	202.00	96.58	.44
1981	5	52.12	36.10	76.46	169.10	68.74	.31
1981	6	1.71	6.00	.00	6.70	57.44	.26
1981	7	10.18	10.88	.00	21.20	69.23	.48
1981	8	1.72	5.89	.00	7.60	145.89	.23
1981	9	25.28	23.90	.00	50.60	155.19	.50
1981	10	61.13	51.90	.00	110.70	168.21	.55
1981	11	72.34	39.73	12.68	135.00	164.83	.54
1981	12	54.29	60.26	.00	118.60	174.43	.46

RATIO: MEAN= .56 STANDARD DEVIATION= .69

TABLE 6-5 : SENSITIVITY STUDY RUN 5 - HIGH GCONST VALUE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
2.00	.75	105.00	600.00	10.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	81.29	39.48	.00	112.50	169.96	.72
1978	2	43.20	19.08	.00	63.40	155.74	.68
1978	3	213.38	46.43	92.26	379.10	130.25	.56
1978	4	24.04	16.96	.00	78.80	113.40	.31
1978	5	21.56	16.24	.00	37.80	70.93	.57
1978	6	39.08	18.52	.00	66.60	46.76	.59
1978	7	.97	8.29	.00	8.20	77.45	.12
1978	8	3.39	6.81	.00	10.20	105.40	.33
1978	9	24.68	16.78	.00	42.00	147.24	.59
1978	10	63.03	27.98	.00	89.40	161.08	.70
1978	11	48.25	30.75	.00	79.20	157.69	.61
1978	12	134.53	40.73	7.01	187.60	172.06	.72
1979	1	127.88	36.18	28.48	193.00	181.44	.66
1979	2	15.30	20.06	.00	33.70	133.96	.45
1979	3	81.09	34.61	.00	117.10	144.77	.69
1979	4	58.51	21.35	.00	80.00	97.71	.73
1979	5	104.92	14.58	.50	117.20	75.06	.90
1979	6	60.66	5.58	11.06	77.10	51.73	.79
1979	7	12.40	10.31	.00	23.40	54.99	.53
1979	8	2.62	3.70	.00	1.40	99.54	1.87
1979	9	10.35	10.35	.00	20.70	131.26	.50
1979	10	29.35	25.74	.00	55.10	172.67	.53
1979	11	68.10	39.60	.00	107.60	160.61	.63
1979	12	23.05	18.75	.00	41.80	215.27	.55
1980	1	81.25	27.74	23.60	134.80	182.40	.60
1980	2	36.58	25.62	.00	49.60	159.22	.74
1980	3	28.63	14.87	.00	45.30	159.99	.63
1980	4	7.30	14.90	.00	22.20	123.71	.33
1980	5	257.10	26.65	141.70	425.50	67.35	.60
1980	6	60.42	10.14	.00	70.00	68.33	.86
1980	7	14.04	8.45	.00	22.50	69.60	.62
1980	8	.02	4.31	.00	4.30	99.91	.00
1980	9	1.11	2.49	.00	3.60	164.85	.31
1980	10	18.63	19.27	.00	37.90	166.68	.49
1980	11	12.63	11.37	.00	24.00	216.35	.53
1980	12	122.39	26.43	34.20	196.50	182.54	.62
1981	1	51.48	16.39	.00	17.80	202.14	2.89
1981	2	104.87	56.25	.00	177.80	137.26	.59
1981	3	15.85	14.74	.00	35.10	186.68	.45
1981	4	131.94	21.70	65.01	202.00	96.58	.65
1981	5	70.55	23.84	71.70	169.10	68.74	.42
1981	6	.30	5.10	.00	6.70	57.44	.04
1981	7	12.81	8.39	.00	21.20	69.23	.60
1981	8	2.44	5.16	.00	7.60	145.89	.32
1981	9	37.01	13.58	.00	50.60	155.19	.73
1981	10	79.43	30.96	.00	110.70	168.21	.72
1981	11	99.12	25.08	.40	135.00	164.83	.73
1981	12	77.09	41.87	.00	118.60	174.43	.65

RATIO: MEAN= .64 STANDARD DEVIATION= .45

TABLE 6-6 : SENSITIVITY STUDY RUN 6 - LOW SOILCAP VALUE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
2.00	.50	52.50	600.00	10.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	14.96	51.62	28.43	112.50	169.96	.13
1978	2	9.64	22.76	30.45	63.40	155.74	.15
1978	3	27.84	63.36	260.16	379.10	130.25	.07
1978	4	8.42	31.09	2.36	78.80	113.40	.11
1978	5	9.62	23.89	3.31	37.80	70.93	.25
1978	6	8.25	21.79	27.57	66.60	46.76	.12
1978	7	.00	9.34	.00	8.20	77.45	.00
1978	8	1.76	8.25	.00	10.20	105.40	.17
1978	9	9.51	24.27	6.85	42.00	147.24	.23
1978	10	13.89	41.30	38.11	89.40	161.08	.16
1978	11	15.67	43.20	19.69	79.20	157.69	.20
1978	12	14.02	60.57	107.98	187.60	172.06	.07
1979	1	10.79	42.49	139.23	193.00	181.44	.06
1979	2	5.58	27.56	2.47	33.70	133.96	.17
1979	3	12.67	42.11	60.72	117.10	144.77	.11
1979	4	15.82	29.95	34.73	80.00	97.71	.20
1979	5	19.00	23.45	77.26	117.20	75.06	.16
1979	6	6.70	6.67	64.34	77.10	51.73	.09
1979	7	5.41	11.49	4.32	23.40	54.99	.23
1979	8	1.77	5.24	.00	1.40	99.54	1.26
1979	9	3.29	18.18	.00	20.70	131.26	.16
1979	10	3.35	33.06	18.50	55.10	172.67	.06
1979	11	10.73	53.90	42.65	107.60	160.61	.10
1979	12	3.81	33.05	5.02	41.80	215.27	.09
1980	1	12.25	39.19	80.84	134.80	182.40	.09
1980	2	7.84	36.58	17.67	49.60	159.22	.16
1980	3	2.46	16.76	24.20	45.30	159.99	.05
1980	4	4.90	17.31	.00	22.20	123.71	.22
1980	5	36.65	31.24	357.61	425.50	67.35	.09
1980	6	17.58	14.70	38.89	70.00	68.33	.25
1980	7	11.19	11.43	.00	22.50	69.60	.50
1980	8	.00	4.30	.00	4.30	99.91	.00
1980	9	.00	3.66	.00	3.60	164.85	.00
1980	10	2.38	27.38	7.85	37.90	166.68	.06
1980	11	.86	18.71	4.62	24.00	216.35	.04
1980	12	11.15	34.40	145.60	196.50	182.54	.06
1981	1	4.24	22.98	37.61	17.80	202.14	.24
1981	2	28.45	73.98	57.71	177.80	137.26	.16
1981	3	2.33	15.51	14.68	35.10	186.68	.07
1981	4	20.86	25.95	172.01	202.00	96.58	.10
1981	5	10.51	28.61	127.46	169.10	68.74	.06
1981	6	.00	5.10	.00	6.70	57.44	.00
1981	7	9.30	11.31	.00	21.20	69.23	.44
1981	8	1.06	6.43	.00	7.60	145.89	.14
1981	9	2.57	22.73	27.13	50.60	155.19	.05
1981	10	17.15	45.25	46.40	110.70	168.21	.15
1981	11	12.20	31.65	80.55	135.00	164.83	.09
1981	12	16.34	54.09	48.02	118.60	174.43	.14

RATIO: MEAN= .16 STANDARD DEVIATION= .20

TABLE 6-7 : SENSITIVITY STUDY RUN 7 - HIGH SOILCAP VALUE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
2.00	.50	157.50	600.00	10.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	102.71	42.35	.00	112.50	169.96	.91
1978	2	46.03	19.98	.00	63.40	155.74	.73
1978	3	258.34	47.06	46.23	379.10	130.25	.68
1978	4	24.84	17.00	.00	78.80	113.40	.32
1978	5	21.47	16.33	.00	37.80	70.93	.57
1978	6	37.99	19.61	.00	66.60	46.76	.57
1978	7	1.04	8.23	.00	8.20	77.45	.13
1978	8	3.34	6.86	.00	10.20	105.40	.33
1978	9	23.88	16.06	.00	42.00	147.24	.57
1978	10	65.47	27.45	.00	89.40	161.08	.73
1978	11	50.48	28.52	.00	79.20	157.69	.64
1978	12	135.87	41.32	.00	187.60	172.06	.72
1979	1	160.40	42.87	.00	193.00	181.44	.83
1979	2	18.84	19.68	.00	33.70	133.96	.56
1979	3	79.46	36.26	.00	117.10	144.77	.68
1979	4	54.56	21.28	.00	80.00	97.71	.68
1979	5	109.85	17.57	.00	117.20	75.06	.94
1979	6	69.59	7.69	.00	77.10	51.73	.90
1979	7	10.33	10.23	.00	23.40	54.99	.44
1979	8	5.35	4.03	.00	1.40	99.54	3.82
1979	9	10.58	9.99	.00	20.70	131.26	.51
1979	10	30.58	24.47	.00	55.10	172.67	.56
1979	11	70.36	37.95	.00	107.60	160.61	.65
1979	12	24.47	17.37	.00	41.80	215.27	.59
1980	1	101.31	28.67	.00	134.80	182.40	.75
1980	2	36.96	25.27	.00	49.60	159.22	.75
1980	3	27.85	15.66	.00	45.30	159.99	.61
1980	4	7.20	14.99	.00	22.20	123.71	.32
1980	5	296.81	32.55	95.66	425.50	67.35	.70
1980	6	60.15	11.28	.00	70.00	68.33	.86
1980	7	13.63	8.69	.00	22.50	69.60	.61
1980	8	.33	4.36	.00	4.30	99.91	.08
1980	9	1.17	2.43	.00	3.60	164.85	.33
1980	10	19.74	18.15	.00	37.90	166.68	.52
1980	11	13.40	10.61	.00	24.00	216.35	.56
1980	12	139.67	28.10	.00	196.50	182.54	.71
1981	1	55.84	17.95	.00	17.80	202.14	3.14
1981	2	107.35	53.48	.00	177.80	137.26	.60
1981	3	11.67	13.88	.00	35.10	186.68	.33
1981	4	176.06	22.69	20.08	202.00	96.58	.87
1981	5	115.19	29.27	21.57	169.10	68.74	.68
1981	6	.48	5.15	.00	6.70	57.44	.07
1981	7	12.54	8.65	.00	21.20	69.23	.59
1981	8	2.49	5.09	.00	7.60	145.89	.33
1981	9	36.28	13.99	.00	50.60	155.19	.72
1981	10	79.59	31.63	.00	110.70	168.21	.72
1981	11	98.15	26.46	.00	135.00	164.83	.73
1981	12	77.29	40.19	.00	118.60	174.43	.65

RATIO: MEAN= .73 STANDARD DEVIATION= .65

TABLE 6-8 : SENSITIVITY STUDY RUN 8 - LOW INFMAX VALUE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
2.00	.50	105.00	300.00	10.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	72.80	46.34	.00	112.50	169.96	.65
1978	2	43.88	21.76	.00	63.40	155.74	.69
1978	3	174.69	51.31	125.73	379.10	130.25	.46
1978	4	22.34	19.30	.00	78.80	113.40	.28
1978	5	19.74	18.06	.00	37.80	70.93	.52
1978	6	36.34	21.25	.00	66.60	46.76	.55
1978	7	.89	8.38	.00	8.20	77.45	.11
1978	8	3.07	7.13	.00	10.20	105.40	.30
1978	9	21.46	18.77	.00	42.00	147.24	.51
1978	10	59.49	33.17	.00	89.40	161.08	.67
1978	11	43.94	35.06	.00	79.20	157.69	.55
1978	12	118.87	46.69	12.80	187.60	172.06	.63
1979	1	111.89	47.71	42.48	193.00	181.44	.58
1979	2	15.47	22.15	.00	33.70	133.96	.46
1979	3	74.54	41.16	.00	117.10	144.77	.64
1979	4	51.73	24.51	.00	80.00	97.71	.65
1979	5	99.57	21.78	6.05	117.20	75.06	.85
1979	6	56.45	8.98	11.86	77.10	51.73	.73
1979	7	10.10	10.42	.00	23.40	54.99	.43
1979	8	4.98	4.38	.00	1.40	99.54	3.56
1979	9	9.31	11.31	.00	20.70	131.26	.45
1979	10	26.55	28.52	.00	55.10	172.67	.48
1979	11	62.75	45.40	.00	107.60	160.61	.58
1979	12	20.88	20.95	.00	41.80	215.27	.50
1980	1	74.62	32.16	23.61	134.80	182.40	.55
1980	2	33.33	28.90	.00	49.60	159.22	.67
1980	3	25.91	17.60	.00	45.30	159.99	.57
1980	4	6.64	15.55	.00	22.20	123.71	.30
1980	5	196.51	32.46	196.13	425.50	67.35	.46
1980	6	59.06	12.27	.00	70.00	68.33	.84
1980	7	13.25	9.10	.00	22.50	69.60	.59
1980	8	.26	4.40	.00	4.30	99.91	.06
1980	9	1.00	2.60	.00	3.60	164.85	.28
1980	10	16.86	21.04	.00	37.90	166.68	.44
1980	11	11.43	12.57	.00	24.00	216.35	.48
1980	12	102.57	31.24	34.20	196.50	182.54	.52
1981	1	52.80	20.55	.00	17.80	202.14	2.97
1981	2	96.84	64.09	.00	177.80	137.26	.54
1981	3	10.96	14.86	.00	35.10	186.68	.31
1981	4	121.39	25.05	72.36	202.00	96.58	.60
1981	5	62.60	29.43	74.07	169.10	68.74	.37
1981	6	.32	5.14	.00	6.70	57.44	.05
1981	7	12.11	9.08	.00	21.20	69.23	.57
1981	8	2.19	5.39	.00	7.60	145.89	.29
1981	9	33.33	17.04	.00	50.60	155.19	.66
1981	10	73.71	37.29	.00	110.70	168.21	.67
1981	11	95.24	28.96	.40	135.00	164.83	.71
1981	12	69.60	48.20	.00	118.60	174.43	.59

RATIO: MEAN= .64 STANDARD DEVIATION= .62

TABLE 6-9 : SENSITIVITY STUDY RUN 9 - LOW EMAX VALUE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
2.00	.50	105.00	600.00	5.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	81.26	37.52	.00	112.50	169.96	.72
1978	2	46.29	19.75	.00	63.40	155.74	.73
1978	3	180.00	45.58	126.04	379.10	130.25	.47
1978	4	25.02	16.82	.00	78.80	113.40	.32
1978	5	21.63	16.17	.00	37.80	70.93	.57
1978	6	38.18	19.41	.00	66.60	46.76	.57
1978	7	1.06	8.22	.00	8.20	77.45	.13
1978	8	3.36	6.84	.00	10.20	105.40	.33
1978	9	24.13	15.79	.00	42.00	147.24	.57
1978	10	66.01	26.93	.00	89.40	161.08	.74
1978	11	51.01	28.00	.00	79.20	157.69	.64
1978	12	124.22	40.53	12.86	187.60	172.06	.66
1979	1	121.08	38.50	42.75	193.00	181.44	.63
1979	2	18.94	19.44	.00	33.70	133.96	.56
1979	3	79.90	35.62	.00	117.10	144.77	.68
1979	4	54.86	20.92	.00	80.00	97.71	.69
1979	5	104.46	16.90	6.12	117.20	75.06	.89
1979	6	58.35	7.07	11.86	77.10	51.73	.76
1979	7	10.33	10.21	.00	23.40	54.99	.44
1979	8	5.38	4.00	.00	1.40	99.54	3.84
1979	9	10.68	9.89	.00	20.70	131.26	.52
1979	10	30.93	24.12	.00	55.10	172.67	.56
1979	11	71.00	37.32	.00	107.60	160.61	.66
1979	12	24.74	17.10	.00	41.80	215.27	.59
1980	1	79.01	27.33	23.61	134.80	182.40	.59
1980	2	37.25	24.98	.00	49.60	159.22	.75
1980	3	28.00	15.51	.00	45.30	159.99	.62
1980	4	7.27	14.92	.00	22.20	123.71	.33
1980	5	200.79	28.09	196.13	425.50	67.35	.47
1980	6	60.23	11.20	.00	70.00	68.33	.86
1980	7	13.66	8.66	.00	22.50	69.60	.61
1980	8	.34	4.36	.00	4.30	99.91	.08
1980	9	1.18	2.42	.00	3.60	164.85	.33
1980	10	19.96	17.93	.00	37.90	166.68	.53
1980	11	13.55	10.46	.00	24.00	216.35	.56
1980	12	107.68	25.85	34.20	196.50	182.54	.55
1981	1	56.23	17.63	.00	17.80	202.14	3.16
1981	2	108.35	52.48	.00	177.80	137.26	.61
1981	3	11.75	13.74	.00	35.10	186.68	.33
1981	4	124.35	21.86	72.61	202.00	96.58	.62
1981	5	66.93	25.09	74.07	169.10	68.74	.40
1981	6	.39	5.13	.00	6.70	57.44	.06
1981	7	12.59	8.60	.00	21.20	69.23	.59
1981	8	2.51	5.06	.00	7.60	145.89	.33
1981	9	36.51	13.76	.00	50.60	155.19	.72
1981	10	80.09	31.15	.00	110.70	168.21	.72
1981	11	98.01	26.19	.40	135.00	164.83	.73
1981	12	78.06	39.39	.00	118.60	174.43	.66

