THE APPLICABILITY OF TWO SIMPLE SINGLE EVENT RAINFALL-RUNOFF MODELS TO CATCHMENTS WITH DIFFERENT CLIMATE AND PHYSIOGRAPHY.

THESIS

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ABSTRACT

The study presents the results of applying two isolated event, constant runoff proportion, conceptual models to a range of catchments drawn from various climatic and physiographic regions of South Africa and the USA. The models can be operated in either lumped or semi-distributed modes. The research progressed through the following stages.

The initial stage involved the calibration of both models on two sets of catchments so that an initial evaluation of the performance of the models could be carried out and any deficiencies in the model structure identified, and where practical, corrected. The models where then calibrated on a further 8 catchments. An important result of the calibration is that for both models to produce reasonably acceptable simulations, at least one parameter has to vary between storms on the same catchment to account for variations in storm or antecedent moisture characteristics.

The next stage consisted of compiling quantitative descriptions of the physical characteristics of the catchments and rainfall events and an attempt to relate the calibrated parameter values to relevant physical characteristics for the purpose of estimating parameter values when calibration is not possible. Despite the difficulties encountered in quantifying some of the hydrological characteristics the general trends exhibited by many of the relationships are encouraging and the format of the combinations of physical variables used, do make sense with respect to the original parameter conceptualisations. The relationships between storm characteristics and parameters of both models are less satisfactory. There is a high degree of scatter and the between-catchment variation in the form of the relationships, indicates that the derived relationships are likely to be of little use for parameter estimation purposes.

The final stage involved a validation exercise in which new parameters were estimated from the physical variable-parameter relationships for all the catchments previously used, as well as a further four. The new parameters were used to re-simulate all the storms and comparison of these results were made with the original calibration results. Both models produced poor results and are unlikely to give reliable results where calibration is not possible. The parameter relationships for the parameters related to storm characteristics are so catchment specific that transfer to other areas will produce unpredictable results.

Foot note:- For compatability with computer printouts decimal full stops are used in the format of real numbers in tables etc.

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CHAPTER 1

1 INTRODUCTION

The research presented in this thesis forms part of larger research project on single event, deterministic models for simulating complete streamflow hydrographs (Hughes and Herald, 1985). This is a Water Research Commission project undertaken by the Hydrological Research Unit of the Department of Geography at Rhodes University. The final report to the Water Research Commission (Hughes and Beater, 1989), concentrates on a discussion of the procedures used and the results obtained from applying four deterministic rainfall-runoff models to the simulation of isolated flood events from a wide range of catchments. This thesis concentrates on two of the models, both of which are constant runoff proportion models and can operate in lumped or semi-distrubuted modes.

The background to the study includes a discussion, later in this chapter, on hydrological modelling philosophy. This is followed by a classification of deterministic models to establish the model's contextual backgrounds and a discussion of the methods of testing models to ascertain their capabilities (chapter 2). Chapter 3 provides more information on single event models, from simple through to more complex types, followed by a detailed description of the two models being tested. These descriptions include background information, the conceptual structure of each model and the perceived associations between model parameters and catchment and storm characteristics. The objectives and aims of the research are described in chapter 4 and a summary of the computer programming considerations and the modelling approaches adopted during the different stages of model testing, is also provided. A description of the test catchments used to calibrate and validate the model is provided in chapter 5. Apart from hydrological information, data on vegetation, soil landuse and geology are provided.

The research programme can be summarised in several definable stages, each one designed to reveal information about the relative usefulness of the models. The initial stage involved the calibration of both models on two sets of catchments with very different climatic and physiographic characteristics. The primary purpose of this stage was to try and identify any obvious deficiencies in the models' structures which could easily be corrected before continuing with the larger data set incorporating far more catchments. The semi-arid, South African, Ecca catchments (Roberts, 1978; Görgens, 1983) and the temperate, forested, USA, North Danville catchments (USDA, 1955-1973) were selected for initial calibration. The results are presented and discussed (chapter 6) with respect to the curve fitting capabilities of the two models, the parameter stability, the physical interpretation of parameters and the ease of model calibration. This stage did not include parameter validation or the comparison of model performance.

The second stage consisted of applying the models to a further 8 groups of catchments drawn from different parts of South Africa and North America. The model testing procedure, involved calibration of the models on the available storm data set. Both models had at least one parameter which varied between events on the same catchment during calibration but those parameters which could assume fixed values were calibrated on a subset of the available storm data, followed by validation on the remaining data. The results of this stage of the calibration are interpreted with respect to the different model types, different catchment types as well as the amount and quality of the available data with which to define the rainfall input.

The next stage involved compiling quantitive descriptions of the physical characteristics of the catchments and the storm data and then attempting to find relationships between the parameter values and relevant characteristics (chapter 7). Generally, there was a lack of detailed information on the soil characteristics of the catchments which meant that the quantification of some physical variables had to be based on ordinal scale indices. It was not expected that perfect or even good relationships would be found initially. The intention was to determine whether single, or more commonly, a combination of catchment characteristics could be found that explains the general trend of differences in parameter values between different catchments. This stage therefore begins to address some of the aims (chapter 4), with respect to examining parameter stability and relationships between parameter values and catchment characteristics.

The next stage consists of assessing the effects on the hydrograph simulations of using the relationships derived from catchment and storm characteristics (chapter 7). This was carried out by re-running the models with parameter values predicted by the general trend lines of the relationships. These new simulation results were then compared with the calibration/simulation results of stage 2. This last stage therefore represents a validation exercise which evaluates the predictive value of the relationship derived to estimate parameter values. Several catchments not used previously were included at this stage to investigate whether the relationship can be considered applicable to areas outside those used to develop them and to assess whether the models can be used successfully on ungauged catchments.

The final stage (chapter 8) involves summarising the main findings of the research and comparing the results obtained from both models (i.e explaining differences and evaluating which model performs more successfully). This is followed by a discussion of the usefulness of these models, for estimating floods. Computer listings of various physical indices, parameters and results are given in the appendices.

1.1 HYDROLOGICAL MODELLING PHILOSOPHY

The derivation of a relationship between catchment rainfall (input) and the resultant runoff (output) is a fundamental hydrological problem. In the great majority of catchments rainfall records do exist, but the more elaborate and expensive streamflow measurements, which are required for the assessment of water resources or estimating the size of damaging flood peaks, are often limited or unavailable. Therefore in such situations an indirect approach to evaluate the runoff response from rainfall must be adopted. This has stimulated research and resulted in the development and widespread use of hydrological simulation models (Bugliarello and Gunther, 1974; Fleming, 1975; Stephenson, 1981; Shaw, 1988).

The use of mathematical models in hydrology may be justified by two principal requirements. The first is research orientated and reflects the need to explain the hydrological cycle as precisely as possible; that is mathematical models provide the opportunity to improve basic knowledge concerning hydrological processes. The second requirement is practical and involves using a hydrological model as a tool to aid solving a hydrological problem (James, 1972; Stephenson, 1981; Linsley, 1982; Weisman, 1982; Kundzewicz, Afouda and Szolgay, 1987; Hendrickson, Sorooshian and Brazil, 1988; Klemes, 1988).

Research orientated requirements may involve a study on the entire hydrological cycle or it could involve study on a localized scale, e.g. the hydrology of a hillslope (Freeze, 1978). These models attempt to formulate, couple and solve the equations of mass, energy and momentum which describe the movement of water over and through the soil (Woolhiser, 1982; Abbott, Bathurst, Cunge, O'Connell and Rasmussen, 1986). However, the data and computing requirements for these physically based models are rigorous, limiting their use to research institutions with the necessary facilities, expertise and time to collect and process data.

Hydrological models are more widely used to aid decision making in water resources planning and management as well as for a vast number of hydro-engineering purposes. These models have less rigorous data and computer requirements and make up the majority of hydrological models. The following list summarises some of the applications for these which hydrological models are used:-

a) Forecasting and predicting hydrologic phenomena - most water resource development projects use prediction models in various aspects of project planning, design, construction and management (Fleming, 1975; Pattison, 1975; Green and Stephenson, 1986a). Knowledge of a catchments flow regime is a major object of water resources management, so as to minimize the hazard to the resident population and damage to the environment in terms of high flows (floods) and low flows (drought) (Shaw, 1988).

b) Engineering applications - there are a variety of engineering tasks that can be accelerated and the results greatly improved by the appropriate use of a hydrological model. The model simulates a situation and is used as an analytical tool in the design process (Green and Stephenson, 1986a). Hydro-engineering tasks include:-

i) Design situation - knowledge of catchment streamflow is necessary to aid in the efficient design and construction of bridges, conduits, dams, flood control structures, etc. (Foroud and Broughton, 1981; Lowing and Mein, 1981; Windsor, 1981).

ii) Record extension - most engineering answers need to be in the form of probability statements. The larger the data sample the more reliable are the estimates of probability. For example a continuous model can be used to lengthen available flow or rainfall records or compute a synthetic record for an ungauged catchment (Laurenson, 1964; Gupta, Orphan and Bird, 1982; Beven, 1983).

iii) Operational simulation - this involves the need to determine the effects of one or several alternative solutions to a particular problem, for example 'real time' reservoir simulation and operation (Jarboe and Haan, 1974).

iv) Data fill-in and data revision - involves the simulation of an existing record to replace missing data. Data revisions are required when streamflow records exist but are unrepresentative of the current flow regime because of changes in catchment conditions. A model may be able to simulate the current flow conditions or even conditions expected to exist at some future time (Linsley, 1982).

v) Hydrologic models may also be used to assess the effect of landuse changes and to estimate sediment and solute load of a river system (Beven and O'Connell, 1982; Fleming, 1984).

In recent years hydrological simulation techniques have increased in popularity resulting in a proliferation of different models. Some of the models are intended for specific applications (event based models), while others are more general in their area of applicability (Green and Stephenson, 1986b). There is also a wide variation in the mathematical formulations adopted by different models to describe the various components of the rainfall-runoff process, and these descriptions may differ not only in terms of concept but also in terms of complexity. Therefore the model user is faced with the problem of selecting an appropriate model, from the many available, for a particular problem. The associations between model complexity and model application are discussed in the following section.

1.1.1 Model complexity

Figure 1.1 demonstrates that the complexity of any approach to modelling the rainfall-runoff processes, encompasses three main aspects. The first is related to the approach adopted to modelling the various components of the hydrological cycle. The other two are related to the levels of spatial and temporal distribution that are allowed for in the model structure. These aspects are not necessarily independent of each other and the methods adopted to model processes can influence the time interval of modelling and the spatial distribution system to be used. As a result of this interdependence it is important that they are compatible with each other in a single model structure. For example, there is no point in incorporating complex physical equations of moisture movement in a model where the spatial variations of that moisture movement are not accounted for (Hughes and Beater, 1989).

A problem often faced by the modeller is the desired level of complexity required in the model. Complex (physically based) models have not consistently shown demonstrable improvements over simpler approaches (Naef, 1981; Görgens, 1983; Loage and Freeze, 1985). This is because prohibitively large amounts of input data are required by physically based models which is one of the main limiting factors in their successful application (Roberts, 1984; Loage and Freeze, 1985). Due to these restrictions, physically based models have not been widely applied, consequently the degree of confidence in their successful application has yet to reach a level to induce the user to invest the considerable time and money to operate them. Model users generally adopt a pragmatic approach to model selection, tending to choose a model that is relatively simple to operate in terms of the required amount of data and the evaluation of parameter values and gives acceptable answers for the intended application.

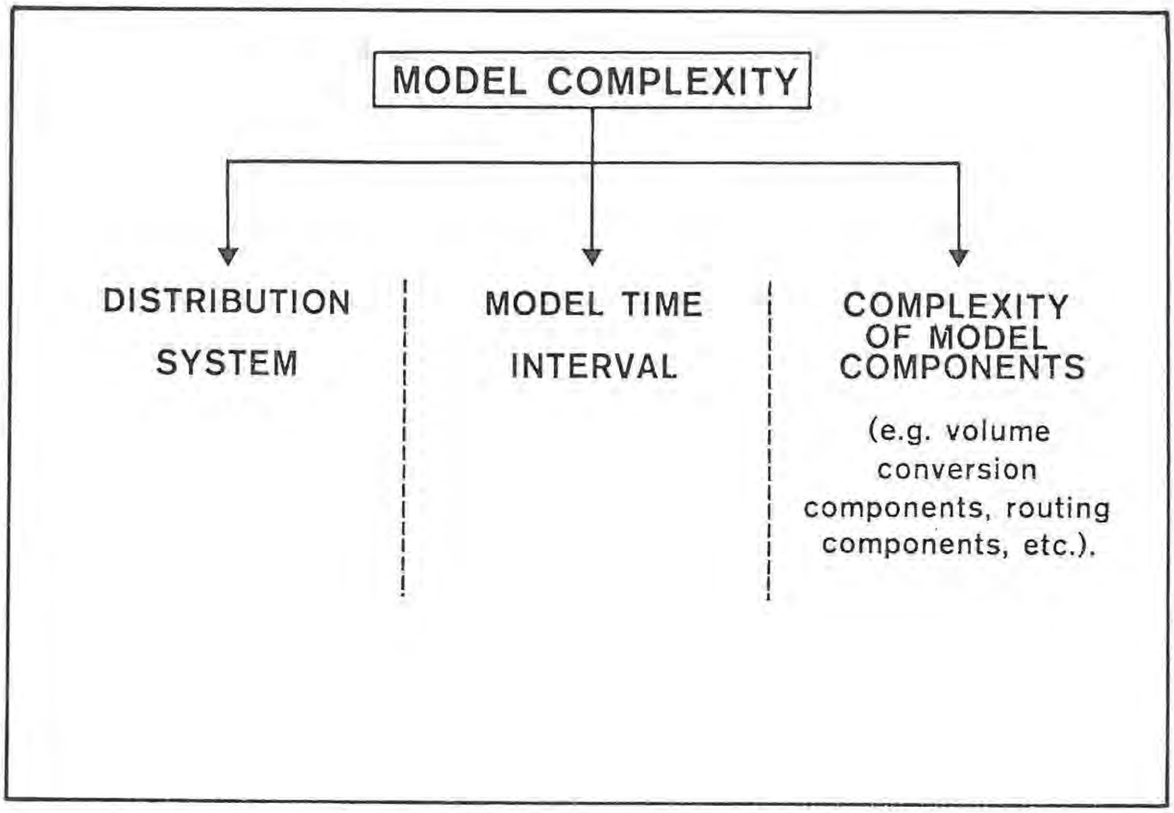


Figure 1.1 Aspects of model complexity.

1.1.2 Model application

Conventionally model applications are considered in terms of the type of output required to solve a particular problem. However, other considerations include catchment type, climate and the availability of data (figure 1.2). Models can generate long sequences of streamflows for surface water resources evaluations or information about flood peaks and volumes may be required for extreme event analysis or for flood forecasting. The level of accuracy for which output information is required must also be considered. In terms of climate a model may have limitations that prevent its valid use in specific climatic regimes. Such climatic considerations may be based upon temperature or evapotranspiration regimes or the range of storm types and rainfall intensities experienced within an area.

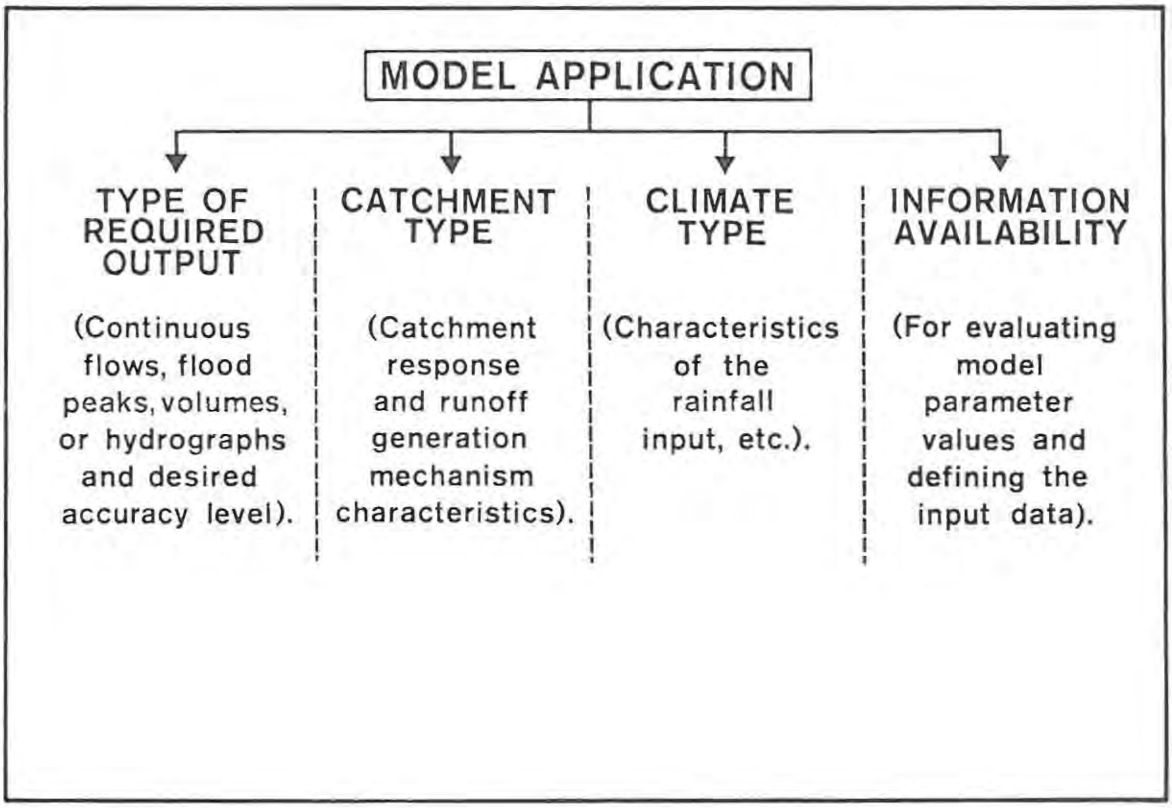


Figure 1.2 Interrelated factors associated with the differentiation of deterministic model applications.

As indicated, it is also necessary to define model applications in terms of the type of catchment to be modelled, its size, landuse, vegetation, geology and soil characteristics as well as the slope steepness and surface drainage pattern. Another distinction could be made based on the degree of spatial variation of physical characteristics that exists within a catchment. A further aspect is the amount and type of information which is available for evaluating the model parameter values and defining the input variables such as rainfall and evapotranspiration. The availability of information is often a limiting factor in the choice of a model to use for a particular application.

The above discussion of complexity and application suggests that it is not an easy task to choose a particular modelling approach for a particular application. All models are imperfect representations of the real hydrological processes. Despite advances in modelling and computer technology and the availability of quantitative mathematical procedures (Pilgrim, 1975) for parameter estimation and testing the many types of models, most of the fundamental decisions remain unclear, resulting in uncertainties. For example it seems logical that the use of a spatial distribution system is required to account for spatial variations in rainfall-runoff characteristics as well as input rainfall or other climatic variables. However the extent to which a distributed model performs more successfully than a lumped model is not known and can be expected to vary between different modelling situations, particularly if the spatial variation of the rainfall or runoff is poorly defined. Similar uncertainties may be associated with identifying the most appropriate time interval over which to carry out model iterations. There can exist a large number of poorly understood interactions between the type of model application and the level of sophistication that is required to produce acceptable results. This problem does not appear to be widely or adequately addressed in the hydrological literature. Only when these interactions are better understood will it be possible to offer some sort of framework for choosing a model for a given application.

CHAPTER 2

2 DETERMINISTIC MODELS

2.1 MODEL CLASSIFICATION

Hydrological models can be divided broadly into two categories; deterministic and statistical (Clarke, 1973; Fleming, 1975; Kundzewicz *et al.*, 1987; Shaw, 1988). Statistical modelling approaches, fall into three categories, namely regression and correlation methods, probabilistic methods and stochastic methods (Fleming, 1975). They recognize chance dependence of hydrological processes (Freeze, 1978) and make use of existing data (hydrological time series, e.g. rainfall or flow records) and statistical principles to generate output in accordance with certain statistical patterns (Salas, Delleur, Yevevich and Lane, 1980; Angus, 1985). In contrast, deterministic models regard hydrological processes as being chance independent (Clarke, 1973). That is, the processes linking rainfall to riverflow are governed by definite physical laws which are generally known, and that a catchment is not a random assembly of different parts but a geomorphological system with catchment characteristics which may vary spatially and temporally but in a known way (Pitman, 1973; Beven, 1983; Müftüoglu, 1984). The division between these two categories may not always be distinct and in providing information for the design engineer or hydrologist, a combination of the deterministic and statistical approaches is proving to be successful (Roberts, 1978; Dawdy, 1982; Green and Stephenson,1986b). For example a stochastic model may be used to lengthen rainfall records and a deterministic model may be used to predict runoff from the generated rainfall (Bonne, 1970; Herald, 1989). The discussion that follows is confined exclusively to deterministic models. The divisions proposed are more general than rigorous and may not encompass all concepts and viewpoints.

Deterministic models may be classified on the basis of model structure (Clarke, 1973; Beven and O'Connell, 1982). They can be described as empirical, conceptual or physically based or alternatively as black box, grey box or white box (Roberts, 1978). Empirical models make no attempt to understand the catchment processes between rainfall input and runoff output (Müftüoglu, 1984; Kundzewicz *et al.*, 1987). Empirical models require rainfall and runoff data for calibration, use curve fitting procedures and generally cannot be applied to the ungauged situation. Widely used empirical models include the Rational Method and Unit Hydrograph procedure (Green and Stephenson, 1986a). Both of these models have been modified so that they can be applied to the ungauged situation. Pilgrim and McDermott (1982) describe a regionalised approach to parameter estimation for the Rational Method and Pirt (1983) describes a synthetic

Unit Hydrograph procedure that has parameters that can be correlated with catchment characteristics and can be used in the ungauged situation.

At the other end of the deterministic modelling 'scale' are the physically based or white box models which define the whole catchment hydrological system with more precise physical equations (Abbott *et al.* , 1986). The interactions of the known physical processes within a catchment which contribute to producing runoff from rainfall are defined. Physical models treat a catchment as a spatially variable system and processes involving a hillslope to the entire catchment may be modelled. This is generally done by dividing the catchment or hillslope into a network of segments in which all hydrologically significant parameters are assumed to be uniform and are in principle measurable in the field (Jayawardena and White, 1977; Beven and O'Connell, 1982; Yen, 1984). The main drawback associated with physically based models is the astronomical amount of field data required to determine the spatially variable parameter values. When combined with the additional factors of model complexity and expertise required to develop the model, significant economic restraints are imposed on their practical application (Loage and Freeze, 1985). Despite these drawbacks, it is clear that physically based models are essential in the field of integrated catchment modelling where elements such as landuse changes, the movement of pollutants and sediments through a catchment and groundwater recharge need to be predicted (Fleming, 1984; Hughes, 1985).

