Appendix D – Soil Moisture Water Balance Model

The soil moisture water balance model (SMWBM) is employed as a preconditioner for assigning groundwater recharge to the MODFLOW model. The pre-conditioning of rainfall recharge through use of the soil moisture accounting model ensures that antecedent soil moisture conditions are considered in a realistic manner.

The model is a deterministic lumped parameter scheme, with algorithms adapted from those developed by Pitman (1976). The model utilises daily rainfall and mean monthly pan evaporation data to calculate soil moisture conditions and estimate percolation to the aquifer.

The model incorporates parameters that characterise the catchment in terms of interception storage, soil moisture storage capacity, soil moisture infiltration, percolation to groundwater, ands various other parameters. While no specific field measurements are available for characterisation of the aquifer material on the Aupouri Peninsula, some parameters have been obtained through reference to published research. Other parameters have been estimated on the basis of experienced judgement in the initial instance and ballpark estimates of wall balance components given in the NRC (1991) report. These were then refined in the process of calibrating overall catchment runoff/percolation against expected runoff (or lack thereof) and aquifer recharge.

The fundamental operation of the model is as follows:

- Daily rainfall is disaggregated into hourly intervals when a rainday occurs[1] to allow refined accounting of soil infiltration and evaporation losses. Rainfall received must first fill a nominal interception storage (PI – see below) before reaching the soil zone, where the net rainfall is assessed as part of the runoff/infiltration calculation.

- Water that penetrates the soil is assigned to a nominal soil moisture storage zone (ST). This zone is subject to evapotranspiration via root uptake (R) according to the mean monthly pan evaporation rate prorated on the current soil moisture status (i.e., soil evaporation (and transpiration) decrease as the soil dries out). The soil moisture zone also provides a source of water for deeper percolation (FT, POW) to the underlying aquifer. If rainfall is of sufficient intensity and duration to fill the soil moisture storage, then surface runoff also occurs.

- The amount of surface runoff is determined after accounting for interception and soil moisture storage. Runoff is controlled by three main factors comprising; the prevailing soil moisture deficit, the nominal soil moisture infiltration capacity (ZMIN & ZMAX), and the proportion of impervious portions of the catchment directly linked to drainage pathways (AI).

[1] For days where no rain occurred in the historical record, a one-day time step is implemented.

- Finally, the model produces daily summarises of the various components of the catchment water balance including surface runoff, percolation to groundwater (groundwater recharge) and total catchment discharge. The groundwater percolation component is employed as the preconditioned recharge in the MODFLOW model.

Model Parameters

Parameters used in the SMWBM of most significance comprise the following, and a summary of values used in each zone is given in Table D1:

ST: Maximum soil moisture capacity

The parameter ST is of major importance in that it is the most significant factor determining the ability of the catchment to regulate runoff for a given rainfall event. The higher the value of ST, potentially the greater the amount of rainfall absorbed by the catchment during wet periods, and during dry period results in more sustained baseflow contributions. Higher values of ST values are also subject to evaporation over a larger volume of soil.

The depth of the ST zone basically prescribes an active zone within which root uptake through plants can occur. The sand dunes are assigned a ST depth of 1000 mm, which relates to a field depth of 4 m assuming an effective porosity of 25%.

SL: Soil moisture storage capacity below which percolation ceases

There is a definable soil moisture state below which percolation ceases due to soil moisture retention. For practical purposes this has been assigned zero in all layers.

ZMIN & ZMAX: Minimum and maximum soil infiltration rate

ZMIN and ZMAX are nominal minimum and maximum infiltration rates in mm/hr. ZMIN ultimately determines the depth of rainfall required in any period to initiate surface runoff and thus has a strong influence on the amount of rainfall entering the soil profile.

ZMAX is the nominal maximum capacity of the soil to infiltrate rainfall and together with ZMIN, regulates the volume of water entering soil moisture storage and the resulting surface runoff.

FT: Percolation rate from soil moisture storage at full capacity

FT (mm/day) is the maximum rate of percolation from the soil moisture storage zone and together with POW controls the rate of percolation to the underlying aquifer system.

POW: Power of the soil moisture-percolation equation

The parameter POW determines the rate at which percolation diminishes as the soil moisture content is decreased. POW therefore has significant effect on the seasonal distribution and reliability of percolation, as well as the total yield from a catchment. Through previous experience a value of two has been assigned to POW.

AI: Impervious portion of catchment

This parameter represents the proportion of impervious zones of the catchment directly linked to drainage pathways (AI) and is assigned zero for the Aupouri aquifer catchments.

R: Evaporation-soil moisture relationship

Together with the soil moisture storage parameters ST and SL, R governs the evaporative process within the model. The rate of evapotranspiration is estimated using a curvilinear relationship relating evaporation to the soil moisture status of the soil. As the soil moisture capacity approaches full, evaporation occurs at a near maximum rate based on the mean monthly pan evaporation rate, and as the soil moisture capacity decreases, evaporation decreases exponentially according to the predefined function.

Table D1. Summary of major parameter settings for each zone.

Zone	Description	ST (mm)	FT (mm/day)	ZMN (mm/hr)	ZMX (mm/hr)	PI (mm)
1	Dune Zone	350	0.8	5	30	5
2	Forested Dune Zone	1000	1.0	5	30	2
3	Plains Zone	200	0.4	0	8	2

Table D2 summarises the characteristics and resulting water balances for each zone identified in the Aupouri aquifer region.

Table D2. Long-term average water balance summary for recharge zones.

Zone	Description	Recharge	Evap.	Runoff	Characteristics
1	Dune Zone	18.1%	81.7%	0.2%	High infiltration capacity, medium soil moisture storage capacity, smaller active root zone, moderate evapotranspiration, low surface runoff.
2	Forested Dune Zone	10.4%	89.5%	0.1%	High infiltration capacity, high soil moisture storage capacity, large active root zone, high evapotranspiration, low surface runoff.
3	Plains Zone	12.0%	64.2%	23.8%	Reduced infiltration capacity, medium soil moisture storage capacity, smaller active root zone, lower evapotranspiration, greater surface runoff (interflow drainage).

Notes:
Values indicate the long-term average as a percentage of rainfall from the 1874 to 1999 record.
Evap. refers to total evaporation losses including interception, evaporation and transpiration.