RATIO: MEAN= .69 STANDARD DEVIATION= .66

TABLE 6-10 : SENSITIVITY STUDY RUN 10 - HIGH EMAX VALUE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
2.00	.50	105.00	600.00	15.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	66.90	52.45	.00	112.50	169.96	.59
1978	2	42.38	23.23	.00	63.40	155.74	.67
1978	3	170.20	56.12	125.48	379.10	130.25	.45
1978	4	20.02	21.44	.00	78.80	113.40	.25
1978	5	18.35	19.45	.00	37.80	70.93	.49
1978	6	35.59	22.01	.00	66.60	46.76	.53
1978	7	.74	8.52	.00	8.20	77.45	.09
1978	8	2.82	7.38	.00	10.20	105.40	.28
1978	9	19.65	20.75	.00	42.00	147.24	.47
1978	10	55.77	36.87	.00	89.40	161.08	.62
1978	11	39.42	39.58	.00	79.20	157.69	.50
1978	12	115.55	50.46	12.77	187.60	172.06	.62
1979	1	108.00	52.01	42.31	193.00	181.44	.56
1979	2	13.38	23.88	.00	33.70	133.96	.40
1979	3	70.90	44.80	.00	117.10	144.77	.61
1979	4	49.99	26.66	.00	80.00	97.71	.62
1979	5	96.14	25.26	6.00	117.20	75.06	.82
1979	6	55.25	10.19	11.86	77.10	51.73	.72
1979	7	9.91	10.60	.00	23.40	54.99	.42
1979	8	4.64	4.71	.00	1.40	99.54	3.32
1979	9	8.45	12.20	.00	20.70	131.26	.41
1979	10	24.08	31.00	.00	55.10	172.67	.44
1979	11	58.98	49.03	.00	107.60	160.61	.55
1979	12	17.53	24.29	.00	41.80	215.27	.42
1980	1	71.26	35.96	23.60	134.80	182.40	.53
1980	2	30.56	31.66	.00	49.60	159.22	.62
1980	3	24.56	18.95	.00	45.30	159.99	.54
1980	4	6.37	15.83	.00	22.20	123.71	.29
1980	5	193.86	35.18	196.13	425.50	67.35	.46
1980	6	58.04	13.19	.00	70.00	68.33	.83
1980	7	12.89	9.49	.00	22.50	69.60	.57
1980	8	.20	4.43	.00	4.30	99.91	.05
1980	9	.84	2.76	.00	3.60	164.85	.23
1980	10	14.17	23.73	.00	37.90	166.68	.37
1980	11	9.60	14.40	.00	24.00	216.35	.40
1980	12	100.04	33.77	34.20	196.50	182.54	.51
1981	1	50.68	22.71	.00	17.80	202.14	2.85
1981	2	90.30	70.69	.00	177.80	137.26	.51
1981	3	10.75	15.01	.00	35.10	186.68	.31
1981	4	120.47	25.94	72.36	202.00	96.58	.60
1981	5	61.07	30.97	74.07	169.10	68.74	.36
1981	6	.29	5.14	.00	6.70	57.44	.04
1981	7	11.77	9.42	.00	21.20	69.23	.56
1981	8	2.02	5.56	.00	7.60	145.89	.27
1981	9	30.55	19.91	.00	50.60	155.19	.60
1981	10	68.55	42.25	.00	110.70	168.21	.62
1981	11	93.58	30.62	.40	135.00	164.83	.69
1981	12	65.07	52.97	.00	118.60	174.43	.55

RATIO: MEAN= .60 STANDARD DEVIATION= .58

TABLE 6-11 : SENSITIVITY STUDY RUN 11 - LOW SDRY VALUE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
2.00	.50	105.00	600.00	10.00	22.50

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	94.96	46.51	.00	112.50	169.96	.84
1978	2	44.91	20.91	.00	63.40	155.74	.71
1978	3	211.60	48.90	91.17	379.10	130.25	.56
1978	4	23.76	17.99	.00	78.80	113.40	.30
1978	5	20.57	17.23	.00	37.60	70.93	.54
1978	6	37.01	20.59	.00	66.60	46.76	.56
1978	7	.97	8.30	.00	8.20	77.45	.12
1978	8	3.22	6.98	.00	10.20	105.40	.32
1978	9	22.70	17.37	.00	42.00	147.24	.54
1978	10	62.65	30.13	.00	89.40	161.08	.70
1978	11	47.56	31.44	.00	79.20	157.69	.60
1978	12	133.36	44.21	.00	187.60	172.06	.71
1979	1	137.22	45.76	20.12	193.00	181.44	.71
1979	2	17.29	20.77	.00	33.70	133.96	.51
1979	3	77.26	38.45	.00	117.10	144.77	.66
1979	4	53.28	22.73	.00	80.00	97.71	.67
1979	5	107.67	19.72	.00	117.20	75.06	.92
1979	6	68.67	8.61	.00	77.10	51.73	.89
1979	7	10.23	10.31	.00	23.40	54.99	.44
1979	8	5.19	4.18	.00	1.40	99.54	3.71
1979	9	10.03	10.56	.00	20.70	131.26	.48
1979	10	28.66	26.41	.00	55.10	172.67	.52
1979	11	66.76	41.47	.00	107.60	160.61	.62
1979	12	22.91	18.92	.00	41.80	215.27	.55
1980	1	98.54	30.50	1.11	134.80	182.40	.73
1980	2	35.34	26.89	.00	49.60	159.22	.71
1980	3	27.01	16.50	.00	45.30	159.99	.60
1980	4	6.94	15.25	.00	22.20	123.71	.31
1980	5	245.47	32.51	147.07	425.50	67.35	.58
1980	6	59.68	11.71	.00	70.00	68.33	.85
1980	7	13.47	8.86	.00	22.50	69.60	.60
1980	8	.30	4.38	.00	4.30	99.91	.07
1980	9	1.10	2.50	.00	3.60	164.85	.30
1980	10	18.49	19.40	.00	37.90	166.68	.49
1980	11	12.55	11.46	.00	24.00	216.35	.52
1980	12	125.98	30.30	11.70	196.50	182.54	.64
1981	1	54.15	19.24	.00	17.80	202.14	3.04
1981	2	102.21	58.67	.00	177.80	137.26	.57
1981	3	11.17	14.68	.00	35.10	186.68	.32
1981	4	144.81	24.11	49.89	202.00	96.58	.72
1981	5	85.16	29.35	51.57	169.10	68.74	.50
1981	6	.39	5.14	.00	6.70	57.44	.06
1981	7	12.31	8.86	.00	21.20	69.23	.58
1981	8	2.33	5.24	.00	7.60	145.89	.31
1981	9	35.01	15.31	.00	50.60	155.19	.69
1981	10	76.84	34.28	.00	110.70	168.21	.69
1981	11	96.68	27.92	.00	135.00	164.83	.72
1981	12	73.46	44.16	.00	118.60	174.43	.62

RATIO: MEAN= .69 STANDARD DEVIATION= .64

TABLE 6-12 : SENSITIVITY STUDY RUN 12 - HIGH SDRY VALUE

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
2.00	.50	105.00	600.00	10.00	67.50

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	51.19	45.70	.00	112.50	169.96	.45
1978	2	42.10	23.51	.00	63.40	155.74	.66
1978	3	124.97	55.78	171.08	379.10	130.25	.33
1978	4	19.60	21.84	.00	78.80	113.40	.25
1978	5	18.09	19.71	.00	37.80	70.93	.48
1978	6	35.45	22.15	.00	66.60	46.76	.53
1978	7	.71	8.55	.00	8.20	77.45	.09
1978	8	2.77	7.43	.00	10.20	105.40	.27
1978	9	19.32	21.13	.00	42.00	147.24	.46
1978	10	55.22	37.42	.00	89.40	161.08	.62
1978	11	38.95	40.05	.00	79.20	157.69	.49
1978	12	81.35	50.29	48.43	187.60	172.06	.43
1979	1	76.79	49.14	73.17	193.00	181.44	.40
1979	2	13.00	24.13	.00	33.70	133.96	.39
1979	3	54.59	42.48	18.63	117.10	144.77	.47
1979	4	48.91	27.00	.90	80.00	97.71	.61
1979	5	74.17	24.51	28.49	117.20	75.06	.63
1979	6	34.36	8.58	34.36	77.10	51.73	.45
1979	7	9.87	10.63	.00	23.40	54.99	.42
1979	8	4.58	4.77	.00	1.40	99.54	3.27
1979	9	8.30	12.35	.00	20.70	131.26	.40
1979	10	23.63	31.46	.00	55.10	172.67	.43
1979	11	58.39	49.60	.00	107.60	160.61	.54
1979	12	16.91	24.90	.00	41.80	215.27	.40
1980	1	49.32	35.49	46.10	134.80	182.40	.37
1980	2	30.06	32.16	.00	49.60	159.22	.61
1980	3	24.41	19.09	.00	45.30	159.99	.54
1980	4	6.32	15.88	.00	22.20	123.71	.28
1980	5	135.33	32.36	257.49	425.50	67.35	.32
1980	6	57.85	13.36	.00	70.00	68.33	.83
1980	7	12.82	9.56	.00	22.50	69.60	.57
1980	8	.19	4.43	.00	4.30	99.91	.04
1980	9	.81	2.79	.00	3.60	164.85	.23
1980	10	13.89	24.01	.00	37.90	166.68	.37
1980	11	9.26	14.74	.00	24.00	216.35	.39
1980	12	70.07	32.81	73.56	196.50	182.54	.36
1981	1	35.20	21.34	16.86	17.80	202.14	1.98
1981	2	89.15	71.85	.00	177.80	137.26	.50
1981	3	10.71	15.03	.00	35.10	186.68	.31
1981	4	89.02	25.55	104.19	202.00	96.58	.44
1981	5	40.16	29.38	96.57	169.10	68.74	.24
1981	6	.28	5.14	.00	6.70	57.44	.04
1981	7	11.71	9.49	.00	21.20	69.23	.55
1981	8	1.99	5.60	.00	7.60	145.89	.26
1981	9	30.03	20.44	.00	50.60	155.19	.59
1981	10	67.72	43.04	.00	110.70	168.21	.61
1981	11	63.18	29.88	31.54	135.00	164.83	.47
1981	12	64.41	53.67	.00	118.60	174.43	.54

RATIO: MEAN= .53 STANDARD DEVIATION= .51

TABLE 6-13 : SENSITIVITY STUDY RESULTS COMPARED WITH REFERENCE RUN

PARAMETER	NEW VALUE	% CHANGE	RATIO MEAN	% CHANGE	RATIO STANDARD DEVIATION	% CHANGE
INTCAP	1.0	-50.0	0.71	+10.9	0.61	-1.6
	3.0	+50.0	0.59	-7.8	0.61	-1.6
GCONST	0.25	-50.0	0.56	-12.5	0.69	+11.3
	0.75	+50.0	0.64	0.0	0.45	-27.4
SOILCAP	52.5	-50.0	0.16	-75.0	0.20	-67.7
	157.5	+50.0	0.73	+14.06	0.65	+4.8
INFMAX	300.0	-50.0	0.64	0.0	0.62	0.0
	900.0	+50.0	0.64	0.0	0.62	0.0
EMAX	5.0	-50.0	0.69	+7.8	0.66	+6.5
	15.0	+50.0	0.60	-6.3	0.58	-6.5
SDRY	22.5	-50.0	0.69	+7.8	0.64	+3.2
	67.5	+50.0	0.53	-17.2	0.51	-17.7

Initially a reference case was established that all other cases could be compared with. An estimate of the likely range of values that the various parameters could assume was made based largely on the values presented in Table 5.1. The midpoint of the range of possible values was used as the reference case value for each of the model parameters.

The reference parameter values used were:

INTCAP: 2.0 mm GCONST: 0.5 SOILCAP: 105 mm

INFMAX: 600 mm EMAX : 10 mm SDRY : 45 mm

The value of each parameter was first decreased by 50% and then increased by 50% while keeping the value of all other parameters constant at the reference case values. The results of the individual runs are given in Tables 6.2 to 6.12 while the results are summarised and analysied in Table 6.13. Note that no run was undertaken for a high value of INFMAX as the low value had no effect upon the model performance which indicated that a higher value would also have no effect.

The sensitivity study indicates that the values of SOILCAP and SDRY have a marked effect on the ratio value. These two parameters control the size of the effective soil store. An increase in SOILCAP or a decrease in SDRY will increase the size of the soil store and in turn increase the ratio value.

The effect of INTCAP upon the mean ratio value was less marked than SDRY or SOILCAP, but was still capable of changing the result by more than 10% over the range of variation considered. The range of possible values with a grass cover is relatively small making the choice of a value comparitively easy but with a different vegetal cover the assignment of a value could be more difficult.

GCONST affected the ratio mean markedly when a low value was used but had no effect on the mean value when a high value was used. The value of GCONST is likely to depend upon the soil type being modelled. The sandy loam being modelled in this study is a relatively free draining soil and hence it is likely that a high value of GCONST should be used, as GCONST determines the rate at which water will drain from the soil store to the groundwater. As mentioned the use of a higher value of GCONST had no effect on the mean ratio value but the sensitivity study results indicate that a high value reduces the variation of the ratio values. This is to be expected as a greater proportion of the rainfall will drain from the surface soil layer within the timestep in which it fell rather than contributing to recharge in a later timestep.

It was found that INFMAX had no effect over the range of values considered. This is not unexpected as surface infiltration rates are not likely to be the governing condition in free draining soils such as the sandy loam considered here. INFMAX could be expected to play a part in the modelling of a soil with a higher clay content, or a semi permeable layer at the surface.

It should be noted that for the assumed parameters runoff only occurs when the soil store is saturated and is not governed by the infiltration characteristics of the soil surface.

EMAX was found to play a relatively minor part in the model performance. The choice of values for EMAX is not critical to the model performance. This is useful as estimates only are available for this parameter.