Between these two extremes (i.e. between physically based and empirical deterministic models) lies the class of conceptual models. Conceptual models are models in which some understanding of the hydrological processes is included in the model formulation, i.e. quasi-physical models (Shaw, 1988). In conceptual modelling the catchment is perceived as consisting of one or more moisture storages (James, 1972; Higgins, 1981) through which rainfall inputs are routed by a process of moisture accounting, eventually to produce streamflow output (figure 2.1). The storage sizes, the transfer (routing) of moisture between storages and the output of streamflow and evapotranspiration are all defined by mathematical relationships (equations) (Nash and Sutcliffe, 1970; McCuen, 1973; IOH, 1975). The structures of the mathematical relationships are usually assumed to be constant for all catchments, but certain coefficients of these relationships, which describe characteristics of the catchment, and are known as model parameters, are allowed to vary from catchment to catchment (Görgens, 1983). The modelling approach for conceptual models could involve calibration of the model on a range of catchments and the development of relationships with physiographic variables from parameter results (James, 1972; Linsley, 1982; Pirt and Bramley, 1985). This approach would involve a great deal of model calibration and verification to test and quantify the relationships developed from physical catchment or storm characteristics.

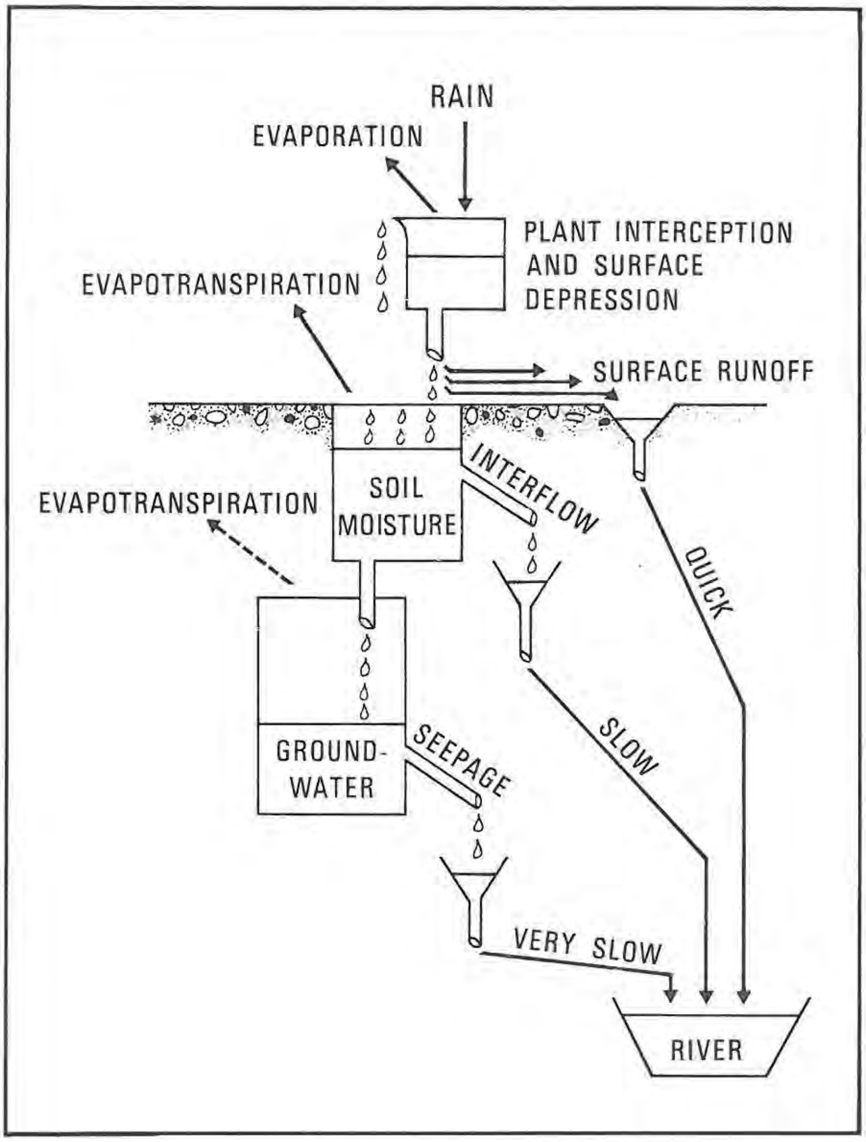


Figure 2.1 Conceptual model of a river catchment through which rainfall inputs are routed by a process of moisture accounting, eventually to produce streamflow output.

The distinction between the above deterministic models is not always obvious (Clarke, 1973) and models apparently firmly based in physics may contain obviously empirical components, for example the infiltration component is often derived empirically (Woolhiser, 1982). Whilst models without reference to physical processes may have parameters for which some physical interpretation can be made, for example the S-curve model of Hughes (1984). Despite this 'greyness' most deterministic models fall into one or another of the above groups.

Deterministic models can also be described as being linear or non-linear models (Clarke, 1973; Shaw, 1988). A linear model assumes that the conversion of rainfall excess into surface runoff occurs in the same way irrespective of the amount of rainfall or runoff that occurs (Nash and Foley, 1982). The great majority of empirical models are linear models. However the process of runoff generation is known to be non-linear (Dawdy, 1982) and therefore most conceptual and all distributed models are nonlinear models.

A further distinction can be made between deterministic models which treat the catchment as a spatially variable system, i.e. distributed models (Beven and O'Connell, 1982) and those which provide a lumped or average description of river basin behaviour (Lee and Delleur, 1976; Troutman, 1985). There are two basic groups of distribution system. One is based upon rectangular grids and the second on drainage units within the catchment. Lumped models are a special case of the second group. Most physically based models use a spatial distribution system to account for spatial variations in response characteristics as well as rainfall or other climatic variables.

The differences between simple lumped models and more physically based distributed models are highlighted by the calibration procedures adopted to determine the appropriate parameter values for a given catchment. Lumped models rely primarily on the comparison between observed and simulated catchment outflows for calibration of the lumped parameters. This curve fitting procedure is necessary because lumped conceptual models typically have parameters which are not directly measurable from catchment or storm characteristics. A period of historical runoff data must therefore be available to calibrate a lumped model. As a result their application is generally restricted to the data base from which they were derived (Miller and Frink, 1984). The Stanford Watershed model is a classic example of a lumped conceptual model (Beven and O'Connell, 1982; Görgens, 1983; Shaw, 1988). In contrast, physically based distributed models attempt to infer parameter values from measurable catchment and/or storm characteristics. It must be noted however, that despite the distributed nature of these models some degree of parameter 'lumping' occurs because the model distribution scale is generally larger than the scale which characterises the operation of the various hydrological processes. The important difference is that the physically based model parameters may be validated by field measurements and are generally more suited for application in the ungauged situation. Distributed models, however, may prove impractical due to their complexity and the large data requirements. Model users prefer models that are relatively simple to operate, and an alternative is a semi-distributed modelling approach which attempts to bridge the gap between the simple lumped approach and the complex distributed modelling approach (Beven and O'Connell, 1982). The semi-distributed approach takes into account the spatial heterogeneity of parameters over a catchment but retains the more simple structure of the less data intensive lumped models. An example of a semi-distributed model is one whereby the sub-catchments are modelled in a lumped way and the resultant sub-catchment outflows are combined and routed through the catchment using a channel routing procedure (Laurenson and Mein, 1985).

Deterministic models can also be sub-divided into models that are concerned with fitting long term hydrologic records (continuous models) and those that model discrete isolated events (floods) (Krzystofowicz and Diskin, 1978; Hughes, 1983a). Thus the choice of deterministic model is determined primarily by the problem facing the modeller. Continuous models are generally used when the hydrologic problem is water resources related (Green and Stephenson, 1986b). Such a model is required to generate long term flow peaks or volumes from long periods of coarse time interval rainfall input data (Bailey and Dobson, 1980; Packman and Kidd, 1980; Beaudoin, Rouselle and Marchi, 1983). Continuous models can also be used for real time flood forecasting, (Serban, 1976; Green, 1979; Beven, Kirkby, Schofield and Tagg, 1984; Anderson and Burt, 1985; Todini, 1988) which require short time interval rainfall data. These models generally involve a water-balance approach, i.e. the moisture storages are modelled continuously, thus precluding the necessity to estimate initial catchment moisture status at the start of an event. However long periods of short period rainfall are rarely available and the data requirements for this type of modelling are large. An alternative approach to real-time flood forecasting is a model which operates continuously but with a coarse time interval between events (Dunsmore, Schulze and Schmidt, 1986).

In many instances, the major focus of interest is on single event analysis rather than the analysis of continuous hydrologic records (Morel-Seytoux, Correio, Hyre and Lindell, 1984). It can be wasteful therefore to run simulations continuously over long periods of time, only to extract a few flood events from the voluminous output available (Krzystofowicz and Diskin, 1978). Isolated event models (IEM) are only concerned with flood events (Linsley, 1982) and are consequently more economical in terms of data, time and effort. Isolated event models can be described as either moisture accounting models or storm runoff models (Hughes, 1983b). The main distinction is that all moisture is accounted for in the accounting type models whereas storm runoff models determine excess rainfall using some simple surrogate estimate. For example, a method which determines excess rainfall when rainfall exceeds the infiltration rate may be used. Generally storm runoff models are less complicated than moisture accounting models because the method avoids the problem of simulating evapotranspiration and soil moisture status (Naef, 1981; Hughes, 1983b).

Isolated event models generally have three basic components:

a) Antecedent moisture component:- For many isolated event models, estimates of initial moisture status have been based on simple decay functions of some number of the previous days' rainfall, which can be modified to include seasonal influences (Hughes, 1984). The level of catchment outflow at the beginning of a storm has also been used. Moisture budgeting techniques to estimate soil moisture deficiencies continuously on a regional scale have been used in several models (Pirt and Bramley, 1985). A review of the available literature shows that no isolated event model attempts to make use of distributed estimates of initial moisture conditions. This could be a major short-coming if it is assumed that the antecedent moisture status of a catchment can play a major role in determining the degree of hydrological response and that the moisture status is likely to be spatially variable.

b) Excess rainfall or direct runoff component:- Excess rainfall refers to that proportion of gross rainfall that contributes to catchment outflow (Garklaus and Oberg, 1986). It is necessary to make a distinction between those models that estimate stormflow and those that estimate total outflows. Stormflow models make no attempt to model the slower responding baseflow component of catchment outflow because its contribution is considered negligible during the major part of a flood hydrograph. This means that some form of separation line between the flow components must be assumed (Dooge, 1973). A commonly used method is that of Hewlett and Hibbert (1967) where stormflow begins when flow rises faster than a separation line of gradient 1.13mm day^{-1} day^{-1} ($5.47*10^{-4}m^3s^{-1}.km^{-2}.h^{-1}$). This may be a useful generalisation but it fails to account for the very big differences that may occur between catchments of different soil physiography. If total flows constitute model output then some attempt has to be made to estimate the amounts of baseflow occurring during the event.

It is possible to identify three procedures used to estimate excess rainfall. These range from simple through to complex.

i) Simple methods use constant runoff ratios (IOH, 1975), or continuing constant loss rates (Laurenson and Mein, 1985) or infiltration equations (Singh and Buapeng, 1977; Garklaus and Oberg, 1986). None of these methods account for the role of subsurface processes. The infiltration equations can form part of a strongly physically based approach to determining excess rainfall (Huggins and Monke, 1966).

ii) Intermediate approaches to determining excess rainfall includes attempts to vary the runoff response as the storm progresses as well as with changes in rainfall intensity. More than one concept of runoff generation may be employed in the estimation of rainfall excess. Examples of this group include several models that have attempted to use the variable source area concepts of runoff generation in either an implicit or explicit way (Lee and Delleur, 1976; Krzystofowicz and Diskin, 1978; Hughes, 1984; Pirt and Bramley, 1985). One of the major problems with the simple group (a) is that the parameter values of the excess rainfall will change for different events even on the same catchment. Therefore, for prediction purposes it would be necessary to estimate loss rates or runoff proportions from a combination of catchment and storm characteristics. It is difficult enough to quantitatively characterise individual storms, let alone relate such measures to model parameters. Intermediate approaches often represent an attempt to allow parameters to remain fixed for any given catchment.

iii) Physically based equations of surface and subsurface flow processes represent the most complex procedures. The SHE model (Abbott *et al.*, 1986) represents such a model.

c) Flow routing component:- The flow routing component is the process of routing excess rainfall through catchment storages to produce the surface runoff hydrograph (Laurenson, 1964). The method selected for routing flow is closely related to the other components of the model. Simple methods can include linear (Bauer and Midgley, 1974; Ponce, 1979; Green, 1979) or nonlinear methods (Hughes and Murrell, 1986), storage routing techniques, instantaneous unit hydrograph methods, or time-area diagrams (O'Donnell, 1966; Dooge, 1973; Watson, 1981). Most of these methods can be applied in both lumped and semi-distributed models. Generally the flow routing component includes a land phase (overland flow and can include subsurface flow) and a channel routing phase (Sherman and Singh, 1982) which can be integrated in one estimation formula. Fully distributed, slope element or grid models often have more complex and physically based routing approaches such as kinematic flow methods (Stephenson, 1980; Dawdy, 1982) or physical hydraulic equations (Danish Hydraulic Institute, 1985).

2.2 MODEL TESTING

Once a deterministic model is selected the evaluation of its performance is divided into two stages. The first stage involves model calibration or estimation of model parameters. That is the models' ability to reproduce runoff hydrographs is determined from the calibration and the results of the calibration are used to establish whether relationships between parameters values and storm or catchment or antecedent moisture status can be determined and whether these relationships are applicable over a range of catchments. The model calibration is followed by a model validation stage in which the results obtained from the calibration are checked on a data set reserved for this purpose, and to determine whether the relationships established between parameters and storm, catchment or antecedent moisture status are transferable. The stability of these relationships on ungauged catchments can then be evaluated.

2.2.1 Model calibration

The main purpose of the model calibration is to obtain a parameter set for a catchment which gives the best possible fit between the simulated and observed hydrographs for the calibration period (Stephenson, 1981; Görgens, 1983; Sorooshian, 1983; Pirt and Bramley, 1985, Hendrickson *et al.*, 1988). The calibration procedure may also involve parameter sensitivity analysis which provides a knowledge of the degree and patterns of interaction between parameters as well as the sensitivity of the fitting statistics to changes in parameter values (James, 1972; Mein and Brown, 1978; Rogers, Beven, Morris and Anderson, 1985).

There are a number of approaches which may be adopted to calibrate rainfall-runoff models (Fleming, 1975; Görgens, 1983).

a) The model parameters are inferred from measurable catchment or storm characteristics. Referred to as an *a priori* approach (Chapman, 1975) it may be applied to distributed physically based conceptual models, for example the SHE model (Beven and O'Connell, 1982). However data requirements for such models are astronomical, thus limiting their use in many cases to small research catchments (Freeze, 1978).

b) Model parameters can also be inferred by so called curve fitting or goodness-of-fit approaches. This involves finding parameters which will ensure close correspondence between specific characteristics of a hydrologic time series and their observed equivalent. Goodness-of-fit criteria are used to determine how closely the observed and simulated time series correspond. This goodness-of-fit calibration procedure can range from being completely objective, achieved when adopting automatic optimization routines (Ibbitt and O'Donnell, 1971; Hendrickson *et al.*, 1988), to being pragmatically subjective, that is trial-and-error fitting by manual alteration of model parameters, thus relying on visual impressions of the correspondence between simulated and observed time series (Pitman, 1976).

c) A third calibration approach involves estimating parameters by employing both *a priori* and goodness-of-fit methods (Görgens, 1983). This means that a number of parameters are physically based and may be estimated from catchment characteristics. For example, Pitman (1976) in his daily input model has 4 physically based parameters out of a total of 13 parameters. For most such models however, the physically based parameters are estimated initially from catchment characteristics and then 'fine-tuned' by goodness-of-fit calibration methods.

Simple conceptual models that utilize constant runoff proportions (Mandeville, 1983; IOH; 1975) are not likely to have many strongly physically based parameters. Therefore events have to be calibrated separately because of variations in runoff proportion due to variations in the rainfall characteristics from event to event.

2.2.2 Fitting criteria

An important part of the modelling process is to establish that the model represents the physical system. This usually involves a comparison between the recorded and modelled response (Fleming, 1984). The following hydrograph characteristics need to be known and used as fitting criteria to determine whether a satisfactory calibration has been achieved (Diskin and Simon, 1977; Sefe and Broughton, 1982; Sorooshian, 1983; Green and Stephenson, 1986b):-

a) total volume of runoff;
b) peak flow rate;
c) timing of peak flow rate;
d) time duration of rise to peak;
e) shape of the recession curve.

The correspondence of simulated and observed hydrographs is measured by a number of statistical procedures or goodness-of-fit criteria known as objective functions (Pilgrim, 1975; Diskin and Simon, 1977; Green and Stephenson, 1986b). There are many types of objective functions available, the choice of which to use is related to the modelling application. The following objective functions should provide a satisfactory assessment of the correspondence between observed and simulated hydrographs:-

a) coefficient of efficiency (Aitken, 1973), (E) - dimensionless measure of the one to one fit;
b) coefficient of determination, (D) - the correlation coefficient squared;
c) percentage error in total runoff volume, (%V);
d) percentage error in peak discharge, (%P);
e) time difference between observed and simulated peaks, (TP).

The coefficient of efficiency is sensitive to systematic errors (i.e. general over or under prediction) between observed and simulated hydrographs whereas the coefficient of determination is not (Nash and Sutcliffe, 1970). Large differences between these coefficients is indicative of systematic errors. High percentage errors in both the peak and volume can also indicate systematic error. Low percentage errors in peak and volume associated with low coefficient values and a large time difference between the observed and simulated peak discharge is indicative of a time shift of the whole hydrograph. Both the coefficients of efficiency and determination can be calculated using untransformed discharge values or using the natural logarithm of the values. Logarithmic transformation removes the bias towards the high values (Dobson, 1983).

The optimisation procedures used for calibrating models range from:-

a) Hand or manual optimisation generally involves modifying one (or more) parameter value and observing the effect on the fitting criteria and then repeating the exercise (Görgens, 1983). However, manual calibration is time consuming and can be confusing particularily if there is a high degree of interaction between parameters, which implies that the modeller needs to have a good understanding of the structure and operation of the model.

b) Objective or automatic optimisation procedures whereby some or all of the parameters are evaluated using an automatic optimising technique (Rosenbrock, 1960; Ibbitt and O'Donnell, 1971; James, 1972; Gupta and Sorooshian, 1985). This procedure implies a lessened reliance on the subjective judgement of the modeller and calibration can be significantly faster. However, only one objective function can be used, therefore it may be necessary to carry out manual adjustments to parameter values to fine tune the model to achieve a better overall correspondence based on several criteria. Problems with automatic optimisation include interaction between parameters that can cause complications and result in sub-optimum results being produced. Likewise, beginning the optimisation with different starting values can result in different final solutions.

Both of the above optimisation procedures can be used to calibrate the lumped and semi-distributed versions of a model. The calibration of a semi-distributed model is more complicated because information concerning differences in hydrologic response between sub-catchments needs to be available. This information must then be interpreted in terms of differences in parameter values. Without this information, changing parameter values of the sub-catchments to improve the fit could be dangerous as well as becoming a time consuming exercise. Despite these drawbacks, the semi-distributed modelling approach should be more successful than the lumped modelling approach, particularly, when there is some degree of spatial variability in the rainfall input data (Berndtsson and Niemcznowicz, 1988).

The complete calibration of isolated event models maybe summarised as follows:-

a) It is necessary to achieve a satisfactory correspondence between observed and simulated discharges for individual events. This could involve the modification of the model components to improve the models performance.

b) It is necessary to establish if, and in what way parameters vary between events on the same catchment.

c) For a model to be calibrated satisfactorily for the range of catchments it is intended to represent, the manner in which parameters vary between catchments needs to be known.

2.2.3 Model validation

Once the calibration of a model is completed it is necessary to check that the calibrated parameter values can be used to satisfactorily simulate events other than those used for the calibration (Sorooshian, 1983; Pirt and Bramley, 1985). This checking procedure is known as parameter validation or verification, the two terms may be used interchangeably, although in this study validation will be used. Model validation can also include a stage in which the successful operation of the model is checked. This involves checking that the computer formulation of the model is correct (Stedinger and Taylor, 1982), that is it is necessary to ensure that moisture is not lost or gained due to the incorrect operation of a particular function. Solutions to functions should also be checked for stability within the range of parameters or variables over which the model is intended to operate. This stage is likely to occur concurrently with calibrating a model.

Once calibration is completed the validation procedure adopted will depend on the type of model. For physically based models the validation consists of testing whether the field-based measurements of parameters produce adequate simulation results. If the model is a relatively sophisticated one, for example the S-curve model (Hughes, 1984), then the parameters might be expected to remain stable for a variety of response characteristics from the same catchment (Fleming, 1975). Validation will include running the model with a set of observed events not included in the calibration and evaluating the simulation results. For simple conceptual models (constant runoff proportion models for example) the validation procedure is different. This is because one or more parameters are expected to vary between events to account for variation in catchment response to rainfall. It would be necessary to evaluate these relationships in order to quantify them, before any worthwhile validation can take place. However for those parameters which do remain stable between events the validation procedure would be as described for the S-curve model. For example the routing parameters of a simple model may be stable for all events on a catchment.

Validation results can indicate further modification of the parameter values established by the initial calibration of a model on a particular catchment or catchments. This involves further calibration to determine whether the modified parameter set can produce satisfactory and improved results for all the available events. The implication is that if additional data becomes available the parameter set may require even more changes. This means that the problem involves determining whether the available set of observed storm events is representative of the range of response types that can be expected from a specific catchment (Görgens, 1983). This depends on the climate and landuse regime of a catchment.

Another stage is to validate the perceived associations between model parameters and physical catchment and or catchment characteristics. If these associations can be established and are then successfully applied to different data sets from the calibrated catchments, then the final level of validation involves the transfer of the parameter relationships to other catchments. This is necessary to establish whether a model can be applied to the ungauged situation.

To summarise the validation of a conceptual model involves the following stages:-

a) validating the computer program structure;

b) validation of calibration parameters on a reserved data set;

c) validation of any techniques developed for the parameter transfer situation so that the model can be used on ungauged catchments.

CHAPTER 3

SINGLE EVENT MODELS

Before describing the two single event models used in this study it is necessary to establish where the models occur within the range of deterministic, single event models. This range covers simple empirical models to complex, physically based models. An important aspect of single event models is their conceptual association with the known realities of runoff generation processes. Some of the theories of runoff generation processes include:-

a) The infiltration excess or Hortonian concept of storm runoff. This concept states that surface runoff only occurs when rainfall intensity exceeds the infiltration rate of the soils of a catchment, implying that the entire catchment can contribute to runoff (Ward, 1975; Dunne, 1978).

b) Translatory or through flow concepts for sub-surface flow in saturated and unsaturated areas of a catchment. The sub-surface movement of water during an event can contribute significantly to storm runoff (Weyman, 1970; Ward, 1975).

c) Dynamic or variable source area concept (VSA) - which makes the assumption that infiltration is seldom a limiting factor and that storm runoff varies with and is generated as surface and sub-surface runoff from the saturated areas around the catchment channel system (Ward, 1975; Bernier, 1985). These saturated areas grow during an event so that the area contributing to runoff increases and this means that the infiltration rate does not have to be exceeded for runoff to occur (McColl, McQueen, Gibson and Heine, 1985).

d) More recently it has become widely accepted that a combination of processes can contribute to runoff generation (Dunne, 1978; Ward, 1984). The dominance of some of these processes over others is dependent largely upon the specific characteristics of a catchment and the prevailing climate.