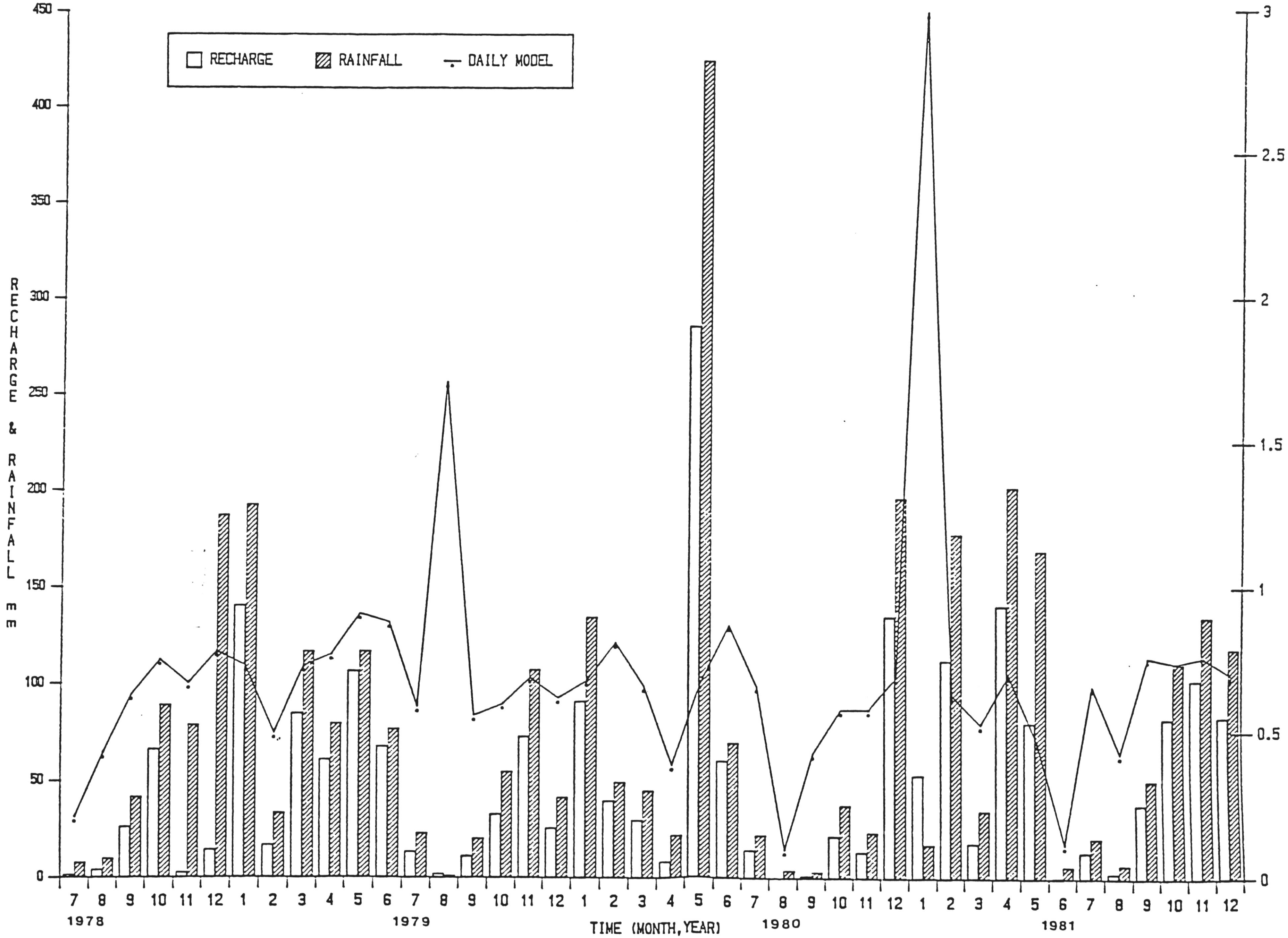

Figure 6-1 : CALIBRATION RUN 2 - GCONST = 0.80

6.3 Calibration Runs

The aim of the calibration runs was to achieve a mean ratio value of 0.70. With the sensitivity study reference case as a starting point this could be achieved by decreasing INTCAP, increasing SOILCAP, decreasing EMAX and decreasing SDRY. As mentioned above EMAX has a relatively small effect and the value to be used is difficult to assess accurately. EMAX was therefore left at the reference case value of 10 mm.

As explained above SDRY and SOILCAP have a complementary effect so therefore only one value need be changed. SOILCAP was increased to 112 mm while leaving SDRY set to 45 mm. Recent involvement by the author with a model study of the Berriquin Irrigation District lead to a value of 1.5 mm for INTCAP. This was the value adopted for grasslands in the Berriquin study after intensive calibration. To date there has been no published description of the Berriquin study.

Higher values of GCONST were shown in the sensitivity study (i.e. above 0.5) to have no effect upon the mean ratio value, but to cause a decrease in variability of the ratio from month to month as the value of GCONST was increased. For the sandy loam soil type modelled it is likely that higher values of GCONST are applicable. Three calibration runs were undertaken using values of 0.70, 0.80 and 0.90 for GCONST. The standard deviation for these three runs was 0.49, 0.43 and 0.40 respectively. The results are given in Tables 6.14, 6.15 and 6.16.

The monthly recharge, rainfall and ratio of runoff to rainfall for Calibration Run 2 (GCONST = 0.80) are plotted in Figure 6.1. It can be seen that while the mean ratio value was 0.70 (see Table 6.15) considerable variation occurred.

TABLE 6-14: CALIBRATION RUN 1 - GCONST = 0.70

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
1.50	.70	112.00	600.00	10.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	87.16	36.68	.00	112.50	169.96	.77
1978	2	44.34	18.45	.00	63.40	155.74	.70
1978	3	222.40	42.22	87.27	379.10	130.25	.59
1978	4	26.23	14.91	.00	78.80	113.40	.33
1978	5	23.04	14.76	.00	37.80	70.93	.61
1978	6	40.30	17.28	.00	66.60	46.76	.61
1978	7	1.74	7.31	.00	8.20	77.45	.21
1978	8	4.32	5.88	.00	10.20	105.40	.42
1978	9	25.55	15.54	.00	42.00	147.24	.61
1978	10	65.75	25.71	.00	89.40	161.08	.74
1978	11	51.67	27.36	.00	79.20	157.69	.65
1978	12	143.43	37.93	.53	187.60	172.06	.76
1979	1	134.47	36.41	24.74	193.00	181.44	.70
1979	2	16.92	18.74	.00	33.70	133.96	.50
1979	3	83.55	32.15	.00	117.10	144.77	.71
1979	4	59.32	20.12	.00	80.00	97.71	.74
1979	5	106.99	14.18	.00	117.20	75.06	.91
1979	6	66.97	5.96	4.37	77.10	51.73	.87
1979	7	13.02	9.33	.00	23.40	54.99	.56
1979	8	3.30	3.63	.00	1.40	99.54	2.36
1979	9	11.27	9.42	.00	20.70	131.26	.54
1979	10	32.29	22.79	.00	55.10	172.67	.59
1979	11	71.59	36.20	.00	107.60	160.61	.67
1979	12	25.27	16.53	.00	41.80	215.27	.60
1980	1	89.18	25.68	17.10	134.80	182.40	.66
1980	2	39.04	23.18	.00	49.60	159.22	.79
1980	3	29.30	14.20	.00	45.30	159.99	.65
1980	4	8.47	13.72	.00	22.20	123.71	.38
1980	5	264.52	26.34	134.54	425.50	67.35	.62
1980	6	60.37	10.34	.00	70.00	68.33	.86
1980	7	14.60	7.89	.00	22.50	69.60	.65
1980	8	.44	3.91	.00	4.30	99.91	.10
1980	9	1.52	2.08	.00	3.60	164.85	.42
1980	10	21.35	16.55	.00	37.90	166.68	.56
1980	11	13.59	10.41	.00	24.00	216.35	.57
1980	12	127.79	25.11	27.70	196.50	182.54	.65
1981	1	54.18	14.65	.00	17.80	202.14	3.04
1981	2	109.98	50.98	.00	177.80	137.26	.62
1981	3	16.47	13.09	.00	35.10	186.68	.47
1981	4	137.83	21.30	59.68	202.00	96.58	.68
1981	5	77.54	23.18	65.37	169.10	68.74	.46
1981	6	.75	4.65	.00	6.70	57.44	.11
1981	7	13.67	7.53	.00	21.20	69.23	.64
1981	8	3.19	4.40	.00	7.60	145.89	.42
1981	9	37.26	13.32	.00	50.60	155.19	.74
1981	10	80.86	29.60	.00	110.70	168.21	.73
1981	11	100.96	23.56	.00	135.00	164.83	.75
1981	12	80.60	37.99	.00	118.60	174.43	.68

RATIO: MEAN= .70 STANDARD DEVIATION= .49

TABLE 6-15 : CALIBRATION RUN 2 - GCONST = 0.80

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
1.50	.80	112.00	600.00	10.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	89.55	34.58	.00	112.50	169.96	.80
1978	2	44.27	17.63	.00	63.40	155.74	.70
1978	3	236.62	40.90	74.48	379.10	130.25	.62
1978	4	26.72	14.23	.00	78.80	113.40	.34
1978	5	23.54	14.26	.00	37.80	70.93	.62
1978	6	41.34	16.25	.00	66.60	46.76	.62
1978	7	1.76	7.26	.00	8.20	77.45	.21
1978	8	4.43	5.77	.00	10.20	105.40	.43
1978	9	26.55	14.96	.00	42.00	147.24	.63
1978	10	66.63	24.14	.00	89.40	161.08	.75
1978	11	52.91	26.10	.00	79.20	157.69	.67
1978	12	145.70	36.22	.51	187.60	172.06	.78
1979	1	140.84	33.79	19.37	193.00	181.44	.73
1979	2	16.99	18.23	.00	33.70	133.96	.50
1979	3	85.25	30.45	.00	117.10	144.77	.73
1979	4	61.37	18.71	.00	80.00	97.71	.77
1979	5	106.90	12.36	.00	117.20	75.06	.91
1979	6	68.03	5.27	4.00	77.10	51.73	.88
1979	7	13.80	9.10	.00	23.40	54.99	.59
1979	8	2.39	3.32	.00	1.40	99.54	1.71
1979	9	11.56	9.14	.00	20.70	131.26	.56
1979	10	33.13	21.96	.00	55.10	172.67	.60
1979	11	73.26	34.42	.00	107.60	160.61	.68
1979	12	25.92	15.88	.00	41.80	215.27	.62
1980	1	91.30	24.51	17.10	134.80	182.40	.68
1980	2	40.01	22.19	.00	49.60	159.22	.81
1980	3	30.06	13.44	.00	45.30	159.99	.66
1980	4	8.69	13.51	.00	22.20	123.71	.39
1980	5	286.43	24.53	114.51	425.50	67.35	.67
1980	6	60.67	9.81	.00	70.00	68.33	.87
1980	7	14.80	7.70	.00	22.50	69.60	.66
1980	8	.42	3.89	.00	4.30	99.91	.10
1980	9	1.56	2.04	.00	3.60	164.85	.43
1980	10	21.90	16.00	.00	37.90	166.68	.58
1980	11	13.94	10.06	.00	24.00	216.35	.58
1980	12	135.25	23.14	27.70	196.50	182.54	.69
1981	1	53.49	13.20	.00	17.80	202.14	3.00
1981	2	112.51	48.54	.00	177.80	137.26	.63
1981	3	18.51	13.04	.00	35.10	186.68	.53
1981	4	140.78	20.71	57.22	202.00	96.58	.70
1981	5	80.30	21.39	64.41	169.10	68.74	.47
1981	6	.77	4.63	.00	6.70	57.44	.12
1981	7	13.98	7.22	.00	21.20	69.23	.66
1981	8	3.28	4.32	.00	7.60	145.89	.43
1981	9	38.23	12.36	.00	50.60	155.19	.76
1981	10	82.36	27.99	.00	110.70	168.21	.74
1981	11	102.02	22.53	.00	135.00	164.83	.76
1981	12	83.01	36.00	.00	118.60	174.43	.70

RATIO: MEAN= .70 STANDARD DEVIATION= .43

TABLE 6-16 : CALIBRATION RUN 3 - GCONST = 0.90

INTCAP	GCONST	SOILCAP	INFMAX	EMAX	SDRY
1.50	.90	112.00	600.00	10.00	45.00

YEAR	MTH	RECHARGE	EVAPOTRANS	RUNOFF	RAINFALL	PET	RATIO
1978	1	91.42	32.81	.00	112.50	169.96	.81
1978	2	44.28	17.10	.00	63.40	155.74	.70
1978	3	250.12	39.60	62.34	379.10	130.25	.66
1978	4	27.16	13.68	.00	78.80	113.40	.34
1978	5	23.93	13.87	.00	37.80	70.93	.63
1978	6	42.18	15.42	.00	66.60	46.76	.63
1978	7	1.77	7.22	.00	8.20	77.45	.22
1978	8	4.52	5.68	.00	10.20	105.40	.44
1978	9	27.35	14.47	.00	42.00	147.24	.65
1978	10	67.17	22.92	.00	89.40	161.08	.75
1978	11	53.99	25.02	.00	79.20	157.69	.68
1978	12	147.08	35.00	.50	187.60	172.06	.78
1979	1	147.21	31.79	14.23	193.00	181.44	.76
1979	2	17.19	17.85	.00	33.70	133.96	.51
1979	3	86.58	29.12	.00	117.10	144.77	.74
1979	4	62.85	17.50	.00	80.00	97.71	.79
1979	5	106.80	11.20	.00	117.20	75.06	.91
1979	6	69.24	4.43	3.63	77.10	51.73	.90
1979	7	14.38	8.87	.00	23.40	54.99	.61
1979	8	1.43	3.08	.00	1.40	99.54	1.02
1979	9	11.80	8.90	.00	20.70	131.26	.57
1979	10	33.81	21.29	.00	55.10	172.67	.61
1979	11	74.62	33.00	.00	107.60	160.61	.69
1979	12	26.45	15.35	.00	41.80	215.27	.63
1980	1	93.67	23.08	17.10	134.60	182.40	.69
1980	2	40.82	21.38	.00	49.60	159.22	.82
1980	3	30.67	12.83	.00	45.30	159.99	.68
1980	4	8.87	13.33	.00	22.20	123.71	.40
1980	5	306.17	23.05	96.27	425.50	67.35	.72
1980	6	61.02	9.33	.00	70.00	68.33	.87
1980	7	14.95	7.55	.00	22.50	69.60	.66
1980	8	.42	3.88	.00	4.30	99.91	.10
1980	9	1.59	2.01	.00	3.60	164.85	.44
1980	10	22.34	15.56	.00	37.90	166.68	.59
1980	11	14.23	9.77	.00	24.00	216.35	.59
1980	12	141.88	21.53	27.70	196.50	182.54	.72
1981	1	52.45	12.09	.00	17.80	202.14	2.95
1981	2	114.58	46.54	.00	177.80	137.26	.64
1981	3	20.53	13.00	.00	35.10	186.68	.58
1981	4	143.11	20.33	55.16	202.00	96.58	.71
1981	5	82.72	19.93	63.45	169.10	68.74	.49
1981	6	.79	4.61	.00	6.70	57.44	.12
1981	7	14.22	6.98	.00	21.20	69.23	.67
1981	8	3.35	4.25	.00	7.60	145.89	.44
1981	9	39.02	11.58	.00	50.60	155.19	.77
1981	10	83.55	26.75	.00	110.70	168.21	.75
1981	11	103.25	21.32	.00	135.00	164.83	.76
1981	12	84.98	34.37	.00	118.60	174.43	.72