Many linear models (empirical and conceptual models) are based upon Hortonian runoff principles, these include the Rational Method, Unit Hydrograph method and most infiltration equations. Some non-linear conceptual models have adopted the dynamic variable source area concept of runoff generation to transform rainfall input to runoff output (Lee and Delleur, 1976). Physically based models generally incorporate several different runoff generation processes and are therefore closer to the current understanding of rainfall-runoff processes as summarised in Ward (1984).

Simple empirical models:- This group consists of empirical formulations where little or no attempt is made to relate the model components to physical reality (Fleming, 1975; Linsley, 1982). The calibration of these models is dependent on the availability of at least some rainfall and runoff records (Shaw, 1988). They are calibrated by curve fitting methods from which statistical relationships between the model parameters and storm or catchment characteristics are established and used for predicting storms not used in the calibration. Although it is difficult to understand how they can be reliably applied to ungauged situations most practicing engineers use these simple methods, particularily when preliminary estimates concerning floods are required (Gupta *et al.*, 1982; Weisman, 1982). A survey in Australia on Design Practices revealed that the Rational method for flood estimation is used approximately 80% of the time on small catchments and the Unit Hydrograph 10% of the time while on large catchments the most frequently used method of flood estimation is the Unit Hydrograph, if flow data is available. Regionalised techniques for estimating parameters of empirical models have been developed in many areas. Examples include the work of Pilgrim and McDermott (1982) in Australia and Bauer and Midgley (1974) in South Africa.

Conceptual models:- This group of models may be sub-divided into conceptual models which account for antecedent moisture conditions and those that do not. Most current moisture accounting models make use of theoretically derived infiltration formulas (Nguyen and Wood, 1981; Hughes, 1984), such as the Green and Ampt (Rawls, Brakensiek and Miller, 1983; Devaurs and Gifford, 1986), Horton or Phillips equations (Singh and Buapeng, 1977; Al-Azawi, 1985). These equations are all based on the Hortonian runoff concept, which suggests that infiltration is spatially invariant, which is clearly not the case. There are infiltration equations which are more compatible with the variable source area concept of runoff generation which implies that infiltration is spatially variable. For example the Richards infiltration equation determines moisture in the unsaturated soil zone in a non-linear way and is used in the physically based SHE model (Abbott *et al.*, 1986). Conceptual models that do not account for antecedent moisture status can be divided into models that determine rainfall excess in a linear way, (constant runoff proportion models) and models that determine excess rainfall in a non-linear way (variable runoff proportion models). Constant runoff proportion models include models with non-linear runoff routing, for example the runoff routing model (RORB) of Laurenson and Mein (1985). RORB is based on the routing of excess rainfall through a series of non-linear storages. Other constant runoff proportion, non-linear routing models include the two models used in this research, namely the Augmented Hydrograph (Mandeville, 1983) and the Flood Studies model (IEM4) (IOH, 1975). An example of a model that determines rainfall excess in a non-linear way is the S-curve model (Hughes, 1984) which includes a variable runoff proportion component and a non-linear routing component.

Physically based models:- These models use more realistic concepts of runoff generation (Dawdy, 1982; Pilgrim and McDermott, 1982) are based on dynamic, non-linear concepts and are ideally suited to distributed modelling. Their main limitation is practical, because vast amounts of hydrological and catchment data are required to operate them successfully.

The models used in this study can be classified as deterministic, conceptual, non-linear, constant runoff proportion, single event models. The following sections summarise the basic structure of the two models selected for testing. Also included is a discussion of the origins of the models and any modifications that were made during an initial testing stage to improve performance. This is followed by a discussion on the physical relevance of model parameters and the initially perceived associations with catchment characteristics.

3.1 SIMPLE ANTECEDENT MOISTURE MODEL (OSE1)

The model described in this section in an extended version of the Isolated Event Model (IEM4), discussed in the Flood Studies Report (IOH) (1975), Mandeville (1983) and Eyre and Crees (1984). OSE1 is a relatively simple model (figure 3.1) which uses a constant runoff proportion to reduce the total rainfall to a net rainfall amount. The original IEM4 model used an exponential relationship between initial soil moisture deficit at the beginning of a storm and the proportion of gross rainfall that contributes to storm runoff. In OSE1 the exponential relationship is replaced by an asymmetric S-curve described by a three parameter hyperbolic tangent (TANH) function (Hughes, 1984). The model estimates the initial moisture status at the start of the storm, but unlike the S-curve model (Hughes, 1984) it applies a constant runoff proportion (ROP) throughout a storm event. The S-curve model is based on the variable source area concept (VSA) of runoff generation.

3.1.1 Conceptual structure of OSE1

OSE1 has three major components; antecedent moisture estimation, volume reduction (runoff generation) and shape transformation (runoff routing). The model has been designed to operate in lumped or semi-distributed format. The semi-distributed version allows for separate modelling of runoff generation from the different sub-catchments and the use of a different routing function (figure 3.1).

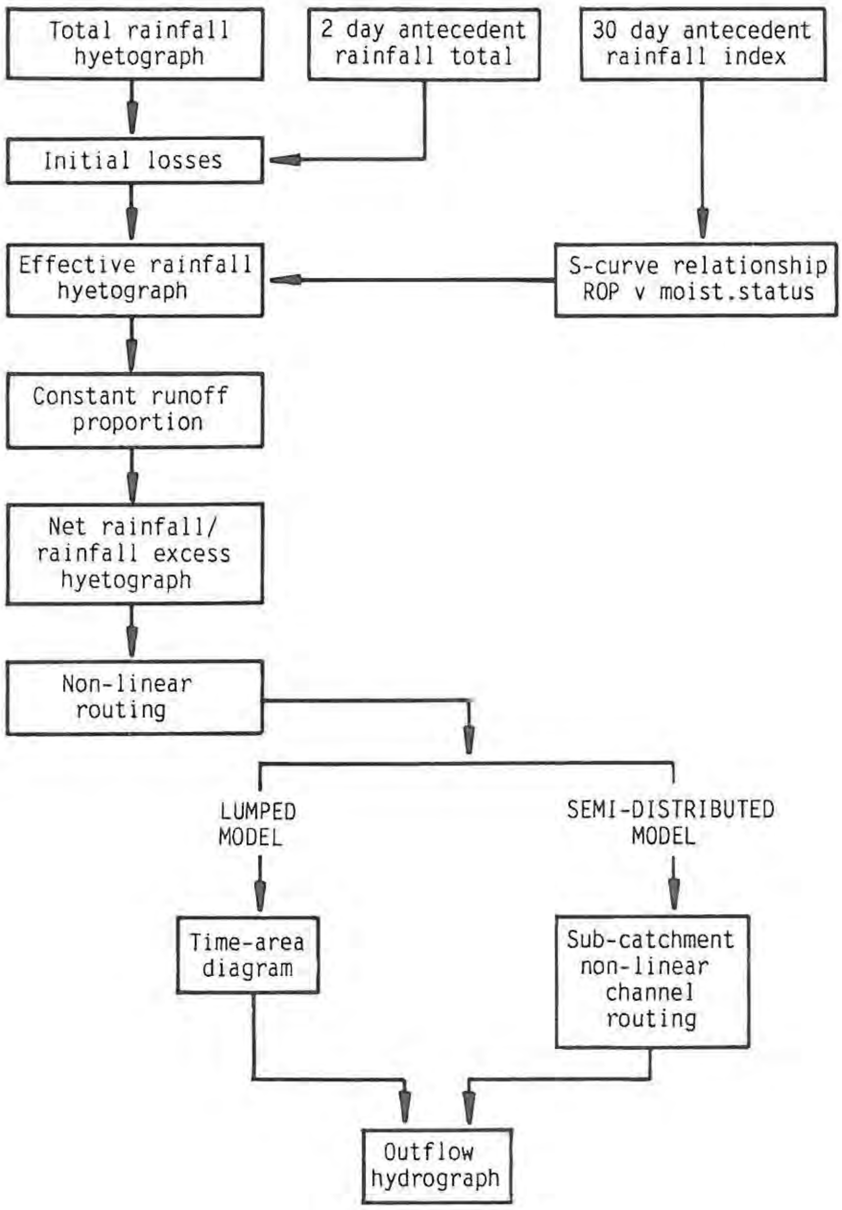


Figure 3.1 Structure of model OSE1 - Simple antecedent moisture model.

Antecedent moisture

A decay function of the form:

$$API=\sum_{i=1}^{n} DR_i . APF^i$$

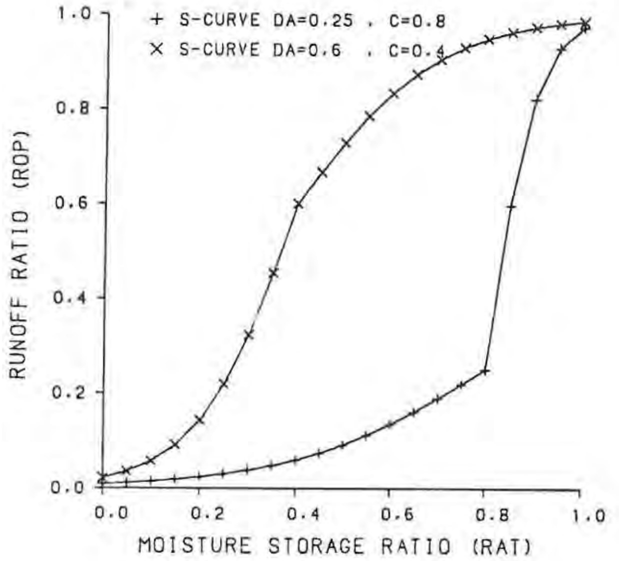
where DR_i = rainfall total i days before an event, is used to calculate the Antecedent Precipitation Index (API) from n days of rainfall prior to an event and model parameter APF ($\leq 1,0$). The number of days and the parameter APF can be varied between events to allow for seasonal effects. API then becomes the estimate of the initial moisture status of the catchment (Hughes, 1984). This is a simplified approach to estimating the antecedent moisture status of a catchment. The addition of a coarse time interval daily moisture accounting model, that would operate over a specified period prior to an event, would improve this component. However, such a daily model (for example, the ACRU model (Schulze, 1984)) would also have parameters that would have to be estimated for all the catchments. This would involve a great deal of extra work, therefore the component is acknowledged as being over simplified but no attempt to improve it is considered.

Runoff generation

The volume reduction component of the model begins with an estimation of initial losses (IL). Initial losses are first satisfied by the antecedent rainfall total for the two days prior to the storm event. Any remaining losses must then be satisfied by the rainfall in the early part of the storm. All remaining rainfall amounts are reduced by a fixed proportion (ROP) which is defined by the relative antecedent moisture status and the shape of the asymmetrical S-curve function. Runoff is generated in any time interval by multiplying the rainfall amount by a fixed runoff proportion (ROP). The runoff proportion (ROP) is defined by the relative moisture status and the shape of the asymmetrical S-curve function. As in the S-curve model (Hughes and Beater, 1987) this function is constructed from two TANH functions having a common point at (DA,C). DA and C are model parameters and their influence on the S-curve is illustrated in figure 3.2. The moisture status of the catchment (RAT) is defined relative to some maximum value (SMAX) which is conceived as the moisture level (mm) at which the complete catchment (or sub-catchment) is contributing directly to runoff (runoff proportion = 1,0).

Runoff routing

Runoff routing in OSE1 is divided into two components, the 'land' and 'channel' phases. The land phase routing is the same in both the lumped and semi-distributed formats of the model but for the channel phase different modelling approaches are used.



For $0 \leq RAT < C$: $ROP = A1(\tanh[B1(RAT-C)]+1)$
For $C \leq RAT \leq 1$: $ROP = A2(\tanh[B2(RAT-C)]+1)+D2$

$A1 = DA$ $\quad$ $A2 = 1-DA$
$B1 = 2/C$ $\quad$ $B2 = 2/(1-C)$
$D2 = 2*DA-1$

Figure 3.2 S-curve relationship used in model OSE1 - showing implicit source area runoff.

The land phase routing uses a non-linear storage-routing relationship of the type $S = KQ^n$, where K and n are model parameters. This equation is combined with the continuity equation ds/dt = I-Q and the solution achieved using the method developed by Hughes and Murrell (1986). In the lumped model this routing component represents the attenuation effects of flow over and below the land surface as well as in the minor tributaries. In the semi-distributed model, the routed flow is conceived to represent the outflow from a nodal point at the sub-catchment centre.

In the lumped model, channel routing is carried out by means of a time-area triangle with an initial delay (Laurenson, 1964; Watson, 1981). Each unit of output from the non-linear land phase routing component is delayed (parameter DEL) and then spread forward in time using an isosceles triangle with variable base length. The base length is calculated from a non-linear function of the output from the land phase routing ($mm.hr^{-1}$). An inverse power function of the form $TA = A.Q^{-B}$ is used, where TA is the base length in hours, Q is discharge in $mm.hr^{-1}$ and A, B are parameters. As the discharge decreases, the triangle becomes more elongated, implying slower routing.

Semi-distributed routing is achieved by routing sub-catchment outflow through a conceptual channel reservoir to the next downstream sub-catchment node. The downstream sub-catchment outflow is added and then routed further downstream. Where the configuration of sub-catchments is such that more than one group of sequentially linked sub-catchments exist than allowance is made for storing hydrograph elements and combining them at a confluence. The routing formulae used is the same as in the land phase but with different parameters. Land phase K is replaced with KC and n with a fixed value of 0.7. As the non-linear routing function only incorporates attenuation, a further parameter is necessary to define the delays of each sub-catchment (CDEL).

The complete parameter set for OSE1 is given in table 3.1, which also lists the alphanumeric symbols and the parameters relevance to either the lumped or semi-distributed form of the model. As a lumped model there are 10 parameters involved. One is used in the antecedent moisture estimation component, four in the conversion of rainfall to runoff depths and five in the routing procedure. If the semi-distributed format is used then 9 parameters are involved and values must be assigned for each sub-catchment. In the computer program the model accepts single values for each of the 9 parameters plus a matrix of sub-catchment factors, expanding the parameter space to 9 * number of sub-catchments. The method of coding allows one or more parameters to be changed easily without changing the relative values for each sub-catchment. Similarly it allows one or more sub-catchment factors to be changed without altering the others.

Although this model is not intended to represent a physically-based approach, (i.e. few, if any of the parameters are measurable in the field) it has been designed such that the parameters should have relevance to some aspect of the physical response system of catchments. The likely physical relevance of the model parameters with storm and/or catchment characteristics is discussed in the following section. The modelling of a wide range of catchments will be necessary to confirm or reject these associations and thus establish the usefulness of OSE1 as a tool for hydrological estimation.

Table 3.1 Summary of OSE1 model parameters.

Symbol	Model type	Description
K	Both	Catchment routing scale parameter
N	Both	Catchment routing power parameter
CDEL	SD	Channel delay time (hr)
KC	SD	Channel routing scale parameter
DEL	LM	Catchment delay time
A	LM	Time area base constant (hr)
B	LM	Time area relation power
SMAX	Both	Maximum soil moisture (MM)
DA	Both	Ordinate of S-curve parameter
C	Both	Abscissa of S-curve parameter
$A^{D}F$	Both	Antecedent precipitation factor
IL	Both	Initial losses

SD = semi-distributed
LM = lumped

3.1.2 Physical relevance of parameters and perceived association with catchment characteristics

Initial losses (IL) gives an indication of that proportion of total rainfall which will not contribute to storm runoff. A wide range of factors are expected to be associated with initial losses and include the following:-

a) Loss of storm runoff due to channel losses, for example the infiltration of channel flow into an alluvial bed could result in significant losses (Renard and Keppel, 1966).

b) Initial losses are also expected to be related to storm characteristics, in particular the amount, intensity and duration of an event.

c) Losses could also be related to topography (depressions causing ponding) and vegetation (interception).

It is apparent that there are no simple associations for this parameter as the above factors are likely to effect initial losses to varying degrees. It is likely that certain factors may be more dominant in different catchment types.

The antecedent precipitation factor (APF) determines the influence which rainfall input prior to an event, has upon the initial moisture status of a catchment. This is dependent upon the proportion of rainfall that leaves the catchment and the amount that is lost due to evapotranspiration. There are a number of physical associations including soil drainage properties, vegetation, topography and landuse. However, there are also climate factors and meteorological influences prevailing at the time of the rainfall input. It is apparent that it is not easy to establish simple associations for this parameter.

Parameter SMAX represents the amount of moisture in storage at the moment when the whole catchment is saturated. It should therefore be evaluated as the moisture holding capacity of the catchment (sub-catchment) and be related to soil characteristics. The parameters DA and C define the relationship between moisture levels below SMAX and the proportion of the catchment that is saturated at the surface (i.e. the S-curve). The S-curve relationship is designed to represent the complex spatial interaction between catchment topography, and the soil water retention capacity of the catchment or sub-catchment. Various authors have addressed the problem of defining source areas either by direct measurement (Kirkby, Callen, Weyman and Wood, 1976) or by estimation (Beven and Kirkby, 1979; O'Loughlin, 1986).

The catchment routing parameters, K and N represent the attenuation effects of routing 'land' flow to the main channel system. It has been found that with this form of non-linear routing equation, it is better to hold N constant between 0.5 and 0.8 (Mein, Laurenson and McMahon, 1974; Mandeville, 1983). K should be related to the predominant mode of flow by which water reaches the main stream channels. If it is overland flow then the length of the flow slope and surface roughness should affect the value of K. If it is mainly saturated sub-surface flow then K may be higher (slow response) and is affected by the lateral drainage characteristics of the soils and sub-stratum. It is likely that a high degree of spatial variation in the runoff response will occur on some catchments making the lumped approach inadequate even on individual storms.

The time-area diagram used in the lumped version of the model has three parameters, DEL, A and B. DEL represents the time delay before a significant response to any amount of rainfall is experienced at the catchment outlet. It is difficult to propose a physical association for this parameter as at least some response to rainfall may be expected immediately, if only from rainfall falling at or near the catchment outlet. Therefore, delay values are expected to be small and the parameter is of less importance than A and B which define the length of the symmetrical time-area triangle for a given value of runoff in $mm.hr^{-1}$. B determines the extent to which this relationship is non-linear, lower values of B suggesting more similar triangles for all ranges of flows. The time-area triangle should be related to the spatial pattern of the channel network and the channel slope variations within this network. Elongated catchment shapes are expected to have longer triangles than rounded shapes, given similar areas and slopes. Higher slopes in channels more distant from the outlet may be expected to indicate shorter triangles. Channel roughness and flow resistance effects may also be important.

Sub-catchment channel routing is controlled by two parameters for each sub-catchment. CDEL represents the delay before a sub-catchment begins to contribute flow at the catchment outlet, while KC represents the attenuation effects of routing the output from the node of a sub-catchment along the channel to the next sub-catchment. Channel length, dimensions, slope and flow resistance (roughness) effects are expected to determine the relative values of both these parameters. Problems are likely to arise if overbank flow occurs, this causes strong attenuation effects within specific reaches, a situation for which the model is not designed to deal with.

3.2 AUGMENTED HYDROGRAPH MODEL (OSE3)

Model OSE3 is a modified version of the Augmented Hydrograph model presented in Mandeville (1983). The central concept of the model was developed by Mandeville while he was involved with isolated event modelling at the Institute of Hydrology, Wallingford, and represents a novel approach to modelling the rainfall-runoff process. In single event modelling the usual procedure is to separate the rainfall-runoff process into two major components (figure 3.3), which are supposedly independent of each other (Tennesse Valley Authority, 1965; Murray and Görgens, 1981; Mandeville, 1983; Rajendran and Mein, 1986). The first step, traditionally, is to estimate volume reduction, that is the transformation of rainfall into storm runoff (often referred to as net or excess rainfall). This step also includes the catchment antecedent moisture status estimation. An excess rainfall hyetograph is produced from the volume reduction procedure and is then applied to the shape transformation component which routes the excess rainfall over and/or beneath the land surface and along the channel network to produce delayed and attenuated streamflow at the outlet.

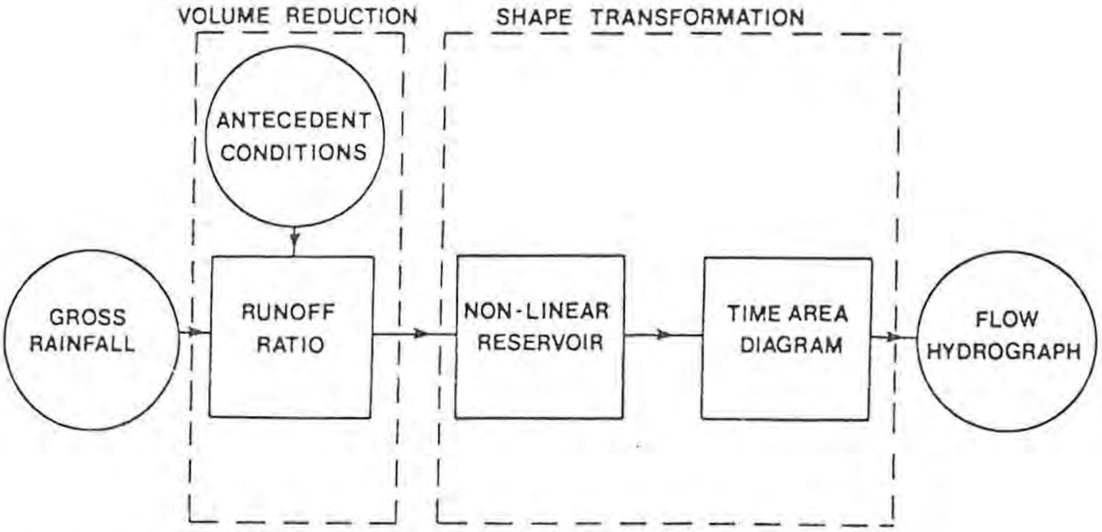


Figure 3.3 Traditional order of model components (from Mandeville, 1983).

The Isolated Event Model (OSE1) described earlier in this chapter is a traditional order rainfall-runoff model. Analysis of this type of model by Mandeville (1983) revealed that the major components were not independent of each other. He therefore proposed a new model, with the same major components as OSE1, but with their order changed (figure 3.4). In the new model the parameters of the shape transformation component do not depend in any way on the volume reduction component.

In the Augmented Hydrograph model, the gross rainfall hyetograph is applied as input to the shape transformation component, the output is a hydrograph with the same volume as that under the gross rainfall hyetograph, but a different shape (figure 3.5). This intermediate hydrograph is termed the augmented hydrograph. The augmented hydrograph is then applied as input to the volume reduction component of the model to produce the flow hydrograph. The augmented hydrograph has the same shape as the flow hydrograph but a larger volume.
The advantages of this approach include:-

a) By reversing the order of the two subsystems, so that the non-linear reservoir precedes the runoff ratio, the large variations in the size of the non-linear reservoir will be reduced (Mandeville, 1983).

b) The new model has the advantage, if it works successfully, of being able to check routing parameters against shape and then reducing the volume to fit the output hydrograph.

c) There is no separation of runoff into stormflow and baseflow; another determination which is difficult to physically measure.

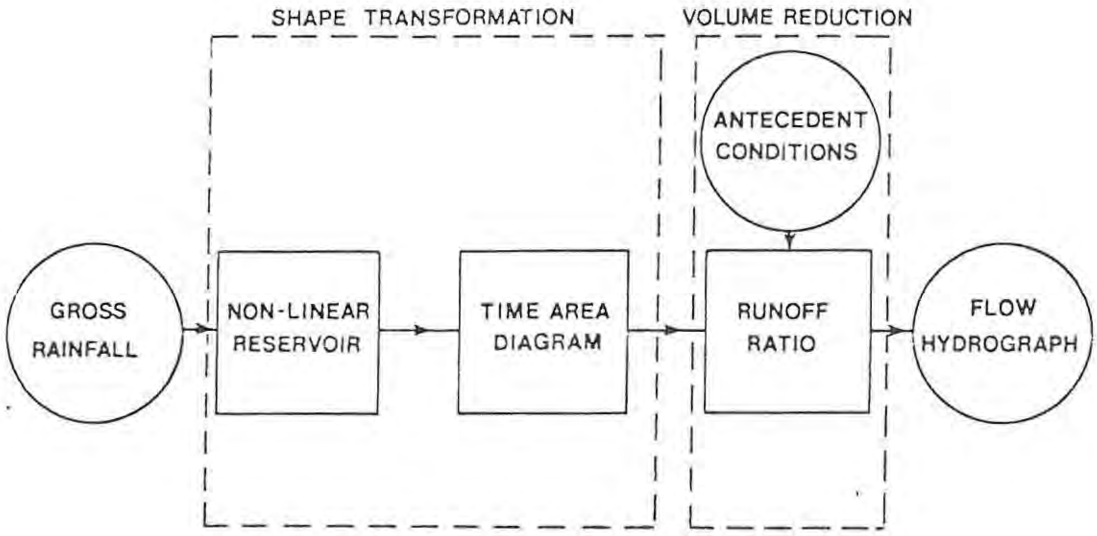


Figure 3.4 Augmented hydrograph model : component order (from Mandeville, 1983).

The Augmented Hydrograph model is based mainly on the results from a detailed study of one catchment and while preliminary results appear promising (Mandeville, 1983) the model hypothesis has not been widely tested or applied. For the model to operate successfully as a hydrological tool it will be necessary to apply the model to a wide range of catchments and to establish whether model parameters can be related to storm and/or catchment characteristics in some way. Only if this were successful could the model be used to estimate hydrographs in the ungauged or design situation. It might be necessary therefore to develop the model further without changing its basic structure. This has been done by identifying conceptual weakness within the model and incorporating additional components where necessary to improve the models flexibility.

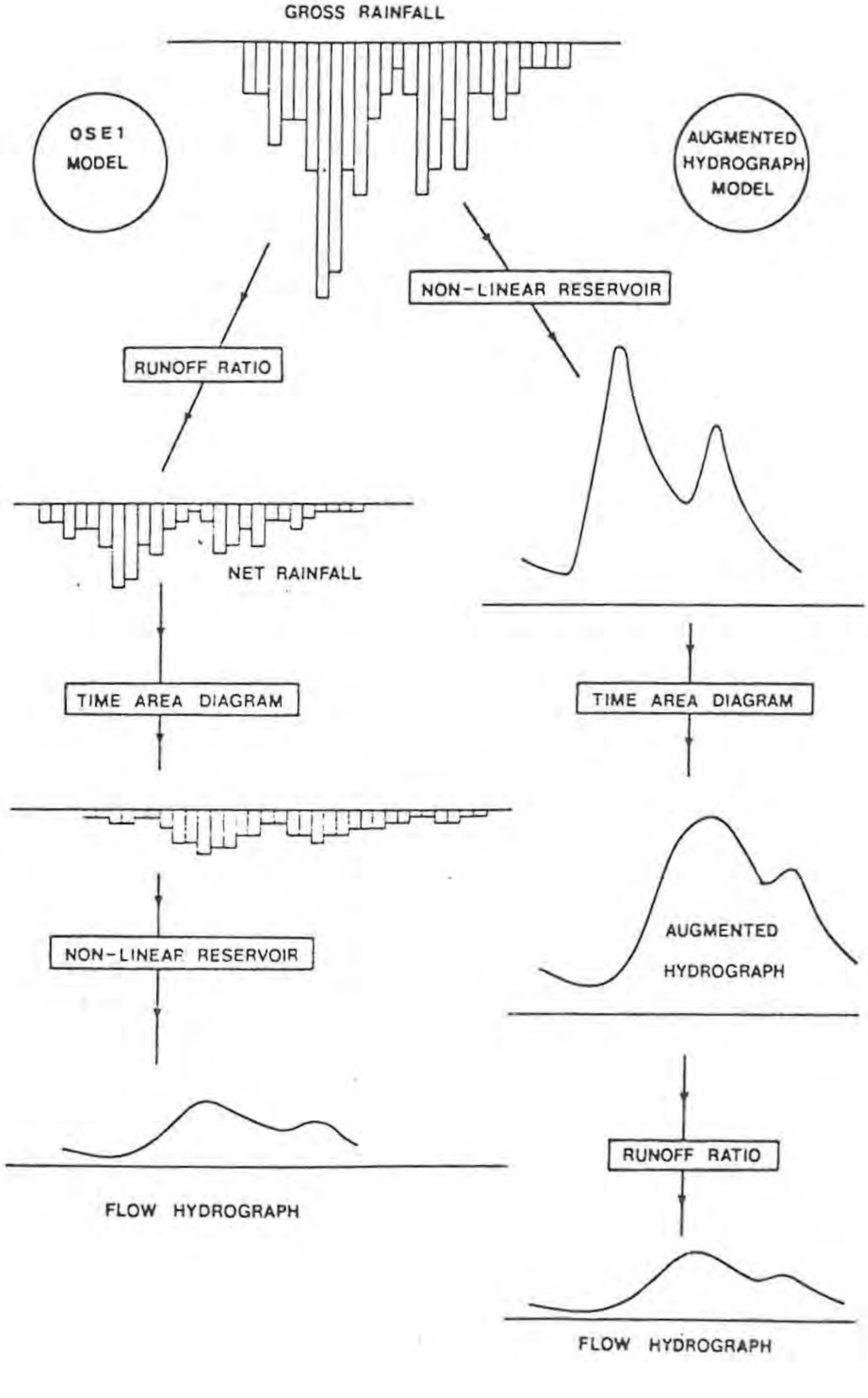


Figure 3.5 Comparison between component responses of OSE1 and OSE3 models (from Mandeville, 1983).

3.2.1 Conceptual structure of the developed Augmented hydrograph model

The form of the Augmented Hydrograph that is being tested can be divided into three major components. On the basis of some initial model runs on events from different catchments, an initial losses component was added to account for antecedent rainfall immediately prior to the event. Initial losses (if any) are first removed from the input rainfall, the remainder is then routed and then reduced to equal the observed runoff depth. As with OSE1, the semi-distributed version allows for separate modelling of runoff generation from the different sub-catchments and the use of a different routing function and it has been designed to run in lumped and semi-distributed format. The initial losses component operates the same way as in model OSE1 and has one parameter (IL, table 3.2).

The shape transformation or runoff routing component involves applying the rainfall hyetograph (minus initial losses) to the routing subsystems to provide output as a hydrograph with the same volume as the rainfall input but with a different shape. Like OSE1, runoff routing is divided into two subsystems referred to as the 'land' and 'channel' phases which operate in the same way (see section 3.1.1).

The intermediate hydrograph produced by the routing subsystems is applied as input to the volume reduction component of the model, in which each of its individual ordinates is reduced by multiplying by the runoff ratio (ROP) to give the flow hydrograph as output. ROP is constant throughout an event. The value for ROP for an event is expected to be dependent upon the variability in total rainfall, temporal intensity patterns and the antecedent moisture status, therefore each event will have a different proportion of rainfall that becomes streamflow. For calibration purposes, ROP values for individual events are estimated as follows (adapted from Mandeville,1983):-

$$ROP = \frac{\text{observed runoff volume - initial runoff volume}}{\text{observed gross rainfall volume - initial losses}}$$

The complete parameter set is given in table 3.2, which also lists the alphanumeric symbols and the parameter relevance to either the lumped or semi-distributed form of the model. In the lumped version, 7 parameters are involved, one is used in the initial losses estimation, five in the shape transformation procedure to produce the intermediate hydrograph and one to effect volume reduction and produce the output hydrograph. In the semi-distributed format, 6 parameters are involved and values must be assigned to these for each sub-catchment.

Table 3.2 Summary of OSE3 model parameters.

Symbol	Model type	Description
K	Both	Catchment routing scale parameter
N	Both	Catchment routing power
CDEL	SD	Channel delay time (hr)
KC	SD	Channel routing scale parameter
DEL	LM	Catchment delay time (hr)
A	LM	Time area base constant (hr)
B	LM	Time area relation power
ROP	Both	Runoff coefficient (proportion or ratio)
IL	Both	Initial losses

SD = semi-distributed
LM = lumped

3.2.2 Physical relevance of parameters and perceived association with catchment and storm characteristics

Ideally the parameters of a simulation model should be closely related to measurable physical catchment or storm characteristics. Differences in parameter values may be considered in terms of physical changes on a catchment or changes in storm characteristics between events or changes in catchment characteristics from one catchment to another (Dickenson and Douglas, 1972). Like OSE1, this model does not represent a physically based approach but the model has been designed such that the parameters should have relevance to some aspect of the physical response system of catchments.

The expected physical relevance of the initial losses parameter and the shape transformation or routing parameters of this model are identical to those for OSE1. This section will concentrated on the perceived physical relevance of the volume reduction parameter (i.e. ROP). According to Mandeville (1983), by changing the order of the major components of the model, so that runoff routing precedes the volume reduction component, the parameters of the two components should be independent of each other. Therefore the routing parameters should remain constant between events on the same catchment and should not be influenced by the volume reduction component (ROP). The routing parameters are expected to be related to topographical catchment characteristics such as slope, slope length, drainage density etc., which do not change. It is expected that the runoff proportion (ROP) will be related to storm characteristics and the catchment antecedent moisture status, which do change between events and soil characteristics which can be considered more stable. Rainfall characteristics such as rainfall volume, duration and intensity are expected to influence the volume of runoff. For example, if a long duration, low intensity event occurs on a 'wet' catchment which has deep, permeable soils, the ROP is likely to be fairly high, because the moisture requirements of a 'wet' catchment are likely to be satisfied quickly.

For the same event, but on a 'dry' catchment the volume of runoff is expected to be lower because a larger proportion of the rainfall will be required to satisfy the catchment moisture requirements before runoff can occur. Similarly, if the same event occurred on catchments with similar antecedent moisture conditions but with different soil characteristics the proportion of runoff is expected to be different. For example, the runoff response of shallow, impermeable soils to rainfall is expected to be different to the response of deep, permeable soils.

The aims and objectives of the research and the research methodology are described in the following chapter and chapter 5 provides a description of the catchments that were used for calibrating and validating the models.

CHAPTER 4

RESEARCH FRAMEWORK

This chapter describes the objectives and aims of the research, it also includes a description of the computer programming considerations and explains the approaches adopted in the different stages of model testing and evaluation, referred to in chapter 1.

4.1 RESEARCH OBJECTIVES, AIMS AND HYPOTHESES

The real value of any hydrological model is expressed by its ability to be applied and solve real problems. One of the objectives of this study is to determine whether the two isolated event models, OSE1 and OSE3 are capable of simulating the flood hydrographs for a number of events, on a wide range of catchments with different climatic conditions.

Specific aims related to this objective include:

a) To discover whether the models are capable of reproducing individual storm hydrographs. An assessment of this capability includes the degree to which the storm hydrograph shape, volume, timing and peak flow rate are successfully simulated.

b) To assess the stability of certain parameter values for a number of events on a single catchment. Multi-storm stability of parameters is desirable so that more meaningful interpretation maybe given to parameter values and parameter interaction.

c) To determine whether certain parameters can be related to measurable catchment or storm or antecedent moisture characteristics. It is desirable that parameters be physically related (although not necessarily physically based) so that techniques can be developed that allow the model to be used on ungauged catchments to estimate storm runoff.

A second objective is to establish whether the semi-distributed versions of the models perform consistently better than the lumped versions. Spatial distribution in hydrological models assist in accounting for spatial variations in response characteristics as well as input rainfall or other climatic variables.

The above objectives are concerned primarily with the individual performance of the models, therefore the third objective of this research is to compare the performance of OSE1 and OSE3. Both models are constant runoff proportion models, with the same major components of volume reduction and shape transformation, however, the order in which the components are applied is different (refer to chapter 3.3) This means that OSE1 determines excess or net rainfall while OSE3 does not.

The following hypotheses concerning the models and related to the objectives and aims are proposed.

a) Both models (i.e. both the lumped and semi-distributed versions) have adequate curve-fitting capabilities where the spatial distribution of rainfall is relatively uniform and well defined. A corollary to this hypothesis is that the models will not always perform satisfactorily when rainfall input is poorly defined.

b) The semi-distributed versions of both models should be more successful than the lumped, particularly when there is some degree of spatial variability in the rainfall input data.

c) Certain parameters will be related to a combination of storm, catchment and antecedent moisture characteristics. It will be possible to develop quantitative relationships between parameter values and certain combinations of indices of catchment, storm or antecedent moisture characteristics. The combinations of physical variables selected will be meaningful in terms of the original parameter conceptualisations.

d) The Augmented hydrograph model (OSE3) will have components that are independent of each other, therefore the parameters will be easier to stabilise than for OSE1.

4.2 COMPUTER PROGRAMMING CONSIDERATIONS

All the computer programming was done by Dr. Hughes of the Rhodes University, Hydrological Research Unit (HRU). In order to facilitate the simple application of the models to each data set, the computer coding of both OSE1 and OSE3 has been included as subroutines in a large program which also included the more complex S-curve model (Hughes and Beater, 1987).

4.2.1 Input data details

The initial step prior to model testing involves the compilation of the input data files from the original breakpoint data sources referred to in chapter 5. A suite of FORTRAN programs were established to reduce or extract from the original data, a set of fixed time interval values of rainfall depth and flow. Stormflows, based on the separation line method of Hewlett and Hibbert (1967) are also calculated and the storm is considered to terminate when such flows become zero. The programs allow the extraction of different combinations of raingauges to produce any number of storm profiles for sub-catchment rainfall input. An example of the resulting rainfall and observed streamflow data input file is given in table 4.1. The time interval can be varied and the data extraction programs are flexible. The selection of the time period of modelling has been based mainly upon the observed response characteristics of the catchments as well as the rainstorm durations. The need for a short time period for the Tombstone catchments is referred to (section 5.8). On the Oxford catchments several of the storms are of relatively short duration and the response from the smaller catchments in this area are quite rapid. A 10 minute time interval was used for this area. A 15 minute time period was used for the remaining catchments. The input data files for any one catchment contain all the storm data for that catchment and the selection of which storm or combination of storms to be modelled in any single model run is achieved using a run control data file.

The storm data for all the catchments are summarised in appendix E. Each table is divided into three sections. The first summarises the characteristics of the storm rainfall and the antecedent rainfall. The second lists the volumes, discharges and timing of total streamflows while the third describes the streamflow that occurs above the Hewlett and Hibbert separation line. Each section of the table includes the storm number and the date and time of the beginning of the storms. The catchment name, code, area and data time interval are given at the top of each table.

Both models require antecedent daily rainfall values which are stored on a separate file. An example of an antecedent rainfall file is given table 4.2.

The third data file contains information concerning the way in which the model should operate (i.e. run control details) plus the essential information about the parameter values and the definition of the catchment variables. An example of the semi-distributed control file for each model is given in table 4.3. These control files are well labelled to facilitate editing between model runs. It is apparent from the format of the control files that the models can be operated in lumped or semi-distributed format, single run or optimisation and single storm or multiple storm, using the same program. This mode of operation makes it easy to change from one mode to another without having to deal with a larger number of different programs and data files. As well as the average parameter values, the control data files also hold the range of these values within which an automatic optimisation routine (included as an option in the model program package) is constrained to operate (if used) and the sub-catchment weighting factors which determine the actual parameter values for each sub-catchment. This method of parameter input is used so that the optimiser only operates on the nominal catchment average parameter values, and any changes to the sub-catchment weights must be made by hand. There is too much interaction between the different values being optimised, for example if a model has 10 parameters and 10 sub-catchments attempting to optimise 10*10 parameters would be impractical. Consequently, the relative values of each parameter for the different sub-catchments must first be determined (or estimated) before optimisation of the nominal parameter value can take place.

The control files for both models allows one or more of the available storms to be selected using the same set of parameter values. This mode of operation allows a single set of parameters to be optimised for a group of storms using the overall fit statistics. Initial moisture conditions and the initial counters for individual storm fit statistics are reset at the beginning of each storm. This multiple storm option is very useful for the models where it is expected that the parameters will remain stable across a range of storm types. The catchment definition variables include catchment area, time interval of modelling, number of sub-catchments and the arrangement of the sub-catchments for the purpose of channel routing in the semi-distributed model versions. Run control details include the number of optimisations (if any) which parameters are to be optimised and which objective function is to be used as a basis for optimisation. There is also a control variable which allows the user to choose the level of detail given in the output.

The output files for both models consist of a summary of the control data and the input data. They also contain summary statistics describing the degree of correspondence between observed and simulated streamflows as well as a lineprinter plot of rainfall and flow data (figure 4.1). In the semi-distributed models the plotted rainfall data represent a single catchment average. The summary statistics given are the percentage errors of the simulated volumes (mm) and peaks (m^3s^{-1}), the coefficient of efficiency using both ordinary and natural logarithm values and the coefficient of determination. There are also options available to output details of the values of different variables at each time interval and the flow from each sub-catchment. These options are extremely useful when trying to evaluate the effects of changes in model parameter values or the relative contribution of individual sub-catchments to total catchment streamflow. A further option is also possible to output rainfall, observed and simulated flows in a format compatible with a general graph plotting program (GENPLOT) developed by Dr. Hughes for use with the Rhodes CALCOMP plotter.

Table 4.1 An example of a rainfall and stormflow input data file.

```
15NORTH DAN.   W1   42.94
 1 30. 7.60    12.00     .25 HRS INTERVAL
 101
RAINFALL  FOR 30. 7.60 12.00   101  1/4 HR PERIODS  MULT= 1.000  CATCH           3
RAINFALL    1.000             G22A
   .76    .76    .89   1.14    .38    .38    .38    .38    .89    .8    1.74   2.16   1.95   1.52   1.02
  1.02   1.02    .00   4.44   1.91    .00   2.16   1.02    .38    .25    .00    .00    .25    .76    .25
   .00    .00   1.91   1.91   1.91   1.91   2.35   2.35   1.82    .76    .06    .06    .06    .06    .00
   .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
   .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
   .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
   .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
RAINFALL    1.000             G16
   .97    .70    .70    .85   1.14    .00    .17    .46    .38    .25   1.71   3.36   1.71   1.84   1.18
   .08   2.22    .57   3.04   2.03   1.01    .76   1.59    .95    .57    .25    .19    .63    .57   1.25
   .13    .55    .76   1.84   2.12   2.67   2.67   1.31    .63    .30    .13    .13    .25    .25    .19
   .06    .06    .06    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
   .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
   .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
   .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
RAINFALL    1.000          G16+22
   .87    .73    .79    .99    .76    .19    .27    .42    .63    .57   1.72   2.76   1.83   1.68   1.10
   .55   1.62    .28   3.74   1.97    .50   1.46   1.30    .66    .41    .13    .09    .44    .66    .75
   .07    .27   1.33   1.87   2.01   2.29   2.51   1.83   1.22    .53    .09    .09    .15    .15    .09
   .03    .03    .03    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
   .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
   .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
   .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00
TOTALFLOW     .04
   .04    .04    .04    .04    .04    .04    .04    .04    .04    .04    .04    .04    .04    .04    .07
   .08    .09    .09    .09    .12    .15    .18    .23    .27    .33    .39    .45    .48    .52    .55
   .68    .82    .91   1.00   1.09   1.18   1.21   1.38   1.62   2.01   2.40   2.76   3.03   3.30   3.58
  3.64   3.97   3.97   3.92   3.81   3.66   3.51   3.37   3.22   3.07   2.92   2.77   2.63   2.48   2.33
  2.18   2.09   2.00   1.91   1.82   1.73   1.64   1.58   1.53   1.48   1.43   1.37   1.32   1.27   1.22
  1.17   1.11   1.06   1.03   1.01    .98    .95    .93    .90    .87    .84    .82    .80    .78    .76
   .74    .72    .70    .68    .66    .64    .62    .60    .58    .56    .54
STORMFLOW     .00
   .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .00    .02
   .03    .03    .03    .02    .04    .07    .09    .14    .17    .23    .28    .33    .36    .39    .42
   .54    .67    .76    .84    .93   1.01   1.03   1.20   1.43   1.82   2.20   2.56   2.82   3.08   3.36
  3.41   3.74   3.73   3.67   3.56   3.40   3.25   3.10   2.95   2.79   2.63   2.48   2.33   2.18   2.02
  1.86   1.77   1.67   1.58   1.48   1.38   1.29   1.22   1.17   1.11   1.06    .99    .93    .88    .82
   .77    .70    .64    .61    .58    .55    .51    .48    .45    .41    .38    .35    .33    .30    .27
   .25    .22    .20    .17    .14    .12    .09    .07    .04    .02    .00
```

Table 4.2 An example of an antecedent rainfall data file.

```
DIEP        1 1
 1 31. 1.70        0.896  30
   0.00   0.00   0.00   0.00   0.00   0.00   0.00   4.20   0.00   0.00
   1.20   0.00   3.00   3.60   1.50   0.00   0.00   4.20   0.00   0.00
   7.00   0.00   0.00   0.00   0.00   0.80   0.00   0.40   0.00  00.00
 2 14. 2.70        0.896  30
   1.50   0.00   0.00   4.20   0.00   0.00   7.00   0.00   0.00   0.00
   0.00   0.80   0.00   0.40   0.00  30.00  25.00  12.50   0.00   0.00
   0.00   0.00   8.50   0.00   0.00   1.50   0.00   0.00   0.00  18.80
 3 25. 8.70        0.896  30
   0.00   0.00   0.00   6.00   0.00   0.00   0.00   0.50   0.00   0.00
   0.00   0.00   0.00   4.50   0.00   0.00   0.00   0.00   0.00   0.00
   2.80   0.00   0.00   0.00   0.00   0.00   3.70   0.00   0.00   4.76
 4  4. 4.71        0.896  30
   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
  13.50   2.50   0.00  26.50   0.00   0.00   9.00  57.00   0.50   0.00
   0.00   0.00   0.00   0.00   2.00   0.00   0.00  10.00   9.50   6.50
 5 29. 7.71        0.896  30
   0.00   0.00   0.00   0.00  31.70   0.00   0.00   0.00   2.50   4.50
   0.00   0.00   0.00   0.00   0.00   9.50   7.50  20.50   1.00   0.00
   0.00   0.00   0.00   0.00   0.00   9.00   0.00   0.00   0.00   8.27
```