RATIO: MEAN= .69 STANDARD DEVIATION= .40

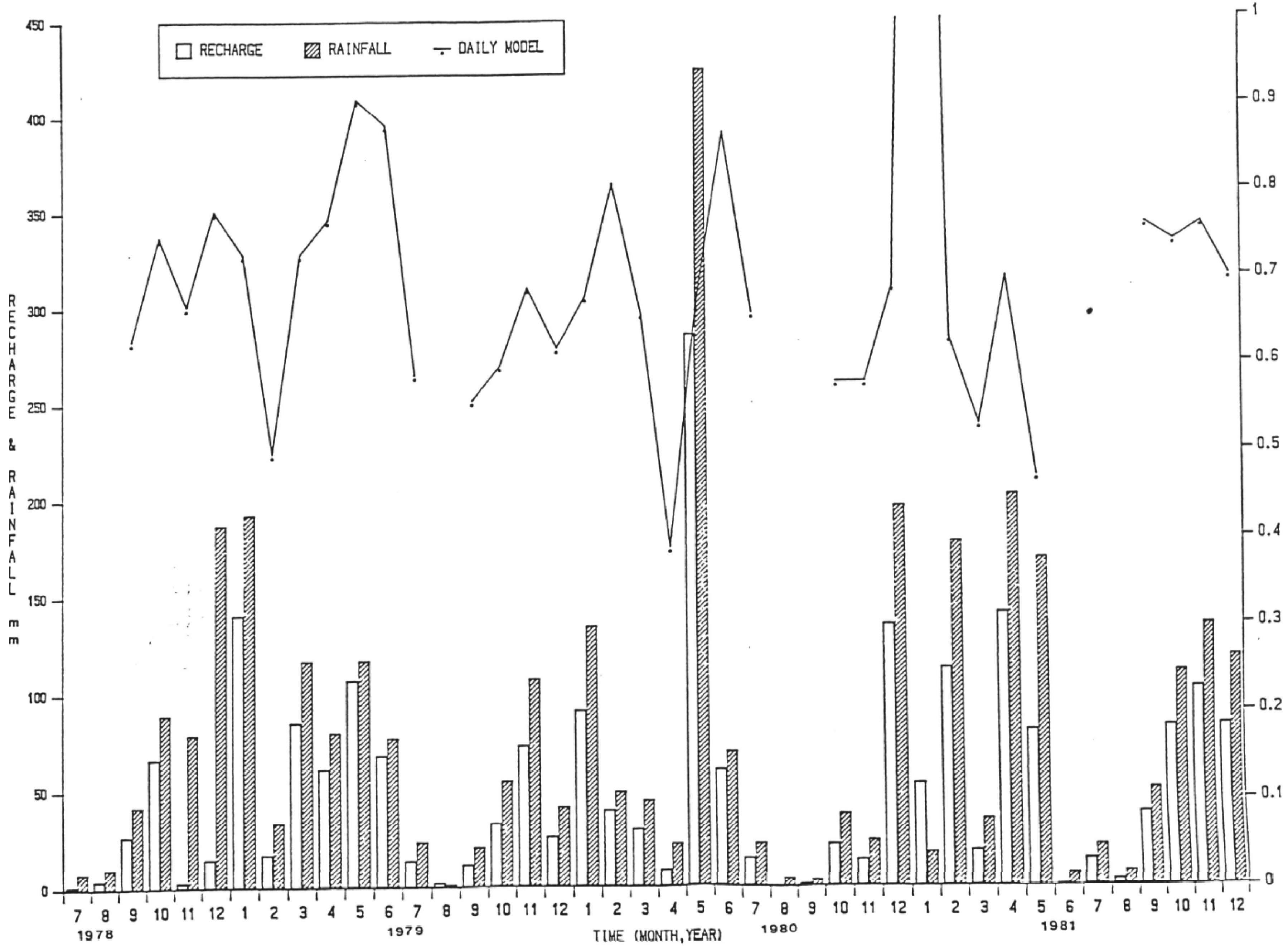

FIGURE 6-2 : CALIBRATION RUN 2 - GCONST = 0.80

Ratio values shown for months where recharge is greater than 5mm

To a certain extent this variation is not important. The aim is to achieve a recharge rate to the groundwater system equal to 70% of the recorded rainfall. The daily model provides the estimated recharge from the bottom of the root zone to the soil. The soil layer over the groundwater system for the Sherwood Borefield varies in thickness from 5 to 10 metres, and contains a variety of soil types(see Figure 3.2). While all the water finding its way to the bottom of the root zone is likely to eventually find its way to the groundwater system there will be a time delay as the water travels the 5 to 10 metres to the groundwater system. This is likely to have an averaging effect. This averaging effect will depend in part on the degree of saturation. For this reason considerable variations in the recharge to rainfall ratio are acceptable as long as the mean value falls in the required range.

The data listed in Table 6.15 and plotted in Figure 6.1 indicates that little recharge to groundwater occurs in some months. The monthly data was analysed to evaluate the effect of excluding the data from any month for which a low recharge was calculated.

Figure 6.2 plots the values of the recharge to rainfall ratio for months in which recharge was greater than 5 mm, while Figure 6.3 repeats the exercise for months in which recharge was greater than 20 mm. These values can be compared with the mean monthly recharge for Calibration Run 2 of 56.47 mm.

It can be observed in Figure 6.2 that by excluding the values of the recharge to rainfall ratio calculated from months with a recharge less than 5 mm the variation of the values is reduced. The mean ratio based on these values is 0.74 with a standard deviation of 0.41.

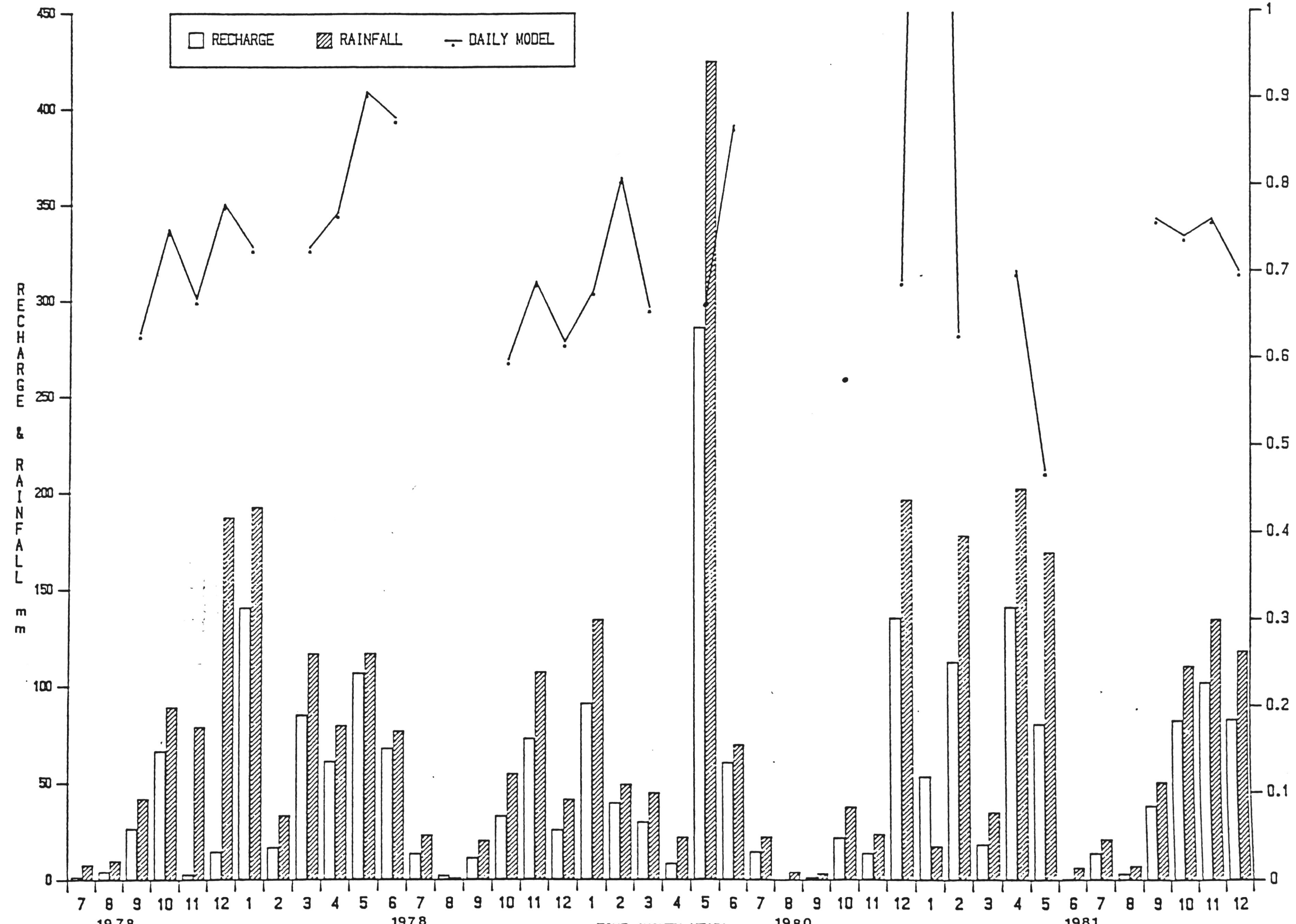

FIGURE 6-3 : CALIBRATION RUN 2 - GCONST = 0.80

Ratio values shown for months where recharge is greater than 20mm

It should be noted that by restricting the range of plotted ratio values to between 0 and 1 the value of 3.00 calculated for January 1981 has effectively been excluded from Figure 6.2 (and from Figure 6.3). The ratio value of 3.0 indicates that the monthly recharge is three times greater than the monthly rainfall. This occured as high rainfall was recorded in the last 2 days of December 1980, some of which contributed to recharge in January 1981. January 1981 was a month of low rainfall. The high ratio value is accounted for by the recharge in January 1981 originating in part from December 1980 rainfall.

Figure 6.3 illustrates ratio values for months when the recharge was greater than 20 mm. The mean ratio based on these values is 0.80 with a standard deviation of 0.45. However these values are distorted by the atypical value of 3.0 amongst a small sample. If this value is excluded the mean value is 0.71 with a standard deviation of 0.10.

It can therefore be seen that a mean value of 0.7 for the recharge to rainfall ratio has been achieved that is valid even if the mean value is weighted according to monthly recharge. Such a weighting takes account of the greater total recharge effect higher monthly recharge values have.

The model was also capable of predicting surface runoff. However no data was available that allowed the accuracy of the runoff predictions to be examined. The calculated values do not appear to be unreasonable.

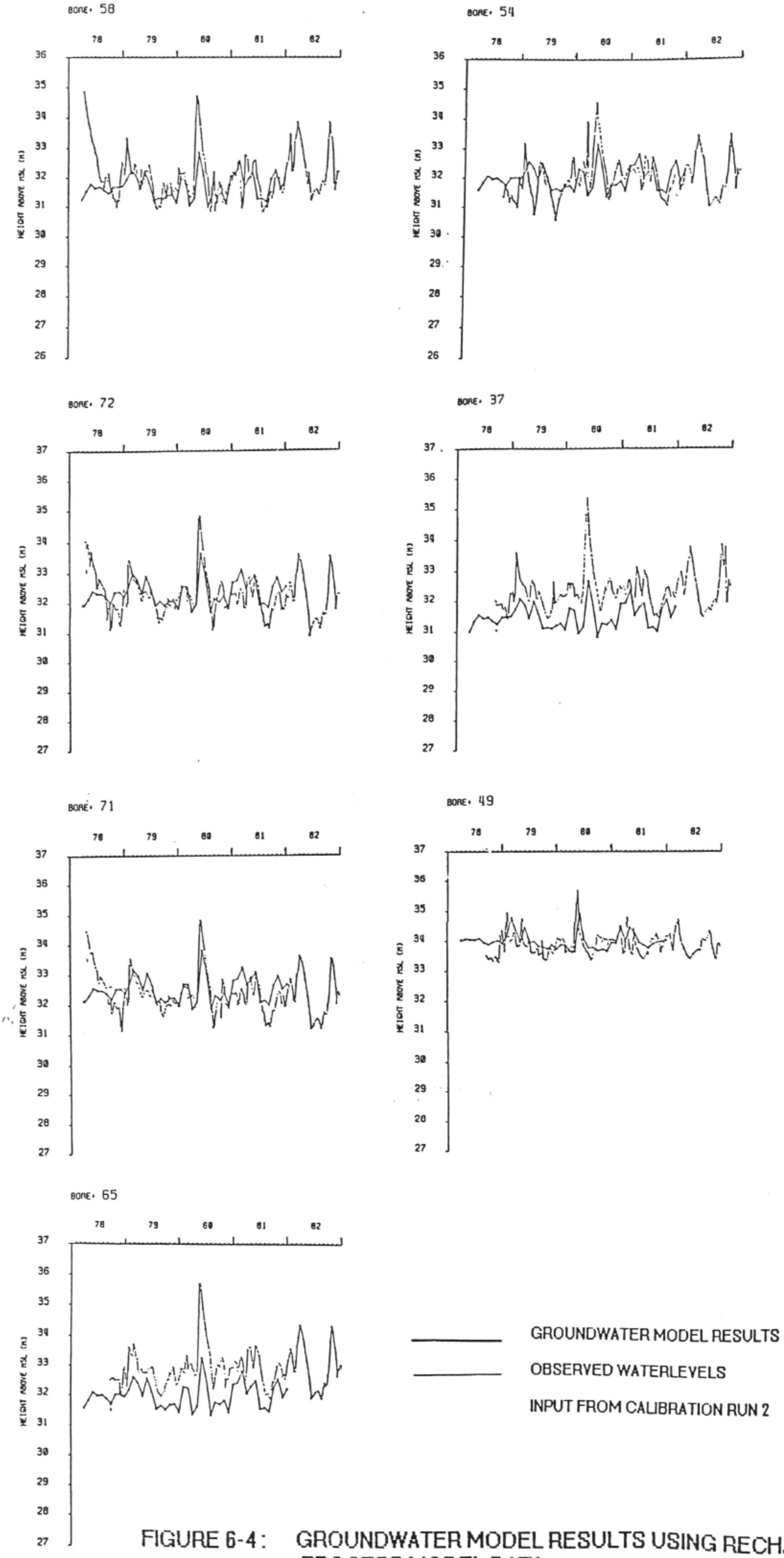

FIGURE 6-4: GROUNDWATER MODEL RESULTS USING RECHARGE PROCESS MODEL DATA

6.4 Rerun of groundwater model using recharge process model data

The recharge values obtained from the calibration runs (Tables 6-14 to 6-16) were used as the groundwater recharge input for the Sherwood Borefield groundwater model.

Comparisons of the simulated hydrographs for bores distributed throughout the borefield indicated that the results produced by the three sets of input data were virtually identical. The magnitude of the computed peaks increased very slightly as the value of GCONST used in the process model reduced from 0.90 to 0.70.

Comparisons of the computed hydrographs with the observed hydrographs using as input data the results from Calibration Run 2 are illustrated in Figure 6-4. The match of the computed and observed hydrographs (the observed hydrographs were sampled at weekly intervals) are reasonably good.

Comparisons with the results produced by Merrick N.P. and Blair A.H. (1986) using the assumption that groundwater recharge was equal to 70% of the monthly rainfall (refer to Figure 4-3) indicate very similar computed bore hydrographs.

7 CONCLUSIONS

The developed model was calibrated by comparing the monthly predictions with the monthly recharge rates previously used for successful calibration of a finite element model. After calibration of the daily model a mean value of 0.7 for the recharge to rainfall ratio was achieved that was valid even if the monthly ratios were weighted according to calculated monthly recharge. Such a weighting takes account of the greater total recharge effect higher monthly recharge values have. This mean ratio agrees with the recharge rate to the groundwater system of 70% of the recorded rainfall previously used by other workers (Merrick, M.P. and Blair, A.H., 1986) to successfully calibrate a finite element model of the Sherwood Borefield groundwater system near Kempsey.

While a mean ratio value of 0.70 was achieved considerable variation about this value occurred. To a certain extent this variation is not important. The daily model provides the estimated recharge to the bottom of the root zone of the soil. The soil layer over the groundwater system for the Sherwood Borefield varies in thicknes from 5 to 10 metres. There will be a time delay as the recharge travels through this layer which is likely to have an averaging effect. This averaging effect will depend in part of the degree of saturation. For this reason considerable variations in the recharge to rainfall ratio are acceptable as long as the mean value falls in the required range.

The model was also capable of predicting surface runoff. However no data was available that allowed the accuracy of the runoff predictions to be examined. The calculated values did not appear to be unreasonable.

The recharge values obtained from the calibration runs were used as the groundwater recharge input for the Sherwood Borefield groundwater model. It was found that the results produced by the three sets of input data were virtually identical. The magnitude of the computed hydrograph peaks increased very slightly as GCONST was reduced.

The match of the computed hydrographs based on the process recharge model data and the observed hydrographs are reasonably good given the simplicity of both the recharge and groundwater conceptual models and the smoothing effects of the groundwater model monthly timestep.

Comparisons of the results produced by assuming that the monthly recharge was equal to 70% of the monthly rainfall with those produced using the process model recharge data indicate very similar bore hydrographs. This is to be expected as the aim of the calibration studies was to achieve a mean monthly recharge equal to 70% of the monthly rainfall

It is possible that further calibration of the recharge process model may give results that produce simulated bore hydrographs that match the observed bore hydrographs more closely. For example further lowering of the value of GCONST may produce a closer match. However time was not available to undertake the required additional groundwater model runs.

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APPENDIX A : CALCULATION OF INCIDENT SOLAR RADIATION AT THE OUTER LIMIT OF THE ATMOSPHERE

The following equations were derived from first principles by the author. For a description of the basic equations used the reader is referred to Kondratyev K. Y., (1969).

When the earth is at its mean distance from the sun, the solar radiation intensity incident upon a surface normal to the sun's rays and at the outer limit of the atmosphere is known as the solar constant. The currently accepted value of the solar constant is 1387 W/m^2.

The intensity of solar radiation $I_{n,o}$ normal to the sun's rays at the outer limit of the atmosphere varies with the earth-sun distance. The earth follows an elliptical path around the sun and the earth-sun varies from 1.47×10^{11} m on the 3rd January (Perihelion) to 1.52×10^{11} m on the 4th July (Aphelion). This causes $I_{n,o}$ to vary in a way that can be closely approximated by the following equation :

$$I_{n,o} = 1387 \times \{ 1 + 0.033 \times \cos[2\pi \times (N-3) / 365.25] \} \ W/m^2$$

where N is the number of days from the start of the year. This equation provides data that closely matches that given in the Smithonian Physical Tables.