Table 4.3 An example of a semi-distributed OSE1 / OSE3 input control file.

```
OXFORD-W12                NAME OF CATCHMENT
OXW12                     CATCHMENT CODE
  92.20                   CATCHMENT AREA
OXW12                     CDC FILENAME HOLDING DATA SOURCE
OXW12A                    CDC FILENAME HOLDING AMI DATA
 1                        TOTALFLOWS ON FILE (1 IF YES)
 1                        STORMFLOWS ON FILE (1 IF YES)
 1                        DATA FOR USE (1=TOTAL,2=STORM)
 0                        HEMISPHERE (1=SOUTH,0=NORTH)
  1.0000                  CONVERSION FACTOR - FLOWS TO CUMECS
  1.0000                  CONVERSION FACTOR - RAINS TO MM
  0.17                    DATA INTERVAL (HOURS)
  5                       NUMBER OF STORMS ON FILE
INCLUSION ARRAY FOR INDIVIDUAL STORMS (1=YES,0=NO)
  1  2  3  4  5
  1  0  0  0  0
OSE1(S/DIST)              MODEL TYPE                                   OSE3(S/DIST)
 15                       NUMBER OF PARAMETERS                          9
 VALUE   UPPER   LOWER            DESCRIPTION                          VALUE   UPPER   LOWER
   1.000   1.000   1.000   1 CHANNEL TIME DELAY   CHANNEL TIME DELAY  1.000   1.000   1.000
   1.000   1.000   1.000   2 CHANNEL ROUTING K    CHANNEL ROUTING K   0.800   0.800   0.800
   0.001   0.001   0.001   3 (lumped parameter)   RUNOFF PROPORTION   0.165   0.200   0.100
   1.500   1.500   1.500   4 (lumped parameter)   BASIN ROUTING N     0.500   0.500   0.500
   0.700   0.700   0.700   5 BASIN ROUTING N      (lumped parameter)  0.001   0.001   0.001
   0.100   0.100   0.100   6 (lumped parameter)   (lumped parameter)  0.001   0.001   0.001
   0.001   0.001   0.001   7 (lumped parameter)   (lumped parameter)  0.001   0.001   0.001
 170.000 170.000 170.000   8 MAXIMUM STORAGE      BASIN ROUTING K    15.000  15.000  15.000
   0.500   0.500   0.500   9 DA IN S-CURVE        LOSSES              0.001   0.001   0.001
   1.400   1.000   1.000  10 C IN S-CURVE
   0.001   0.001   0.001  11 (parameter applicable to model OSE2)
   0.001   0.001   0.001  12 (parameter applicable to model OSE2)
   0.880   0.900   0.900  13 WINTER API FACTOR(-0.05 SUMMER)
   0.001   0.001   0.001  14 INITIAL LOSSES
   1.000   1.000   1.000  15 A IN TANH CURVE
```

```
 1                       LUMPED OR SEMI-DIST. (0 OR 1)
 8                       NUMBER OF SUBCATCHMENTS
        SUBCATCHMENT PARAMETER FACTORS
SUB-CATCH    1    2    3    4    5    6    7    8
AREA %      9.1  8.9  4.3  7.8 10.1  8.5 12.7 10.9
PARAMETER 1 1.53 1.53 1.70 1.53 0.85 1.70 1.19 1.70
PARAMETER 2 0.78 0.86 0.50 0.83 0.86 0.50 0.80 0.50
PARAMETER 3 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
PARAMETER 4 0.80 0.80 0.70 0.90 1.28 0.67 1.28 0.90
PARAMETER 5 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
PARAMETER 6 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
PARAMETER 7 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
PARAMETER 8 1.00 1.00 1.00 1.10 1.10 1.00 1.10 1.00
PARAMETER 9 0.98 0.98 0.98 0.98 0.88 0.90 0.88 0.90
PARAMETER10 0.11 0.11 0.09 0.09 0.09 0.07 0.07 0.07
PARAMETER11 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
PARAMETER12 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
PARAMETER13 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
PARAMETER14 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
PARAMETER15 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NUMBER OF STORM PROFILES FOR EACH STORM
STORM NO.     1    2    3    4    5
N.OF PROFS.   8   11   12    1    1
STORM PROFILE AND MULTIPLIER FOR USE IN EACH SUBCATCHMENT
SUB-CATCH    1    2    3    4    5    6    7    8
ST. 1         5    2    2    2    8    6    4    7
            1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
ST. 2         7    8    8    8    9   10   11    4
            0.92 0.92 0.99 0.88 0.81 0.77 1.00 0.87
ST. 3         5   12    6    6    9   10   11    4
            1.36 1.10 1.01 0.88 0.97 1.10 1.10 0.96
ST. 4         1    1    1    1    1    1    1    1
            0.82 0.93 0.98 1.01 1.09 0.97 1.01 0.93
ST. 5         1    1    1    1    1    1    1    1
            1.00 1.04 1.12 1.07 1.00 1.19 1.12 1.24
RUN INFORMATION CONTROL
 0                       OPTIMISATION OR NOT (1=YES)
  5                      NUMBER OF OPTIMISATIONS
 1                       COEFF. OF EFFICIENCY (NO TRANS.)
 0                       COEFF. OF EFFICIENCY (LN TRANS.)
 0                       ABS.FRACTION ERROR IN PEAK AND VOL.
OS*I-                    LINEPRINTER PLOTTING SYMBOLS
  1.000    1.000         LINEPRINTER PLOT SCALES
 0                       OUTPUT TABLE (0=NO ,1=YES ,2=NODAL FLOWS)
   SUBCATCHMENT SEQUENCE CODES
 24
 99  1 99  2 99  3  4 88 88  5 99  6  7 88 99  8 88 77
```

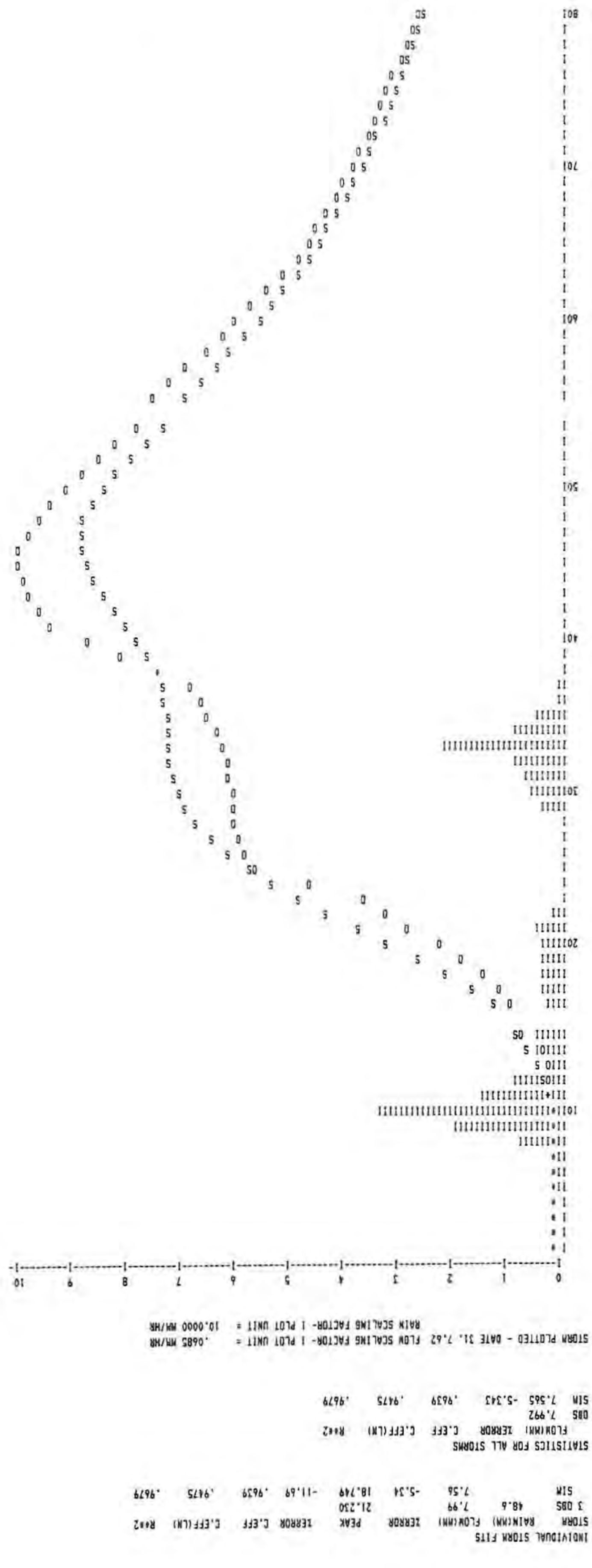


Figure 4.1 Output from the model program for OSE1 and OSE3.

The definition of the sub-catchments for the semi-distributed models, is not always clearcut, particularly when this must be done without knowing the effect of different sub-catchment pattern choices. For some of the catchments, the drainage and relief patterns suggest fairly obvious sub-catchment divisions, given the constraint that a greater number of sub-catchments not only increases the computer run time (Beven and O'Connell, 1982), but also the number of sub-catchment parameters that have to be quantified. Where small gauged sub-catchments are nested within larger gauged areas, sub-catchments have been defined for the large area at the scale of the small gauged areas. It is then possible to check the runoff simulations at some areas within the total area. Where obvious changes in physical catchment characteristics exist, then at least some of the boundaries between sub-catchments are easy to define given the desire for a high degree of internal homogeneity. However, the definition of sub-catchments can also be related to the raingauge network which are to provide the different input storm profiles. If some gauge locations are relatively close and they experience different rainfalls, it is clearly worth creating small sub-catchments that can accommodate these differences. The sequence in which the flow is routed through the channel network is also user defined in the models and scope exists for storing output from sets of sub-catchments to be added to output from other sets latter in the sequence. There is nothing to prevent the definition of just channel segments (without significant catchment area) as sub-catchments. In this case only the channel routing parameters would be relevant. This approach to spatial distribution is flexible and has more physical relevance (Hughes and Herald, 1987) then the conventional grid square approach.

In the program code for the models, the number of sub-catchments is limited to 20 but could be increased if required. While the size, number and organisation of the sub-catchments will have some effect on the modelling results, the effects are likely to be highly dependent upon the nature of the storm input on any specific catchment. It is therefore difficult to make any general recommendation beyond those related to homogeneity and the pattern of the raingauge network referred to above.

4.2.2. Validation of the computer programs

This aspect of model validation entails ensuring that the computer coding of the model adequately represents the conceptual structure. The detailed output option referred to earlier in this chapter is used to ensure that model storages and outputs are calculated and updated correctly. Examination of the detailed output also ensures that moisture is not unintentionally lost and that changes in modelling time interval do not effect the operation of the computer algorithms.

4.3 MODEL CALIBRATION AND VALIDATION FOR INDIVIDUAL CATCHMENTS

4.3.1 Calibration details

The two models are programmed as subroutines of the same modelling package and their calibration share certain similarities. The initial parameter values are decided upon using the perceived associations with physical catchment characteristics discussed in chapter 3. Modifications are made to the parameter values mainly by hand optimisation. This is based upon experience of the effects of changing the values of different parameters and an assessment of the simulation results to determine what aspect of the simulated runoff response requires modification. Often the automatic optimiser is useful to improve the values of some parameters or to attempt to find the best balance between two or more parameters which have similar effects on the runoff response. The effects on the simulated hydrograph using the automatic optimiser are complex and it is only occasionally a useful way of determining the best overall fit for a group of events. As mentioned previously, any changes to the sub-catchment weighting factors for the parameter values can only be done by hand. Any changes made are based upon an examination of the simulation results combined with a consideration of the relative amounts and intensity of rainfall over the sub-catchments and their position relative to other sub-catchments and the catchment outlet. The latter will affect the degree of attenuation and delay that the sub-catchment runoff undergoes before contributing to the shape of the total catchment hydrograph. The shape transformation component, i.e. the routing parameters, for both models are calibrated in the above way.

Although the models are very similar, each model has a different method of calibrating the volume reduction parameters. For model OSE1 the first calibration step is to establish the values of the S-curve and antecedent rainfall index parameters. Using a micro-computer, interactive graphics program, these parameter values can be varied in order to fit the S-curve (or curves) to plotted points represented by the observed runoff ratio (runoff depth/catchment average rainfall) and the estimated initial moisture status (antecedent rainfall index/maximum moisture storage) of the calibration storms (figure 4.2). The position of the storm points can be moved horizontally by varying the antecedent rainfall index (APF) or the maximum soil moisture (SMAX) parameter values. Alternatively the shape of the S-curve can be changed by varying the coordinates of the inflexion point (3.0: 5.5 in figure 4.2). It was anticipated that more than one S-curve shape would be applicable to each catchment, with the changes in the S-curves related to variations in rainfall intensity, duration or total amount. In calibrating the S-curves an attempt was made to group the calibration events and to keep the number of different curves to a minimum. This procedure was followed to try and make it easier to relate the S-curve parameters to storm characteristics at a later stage.

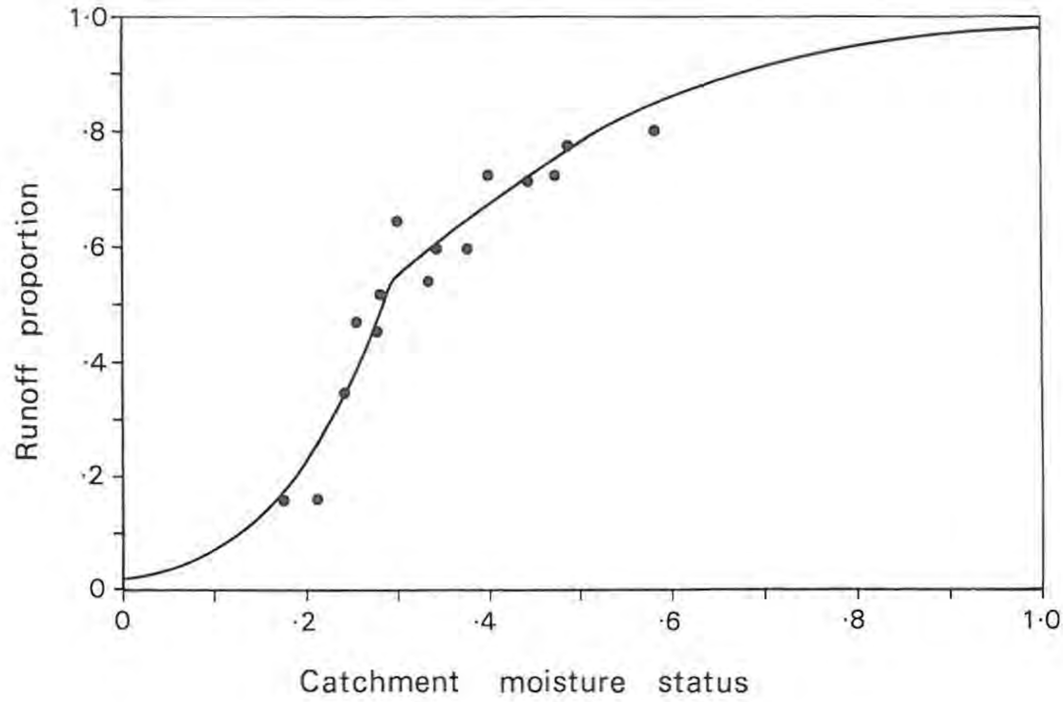


Figure 4.2 Example of an S-curve plot (using PC screen graphics) with observed data points superimposed to assist OSE1 parameter calibration.

For model OSE3 the runoff proportion is calculated from the ratio of observed runoff depth to average rainfall depth. As with the S-curve parameters of OSE1, the runoff proportions of OSE3 are expected to vary between storm events on the same catchment and consequently groups of events cannot be calibrated together.

4.3.2 Parameter validation details

The major volume reduction parameters of models OSE1 and 3 generally require calibration on an individual storm basis. Without formulating some kind of relationship between these parameters and storm characteristics (for a specific catchment), parameter validation is more or less meaningless except for the routing parameters. The only way in which validation can take place is to group events on the basis of their storm characteristics (intensity, duration and total depth) and divide each group up into calibration and validation sub-sets. This is much the same as calibrating all storms individually and subsequently noting similarities (or differences) in the volume conversion parameters for storms with similar characteristics.

4.3.3 Model evaluation and comparison details

The method of calibration for both models is similar thus making it possible to compare the calibration/validation routines on individual catchments. The results for the individual catchments can be used to reveal several areas of comparison between the two models and their different versions (lumped and semi-distributed). Only at a later stage can the predictability of the parameters that determine the runoff proportion be assessed. The procedure for evaluating and comparing the models has been designed to provide answers to the following group of questions.

a) What aspect of the storm simulations are most affected by which parameters and to what degree? How is this parameter sensitivity affected by differences in storm characteristics or response characteristics?

b) Do the results indicate that the parameters of OSE1 and OSE3, other than the main volume conversion parameters, can remain constant for all storms on the same catchment?

c) Do there appear to be patterns in the variation of the values of the main volume conversion parameters of models OSE1 and OSE3 that could be attributable to differences in storm characteristics?

d) Are there any situations (storm type or catchment type) where one of the models clearly performs better than the other? Can this better performance be related to a specific feature of the model structure?

e) Do the semi-distributed versions of the models consistently perform better than the lumped versions? If not, is there a particular situation for which either of the versions demonstrates improved performance?

It should be emphasised that the phrasing of these questions places a great deal of emphasis on the likelihood of the answers being heavily dependent upon not only the characteristics of the storm but also the physical properties of the catchment that control the runoff response. If the point is shown to be relevant by the results of this study it is clear that any hydrological model simulation results must be viewed in the context of the data set used to obtain those results. Conclusions drawn from hydrological simulation studies could not be considered generally applicable unless an extremely comprehensive set of catchments and storms were used. Chapter 7 presents the individual catchment simulations and concentrates on using the results to attempt to answer the above questions.

4.4 THE PROCEDURE FOR DERIVING RELATIONSHIPS BETWEEN PARAMETER VALUES AND CATCHMENT OR STORM CHARACTERISTICS

The usefulness of any hydrological model is probably best measured by the success with which it can be applied to situations where calibration is not possible. This aspect is covered to a certain extent by the individual catchment validations that form part of the previous sections test procedure. However, such validations only allow the models to be extended to storms over a catchment for which the model has been calibrated or at best where calibration on an adjacent and very similar catchment is possible. It has already been stated that validation of all the parameters of OSE1 and OSE3 is not possible as their parameters are likely to be storm specific. Extending the application of either of the models to other catchments, where calibration is not possible, has not been discussed yet. There is, however, a need to understand the limitations that exist in applying models to ungauged catchments. The part of the model testing procedure outlined in this section is designed to investigate the possibility of deriving relationships between model parameter values and quantifiable catchment and storm characteristics.

The starting point for this procedure is to identify those characteristics that can be evaluated from the types of information source available. Chapter 5 shows that while the data used in the study are drawn from essentially well instrumented research catchments, the information that is available on their physical characteristics is less than complete. This level of detail is more typical of the situation that may be faced under 'applied' conditions rather than under 'research' conditions. In one sense this gives the study a realistic image. However, the lack of detail also means that a degree of subjectivity and imprecision is inherent in the quantification of certain characteristics. As this was recognised at the outset, the evaluation of certain physical variables was confined to the ordinal scale of measurement. This procedure consisted of assigning ranked indices between 1 and 10. The physical characteristics form two basic groups; those that can be measured in a straightforward manner from topographic maps and those that must be ranked from catchment descriptions. Each variable is discussed separately below and the values assigned to the sub-catchments of the test catchments are given in appendix B. Where nested catchment situations occur, the sub-catchments are only included once. For example (at the top of the listings in appendix B) sub-catchments 1 to 3 of TM11 are also sub-catchments 1 to 3 of Tombstone TM8. A second group consisting of storm characteristics are also discussed below and can be evaluated from the storm data summaries given in appendix E.

4.4.1 Catchment slope (SLOPE)

Catchment slope is readily measured from contour maps using the equation :

$$SLOPE = \frac{\text{total contour length} * \text{contour interval}}{\text{catchment area}}$$

Variations in the calculated value of this variable are inevitable if maps compiled at different original scales are used. However, such variations are likely to be small if maps of similar scale and detail are used. For the South African catchments 1 : 50 000 scale maps were used in this study, while those given in USDA (1955-1973) were used for the USA catchments. Hughes (1983b) demonstrated the importance of slope as a physical variable affecting runoff response in the southern Cape region and Hughes (1985) found it a useful variable for estimating the parameters of monthly time interval water resource models.

4.4.2 Drainage density (DDENS)

While being similarly easy to measure from topographic maps, the effect of map scale and detail is likely to be greater than for SLOPE. A great deal depends upon the degree to which small ephemeral channels are included as well as what the map compiler chose to define as a channel. The runoff generation theories of Hewlett and Hibbert (1967) as well as others suggest that the channel network expands during storm events. Drainage density may therefore be considered a dynamic variable that is difficult to quantify. For the purpose of this study it has been based upon the channels identified by the map compilers.

4.4.3 Time of concentration (TC)

There appear to be a number of different equations for this variable that have been reported in the literature, however, the majority are based upon the length and slope of a channel segment. The measure used in this study can be calculated from the equation:

$$TC = 0.00025 * \frac{L*1000^{0.8}}{S^{0.5}} \qquad \text{(Shaw, 1988)}$$

Where L = channel length (km) with channel length being the distance from the sub-catchment centre of gravity to the catchment outlet

and S = average slope over the channel length ($m.m^{-1}$).

As will be seen later TC is used to assist in the evaluation of sub-catchment channel delays, hence the length and slope components are related to the section of channel over which that delay is deemed to take place.

4.4.4 Channel order (ORD1)

In the same way as drainage density, the evaluated channel order will also be dependent upon map scale and detail. There is little that can be done about this problem except to attempt to always use map sources compiled using similar principles. There are also several different approaches to stream ordering. In this study, the scheme (Shreve, 1966) has been used which evaluates stream order as the sum of the upstream headwater tributaries.

4.4.5 Channel distance (CDIST)

This variable is evaluated for channel routing purposes and is measured as the length (km) of the channel segment which the conceptual storages are designed to represent. This normally means the distance from one sub-catchment centre of gravity to the next one downstream. The actual channel segments over which the distance is measured depends upon the arrangement of the sub-catchments and the conceptualisation of the storages in the channel storage-routing component of the models.

4.4.6 Soil depth (DEPTH)

Soil depth represents an obviously important and hydrologically significant variable. However, there is very little direct information available about this as well as the other soil variables for any of the catchments. Even where some indication of the depth is given, there is usually little information about the spatial variation of depth. This is understandable given the amount of work involved in collecting this information. The values given in appendix B must therefore be viewed in the light of the degree of extrapolation that has been necessary. Integer values between 1 and 10 have been assigned most sub-catchments but occasionally a midway point between two integers was considered desirable. The greatest values have been given to the Tombstone, Cedara and some Zululand sub-catchments. The arid Tombstone soils are developed on alluvial sands and gravels and the assumption has been made that the effective hydrological depth is high. The descriptions of the Cedara and relevant Zululand sub-catchments imply comparatively deep soils. Conversely, other Zululand sub-catchments (5, 6 and 7) are described as having thin soils with a high proportion of bare rock. These have therefore been assigned the lowest values.

4.4.7 Infiltration characteristics (INFIL)

There is even less information about this physical characteristic than soil depth and a heavy reliance has been placed upon descriptions of the texture of the surface soil layers. For example the coarse texture of the Tombstone soils suggests a high value.

4.4.8 Permeability characteristics (PERMC)

The information given in the USDA (1955-1973) reports offer relative descriptions of the sub-surface permeability of the soils. This information proved useful and was combined with details of soil texture to derive the indices of permeability. The low values given for the Ecca seem to be justified by the *in-situ* drainage studies conducted by Moolman (1985) in this area. The relatively high values for the southern Cape soils have been assigned to account for the stoney soils of the hill tops as well as the observed occurrence of macro-pores in the deeper, humus rich, soils found on many of the slopes.

4.4.9 Water holding capacity (WHCAP)

As with the permeability characteristics, WHCAP is largely based upon textural descriptions. It was expected that, combined with soil depth, this variable would be important for estimating those parameters related to the maximum moisture retention capabilities of the sub-catchments. However this variable has not been quantified with much precision. An approximate inverse relation between WHCAP and PERMC might be expected (compare the values for the fine grained Ecca soils and the lighter textured Bethlehem soils) but clearly the real situation is not as simple as that.

4.4.10 Slope to valley soil ratio (SL/V)

This variable was added to account for the spatial pattern (with respect to the distance from the main drainage channels) of soil depth within sub-catchments. The importance of including such a measure is based upon the scale of sub-catchment definition used (up to 14,7 km^2). The variable is an estimation of the ratio of soil depth on the valley sides to that in the valley bottom. In the flatter catchments, which have relatively uniform soil depths (Bethlehem, for example), the ratio has been set close to unity. However, in the Ecca in particular there is a great difference between the thin soils of the valley sides and the deeper alluvial soils in some of the valley bottoms.

4.4.11 Vegetation characteristics (VEGC)

The vegetation cover characteristics of a catchment are important from a hydrological point of view. Vegetation affects the evapotranspiration (not important in isolated event modelling except with respect to antecedent moisture status) and interception characteristics of a catchment as well as infiltration and surface runoff. The effect of roots may also play a major role in determining secondary permeabilities. Quantifying vegetation cover proved to be an easier task than that for the soil variables. This may be partly a consequence of the great range that exists in the data set from the sparse cover of the Tombstone catchments to the dense indigenous forests of the southern Cape. It should be noted that three sets of data exist for most of the Oxford catchments. These have been included to account for the documented (USDA, 1955-1973, section 5.7) seasonal variation in land use and cover characteristics of this area. No such major distinction was evident for the other catchments because, either the cover characteristics are less seasonal, or the storms have all been drawn from a single season.

4.4.12 Energy characteristics (ENERGY)

This final physical variable is a measure of the radiation energy input experienced by the catchments. Its evaluation has been mainly based upon figures given for mean daily temperatures. The values of the index given in appendix B refer to the season in which either all or most of the storm data for that catchment occurred. For example, the majority of the Ecca storms used occurred in winter while those of the southern Cape occurred in spring and autumn.

4.4.13 Storm characteristic indices

Included in this group are two measures of antecedent precipitation. One is a decay function of the previous 30 days rainfall and is the same index as that used in model OSE1 which has an antecedent moisture component. The other is the previous 2 day rainfall total and can be viewed as an antecedent surface storage factor rather than an antecedent soil moisture index. The other indices are based upon the intensity, depth and duration characteristics of the rainstorm event and are itemized below.

a) Total rainfall depth.
b) Total rainfall duration.
c) Maximum intensity for the time interval used.
d) Mean intensity (total depth/duration).
e) Percentage of the total depth falling in the four quartiles of the storm duration.

It would be strictly correct to quantify these indices for the rain profiles relevant to each sub-catchment and then relate the values to the relevant sub-catchment parameters. However, for simplicity the values used in this analysis are based upon the average catchment rainfall profile. Where large spatial variations in the various indices occur this method of quantifying them will obviously affect the results and should be considered when the results are evaluated.

4.5 DERIVATION OF RELATIONSHIPS

The derivation of the relationships between parameter values and physical characteristics is confined to the semi-distributed versions of the models. This avoids the problem of attempting to estimate average catchment characteristics in an area where these may be highly spatially variable as would be necessary if the lumped model results were to be included. The conventional approach to deriving relationships between physical catchment or storm variables and model parameters would almost certainly be some kind of least squares regression analysis (James, 1972). However, most of the statistical packages available for carrying out such analyses are restricted to linear combinations of the independent variables or of transformations of these variables. The type of relationships expected would not fit this pattern and therefore an alternative approach was adopted. The method is still based upon a least squares fitting procedure but the regression coefficient calculated is used more as confirmation of a visual assessment of the degree of fit. Furthermore, the type of relationships are not restricted to linear combinations.

The approach makes use of a computer BASIC program operated on a PC interactively. All sub-catchment parameter and characteristic indices values are read into arrays, the form of the relationship to be tested is entered interactively and sets of X and Y values calculated and plotted using screen graphics. For a specific parameter (usually the Y values) any combination of characteristic indices can be put together, a new (X) variable computed and the relationship between them viewed. An optional component of the program allows the R^2 (coefficient of determination) to be calculated. The objective is to find the combination (linear or otherwise) of physical characteristic variables (transformed or not) that produces the best linear relationship with each model parameter (transformed or not).

The starting point was usually a simple combination of those variables deemed to be most relevant to the particular parameter. The perceived associations between parameter values and catchment characteristics discussed in chapter 3 were used to suggest which variables to start with. An assessment of the initial relationships as well as a knowledge of the differences between the characteristics of each catchment area were used to suggest changes to the form of the equations. Given the imprecision with which some physical variables are quantified as well as model limitations, it was never expected that relationships with a low degree of scatter would be produced. The exercise consists mainly of identifying relationships between parameter values and catchment characteristics which produce the least amount of scatter (James, 1972). A further constraint is that the relationships should have some meaning in the context of the individual parameter conceptualisations and not be simply mathematical abstractions. For example, channel routing parameters were expected to be related to the channel characteristics rather than such as soil depth or water holding capacity.

In addition storm characteristics are expected to effect the values of some parameters. It is therefore necessary to carry out an additional procedure to derive relationships between these parameters and storm characteristics. One of the problems is separating the influences of catchment characteristics and storm characteristics. The procedure used in this study is to calculate the average parameter value over the range of storm events for a specific sub-catchment.

This is then considered to be the representative value to be used in the derivation of relationships with catchment characteristics. The actual values, which vary between storms, can then be used to quantify relationships between these values and storm characteristics. The problem of the effect of spatial variations (between sub-catchments) in storm characteristics is recognised but no attempt has been made to include it. If this effect had been allowed for, the dimensions of the model testing exercise would have increased, especially during calibration. The above calibration procedure is particularily relevant to model OSE1. The results of this part of the study are presented and discussed in chapter 7.

4.6 THE PROCEDURE FOR ASSESSING THE USEFULNESS OF THE RELATIONSHIPS BETWEEN PARAMETER VALUES AND CATCHMENT OR STORM CHARACTERISTICS

The 'usefulness' of the relationships is defined in the context of this study as the extent to which they be used to estimate parameter values when calibration is not possible. This may be viewed as the final level of model validation, assuming of course that the definition of such relationships are to be considered part of the model. The first approach to investigating the question of usefulness is to calculate new parameter values from the derived relationships for all the sub-catchments. The models can then be run with the new parameter values and the new simulated flows compared with observed flows. The success of these simulations should be indicative of the accuracy with which storms on ungauged catchments can be simulated. There is of course the usual limitation that the results can only really be considered relevant to catchments within the range of characteristics represented by the test data set. Clearly the greater the degree of scatter of the original parameter values around the relationships, the more the new parameter values will differ from the originals. This could also be taken to mean that a high degree of scatter will result in poor validation results. However, the existence of interaction between parameter values suggests that this will not necessarily be the case. Major changes to several parameter values may have a variety of effects on the simulated flows which tend toward cancelling each other out and produce results closely similar to the original calibration results.

The final testing phase is to estimate the values of the relevant characteristics for a group of gauged catchments not previously used and substitute these values into the relationships to obtain model parameter values. An assessment of the level of accuracy achieved by simulations using these parameter values should further indicate the applicability to ungauged catchments of the combined model/parameter quantification approach. Of the catchments that are listed in table 4.1, four were reserved for this final testing phase. Two of these are located in the southern Cape (Karatara - K4M02 and Diep - K4M03) while the others are the Chickasha catchments of the US southwestern Prairies.

This chapter has outlined the procedures that have been followed in the study to enable the models to be evaluated and compared. There are essentially two levels of evaluation. The first is based upon the capability of the models to simulate a variety of storm events on individual catchments after some form of calibration. The second level represents an evaluation of the likelihood of success in applying the models to situations where calibration is not possible and the parameter values have to be estimated from derived relationships with catchment and/or storm characteristics.

CHAPTER 5

5 TEST CATCHMENTS

In order to satisfy the objectives and aims in chapter 4, a wide range of storm data are required. Storm data accumulated by the Rhodes University, HRU single event data bank is believed to represent a diverse enough base and is of sufficiently high quality for testing and assessing the models. However, it must be recognised that within this data set there will be variations in the level of detail and quality of the data and that these effects must be considered in the interpretation of the results obtained. Specifically, the number and spatial distribution pattern of raingauges will affect the accuracy with which the input storm rainfall can be defined (Beven and Hornberger, 1982; Roberts, 1984).

The catchments that have been used for assessing the models are drawn from different climatic zones of South Africa and the United States of America. They cover a wide variety of vegetation, soil and geologic characteristics and human activity. The distribution of these catchments is shown in figures 5.1 and 5.2.

Within South Africa several catchment areas, have been established for research purposes. These catchments are operated by various universities, government departments and research institutions. Reference to figure 5.1 indicates that six regions of South Africa are covered by the data that have been used. These include catchments in Natal (De Hoek and Cedara, obtained from the Department of Agricultural Engineering, University of Natal, Pietermaritzburg), Zululand (also obtained from Pietermaritzburg), Orange Free State (Bethlehem, obtained from the Hydrological Research Institute, Department of Water Affairs), and the eastern and southern Cape (Ecca and S. Cape, available from Rhodes HRU).

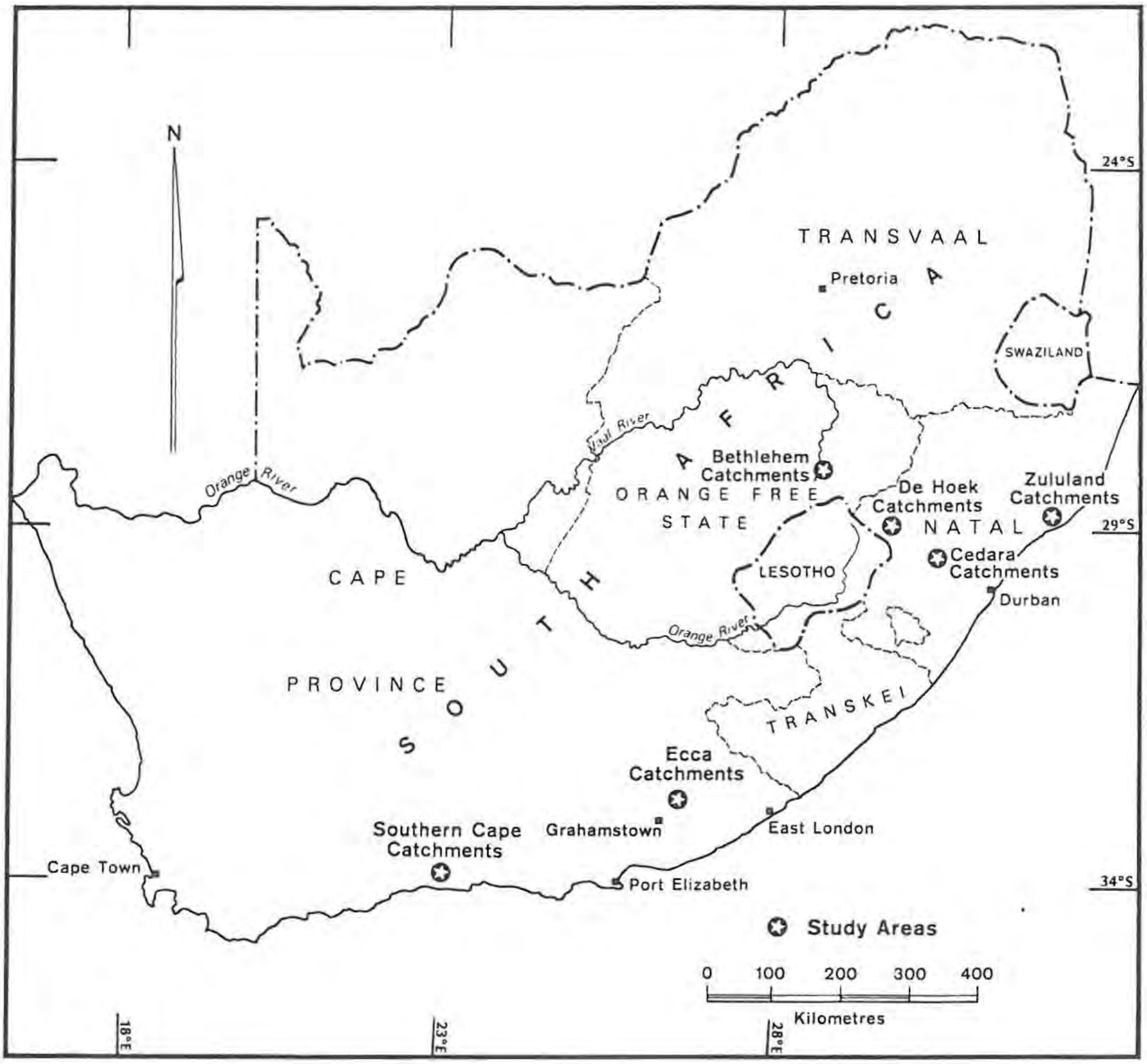


Figure 5.1 Distribution of test catchments within South Africa.

The single event data (i.e. rainfall and streamflow) for the catchments in the United States were extracted from the various miscellaneous publications of the United States Department of Agriculture, (USDA), Agricultural Research Service (USDA, 1955 to 1973). Copies of these volumes are held by the Department of Agricultural Engineering, University of Natal, Pietermaritzburg. It was possible to extract four sets of medium sized catchments from climatically and physiographically different parts of the United States. The four areas (figure 5.2) are Arizona (Tombstone) in the arid south west, Mississippi (Oxford) in the south eastern central region, Vermont (North Danville) in the north east and Oklahoma (Chickasha) in the south western prairies.

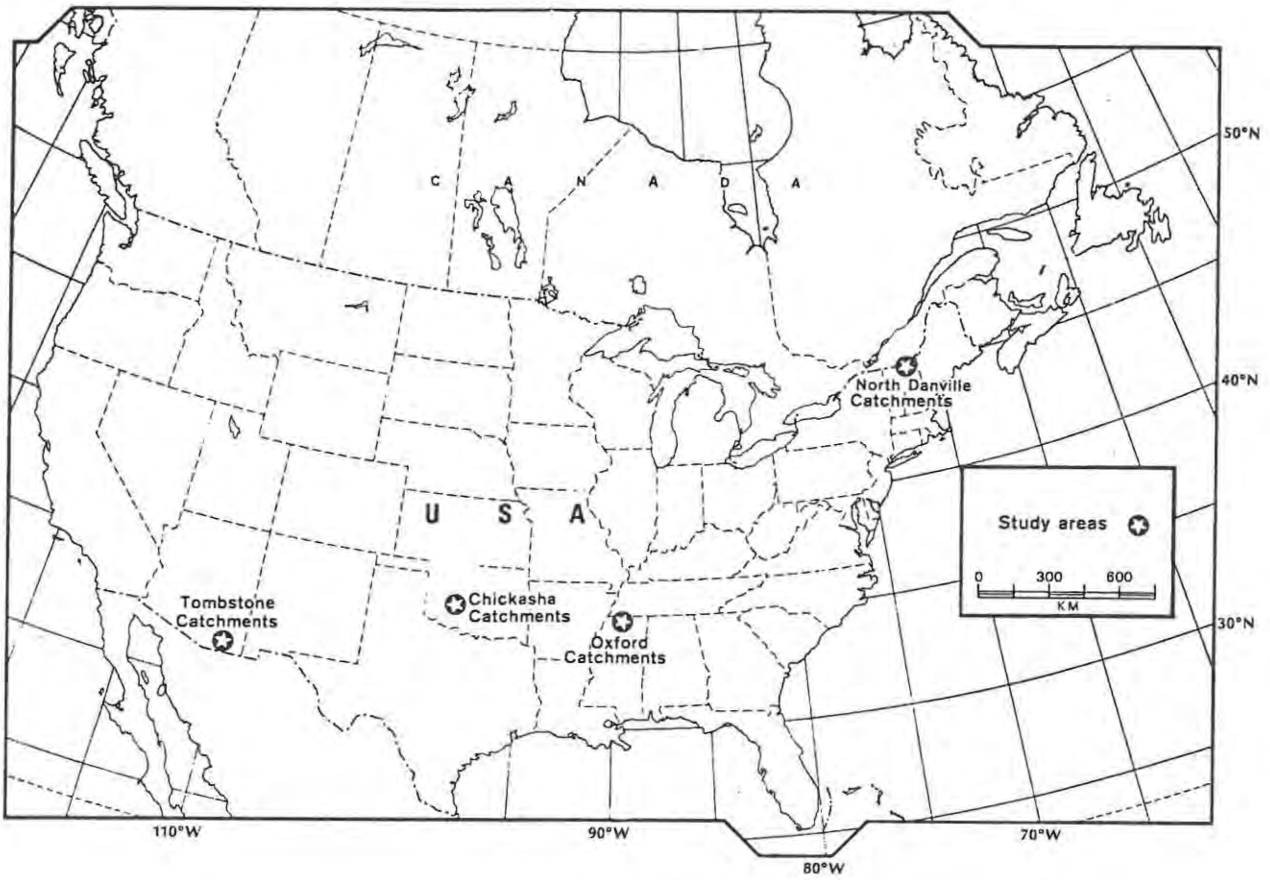


Figure 5.2 Distribution of test catchments within the U.S.A.

Tables 5.1 and 5.2 summarises the 33 catchments that are used in this study. Listed in the tables are the catchment areas, the total number of events extracted from the available data (313), the range of catchment slopes, the location and a brief description of the climate and physical characteristics of the catchments. The remainder of this chapter supplies a more detailed

Table 5.1 Summary of the South African test catchments and their general characteristics

Catchment Name	Area (km^2)	No. of storm events	Location	Slopes (%)	Climate	Generally Represents
ECCA :						
Q9M20	73	15	E. Cape South Africa	13-20	Semi-arid MAP=490mm All year round rain-fall.	Steeply sloping valley sides with thin soils & fine grained alluvial soils in valley bottom. Scrub brush with brush with sparse ground cover.
Q9M21	9	14				
DE HOEK :						
V1M19	15	16	Natal S. Africa	10-35	Sub-humid summer rain-fall area. MAP=720 -1115mm.	Two distinct physiographic zones of valley & plateau Variable soils developed on mudstones & sandstones. Shallow & stoney on steep slopes, deeper silty clays to clayey loams elsewhere. Grass-land (overgrazed in places) vegetation. Many soil conser-vation structures.
CEDARA :						
U2M16	5	10	Natal S. Africa	12-20	Humid summer rainfall area MAP=875mm	Forest, pastures & cropland. Mainly deep, dolerite derived soils with low surface runoff potential.
ZULULAND :						
W1M15	14	15	Kwa-Zulu S. Africa	16-34	Humid summer rainfall area. MAP=1000mm.	Mixed Eucalyptus plantation, indigenous forest & grassland. Soils variable from bare rock to deep soils.
W1M16	3	15				
BETHLEHEM :						
C8M25	83	11	O.F.S. South Africa	3-4	Temperate summer rain-fall area. MAP=700mm	Cultivated & natural grassland. Light sandy soils with clayey soils in valley bottoms. Large number of farm dams.
SOUTHERN CAPE :						
K3M01	48	17	S. Cape coast S. Africa	22-48	Sub-humid MAP=900mm All year round rainfall.	Steeply sloping mountain catchments with bushland (fynbos), pine plantations & indigenous forest mixed. Variable soils, deep in lower areas but shallow & stoney on hill tops.
K3M04	34	18				
K4M02	22	7				
K4M03	35	12				

description of each group of catchments and discusses the nature of the available data for the purposes of defining input rainfall as well as quantifying their physical characteristics. Simplified maps illustrating the drainage pattern, the position of individual gauged catchments in each area and the location of raingauges are included.

Table 5.2 Summary of the U.S.A. test catchments and their general characteristics

Catchment Name	Area (km^2)	No. of storm events	Location	Slopes (%)	Climate	Generally Represents
NORTH DANVILLE :						
ND1	43	15	Vermont N.E. USA	11-16	Temperate MAP=1000mm snowcover in winter.	Sloping forest and farmland having loamy soils of moderate depth with moderate to high permeability developed on glacial till deposits.
ND5	112	15				
TOMBSTONE :						
TM1	150	2	Arizona South-west USA	8-12	Arid to semi-arid MAP=350mm Predominantly summer rains.	Desert grass & scrubland region. Soils are moderately permeable gravelly loams mainly underlain by deep alluvial deposits.
TM2	114	5				
TM3	9	11				
TM6	95	2				
TM8	15	11				
TM11	8	12				
OXFORD :						
OXW4	8	5	Mississippi S.E. Central USA	7-13	Temperate MAP=1350mm All year round rainfall.	Cultivated, eroded uplands with seasonal variation in vegetation cover. Silty loam soils with moderate to rapid permeabilities. Relatively wide and flat alluvial valleys. Large number of desilting and retention dams.
OXW5	5	9				
OXW10	22	12				
OXW12	92	12				
OXW17	130	13				
OXW32	81	14				
OXW35	30	12				
CHICKASHA :						
CH111	68	5	Oklahoma South-Western Prairies USA	5-6	Temperate MAP=700mm predominantly summer rain-fall.	Range & cultivated land with some woods. Relatively deep alluvial soils with moderate permeability derived from sandstones.
CH512	92	8				

5.1 ECCA CATCHMENTS

Figure 5.3 illustrates the Ecca catchments and the location of the flow and rainfall gauging stations. The Ecca is a tributary of the Great Fish River and situated in the semi-arid eastern Cape Province. Roberts (1978) and Görgens (1983) provide detailed descriptions of the climate and physical characteristics of the catchments. The catchment is underlain by interbedded shales and sandstones with harder formations of quartzite and tillite on the southern boundary. The headwater areas and valley bottoms are characterised by shallow slopes and separated by very steep slopes forming the valley sides. Soil depth is strongly related to slope, being thin and stoney on most valley sides but deeper in parts of the valley bottoms where they are associated with an uneven spread of alluvial and colluvial deposits. The deeper soils are fine grained with low permeabilities.

Vegetation consists of succulent to sub-succulent bush with variable density. Ground cover is temporally variable, disappearing from large parts of the catchment during droughts but reappearing after wetter periods. These variations appear to be more important than any seasonally related changes.