To calculate the solar radiation Rs incident upon a horizontal surface (with respect to the surface below) at the outer limit of the atmosphere over a complete day we have :

$$dRs = I_{h,o}\, dt = I_{n,o} \times \{ [\cos(l) \times \cos(h) \times \cos(d) + \sin(l) \times \sin(d)] / w \}\, dh$$

where :

$I_{h,o}$ = the intensity of solar radiation on a horizontal surface at the outer limit of the

a atmosphere (W/m^2)

l = latitude (radians)

h = hour angle (radians)

d = solar declination (radians)

w = earth's angular velocity (= 7.272×10^{-5} radians/second)

For one day, $I_{n,o}$ and d may be considered as constants. For a particular site l will be a constant. Since hour angles are symmetrical with respect to solar noon, we have :

$$Rs = 2 \times I_{n,o} / w \times [\cos(l) \times \cos(d) \times \int_0^H \cos(h)\, dh + \sin(l) \times \sin(d) \times \int_0^H dh]$$

where H is the hour angle of sunrise and sunset in radians.

H may be found from :

$$\sin(a) = \cos(l) \times \cos(h) \times \cos(d) + \sin(l) \times \sin(d)$$

by setting the solar elevation a equal to zero. This gives :

$$H = \cos^{-1} [-\tan(l) \times \tan(d)]$$

The solar declination d may be calculated from :

$$d = 23.5 \times \sin \{ 2m \times (n-81) / 365.25 \}$$
$$= 23.5 \times \sin \{ 0.9856 \times (N-81) \}$$

where again the angles are in radians.

Integration gives :

$$Rs = 2 / w \times I_{n,o} \times \sin(l) \times \sin(d) \times [H - \tan(H)] \quad J/m^2$$

APPENDIX B : CALCULATION OF HUMIDITY

The equations developed in this appendix were derived from first principles by the author. For a background to the basic equations used the reader is referred to Threlkeld J. L.,1970 and Wiesner C. J., 1970.

B-1 Definition of relative humidity

The relative humidity f is the mass of water vapour (m) in a volume of air relative to the mass the sample would contain if it was saturated (m_s). The ratio of the mass of water vapour to the mass of dry air in a given volume is called the mixing ratio w.

We have : $f = 100/1 \times m / m_s = 100 \times w / w_s$ (%)

From the equation of state it can be shown that :

$$f = 100 \times w / w_s = 100 \times (e / e_s) \times [(p - e_s) / (p - e)]$$

where e and e_s are the water vapour pressure and the saturated water vapour pressure respectively, and p is the atmospheric pressure.

Since $e << e_s << p$ $\quad f \approx 100 \times e / e_s$

B-2 Calculation of humidity f from wet and dry-bulb temperature

The wet-bulb process consists of saturating a sample of air by evaporating water into it. The energy required to evaporate the water comes from the air. The process takes place at a constant pressure over a short period of time.

The heat loss associated with the evaporation of dw Kg of water is $-L \times dw$ where L is the latent heat of vapourisation of water (2454 KJ / Kg at 20°C).

The heat extracted from a unit mass of air is $Cp \times dT$ where Cp is the specific heat of air at a constant pressure (999 J / Kg / °C at 20°C).

As these heat losses and gains must be equal we have :

$$-L \times dw = Cp \times dT$$

Integrating from the initial state w(Ta),Ta to the final state w_s(Tw),Tw where w(Ta) is the mixing ratio at the dry-bulb temperature Ta and w_s(Tw) is the mixing ratio at the wet-bulb temperature Tw we have :

$$Cp\,(Tw - Ta) = -L\,[\,w_s(Tw) - w(Ta)\,]$$

ie. $$ws(Tw) - w(Ta) = (Cp / L) \times (Ta - Tw)$$

ie. $$w(Ta) = w_s(Tw) - (Cp / L) \times (Ta - Tw)$$

$(Cp/L=4.2x10^{-4}\,{}^{o}C\text{-}1$ at $20^{o}C)$

We wish to evaluate $f = 100 \times w(Ta) / w_s(Ta) = 100 \times e(Ta) / e_s(Ta)$. From the Clausius Clapeyron equation we have :

$$e_s(Ta) = \exp[21.43 - 5353 / (273.15 + Ta)] \quad (Ta\ {}^{o}C)$$

and $$w_s(Ta) = [\,0.622 / p(mb)\,] \times e_s(Ta)$$

similarly $$ws(Tw) = [\,0.622 / p(mb)\,] \times \exp[21.43 - 5353 / (273.15 + Tw)\,]$$

where Tw is in °C.

From above we have :

$$w(Ta) = ws(Tw) - [\,Cp / L\,] \times [\,Ta - Tw\,]$$

and $$f = w(Ta) / w_s(Tw)$$

Hence if Ta and Tw are known f and e_s can be calculated. The error introduced by assuming a standard atmospheric pressure of 1013 mb is very small.

APPENDIX C : PROGRAM LISTING - CALCULATION OF MODEL DATA

PROGRAM NAME : CALDAT.FOR
COMPILER : MICROSOFT FORTRAN
COMPUTER : PC-XT WITH MS-DOS OPERATING SYSTEM

```
C     PROGRAM TO CALCULATE DAILY AND MONTHLY
C     MODEL DATA FILES (DAY.DAT & MTH.DAT)
C     FROM MET. DATA(MET.DAT).
      DIMENSION RA(365)
      INTEGER YR,LYR,MTH,LMTH,DAY,LDAY,RDAY
      REAL LAT,MPET,MRAIN
C     CONVERSION FACTOR FOR DEGREES TO RADIANS
      DTR=0.0174533
C     CALCULATE Ra
      PI=3.14159
C     LAT=LATTITUDE IN DEGREES
      LAT=-31.0833
      LAT=LAT*DTR
      DO 20 N=1,365
         CN=N
         D=DTR*23.5*SIN((2.0*PI*(CN-81.0))/365.25)
         IF(CN.EQ.81.) THEN
            D=D1
         ENDIF
         D1=D
         RI=1387.0*(1.0+0.033*COS((2.0*PI*(CN-3.0))/365.25))
         H=ACOS(-TAN(LAT)*TAN(D))
C        CALCULATE Ra IN JOULES
         W=7.272E-05
         RA(N)=(2.0/W)*RI*SIN(LAT)*SIN(D)*(H-TAN(H))
C        CALCULATE Ra IN MJ
         RA(N)=RA(N)/1.0E+06
C        CALCULATE Ra IN mm
         RA(N)=RA(N)/2.47
   20 CONTINUE
      OPEN(UNIT=7,FILE='DAY.DAT',STATUS='NEW')
      OPEN(UNIT=8,FILE='MET.DAT',STATUS='OLD')
      OPEN(UNIT=9,FILE='MTH.DAT',STATUS='NEW')
      N=1
      RDAY=0
      MRAIN=0.0
      MPET=0.0
   30 READ(8,40) YR,MTH,DAY,TDRY,TWET,WIND,RAIN,FC
   40 FORMAT(I5,2I3,5F10.2)
      IF(YR.EQ.1982) GOTO 60
C     1980 IS A LEAP YEAR
      IF((MTH.EQ.2).AND.(DAY.EQ.29))THEN
        N=N-1
      ENDIF
C     CONVERT WIND FROM KNOTS AT TO KM/DAY
      WIND=(WIND*44.448*0.75)**0.95
C
C     CALCULATE HUMIDITY (F) AND SATURATED DRY BULB
C     VAPOUR PRESSURE (ESD)
C     WSW=SATURATION MIXING RATIO AT WET BULB TEMPERATURE
C     WSD=     "          "         "   "  DRY  "          "
C     WD=MIXING RATIO AT DRY BULB TEMPERATURE
      WSW=(0.622/1013.0)*EXP(21.43-(5353.0/(273.15+TWET)))
      ESD=EXP(21.43-(5353.0/(273.15+TDRY)))
      WSD=(0.622/1013.0)*ESD
      WD=WSW-4.09E-04*(TDRY-TWET)
      F=WD/WSD
C
```

```
C     CALCULATE NET RADIATION RN
        R=0.25
        C1=0.26
        C2=0.49
        C3=0.10
        C4=0.90
        C5=0.56
        C6=0.078
        SBC=1.985E-09
        ETA=1.00
        CF=1.0-FC
      RN=(1.-R)*(C1+C2*CF)*RA(N)-ETA*SBC*((273.15+TDRY)**4)*(C3+C4*CF)
     &*(C5-C6*SQRT(ESD*F))
C
C     CALCULATE THE ADVECTED ENERGY EA
      EDIF=ESD*(1.0-F)
      EA=EDIF*0.27*(1.0+(WIND/100.0))
C
C     CALCULATE S & G FACTORS
      F1=1.0/(1.0+0.66/((0.00815*TDRY+0.8912)**7))
      F2=1.0-F1
C
C     CALCULATE POTENTIAL EVAPOTRANSPIRATION PET
      PET=F1*RN+F2*EA
C      WRITE(*,42) YR,MTH,DAY,RN,EA,F1*RN,F2*EA,PET
C 42   FORMAT(I5,2I3,5F10.2)
C
C     WRITE DATA TO DAY.DAT
      WRITE(7,45) YR,MTH,DAY,RAIN,PET
  45  FORMAT(I5,2I4,2F10.2)
      IF((MTH.EQ.12).AND.(DAY.EQ.31)) THEN
         N=1
      ELSE
         N=N+1
      ENDIF
      IF(DAY.LT.LDAY) GOTO 60
  50  IF(RAIN.GT.0.0) THEN
        RDAY=RDAY+1
      ENDIF
      MRAIN=MRAIN+RAIN
      MPET=MPET+PET
      LDAY=DAY
      LMTH=MTH
      LYR=YR
      GOTO 30
  60  WRITE(9,70) LYR,LMTH,RDAY,MRAIN,MPET
      WRITE(*,70) LYR,LMTH,RDAY,MRAIN,MPET
  70  FORMAT(I5,I4,I4,2F10.2)
      IF(YR.EQ.1982) GOTO 80
      RDAY=0
      MRAIN=0.0
      MPET=0.0
      GOTO 50
  80  CLOSE(UNIT=7)
      CLOSE(UNIT=8)
      CLOSE(UNIT=9)
      STOP
      END
```

APPENDIX D : PROGRAM LISTING - MODEL

PROGRAM NAME	: DAY.FOR
COMPILER	: MICROSOFT FORTRAN
COMPUTER	: PC-XT WITH MS-DOS OPERATING SYSTEM

```
C       DAILY TIMESTEP PROCESS MODEL
        INTEGER YR,MTH,DAY,LYR,LMTH,LDAY
        REAL P,EPOT,INT,INTCAP,PEFF,EINT,INFPOT,INFIL
        REAL R,SW,ESPOT,ESOIL,RECHAR,MRECHAR,MELOSS
        REAL MR,MRAIN,MPET,RATIO,SOILCAP,SDRY
        REAL GCONST,INFMAX,EMAX,ELOSS,TRATIO,SRATIO
        REAL MRATIO,SDRATIO
C
C       ****************************************************************
C       READ IN MODEL PARAMETERS,PRINT THEM AND PRINT HEADINGS FOR
C       DAILY MODEL RUN
        OPEN(UNIT=7,FILE='DAY.DAT',STATUS='OLD')
        READ(7,*) INTCAP,GCONST,SOILCAP,INFMAX,EMAX,SDRY
        WRITE(*,10)
   10   FORMAT('  INTCAP  GCONST SOILCAP  INFMAX    EMAX    SDRY')
        WRITE(*,20) INTCAP,GCONST,SOILCAP,INFMAX,EMAX,SDRY
   20   FORMAT(6F8.2,/)
        WRITE(*,25)
   25   FORMAT(' YEAR MTH RECHARGE  EVAPOTRANS  RUNOFF   RAINFALL  PET
     &      RATIO')
C
C       ****************************************************************
C       INTIALISE VALUES
        INT=INTCAP/2.0
        SW=SOILCAP/2.0
        MRECHAR=0.0
        MELOSS=0.0
        MR=0.0
        MRAIN=0.0
        MPET=0.0
        TRATIO=0.0
        SRATIO=0.0
        LDAY=1
        LMTH=1
        LYR=1977
C
C       ****************************************************************
C       RUN DAILY MODEL
   30   READ(7,40) YR,MTH,DAY,P,PET
   40   FORMAT(I5,2I4,2F10.2)
        EPOT=PET
        IF(YR.EQ.1982) GOTO 60
        IF(DAY.LT.LDAY) GOTO 60
C       ****************************************************************
C       INTERCEPTION STORE
   45   INT=INT+P
        IF(INT.GE.INTCAP) THEN
           PEFF=INT-INTCAP
           INT=INTCAP
        ELSE
           PEFF=0.0
        ENDIF
        EINT=MIN(INT,EPOT)
        EPOT=MAX((EPOT-EINT),0.0)
        INT=INT-EINT
C       ****************************************************************
C       SOIL STORE
        INFPOT=INFMAX*(1.0-(SW/SOILCAP))
        INFIL=MIN(PEFF,INFPOT)
        R=PEFF-INFIL
        SW=SW+INFIL
        IF(SW.GT.SOILCAP) THEN
           R=R+SW-SOILCAP
           SW=SOILCAP
        ENDIF
```

```
      ESPOT=MIN(EPOT,(EMAX*((SW-SDRY)/(SOILCAP-SDRY))))
      IF(ESPOT.LT.0.0) THEN
         ESPOT=0.0
      ENDIF
      ESOIL=MIN(SW,ESPOT)
      EPOT=EPOT-ESOIL
      SW=SW-ESOIL
      RECHAR=MAX(0.0,(GCONST*(SW-SDRY)))
      SW=SW-RECHAR
C     ****************************************************************
      ELOSS=EINT+ESOIL
      IF(DAY.LT.LDAY) GOTO 60
   50 MRECHAR=MRECHAR+RECHAR
      MELOSS=MELOSS+ELOSS
      MR=MR+R
      MRAIN=MRAIN+P
      MPET=MPET+PET
      LDAY=DAY
      LMTH=MTH
      LYR=YR
      GOTO 30
C
C     ****************************************************************
C     CALCULATE MONTHLY RATIO OF RECHARGE/RAINFALL ALLOWING FOR
C     ZERO RAINFALL
   60 IF(MRAIN.NE.0.0) THEN
         RATIO=MRECHAR/MRAIN
      ELSE
         RATIO=MRECHAR/(MRAIN+0.000001)
      ENDIF
C     USE FIRST 6 MONTHS AS A WARM-UP PERIOD
      IF((LYR.EQ.1978).AND.(LMTH.LT.7)) GOTO 65
C     COUNTERS FOR RATIO STATISTICS
      TRATIO=TRATIO+RATIO
      SRATIO=SRATIO+RATIO*RATIO
C
C     PRINT MONTHLY DATA
   65 WRITE(*,70) LYR,LMTH,MRECHAR,MELOSS,MR,MRAIN,MPET,RATIO
   70 FORMAT(I5,I3,6F10.2)
      IF((LYR.EQ.1978).AND.(LMTH.EQ.6)) THEN
       WRITE(*,75)
   75  FORMAT(/)
      ENDIF
      IF(YR.EQ.1982) GOTO 80
C
C     RESET MONTHLY COUNTERS TO ZERO
      MRECHAR=0.0
      MELOSS=0.0
      MR=0.0
      MRAIN=0.0
      MPET=0.0
      GOTO 50
C
C     ****************************************************************
C     CALCULATE AND PRINT RATIO STATISTICS FOR 42 MONTHS(7/78-12/81)
C
   80 CLOSE(UNIT=7)
      MRATIO=TRATIO/42.0
      SDRATIO=(SRATIO-(TRATIO*TRATIO/42.0))/42.0
      SDRATIO=SQRT(SDRATIO)
      WRITE(*,90) MRATIO,SDRATIO
   90 FORMAT(//,' RATIO: MEAN=',F6.2,'  STANDARD DEVIATION=',F6.2,//)
      STOP
      END
```

APPENDIX E : DATA LISTING - MODEL DATA

The data used by the daily model is listed in one month blocks. The order is :

YEAR, MONTH, DAY, RAINFALL(mm), POTENTIAL EVAPOTRANSPIRATION(mm)

1978	1	1	.00	6.48
1978	1	2	.00	4.41
1978	1	3	13.00	7.40
1978	1	4	.00	5.64
1978	1	5	29.00	2.58
1978	1	6	5.60	5.75
1978	1	7	.00	7.12
1978	1	8	.00	5.78
1978	1	9	.00	4.77
1978	1	10	.00	7.33
1978	1	11	.00	11.47
1978	1	12	.00	2.72
1978	1	13	1.00	6.29
1978	1	14	.00	4.85
1978	1	15	.00	5.10
1978	1	16	1.70	12.91
1978	1	17	.20	8.68
1978	1	18	.00	7.64
1978	1	19	9.60	6.33
1978	1	20	1.60	3.01
1978	1	21	12.40	4.23
1978	1	22	.00	5.49
1978	1	23	.00	5.35
1978	1	24	.00	5.54
1978	1	25	4.60	2.67
1978	1	26	6.00	3.69
1978	1	27	.80	5.66
1978	1	28	2.00	2.60
1978	1	29	23.80	3.23
1978	1	30	.80	2.39
1978	1	31	.40	2.85
1978	2	1	2.60	4.01
1978	2	2	32.00	2.44
1978	2	3	6.00	2.54
1978	2	4	14.20	4.25
1978	2	5	1.00	5.05
1978	2	6	.00	5.03
1978	2	7	.00	5.68
1978	2	8	.00	8.18
1978	2	9	.00	7.89
1978	2	10	.00	6.53
1978	2	11	.00	3.68
1978	2	12	1.00	6.17
1978	2	13	.00	5.55
1978	2	14	.00	7.72
1978	2	15	.20	6.52
1978	2	16	1.80	4.68
1978	2	17	.00	6.42
1978	2	18	.00	5.75
1978	2	19	.00	5.76
1978	2	20	.00	6.44
1978	2	21	.00	6.91
1978	2	22	.00	7.00
1978	2	23	1.80	3.80
1978	2	24	1.60	4.82
1978	2	25	.00	5.48
1978	2	26	1.20	5.49
1978	2	27	.00	6.32
1978	2	28	.00	5.63
1978	3	1	27.00	5.40
1978	3	2	.60	5.22
1978	3	3	.00	5.83
1978	3	4	.00	2.90
1978	3	5	2.00	5.21
1978	3	6	.00	6.37
1978	3	7	.00	5.31
1978	3	8	.00	5.92
1978	3	9	4.20	6.72
1978	3	10	.20	4.59
1978	3	11	1.00	2.81
1978	3	12	3.80	3.20
1978	3	13	9.20	4.11
1978	3	14	.80	5.96
1978	3	15	6.80	2.96
1978	3	16	10.00	5.50
1978	3	17	29.50	2.34
1978	3	18	48.00	1.87
1978	3	19	117.00	1.99
1978	3	20	70.80	2.01
1978	3	21	21.40	4.48
1978	3	22	9.00	3.73
1978	3	23	2.00	5.96
1978	3	24	.00	2.71
1978	3	25	7.20	4.12
1978	3	26	.00	4.24
1978	3	27	.00	6.19
1978	3	28	.00	2.37
1978	3	29	6.60	5.43
1978	3	30	.00	2.71
1978	3	31	2.00	2.09
1978	4	1	40.00	1.52
1978	4	2	12.00	1.58
1978	4	3	2.20	6.78
1978	4	4	.00	3.49
1978	4	5	.00	4.76
1978	4	6	.00	2.13
1978	4	7	4.00	4.73
1978	4	8	.00	3.71
1978	4	9	8.40	2.06
1978	4	10	.00	2.62
1978	4	11	.00	2.82
1978	4	12	.00	3.95
1978	4	13	.00	5.08
1978	4	14	8.00	4.70
1978	4	15	4.00	7.42
1978	4	16	.00	7.52
1978	4	17	.20	4.70
1978	4	18	.00	2.51
1978	4	19	.00	4.05
1978	4	20	.00	2.46
1978	4	21	.00	3.58
1978	4	22	.00	2.51
1978	4	23	.00	2.83
1978	4	24	.00	3.95
1978	4	25	.00	3.57
1978	4	26	.00	3.78
1978	4	27	.00	5.73
1978	4	28	.00	4.04
1978	4	29	.00	2.48
1978	4	30	.00	2.34
1978	5	1	.00	3.34
1978	5	2	.00	2.54
1978	5	3	.00	2.68
1978	5	4	4.00	3.28
1978	5	5	1.60	2.32
1978	5	6	.00	1.99
1978	5	7	.00	1.80
1978	5	8	.20	2.34
1978	5	9	3.80	2.89
1978	5	10	1.20	1.02
1978	5	11	10.60	3.10
1978	5	12	.00	4.01
1978	5	13	.00	4.71
1978	5	14	.00	2.06
1978	5	15	.00	1.45
1978	5	16	.00	2.10
1978	5	17	.40	1.96
1978	5	18	.20	1.34
1978	5	19	5.80	1.13
1978	5	20	9.00	1.46
1978	5	21	1.00	3.90
1978	5	22	.00	4.78
1978	5	23	.00	1.51
1978	5	24	.00	2.41
1978	5	25	.00	1.46
1978	5	26	.00	2.17
1978	5	27	.00	1.16
1978	5	28	.00	1.33
1978	5	29	.00	2.23
1978	5	30	.00	1.14
1978	5	31	.00	1.32
1978	6	1	9.00	2.36
1978	6	2	2.00	.94
1978	6	3	2.00	1.06
1978	6	4	.00	.84
1978	6	5	.00	1.25
1978	6	6	.00	.83
1978	6	7	.00	1.06
1978	6	8	.00	1.00
1978	6	9	.00	3.45
1978	6	10	.00	.84
1978	6	11	.00	.83
1978	6	12	2.00	1.69
1978	6	13	.00	1.08
1978	6	14	.00	2.76
1978	6	15	.00	.96
1978	6	16	8.40	2.44
1978	6	17	.00	.96
1978	6	18	.00	1.12
1978	6	19	.00	2.10
1978	6	20	37.20	4.02
1978	6	21	3.20	4.03
1978	6	22	.00	1.20
1978	6	23	.20	1.15
1978	6	24	.00	.78
1978	6	25	.00	.98
1978	6	26	.00	2.65
1978	6	27	.00	1.16
1978	6	28	.60	.78
1978	6	29	1.80	.94
1978	6	30	.20	1.50

1978	7	1	.00	1.14
1978	7	2	1.80	.77
1978	7	3	2.20	7.66
1978	7	4	.00	4.35
1978	7	5	.00	3.92
1978	7	6	.00	7.65
1978	7	7	.00	2.23
1978	7	8	.00	.45
1978	7	9	.00	1.28
1978	7	10	.40	1.29
1978	7	11	1.40	1.87
1978	7	12	.00	1.92
1978	7	13	.00	1.19
1978	7	14	.00	1.91
1978	7	15	.00	1.21
1978	7	16	.00	1.26
1978	7	17	.60	1.50
1978	7	18	.00	2.61
1978	7	19	.00	1.81
1978	7	20	.00	1.43
1978	7	21	.00	1.96
1978	7	22	.00	1.52
1978	7	23	.00	8.26
1978	7	24	.00	1.90
1978	7	25	.00	3.66
1978	7	26	.00	2.78
1978	7	27	.00	3.04
1978	7	28	1.80	2.60
1978	7	29	.00	1.39
1978	7	30	.00	1.34
1978	7	31	.00	1.55
1978	8	1	.00	2.14
1978	8	2	.00	2.95
1978	8	3	.00	4.11
1978	8	4	.00	4.85
1978	8	5	1.00	1.12
1978	8	6	4.00	1.10
1978	8	7	1.80	2.52
1978	8	8	.20	1.51
1978	8	9	.00	5.60
1978	8	10	.00	1.79
1978	8	11	.00	3.79
1978	8	12	.00	1.87
1978	8	13	.00	8.58
1978	8	14	.00	4.61
1978	8	15	.00	2.97
1978	8	16	.00	3.76
1978	8	17	.00	3.90
1978	8	18	.00	1.28
1978	8	19	3.00	1.32
1978	8	20	.20	2.13
1978	8	21	.00	2.72
1978	8	22	.00	3.70
1978	8	23	.00	8.17
1978	8	24	.00	7.13
1978	8	25	.00	3.87
1978	8	26	.00	2.09
1978	8	27	.00	4.63
1978	8	28	.00	3.22
1978	8	29	.00	2.04
1978	8	30	.00	3.37
1978	8	31	.00	2.56
1978	9	1	.00	2.40
1978	9	2	.60	2.73
1978	9	3	.00	4.92
1978	9	4	.00	2.50
1978	9	5	10.00	4.46
1978	9	6	.00	2.47
1978	9	7	1.20	2.56
1978	9	8	.40	5.42
1978	9	9	.00	4.73
1978	9	10	.00	4.94
1978	9	11	.00	4.34
1978	9	12	.00	6.76
1978	9	13	.00	14.74
1978	9	14	.00	13.39
1978	9	15	.00	5.95
1978	9	16	.00	3.28
1978	9	17	.00	3.24
1978	9	18	.00	5.51
1978	9	19	.00	5.06
1978	9	20	.20	6.97
1978	9	21	.60	6.06
1978	9	22	.00	4.72
1978	9	23	16.00	3.44
1978	9	24	.00	5.50
1978	9	25	.40	3.62
1978	9	26	.00	4.33
1978	9	27	.00	4.68
1978	9	28	.00	2.09
1978	9	29	9.60	3.16
1978	9	30	3.00	3.27
1978	10	1	3.00	4.13
1978	10	2	.00	5.30
1978	10	3	.00	5.40
1978	10	4	.00	3.67
1978	10	5	3.80	7.03
1978	10	6	.20	2.78
1978	10	7	18.00	2.03
1978	10	8	16.00	2.37
1978	10	9	2.20	3.09
1978	10	10	12.00	5.32
1978	10	11	.00	4.57
1978	10	12	.00	5.67
1978	10	13	.00	7.57
1978	10	14	.00	5.44
1978	10	15	.00	1.91
1978	10	16	26.20	5.63
1978	10	17	.00	5.58
1978	10	18	.20	4.41
1978	10	19	6.20	9.39
1978	10	20	.00	7.48
1978	10	21	.00	4.94
1978	10	22	.00	2.68
1978	10	23	.00	5.72
1978	10	24	.00	6.12
1978	10	25	.00	6.63
1978	10	26	.00	7.94
1978	10	27	.00	8.11
1978	10	28	.00	4.54
1978	10	29	.00	3.68
1978	10	30	1.60	6.41
1978	10	31	.00	5.54
1978	11	1	.20	2.79
1978	11	2	15.00	4.07
1978	11	3	2.00	6.24
1978	11	4	.00	3.08
1978	11	5	2.00	3.24
1978	11	6	.80	3.53
1978	11	7	7.80	2.67
1978	11	8	17.40	6.17
1978	11	9	.20	5.34
1978	11	10	.00	3.30
1978	11	11	10.00	4.02
1978	11	12	5.00	5.00
1978	11	13	6.80	2.43
1978	11	14	12.00	5.00
1978	11	15	.00	5.20
1978	11	16	.00	4.93
1978	11	17	.00	5.37
1978	11	18	.00	7.08
1978	11	19	.00	6.10
1978	11	20	.00	8.37
1978	11	21	.00	7.69
1978	11	22	.00	6.12
1978	11	23	.00	5.37
1978	11	24	.00	5.30
1978	11	25	.00	6.15
1978	11	26	.00	6.27
1978	11	27	.00	6.11
1978	11	28	.00	7.44
1978	11	29	.00	8.62
1978	11	30	.00	4.69
1978	12	1	5.00	2.67
1978	12	2	.40	2.79
1978	12	3	.00	5.91
1978	12	4	10.00	2.99
1978	12	5	.40	5.56
1978	12	6	.00	6.55
1978	12	7	.00	6.45
1978	12	8	.00	6.45
1978	12	9	.00	5.00
1978	12	10	.80	3.79
1978	12	11	10.00	5.05
1978	12	12	.00	6.84
1978	12	13	4.60	4.43
1978	12	14	8.00	5.84
1978	12	15	.60	9.82
1978	12	16	.00	3.91
1978	12	17	.00	5.01
1978	12	18	5.80	7.43
1978	12	19	.00	7.33
1978	12	20	.00	10.58
1978	12	21	.00	6.78
1978	12	22	.00	3.79
1978	12	23	6.00	2.65
1978	12	24	2.00	5.95
1978	12	25	.00	6.21
1978	12	26	.00	6.20
1978	12	27	69.00	4.64
1978	12	28	39.00	4.67
1978	12	29	24.00	5.18
1978	12	30	2.00	5.40
1978	12	31	.00	6.19

1979	1	1	.00	6.18
1979	1	2	.00	5.98
1979	1	3	.00	5.21
1979	1	4	.00	4.67
1979	1	5	1.80	4.97
1979	1	6	.00	8.44
1979	1	7	.00	8.64
1979	1	8	.00	8.31
1979	1	9	.00	8.22
1979	1	10	.00	6.97
1979	1	11	.00	8.10
1979	1	12	.00	5.28
1979	1	13	.00	6.73
1979	1	14	.00	7.76
1979	1	15	.00	8.23
1979	1	16	.00	3.96
1979	1	17	.00	5.84
1979	1	18	3.00	3.49
1979	1	19	3.20	6.46
1979	1	20	2.40	5.24
1979	1	21	1.80	4.57
1979	1	22	14.20	4.69
1979	1	23	51.40	3.21
1979	1	24	77.80	4.04
1979	1	25	.80	5.46
1979	1	26	.80	7.44
1979	1	27	.80	4.14
1979	1	28	29.20	5.86
1979	1	29	4.40	4.84
1979	1	30	.00	4.57
1979	1	31	1.40	3.94

1979	2	1	.10	7.09
1979	2	2	.60	5.68
1979	2	3	1.20	4.65
1979	2	4	.80	5.85
1979	2	5	11.00	3.48
1979	2	6	.00	3.10
1979	2	7	3.00	4.86
1979	2	8	.60	4.21
1979	2	9	.80	4.36
1979	2	10	.00	6.12
1979	2	11	.00	6.35
1979	2	12	.10	4.86
1979	2	13	.10	5.27
1979	2	14	.00	4.69
1979	2	15	.00	4.86
1979	2	16	.00	6.29
1979	2	17	.00	2.58
1979	2	18	.00	3.53
1979	2	19	.20	4.96
1979	2	20	11.00	4.36
1979	2	21	1.40	5.00
1979	2	22	1.40	4.79
1979	2	23	.00	4.72
1979	2	24	.00	5.76
1979	2	25	.00	5.19
1979	2	26	.00	3.16
1979	2	27	.00	5.40
1979	2	28	1.40	2.79

1979	3	1	2.80	3.00
1979	3	2	.20	4.35
1979	3	3	2.20	5.08
1979	3	4	6.60	2.17
1979	3	5	12.00	3.17
1979	3	6	2.00	6.22
1979	3	7	.00	8.03
1979	3	8	.00	4.03
1979	3	9	.00	5.57
1979	3	10	.00	5.68
1979	3	11	.00	7.34
1979	3	12	.00	3.02
1979	3	13	3.40	3.71
1979	3	14	.10	5.36
1979	3	15	4.40	2.63
1979	3	16	3.00	2.27
1979	3	17	24.20	1.80
1979	3	18	46.40	4.98
1979	3	19	2.60	7.77
1979	3	20	.20	4.95
1979	3	21	.00	4.28
1979	3	22	5.20	4.90
1979	3	23	.00	4.75
1979	3	24	.00	5.26
1979	3	25	.00	5.14
1979	3	26	.00	7.06
1979	3	27	.00	4.59
1979	3	28	.00	5.63
1979	3	29	.80	5.35
1979	3	30	.60	3.28
1979	3	31	.40	3.40

1979	4	1	.00	3.73
1979	4	2	.00	3.98
1979	4	3	.00	4.68
1979	4	4	.00	4.52
1979	4	5	.00	3.86
1979	4	6	.00	3.32
1979	4	7	.00	3.58
1979	4	8	.00	3.07
1979	4	9	.00	3.07
1979	4	10	14.00	3.90
1979	4	11	.20	3.06
1979	4	12	.00	3.03
1979	4	13	.00	3.56
1979	4	14	.00	2.39
1979	4	15	.00	2.54
1979	4	16	1.40	2.35
1979	4	17	10.00	2.52
1979	4	18	1.80	2.47
1979	4	19	6.60	3.82
1979	4	20	.20	2.75
1979	4	21	.00	2.87
1979	4	22	.00	2.57
1979	4	23	.00	2.98
1979	4	24	.00	2.86
1979	4	25	.10	2.80
1979	4	26	.00	2.54
1979	4	27	.20	3.54
1979	4	28	40.40	1.90
1979	4	29	4.70	4.00
1979	4	30	.40	5.45