The climate is semi-arid with relatively low (MAP = 490mm with little seasonality) and erratically occurring rainfall and high potential evapotranspiration losses (annual mean 1360mm, with peaks of 173mm month^{-1} in December and January). The main storm type in summer is caused by convectional or convergence uplift resulting in short duration and often high intensity storms. Rainfall amounts and intensities can be spatially very variable with the valley bottoms receiving the highest falls. The runoff response from the steep and thin-soil valley sides can be high during such events but losses in the channels and alluvial valley bottoms result in only minor flow events at the gauging weirs. The most important runoff generating events are long duration, relatively lower intensity frontal or advection storms. While these can occur all year round they appear to be more common in winter. If they occur after a dry period, no flow occurs until at least 30mm of rain has fallen after which runoff proportions progressively increase. Spatial variations in rainfall amount and intensity during these events are usually low but there is a minor orographic effect giving rise to higher rainfalls on the south and east catchment boundaries.

Figure 5.4 illustrates the sub-catchment division that has been used for catchment Q9M20. The diagram shows the sub-catchment nodes and conceptual storages that are used to route modelled flows through the channel network.

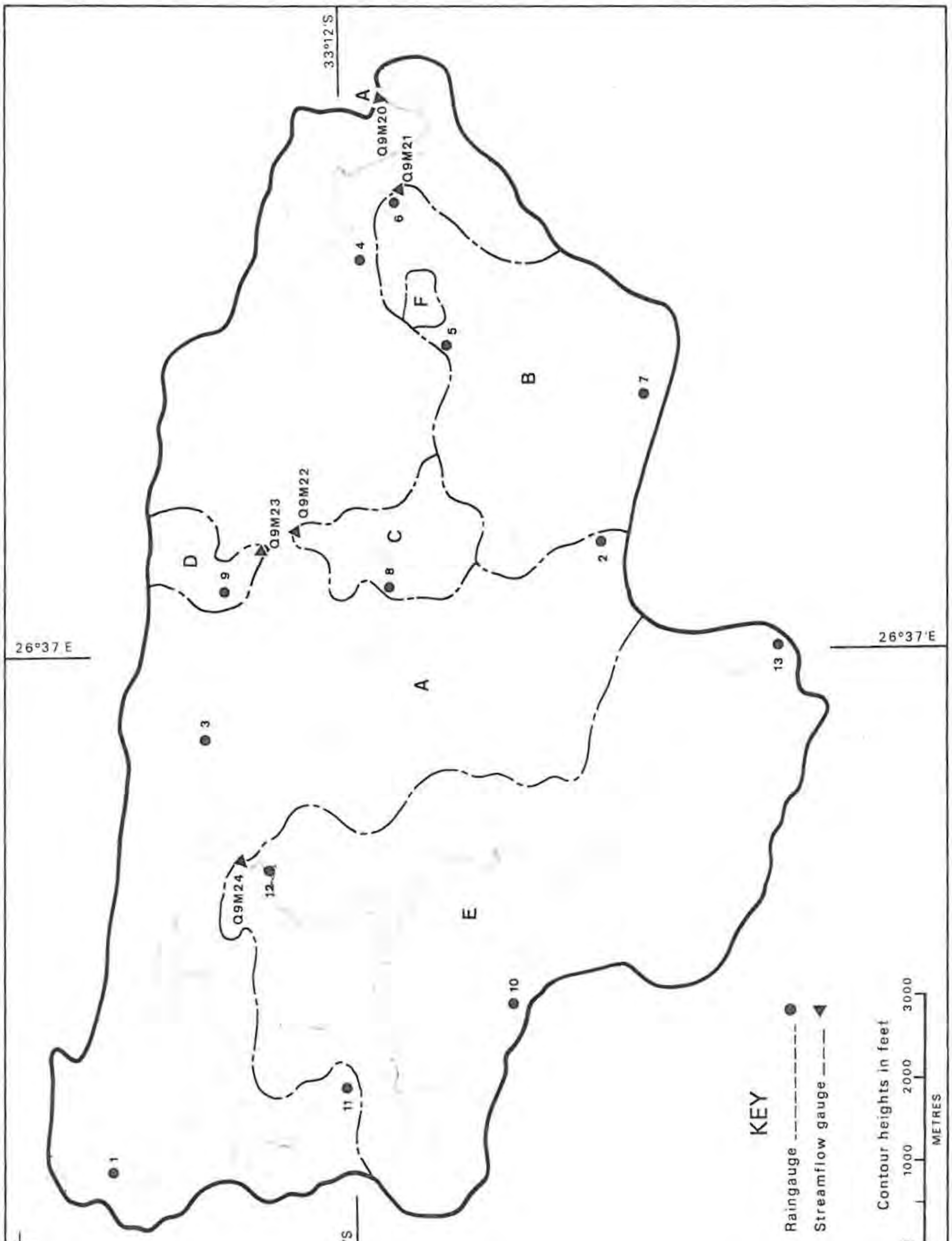


Figure 5.3 Ecca catchments and hydrological gauging network (from Görgens, 1983). The raingauge density for Q9M20 (73km^2) is 1 gauge per 7.3km^2.

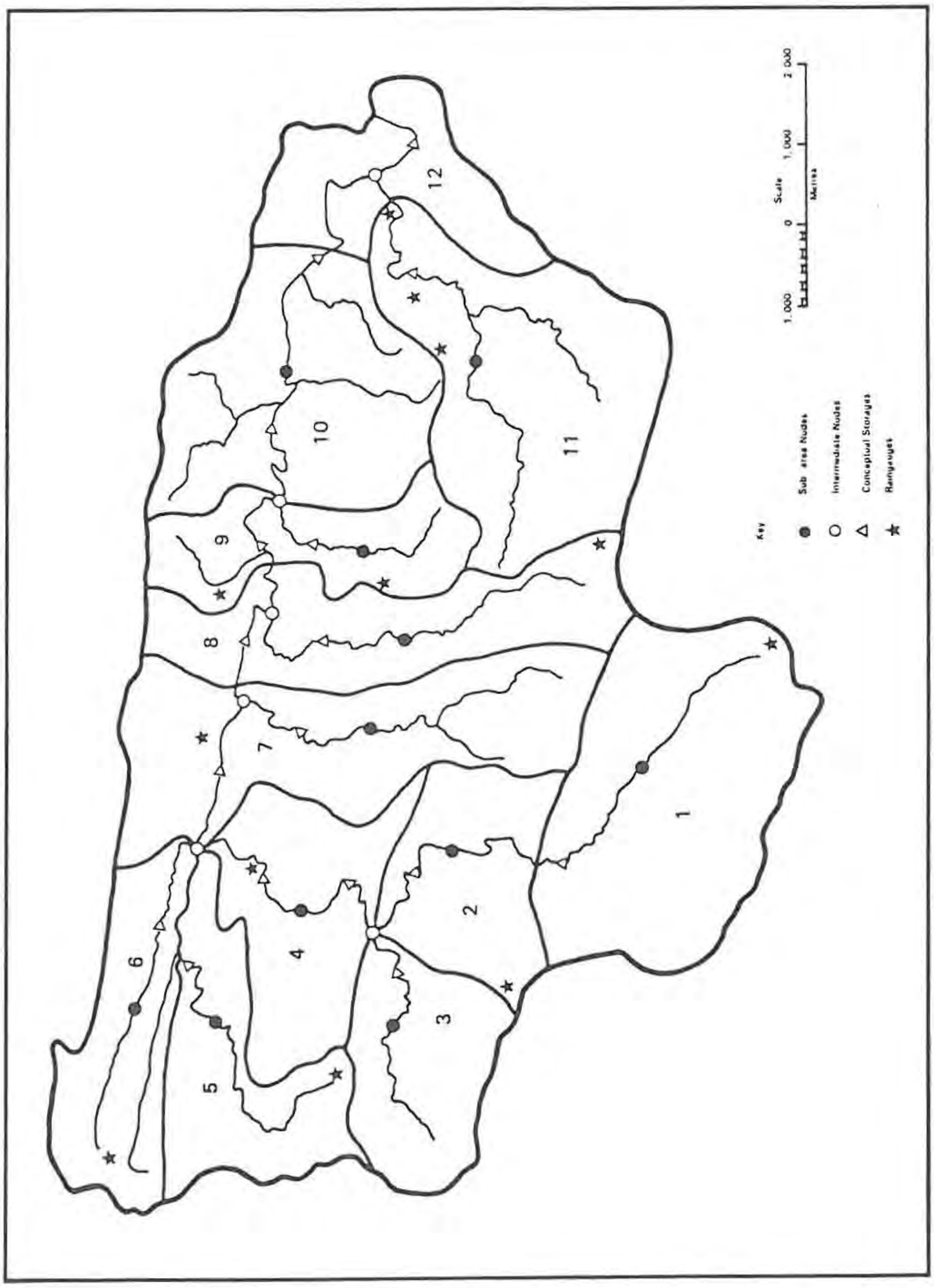


Figure 5.4 Sub-catchment definition for the gauged Ecca catchments.

5.2 DE HOEK CATCHMENT

The De Hoek catchment is located at the base of the Drakensberg mountains in the Natal Midlands, to the west of Estcourt. Information about the catchment used (VIM19) is available from Hope and Mulder (1979) and Schulze (1985). Figure 5.5 illustrates that there are three physiographic divisions; the plateau area, the steep escarpment and the valley of the so called De Hoek 'amphitheatre'. The valley and plateau are underlain by mudstones, while the escarpment is made up of sandstones. Dolerite sills and dykes occur in the valley and on the plateau. Soil variations are related to the physiographic divisions. The upland soils are silt clay and clay loams with relatively rapid permeabilities. Escarpment soils are very thin and stoney. The valley bottom soils are more variable with clay loams and loamy duplex soils having permeabilities ranging from moderate to very slow. There is limited information on soil depth for the plateau and valley areas. The plateau soils are generally deeper than 750mm, while the valley soils appear to be very variable but can have much deeper subsoils. Vegetation is dominantly grazed grassland and bush with some cultivation and wattle plantations.

The catchments lie in a summer rainfall region and consequently all the events used in the model tests occurred in the months October to March. Long term rainfall figures from representative stations indicate (Schulze, 1985) that differences will exist between rainfall on the plateau (MAP = 1115mm) and in the valley (MAP = 723mm). Mean annual A-pan evaporation is over 1500mm with the months of October and January experiencing greater than 150mm on average. Rainfall data are available from four gauges; two in the valley and two on the plateau (figure 5.5). There are a large number of small farm dams and soil conservation structures as well as a relatively large dam structure in the centre of the catchment.

5.3 CEDARA CATCHMENT

The Cedara catchment is located close to Pietermaritzburg in the Natal Midlands (figure 5.1 and 5.6). Catchment U2M16 is drained by the Rietspruit which is tributary to the Mgeni River. A large amount of information about U2M16 is available in Schulze (1979). The catchment is underlain by shales which have been intruded by dolerite sills and dykes. Slopes are moderate and average less than 20%. The upstream southern parts of the catchment have the steepest slopes but are rarely over 30%. Soils are generally deep (over 1m) and are dolerite derived with relatively high clay percentages (>50%). These soils are considered by Schulze (1979) to have a low runoff potential. About 57% of the catchment is covered by pine plantations, eucalyptus or wattle trees. Some 12% of the catchment is occupied by smallholdings and farms growing a variety of crops and 8% by scrub. The remaining area is occupied by veld under controlled grazing.

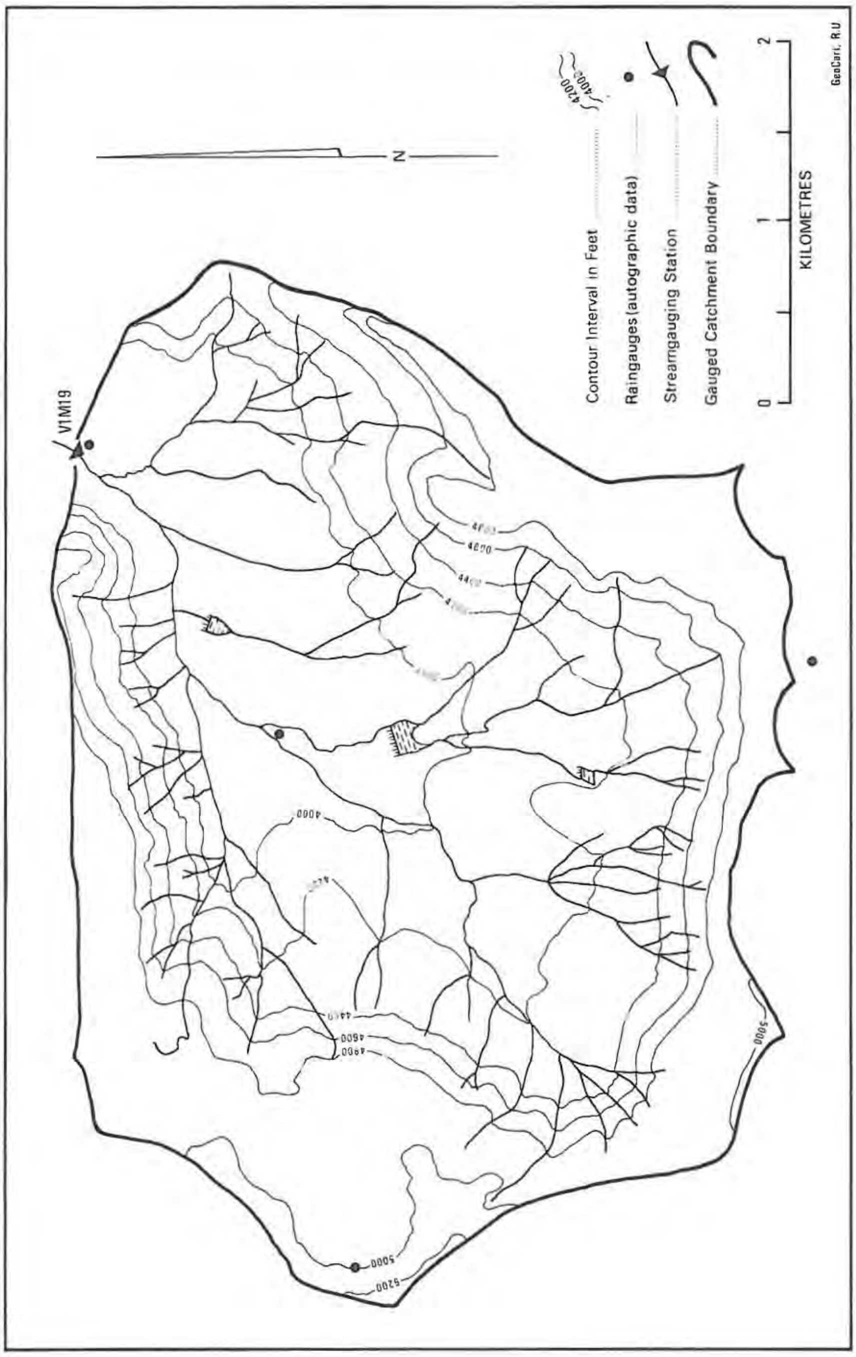


Figure 5.5 De Hoek catchment and raingauge locations with the escarpment of the amphitheatre indicated by the contours marked (total area of 15km^2; raingauge density is 1 gauge per 3.75km^2).

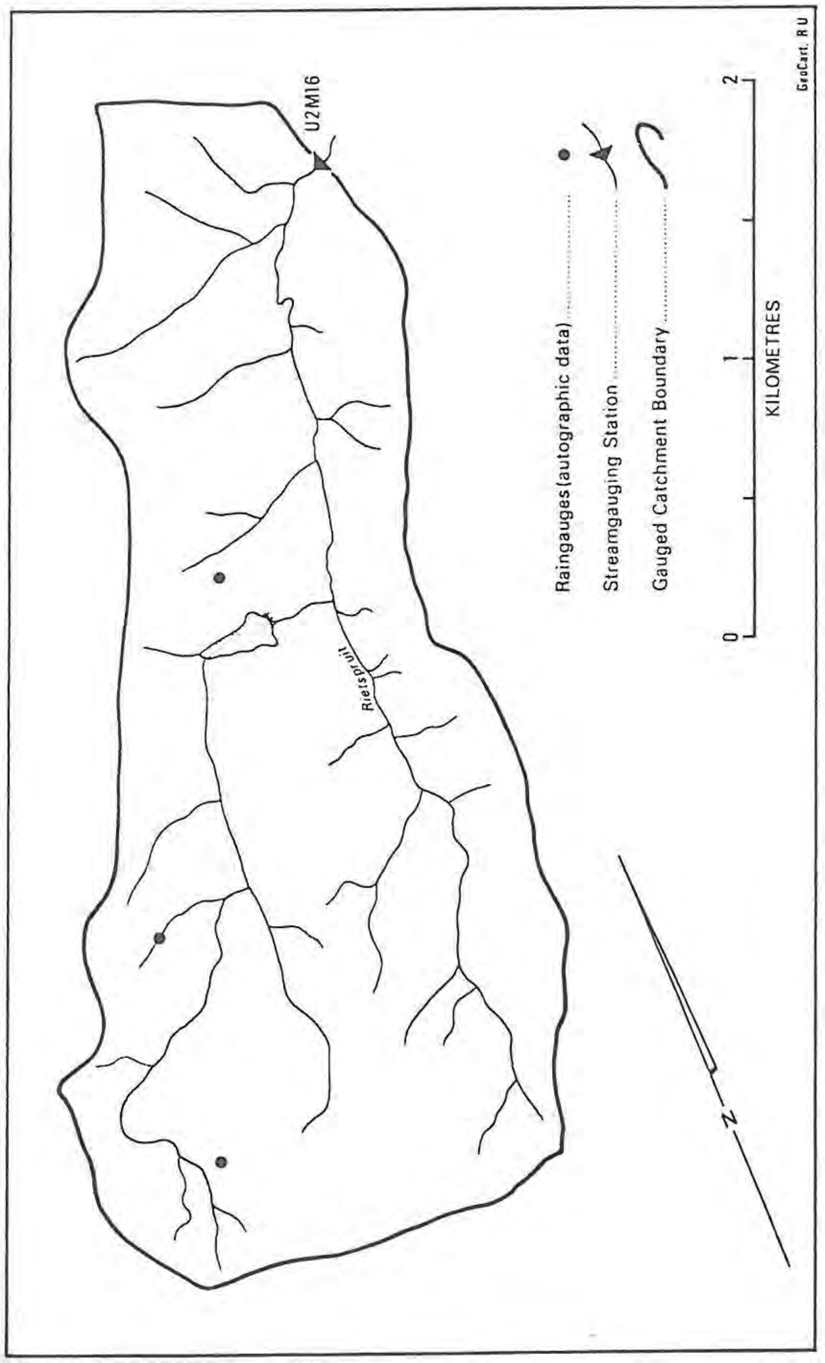


Figure 5.6 Cedara catchment and location of raingauges used (total area of 5km^2; raingauge density is 1 gauge per 1.7km^2).

Mean annual rainfall is approximately 875mm with 79% falling in the summer months when mean daily evaporation exceeds 4mm (Schulze, 1979). As with the other summer rainfall areas of South Africa all the storms used occurred in summer and are relatively short duration events with a variable degree of spatial variability in rainfall amount. Except for events at the beginning of the wet season, antecedent rainfall totals are usually quite high due to the frequency of occurrence of storm events.

5.4 ZULULAND CATCHMENTS

The Zululand catchments are situated south east of Empangeni close to the Natal/Kwa Zulu coast. Catchment information is derived from Hope and Mulder (1979). The northern parts of the catchment are underlain by biotite granite gneiss while to the south the rocks are less resistant biotite quartzo-feldspathic schists. There is an abrupt rise of about 100m coinciding with the north-south orientated drainage pattern (figure 5.7) in the centre of W1M15. Hope and Mulder (1979, p78) present a useful 'hydrological response unit' map which incorporates soil type and depth, slope and landuse. Soils are dominated by coarse textured soils but of variable depth. Deeper soils occur along the river channels while a high proportion of bare rock areas occur in the western part of W1M15 south of the W1M16 catchment boundary. Landuse is predominantly grassland with some agricultural crops, eucalyptus plantations and indigenous forest. Marshland grasses and vegetation occur adjacent to most of the main river channels.

Mean annual rainfall is approximately 1000mm, while annual A-pan evaporation is generally above 1700mm. As with the Natal catchments all the storms are drawn from summer months (October to March). However, the majority of the events used are of much longer duration than those used for De Hoek and Cedara but relatively high intensities are also experienced. The longer duration events experienced in this area compared to the Natal Midlands, is a reflection of the coastal location of the Zululand catchments. The rainfall generating mechanisms are more a consequence of orographic uplift of maritime air circulating inland then the more common convective mechanisms of the Natal Midlands. Spatial variation in rainfall is also comparatively reduced. While data from only three raingauges are available, the gauges are positioned to represent the main physiographic zones.

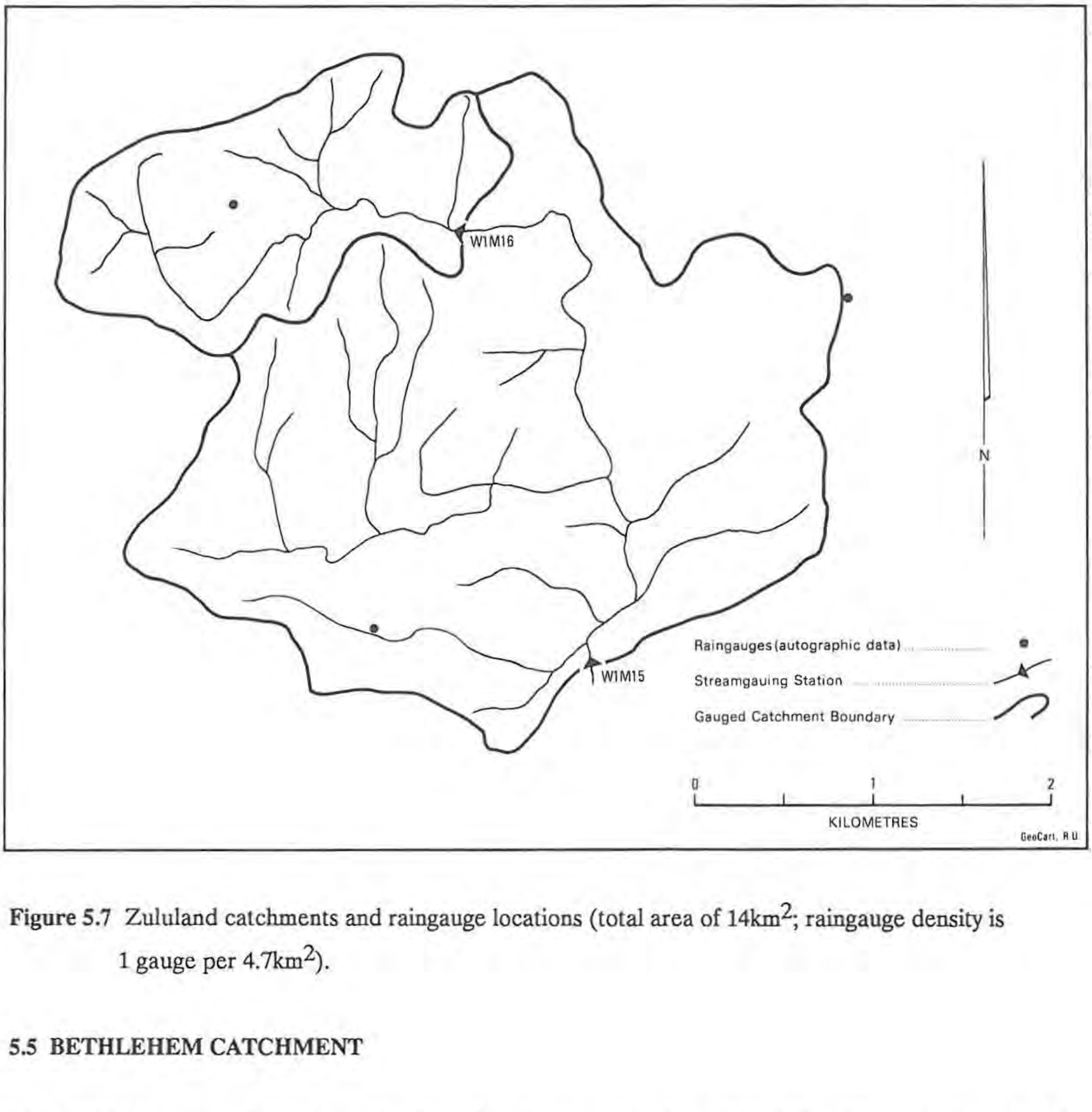


Figure 5.7 Zululand catchments and raingauge locations (total area of 14km^2; raingauge density is 1 gauge per 4.7km^2).