1979	5	1	.20	2.65
1979	5	2	.00	2.63
1979	5	3	.10	2.63
1979	5	4	.00	1.57
1979	5	5	23.60	1.30
1979	5	6	56.40	1.24
1979	5	7	14.40	1.18
1979	5	8	4.40	4.81
1979	5	9	.10	4.03
1979	5	10	.00	2.48
1979	5	11	.00	3.42
1979	5	12	.00	4.26
1979	5	13	.00	1.55
1979	5	14	.00	2.30
1979	5	15	.00	2.56
1979	5	16	.00	4.61
1979	5	17	.00	2.14
1979	5	18	.00	2.44
1979	5	19	.00	1.72
1979	5	20	.00	1.16
1979	5	21	8.80	1.19
1979	5	22	8.80	4.52
1979	5	23	.10	2.34
1979	5	24	.00	1.47
1979	5	25	.00	2.29
1979	5	26	.00	1.79
1979	5	27	.00	1.20
1979	5	28	.10	2.02
1979	5	29	.00	2.00
1979	5	30	.00	2.47
1979	5	31	.20	3.09

1979	6	1	.00	5.75
1979	6	2	.00	2.75
1979	6	3	.00	1.29
1979	6	4	.00	1.19
1979	6	5	.40	1.38
1979	6	6	.00	1.48
1979	6	7	.00	1.38
1979	6	8	.00	1.64
1979	6	9	.10	1.17
1979	6	10	.00	1.05
1979	6	11	.00	1.18
1979	6	12	.00	1.87
1979	6	13	.00	2.62
1979	6	14	.00	1.97
1979	6	15	.00	1.48
1979	6	16	.00	1.25
1979	6	17	.00	1.15
1979	6	18	.00	1.13
1979	6	19	.00	1.40
1979	6	20	5.20	.74
1979	6	21	71.00	1.22
1979	6	22	.20	1.98
1979	6	23	.20	3.26
1979	6	24	.00	2.91
1979	6	25	.00	1.14
1979	6	26	.00	1.32
1979	6	27	.00	1.33
1979	6	28	.00	1.27
1979	6	29	.00	2.01
1979	6	30	.00	1.42

1979	7	1	.00	1.07
1979	7	2	.00	1.20
1979	7	3	.10	1.06
1979	7	4	.00	2.40
1979	7	5	.00	2.38
1979	7	6	.00	2.34
1979	7	7	.10	1.29
1979	7	8	.00	1.66
1979	7	9	.00	1.75
1979	7	10	.00	2.88
1979	7	11	.00	2.37
1979	7	12	.00	1.39
1979	7	13	.00	1.52
1979	7	14	.10	1.25
1979	7	15	.60	1.11
1979	7	16	2.00	1.55
1979	7	17	.10	1.64
1979	7	18	.00	1.71
1979	7	19	.00	1.66
1979	7	20	.00	1.39
1979	7	21	.20	1.36
1979	7	22	.00	1.52
1979	7	23	.00	2.05
1979	7	24	.00	1.46
1979	7	25	.00	1.79
1979	7	26	3.60	4.65
1979	7	27	.10	1.80
1979	7	28	.30	1.49
1979	7	29	.00	.88
1979	7	30	14.20	2.12
1979	7	31	2.00	2.25
1979	8	1	.10	1.91
1979	8	2	.00	1.63
1979	8	3	.00	2.05
1979	8	4	.10	2.16
1979	8	5	.00	1.57
1979	8	6	.00	1.22
1979	8	7	.00	1.89
1979	8	8	.00	1.71
1979	8	9	.00	4.78
1979	8	10	.00	3.58
1979	8	11	.00	2.34
1979	8	12	.00	3.25
1979	8	13	.00	6.84
1979	8	14	.00	6.64
1979	8	15	.00	3.97
1979	8	16	.00	3.84
1979	8	17	.00	2.39
1979	8	18	.00	1.31
1979	8	19	.60	2.22
1979	8	20	.00	2.97
1979	8	21	.00	3.42
1979	8	22	.00	4.23
1979	8	23	.00	4.47
1979	8	24	.00	2.96
1979	8	25	.00	2.18
1979	8	26	.00	3.15
1979	8	27	.00	3.81
1979	8	28	.60	4.58
1979	8	29	.00	3.87
1979	8	30	.00	4.17
1979	8	31	.00	4.23
1979	9	1	.00	5.44
1979	9	2	.00	3.75
1979	9	3	.00	3.46
1979	9	4	.80	1.56
1979	9	5	.20	2.66
1979	9	6	.00	4.84
1979	9	7	.00	5.72
1979	9	8	.00	3.78
1979	9	9	.00	3.42
1979	9	10	.00	5.42
1979	9	11	.10	3.06
1979	9	12	6.20	10.61
1979	9	13	.00	2.95
1979	9	14	.00	4.70
1979	9	15	.00	2.95
1979	9	16	.00	3.86
1979	9	17	.00	2.90
1979	9	18	.00	2.98
1979	9	19	.00	4.66
1979	9	20	.40	8.08
1979	9	21	.40	4.60
1979	9	22	.10	3.78
1979	9	23	.00	3.49
1979	9	24	.00	9.20
1979	9	25	5.40	2.14
1979	3	26	7.00	3.22
1979	9	27	.00	6.41
1979	9	28	.00	5.88
1979	9	29	.10	2.75
1979	9	30	.00	2.99
1979	10	1	.00	7.64
1979	10	2	.60	5.69
1979	10	3	.00	6.63
1979	10	4	.00	2.17
1979	10	5	1.80	2.01
1979	10	6	3.00	2.60
1979	10	7	2.60	7.89
1979	10	8	.00	9.32
1979	10	9	.00	6.35
1979	10	10	.00	5.36
1979	10	11	.00	7.25
1979	10	12	.00	6.94
1979	10	13	.00	7.07
1979	10	14	.00	5.35
1979	10	15	.00	6.43
1979	10	16	3.60	2.55
1979	10	17	6.20	4.47
1979	10	18	.00	4.42
1979	10	19	.00	2.60
1979	10	20	2.80	2.44
1979	10	21	.80	4.41
1979	10	22	.00	6.90
1979	10	23	.00	7.85
1979	10	24	.00	3.68
1979	10	25	28.00	5.84
1979	10	26	.60	4.59
1979	10	27	.10	5.35
1979	10	28	.60	2.45
1979	10	29	4.40	13.05
1979	10	30	.00	6.89
1979	10	31	.00	6.48
1979	11	1	.00	6.20
1979	11	2	.00	4.15
1979	11	3	4.00	4.86
1979	11	4	.00	5.39
1979	11	5	.00	6.02
1979	11	6	.00	6.17
1979	11	7	1.00	3.52
1979	11	8	1.40	2.51
1979	11	9	7.80	2.33
1979	11	10	23.60	2.91
1979	11	11	1.60	4.18
1979	11	12	3.20	4.38
1979	11	13	33.00	7.17
1979	11	14	11.40	5.55
1979	11	15	.00	6.74
1979	11	16	.00	4.64
1979	11	17	1.40	5.93
1979	11	18	.00	4.53
1979	11	19	.00	6.54
1979	11	20	.00	3.62
1979	11	21	9.20	5.67
1979	11	22	1.80	6.81
1979	11	23	.60	4.59
1979	11	24	4.20	5.01
1979	11	25	3.40	7.54
1979	11	26	.00	7.37
1979	11	27	.00	8.32
1979	11	28	.00	6.24
1979	11	29	.00	5.57
1979	11	30	.00	6.15
1979	12	1	.00	4.58
1979	12	2	.00	10.00
1979	12	3	.00	7.57
1979	12	4	.00	7.36
1979	12	5	.00	9.22
1979	12	6	14.80	7.74
1979	12	7	.00	7.49
1979	12	8	.10	4.82
1979	12	9	9.60	5.60
1979	12	10	.00	7.24
1979	12	11	.00	9.60
1979	12	12	.60	6.11
1979	12	13	.00	5.51
1979	12	14	.00	5.79
1979	12	15	1.80	2.58
1979	12	16	1.60	6.01
1979	12	17	.00	8.54
1979	12	18	.00	8.76
1979	12	19	.00	14.03
1979	12	20	.00	5.44
1979	12	21	.00	7.72
1979	12	22	4.00	7.25
1979	12	23	.00	5.15
1979	12	24	8.80	6.18
1979	12	25	.20	5.72
1979	12	26	.10	8.11
1979	12	27	.00	5.74
1979	12	28	.20	5.94
1979	12	29	.00	5.86
1979	12	30	.00	7.50
1979	12	31	.00	6.11

1980	1	1	.00	6.99
1980	1	2	85.60	2.67
1980	1	3	5.00	3.70
1980	1	4	1.00	2.91
1980	1	5	.60	3.02
1980	1	6	.40	4.01
1980	1	7	.00	6.77
1980	1	8	.00	10.84
1980	1	9	.00	10.12
1980	1	10	.00	3.68
1980	1	11	.00	8.75
1980	1	12	.00	3.23
1980	1	13	9.80	5.28
1980	1	14	1.60	3.42
1980	1	15	2.80	7.59
1980	1	16	.00	9.11
1980	1	17	.00	7.09
1980	1	18	.00	8.02
1980	1	19	.00	5.72
1980	1	20	.00	4.20
1980	1	21	11.80	5.83
1980	1	22	.00	5.35
1980	1	22	.00	5.34
1980	1	23	.00	6.14
1980	1	24	.00	5.00
1980	1	25	.00	7.70
1980	1	26	.00	4.21
1980	1	27	1.20	2.40
1980	1	28	2.40	3.72
1980	1	29	.00	8.39
1980	1	30	.00	6.02
1980	1	31	12.60	5.18
1980	2	1	.00	8.03
1980	2	2	1.00	5.01
1980	2	3	.00	3.22
1980	2	4	25.00	2.82
1980	2	5	1.20	2.96
1980	2	6	8.20	6.46
1980	2	7	.00	3.40
1980	2	8	.00	7.04
1980	2	9	2.00	6.65
1980	2	10	.20	3.30
1980	2	11	.00	3.83
1980	2	12	.40	6.42
1980	2	13	.40	6.43
1980	2	14	.40	7.37
1980	2	15	.10	10.32
1980	2	16	.00	4.48
1980	2	17	.00	6.48
1980	2	18	.00	5.66
1980	2	19	3.60	3.84
1980	2	20	.00	6.38
1980	2	21	.00	6.93
1980	2	22	.00	7.75
1980	2	23	3.30	2.31
1980	2	24	2.00	5.30
1980	2	25	.00	7.34
1980	2	26	.00	4.70
1980	2	27	1.00	5.64
1980	2	28	.00	3.81
1980	2	29	.80	5.32
1980	3	1	2.60	4.91
1980	3	2	.00	5.78
1980	3	3	.20	7.01
1980	3	4	.00	6.55
1980	3	5	.00	4.61
1980	3	6	.00	3.97
1980	3	7	.00	6.16
1980	3	8	.00	5.91
1980	3	9	.00	4.32
1980	3	10	33.80	4.58
1980	3	11	1.00	4.08
1980	3	12	3.00	4.27
1980	3	13	2.20	4.16
1980	3	14	.10	5.60
1980	3	15	.00	5.10
1980	3	16	.10	5.55
1980	3	17	.00	4.27
1980	3	18	.00	5.18
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1980	3	30	.60	4.98
1980	3	31	.00	6.68
1980	4	1	.00	5.76
1980	4	2	.00	4.83
1980	4	3	.00	5.53
1980	4	4	.00	6.31
1980	4	5	.00	5.27
1980	4	6	.00	5.25
1980	4	7	.00	5.07
1980	4	8	.20	6.62
1980	4	9	.00	8.66
1980	4	10	.00	4.63
1980	4	11	.40	2.64
1980	4	12	.00	4.27
1980	4	13	.00	3.69
1980	4	14	1.40	3.24
1980	4	15	2.00	2.26
1980	4	16	1.40	3.34
1980	4	17	.00	3.88
1980	4	18	.80	1.99
1980	4	19	8.80	2.59
1980	4	20	3.20	2.67
1980	4	21	1.40	3.69
1980	4	22	.00	3.02
1980	4	23	.00	4.23
1980	4	24	.00	3.29
1980	4	25	.00	4.41
1980	4	26	2.60	2.72
1980	4	27	.00	2.43
1980	4	28	.00	4.34
1980	4	29	.00	3.90
1980	4	30	.00	3.18
1980	5	1	.00	3.36
1980	5	2	13.80	1.90
1980	5	3	5.40	2.26
1980	5	4	4.40	1.80
1980	5	5	19.00	1.61
1980	5	6	39.00	1.16
1980	5	7	45.40	1.33
1980	5	8	62.60	1.11
1980	5	9	157.00	1.74
1980	5	10	62.60	1.62
1980	5	11	.20	6.68
1980	5	12	.00	5.83
1980	5	13	.20	2.27
1980	5	14	.00	1.78
1980	5	15	3.20	1.49
1980	5	16	3.70	2.27
1980	5	17	.20	2.19
1980	5	18	.00	2.05
1980	5	19	.00	2.27
1980	5	20	.00	2.75
1980	5	21	.00	1.55
1980	5	22	.00	1.69
1980	5	23	.00	3.37
1980	5	24	.00	2.02
1980	5	25	.00	1.89
1980	5	26	.00	2.24
1980	5	27	.60	1.51
1980	5	28	1.40	.86
1980	5	29	6.40	1.25
1980	5	30	.00	1.67
1980	5	31	.40	1.83
1980	6	1	.10	2.56
1980	6	2	.00	1.64
1980	6	3	.00	5.08
1980	6	4	.00	2.17
1980	6	5	.00	2.19
1980	6	6	.00	1.58
1980	6	7	.00	1.86
1980	6	8	.00	1.48
1980	6	9	.00	1.25
1980	6	10	.00	2.85
1980	6	11	.00	2.37
1980	6	12	.00	2.41
1980	6	13	16.00	1.32
1980	6	14	19.00	.76
1980	6	15	23.20	1.29
1980	6	16	.40	1.16
1980	6	17	1.40	1.98
1980	6	18	.00	6.44
1980	6	19	.00	4.43
1980	6	20	9.00	2.13
1980	6	21	.10	2.40
1980	6	22	.00	2.71
1980	6	23	.00	2.08
1980	6	24	.00	.99
1980	6	25	.00	1.38
1980	6	26	.40	1.42
1980	6	27	.00	1.20
1980	6	28	.40	4.01
1980	6	29	.00	2.58
1980	6	30	.00	2.61

1980	7	1	.00	1.11
1980	7	2	.00	3.64
1980	7	3	.00	1.55
1980	7	4	.00	4.94
1980	7	5	.10	4.66
1980	7	6	.00	2.10
1980	7	7	.00	1.35
1980	7	8	.00	1.42
1980	7	9	.00	2.06
1980	7	10	.00	5.25
1980	7	11	.00	2.19
1980	7	12	.00	1.71
1980	7	13	.00	1.59
1980	7	14	.00	1.47
1980	7	15	.00	1.41
1980	7	16	7.20	1.78
1980	7	17	.20	1.79
1980	7	18	.20	2.46
1980	7	19	.00	1.38
1980	7	20	.00	1.79
1980	7	21	.00	3.72
1980	7	22	.00	2.77
1980	7	23	.00	2.68
1980	7	24	.00	2.57
1980	7	25	.00	2.72
1980	7	26	8.40	1.62
1980	7	27	3.60	1.16
1980	7	28	1.80	.87
1980	7	29	1.00	1.84
1980	7	30	.00	1.52
1980	7	31	.00	2.48

1980	8	1	.00	2.57
1980	8	2	.00	2.07
1980	8	3	.00	3.95
1980	8	4	.00	2.38
1980	8	5	.00	2.96
1980	8	6	.00	2.64
1980	8	7	.00	3.35
1980	8	8	.00	3.03
1980	8	9	.00	2.39
1980	8	10	.00	2.40
1980	8	11	.00	2.48
1980	8	12	.00	1.98
1980	8	13	.00	2.81
1980	8	14	.00	4.08
1980	8	15	.00	6.59
1980	8	16	.20	3.57
1980	8	17	.00	1.89
1980	8	18	.00	3.13
1980	8	19	.00	3.25
1980	8	20	.00	2.50
1980	8	21	2.00	2.73
1980	8	22	.80	3.32
1980	8	23	.10	3.11
1980	8	24	.00	3.42
1980	8	25	.00	1.78
1980	8	26	1.20	2.92
1980	8	27	.00	3.89
1980	8	28	.00	3.22
1980	8	29	.00	4.63
1980	8	30	.00	3.80
1980	8	31	.00	7.07

1980	9	1	.00	5.25
1980	9	2	.10	4.24
1980	9	3	.00	4.42
1980	9	4	.00	3.65
1980	9	5	.00	6.35
1980	9	6	.00	2.96
1980	9	7	.00	6.00
1980	9	8	.00	6.27
1980	9	9	.00	8.95
1980	9	10	.00	6.37
1980	9	11	.00	3.97
1980	9	12	.00	3.29
1980	9	13	3.40	3.72
1980	9	14	.10	4.78
1980	9	15	.00	8.23
1980	9	16	.00	5.33
1980	9	17	.00	4.08
1980	9	18	.00	16.43
1980	9	19	.00	6.05
1980	9	20	.00	4.78
1980	9	21	.00	5.63
1980	9	22	.00	4.36
1980	9	23	.00	4.71
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1980	9	26	.00	6.60
1980	9	27	.00	4.34
1980	9	28	.00	3.42
1980	9	29	.00	5.33
1980	9	30	00	5.48

1980	10	1	.00	5.69
1980	10	2	.00	4.65
1980	10	3	.00	3.98
1980	10	4	3.40	6.18
1980	10	5	.00	4.30
1980	10	6	.00	3.82
1980	10	7	.00	4.16
1980	10	8	2.00	7.05
1980	10	9	.00	5.61
1980	10	10	.10	5.38
1980	10	11	.20	4.70
1980	10	12	.00	5.84
1980	10	13	.00	8.87
1980	10	14	.00	5.22
1980	10	15	.00	5.80
1980	10	16	.00	5.30
1980	10	17	.00	3.54
1980	10	18	5.20	3.35
1980	10	19	1.60	3.95
1980	10	20	4.20	4.97
1980	10	21	18.00	6.24
1980	10	22	.00	6.23
1980	10	23	.00	7.08
1980	10	24	.00	4.87
1980	10	25	2.80	6.42
1980	10	26	.00	3.14
1980	10	27	.40	4.53
1980	10	28	.00	6.27
1980	10	29	.00	6.49
1980	10	30	.00	6.56
1980	10	31	.00	6.49

1980	11	1	.00	6.38
1980	11	2	.00	8.51
1980	11	3	.00	8.18
1980	11	4	.00	7.70
1980	11	5	.00	6.28
1980	11	6	.40	11.71
1980	11	7	.00	5.03
1980	11	8	5.00	5.79
1980	11	9	.00	5.51
1980	11	10	15.00	7.77
1980	11	11	.00	5.59
1980	11	12	.00	5.45
1980	11	13	.00	6.27
1980	11	14	.00	6.44
1980	11	15	.00	7.32
1980	11	16	.00	7.27
1980	11	17	1.00	8.56
1980	11	18	.00	8.90
1980	11	19	.00	7.92
1980	11	20	1.20	6.38
1980	11	21	.00	8.63
1980	11	22	1.00	6.54
1980	11	23	.00	5.44
1980	11	24	.00	8.09
1980	11	25	.00	6.10
1980	11	26	.40	5.96
1980	11	27	.00	7.83
1980	11	28	.00	14.12
1980	11	29	.00	4.75
1980	11	30	.00	6.93

1980	12	1	.00	6.23
1980	12	2	.00	6.19
1980	12	3	.10	4.87
1980	12	4	.00	4.51
1980	12	5	.80	3.68
1980	12	6	96.20	2.67
1980	12	7	2.40	4.97
1980	12	8	2.20	4.44
1980	12	9	2.20	3.50
1980	12	10	5.80	6.13
1980	12	11	.00	6.36
1980	12	12	.00	7.92
1980	12	13	.00	9.07
1980	12	14	.00	7.31
1980	12	15	13.40	6.59
1980	12	16	.20	5.87
1980	12	17	.00	7.38
1980	12	18	.00	6.49
1980	12	19	.00	7.73
1980	12	20	.20	7.19
1980	12	21	.00	5.88
1980	12	22	.00	6.74
1980	12	23	.00	6.90
1980	12	24	.00	7.13
1980	12	25	.00	7.00
1980	12	26	.00	6.34
1980	12	27	.00	5.30
1980	12	28	.00	8.53
1980	12	29	.00	3.65
1980	12	30	28.00	5.28
1980	12	31	45.00	.69

1981	1	1	.40	5.26
1981	1	2	.60	4.69
1981	1	3	.00	4.53
1981	1	4	.00	6.87
1981	1	5	.00	5.92
1981	1	6	.00	5.91
1981	1	7	.00	6.22
1981	1	8	3.40	6.42
1981	1	9	2.60	4.61
1981	1	10	.20	6.53
1981	1	11	.00	5.83
1981	1	12	.00	5.85
1981	1	13	6.00	9.83
1981	1	14	.00	7.33
1981	1	15	.00	5.93
1981	1	16	.00	6.62
1981	1	17	.00	8.04
1981	1	18	1.00	6.10
1981	1	19	.00	5.38
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1981	1	25	.00	6.25
1981	1	26	.00	6.95
1981	1	27	.00	7.21
1981	1	28	.00	7.27
1981	1	29	.00	8.37
1981	1	30	.60	5.76
1981	1	31	3.00	8.02
1981	2	1	19.60	4.58
1981	2	2	6.20	4.13
1981	2	3	9.60	4.96
1981	2	4	22.60	4.48
1981	2	5	.20	4.91
1981	2	6	7.40	3.32
1981	2	7	24.40	3.32
1981	2	8	10.40	4.75
1981	2	9	.20	4.79
1981	2	10	.00	4.28
1981	2	11	1.20	4.84
1981	2	12	.80	6.25
1981	2	13	.60	4.23
1981	2	14	10.20	4.98
1981	2	15	10.20	4.32
1981	2	16	3.00	3.92
1981	2	17	.00	5.06
1981	2	18	.00	4.52
1981	2	19	.00	4.91
1981	2	20	14.60	3.94
1981	2	21	6.40	5.12
1981	2	22	10.40	2.93
1981	2	23	16.40	5.56
1981	2	24	.00	5.19
1981	2	25	.00	5.26
1981	2	26	.00	8.09
1981	2	27	1.00	8.59
1981	2	28	2.40	6.03
1981	3	1	2.00	6.18
1981	3	2	.00	5.53
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1981	3	4	.20	5.89
1981	3	5	.00	9.09
1981	3	6	.00	8.15
1981	3	7	.00	7.00
1981	3	7	2.20	7.68
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1981	3	9	.00	5.52
1981	3	10	.00	7.30
1981	3	11	.00	5.87
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1981	3	14	.00	6.20
1981	3	15	.00	4.94
1981	3	16	.00	5.41
1981	3	17	.00	5.30
1981	3	18	.00	5.88
1981	3	19	.00	6.30
1981	3	20	.00	6.37
1981	3	21	.00	6.63
1981	3	22	.00	4.85
1981	3	23	.00	4.56
1981	3	24	.00	4.87
1981	3	25	.00	5.10
1981	3	26	.00	7.07
1981	3	27	.00	6.41
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1981	3	29	1.40	3.33
1981	3	30	2.70	3.23
1981	3	31	24.40	4.85
1981	4	1	7.90	2.75
1981	4	2	16.50	1.85
1981	4	3	122.00	2.22
1981	4	4	30.20	1.97
1981	4	5	1.80	2.06
1981	4	6	15.00	2.59
1981	4	7	1.80	4.11
1981	4	8	.00	2.54
1981	4	9	.00	2.97
1981	4	10	.20	3.98
1981	4	11	.00	6.12
1981	4	12	.00	4.33
1981	4	13	.20	3.17
1981	4	14	.00	4.23
1981	4	15	.00	3.61
1981	4	16	.00	3.56
1981	4	17	.00	3.27
1981	4	18	.00	3.08
1981	4	19	.20	3.84
1981	4	20	.00	3.22
1981	4	21	.00	2.56
1981	4	22	.20	3.06
1981	4	23	.00	4.05
1981	4	24	6.00	2.59
1981	4	25	.00	3.73
1981	4	26	.00	2.80
1981	4	27	.00	2.69
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1981	4	29	.00	3.10
1981	4	30	.00	3.60
1981	5	1	3.00	3.33
1981	5	2	6.20	2.85
1981	5	3	.00	3.02
1981	5	4	.20	1.88
1981	5	5	5.80	2.30
1981	5	6	.20	1.93
1981	5	7	.20	1.51
1981	5	8	2.40	2.09
1981	5	9	.00	2.33
1981	5	10	.00	1.46
1981	5	11	.00	2.04
1981	5	12	.00	3.44
1981	5	13	.00	1.66
1981	5	14	3.00	1.89
1981	5	15	1.80	1.52
1981	5	16	.00	1.80
1981	5	17	.00	1.80
1981	5	18	.20	2.02
1981	5	19	.00	4.66
1981	5	20	.00	2.54
1981	5	21	1.80	1.35
1981	5	22	11.00	1.66
1981	5	23	131.00	3.39
1981	5	24	.00	4.47
1981	5	25	.00	2.70
1981	5	26	.20	1.27
1981	5	27	.00	1.73
1981	5	28	.00	2.12
1981	5	29	.00	1.17
1981	5	30	1.20	1.83
1981	5	31	.90	.98
1981	6	1	2.20	.91
1981	6	2	.00	1.97
1981	6	3	.00	6.27
1981	6	4	.00	2.05
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1981	6	16	.00	1.41
1981	6	17	.00	1.62
1981	6	18	.00	.75
1981	6	19	.00	1.00
1981	6	20	.20	2.34
1981	6	21	2.30	.87
1981	6	22	.40	1.36
1981	6	23	.40	1.36
1981	6	24	.00	2.87
1981	6	25	.00	2.28
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1981	6	28	.00	2.47
1981	6	29	.00	1.82
1981	6	30	.00	1.12

1981	7	1	.00	1.53
1981	7	2	.00	1.98
1981	7	3	.00	2.49
1981	7	4	.00	4.11
1981	7	5	.00	4.09
1981	7	6	.00	1.58
1981	7	7	.00	1.04
1981	7	8	.00	1.19
1981	7	9	.00	2.18
1981	7	10	.00	2.40
1981	7	11	.20	1.87
1981	7	12	.00	3.39
1981	7	13	.00	1.30
1981	7	14	.00	2.67
1981	7	15	.00	2.05
1981	7	16	.00	1.64
1981	7	17	.00	2.42
1981	7	18	.00	1.73
1981	7	19	4.40	.82
1981	7	20	7.40	1.40
1981	7	21	.20	1.23
1981	7	22	6.00	2.43
1981	7	23	.00	2.35
1981	7	24	.00	2.31
1981	7	25	2.80	1.94
1981	7	26	.00	1.46
1981	7	27	.00	1.69
1981	7	28	.00	1.75
1981	7	29	.20	5.83
1981	7	30	.00	2.86
1981	7	31	.00	3.50
1981	8	1	.00	1.96
1981	8	2	.00	2.67
1981	8	3	.00	2.08
1981	8	4	.00	5.48
1981	8	5	.00	4.69
1981	8	6	.00	3.51
1981	8	7	.00	6.59
1981	8	8	.00	3.99
1981	8	9	.00	7.03
1981	8	10	.00	8.11
1981	8	11	.00	3.11
1981	8	12	.00	2.95
1981	8	13	.00	2.55
1981	8	14	.20	5.95
1981	8	15	.00	7.90
1981	8	16	.00	4.43
1981	8	17	.00	3.41
1981	8	18	.00	10.25
1981	8	19	.00	3.87
1981	8	20	.00	4.80
1981	8	21	.00	11.27
1981	8	22	.00	6.00
1981	8	23	.00	4.33
1981	8	24	.00	3.90
1981	8	25	.00	2.55
1981	8	26	4.60	2.36
1981	8	27	.40	1.83
1981	8	28	2.40	3.01
1981	8	29	.00	6.72
1981	8	30	.00	3.41
1981	8	31	.00	5.18
1981	10	1	.40	8.16
1981	10	2	.00	5.88
1981	10	3	.00	7.14
1981	10	4	18.40	3.24
1981	10	5	18.40	3.45
1981	10	5	.00	5.26
1981	10	6	.00	5.31
1981	10	7	.00	6.31
1981	10	8	.00	6.21
1981	10	9	.00	6.13
1981	10	10	.40	6.28
1981	10	11	.00	6.80
1981	10	12	.00	3.87
1981	10	13	16.60	3.71
1981	10	14	.00	5.21
1981	10	15	.00	3.63
1981	10	16	15.90	7.22
1981	10	17	.00	4.21
1981	10	18	13.40	1.99
1981	10	19	18.00	3.46
1981	10	20	.40	3.04
1981	10	21	3.00	4.32
1981	10	22	2.40	3.46
1981	10	23	3.00	7.27
1981	10	24	.20	5.09
1981	10	25	.00	4.35
1981	10	26	.00	5.77
1981	10	27	.00	6.43
1981	10	28	.00	5.88
1981	10	29	.00	6.74
1981	10	30	.20	5.38
1981	10	31	.00	7.01
1981	9	1	.00	8.33
1981	9	2	.00	4.50
1981	9	3	.00	3.27
1981	9	4	.00	3.64
1981	9	5	.00	5.29
1981	9	6	.80	4.14
1981	9	7	.00	5.17
1981	9	8	.00	4.76
1981	9	9	.00	6.14
1981	9	10	.00	3.08
1981	9	11	.00	4.29
1981	9	12	.00	4.08
1981	9	13	1.30	3.85
1981	9	14	.00	2.81
1981	9	15	.00	4.25
1981	9	16	.00	5.14
1981	9	17	.00	5.08
1981	9	18	.00	5.38
1981	9	19	.00	6.04
1981	9	20	1.30	3.79
1981	9	21	35.60	4.36
1981	9	22	.00	4.59
1981	9	23	.20	2.61
1981	9	24	.00	5.75
1981	9	25	.00	8.39
1981	9	26	.00	4.31
1981	9	27	11.40	11.34
1981	9	28	.00	9.23
1981	9	29	.00	5.47
1981	9	30	.00	6.11
1981	11	1	10.40	3.34
1981	11	2	62.40	2.83
1981	11	3	29.80	2.12
1981	11	4	8.00	3.79
1981	11	5	8.80	4.85
1981	11	6	.00	4.15
1981	11	7	.00	5.09
1981	11	8	.00	5.60
1981	11	9	.00	5.00
1981	11	10	1.80	6.27
1981	11	11	.00	4.30
1981	11	12	.00	4.20
1981	11	13	.80	7.54
1981	11	14	5.20	7.08
1981	11	15	.00	4.22
1981	11	16	.00	7.19
1981	11	17	.00	7.51
1981	11	18	.00	6.25
1981	11	19	.00	2.98
1981	11	20	.20	3.70
1981	11	21	3.20	4.62
1981	11	22	1.40	4.82
1981	11	23	1.00	7.46
1981	11	24	.00	6.22
1981	11	25	.00	7.55
1981	11	26	.20	9.15
1981	11	27	.00	8.49
1981	11	28	.00	6.74
1981	11	29	.00	7.02
1981	11	30	1.80	4.75
1981	12	1	.80	4.81
1981	12	2	16.00	2.98
1981	12	3	2.60	3.43
1981	12	4	.00	6.57
1981	12	5	.00	5.57
1981	12	6	.00	8.03
1981	12	7	.00	7.73
1981	12	8	.00	7.57
1981	12	9	.00	7.17
1981	12	10	.00	7.23
1981	12	11	.00	7.83
1981	12	12	.00	9.39
1981	12	13	.00	8.39
1981	12	14	.40	5.60
1981	12	15	12.40	6.41
1981	12	16	.00	5.49
1981	12	17	.00	4.93
1981	12	18	.00	4.84
1981	12	19	.00	5.30
1981	12	20	34.00	5.34
1981	12	21	1.40	5.07
1981	12	22	2.00	4.90
1981	12	23	.00	3.60
1981	12	24	.00	3.76
1981	12	25	25.00	5.78
1981	12	26	8.00	3.93
1981	12	27	3.20	4.49
1981	12	28	1.80	5.89
1981	12	29	.00	5.52
1981	12	30	7.00	3.10
1981	12	31	4.00	3.78