5.5 BETHLEHEM CATCHMENT

The Bethlehem research catchment is situated in the upper reaches of the Wilge River, a tributary of the Vaal River, in the dryland farming area of the eastern Orange Free State. The information about physical characteristics is drawn from Mason-Williams (1984) and Maaren (1979). The majority of the area is underlain by mudstones with some thin interbedded sandstone bands and several dolerite dyke and sill intrusions. The catchment is characterised by gently sloping relief with slopes mainly in the 0 - 6% category. There are a significant number of surface depressions, or pans, covering areas of up to several hectares.

Away from the major streams, the soils are dominantly light sandy topsoils overlying fine sandy loams. The soils adjacent to the major streams are heavy, structured clays. Intermediate duplex type soils, with light sandy surface horizons overlying clays also occur. Soil depth is variable but is on average about 600mm in the upper slope areas. The vegetation pattern is a mixture of dryland cropping, dominated by maize and wheat, planted pastureland and natural grassland veld. Some of the cultivated land is contoured while much of the natural veld is overgrazed and subject to erosion. There are a large number of farm dams within the catchment and 59% of the catchment area lies above these dams. These can be expected to have some impact on the runoff response.

Mean annual rainfall is about 700mm with 79% on average falling in the months October to March. Mean daily maximum temperatures during this period are above 24^{o}C while mean daily S-pan evaporation is 4,7mm or greater. All of the events used in the model tests are summer storms which are frequently characterised by spatially variable amounts and intensity. Figure 5.8 illustrates the distribution of raingauges for which intensity data are available for some of the storms. There are an additional three gauges outside the limits of the diagram which have assisted in determining spatial patterns. All of the storms used are of relatively short duration (rainfall lasting less than 3h) with relatively high intensities in the central area of the storm.

5.6 SOUTHERN CAPE CATCHMENTS

These four catchments are situated in the coastal area of the southern Cape Province between George and Knysna and have their headwaters in the Outeniqua Mountains (figure 5.9). The gauging weirs are part of the national Water Affairs network, from whom the water level recorder charts were obtained. The rainfall data are available from several sources. The Weather Bureau operate a number of daily raingauges in the area plus a single autographic gauge at George. During the 1970's Water Affairs operated several autographic gauges in a small area to the east of George. Rhodes University HRU have operated a continuously recording raingauge network in the area since the early 1980's. Mean annual rainfall varies from as low as 500mm near the coast in the western part of the region to over 1200mm in the Outeniqua mountains. Annual potential evapotranspiration is approximately 1050mm with a maximum of about 140mm.month^{-1} in December and January and minimums of 54mm during May to July. Further details of the raingauge network as well as the regions characteristics can be obtained from Hughes and Görgens (1981), Hughes (1982), and Hughes and Wright (1988).

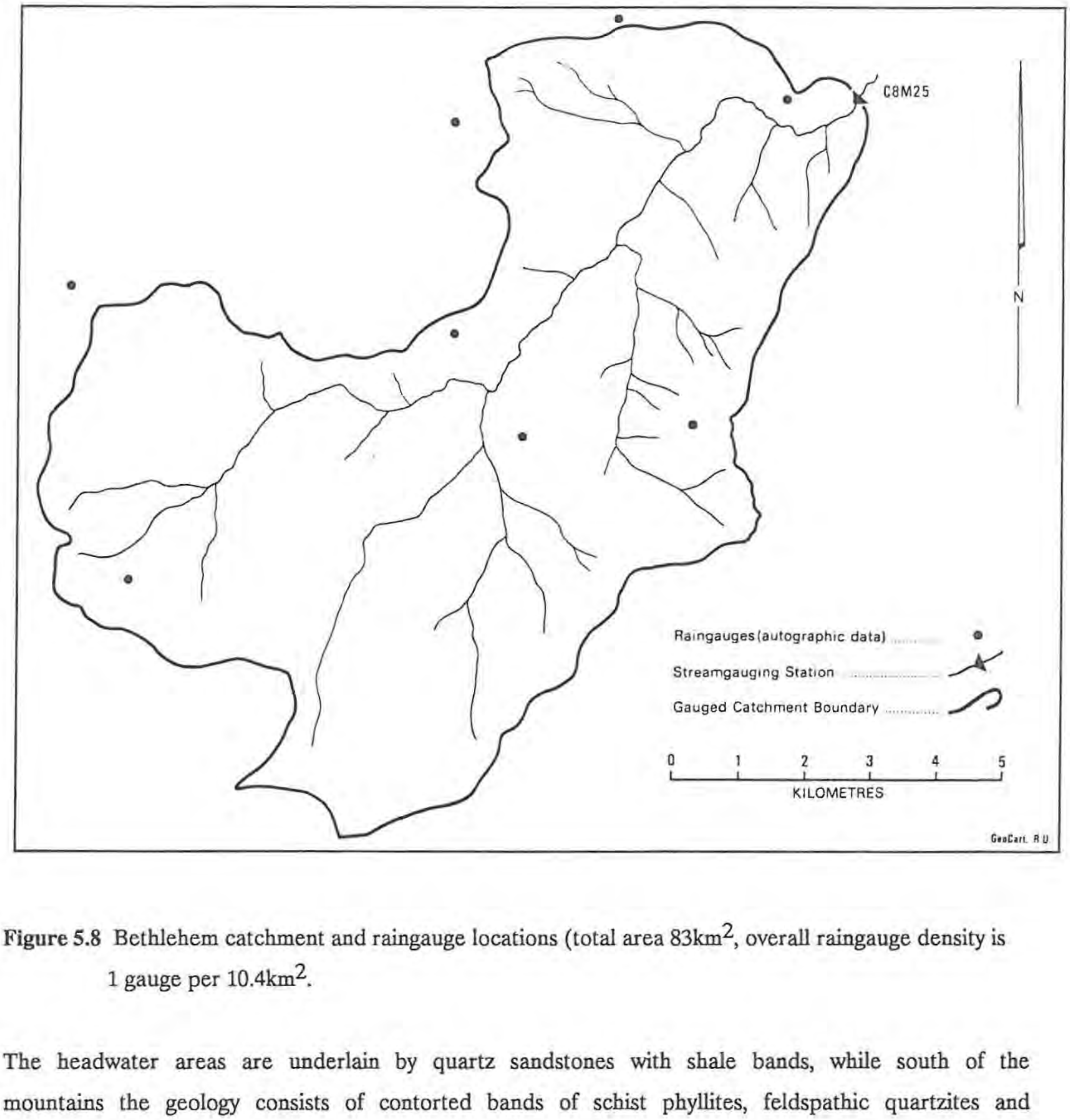


Figure 5.8 Bethlehem catchment and raingauge locations (total area $83km^2$, overall raingauge density is 1 gauge per $10.4km^2$.

The headwater areas are underlain by quartz sandstones with shale bands, while south of the mountains the geology consists of contorted bands of schist phyllites, feldspathic quartzites and schists within which there are outcrops of intrusive granites (Tyson, 1971). There are three main physiographic zones, consisting of the Outeniqua mountains, the steeply sloping foothills zone and the incised coastal platform. There are also three main vegetation types in the region. The exposed mountains and parts of the foothills are covered with the natural bush vegetation (Fynbos). The other form of natural vegetation is the dense temperate forest dominated by yellowwoods, wild elder and ironwood. These forests have been cleared in many places to be replaced by managed pine plantations.

There is inevitably a great deal of variety in the cover characteristics of these plantations depending upon their stage of growth.

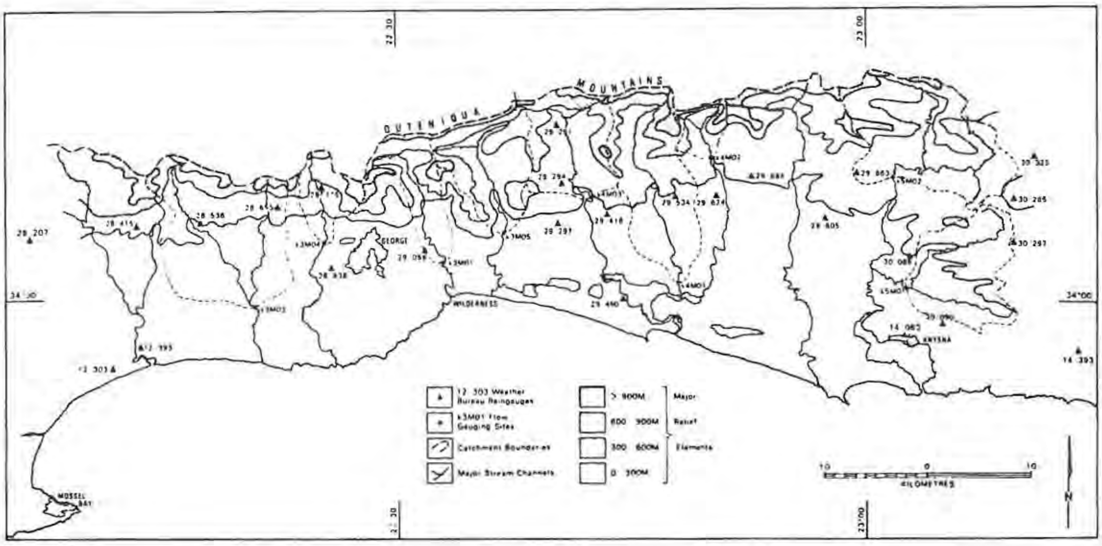


Figure 5.9 Southern Cape coastal area illustrating topography, gauged catchments and raingauge network.

Azonal soils are found on the steeper slopes and are generally shallow and sandy in texture. In other areas humus-rich soils have developed and can be relatively deep (about 2m). Exposures of some soil profiles alongside forestry service roads indicates that subsurface piping may play a significant role in the hydrological response of these catchments.

The four catchments included in this study are the Malgas (K3M04, northwest of George), Kaaimans (K3M01, northeast and east of George), Diep (K4M03, northeast of Wilderness) and Karatara (K4M02, a small headwater catchment midway between Knysna and Wilderness). Being part of a national network, the gauging weirs were not originally designed for measuring high flows. However, the rating curves were checked and extended by Ninham Shand Inc. using a backwater estimation technique (Hughes and Herald, 1985). Figures 5.10 to 5.13 illustrate the drainage patterns and positions of the relevant raingauges for each catchment. Figure 5.11 shows no raingauges on the diagram and this illustrates one of the major problems with attempting to simulate flood events for these catchments. The steep slopes and forest vegetation prevent raingauges from being sited at locations most suitable for assessing catchment rainfall input. In many cases, storm rainfall definition relies upon the use of a gauge (or gauges) close to the catchment for the intensity distribution plus additional autographic and daily gauges further away to assist in determining the spatial variation of storm total. A detailed study of the short term spatial variability of rainfall by Hughes and Wright (1988) indicates that the patterns are complex and not easy to define given the amount of data available. They found a fairly high degree of similarity in the timing and shape of individual station storm profiles, but there is less consistency in the pattern of storm totals.

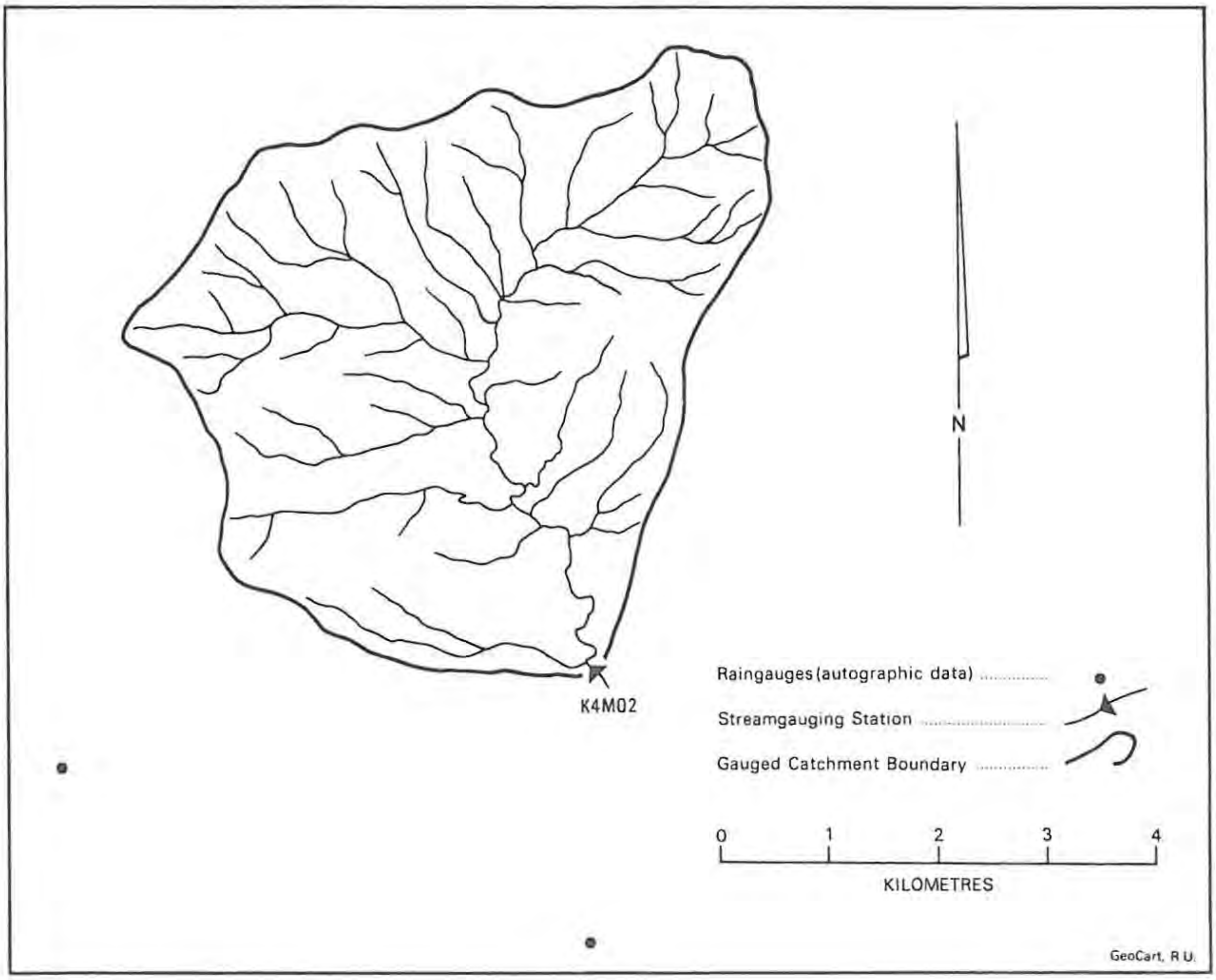


Figure 5.10 Karatara (K4M02) catchment and raingauge locations (total area of 22km^2; no raingauges within the catchment boundary).

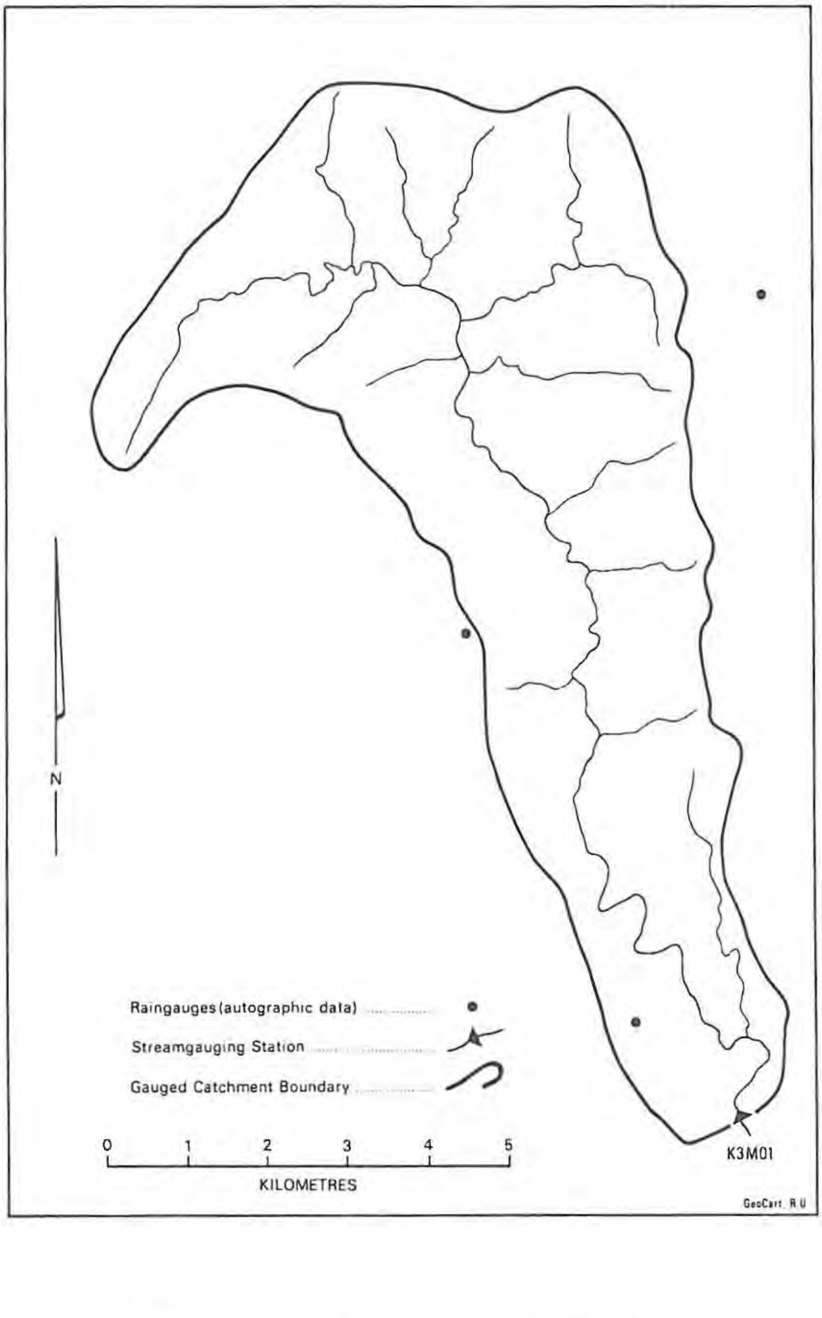


Figure 5.11 Kaaimans (K3M01) catchment and raingauge locations (total area of 48km^2; raingauge density is 1 gauge per 16km^2).

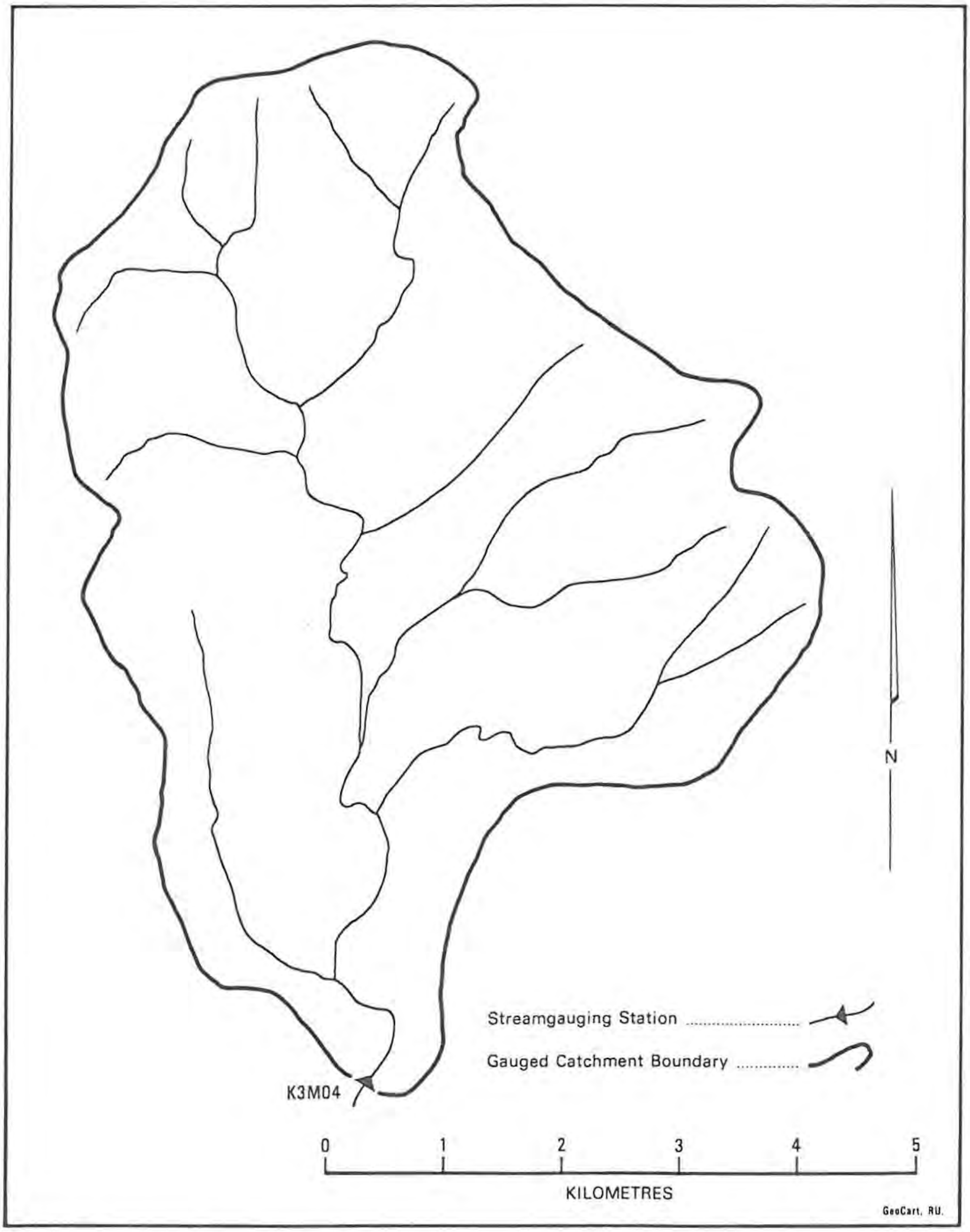


Figure 5.12 Malgas (K3M04) catchment and raingauge locations (total area of $34km^2$; no raingauges lie within the catchment boundary).

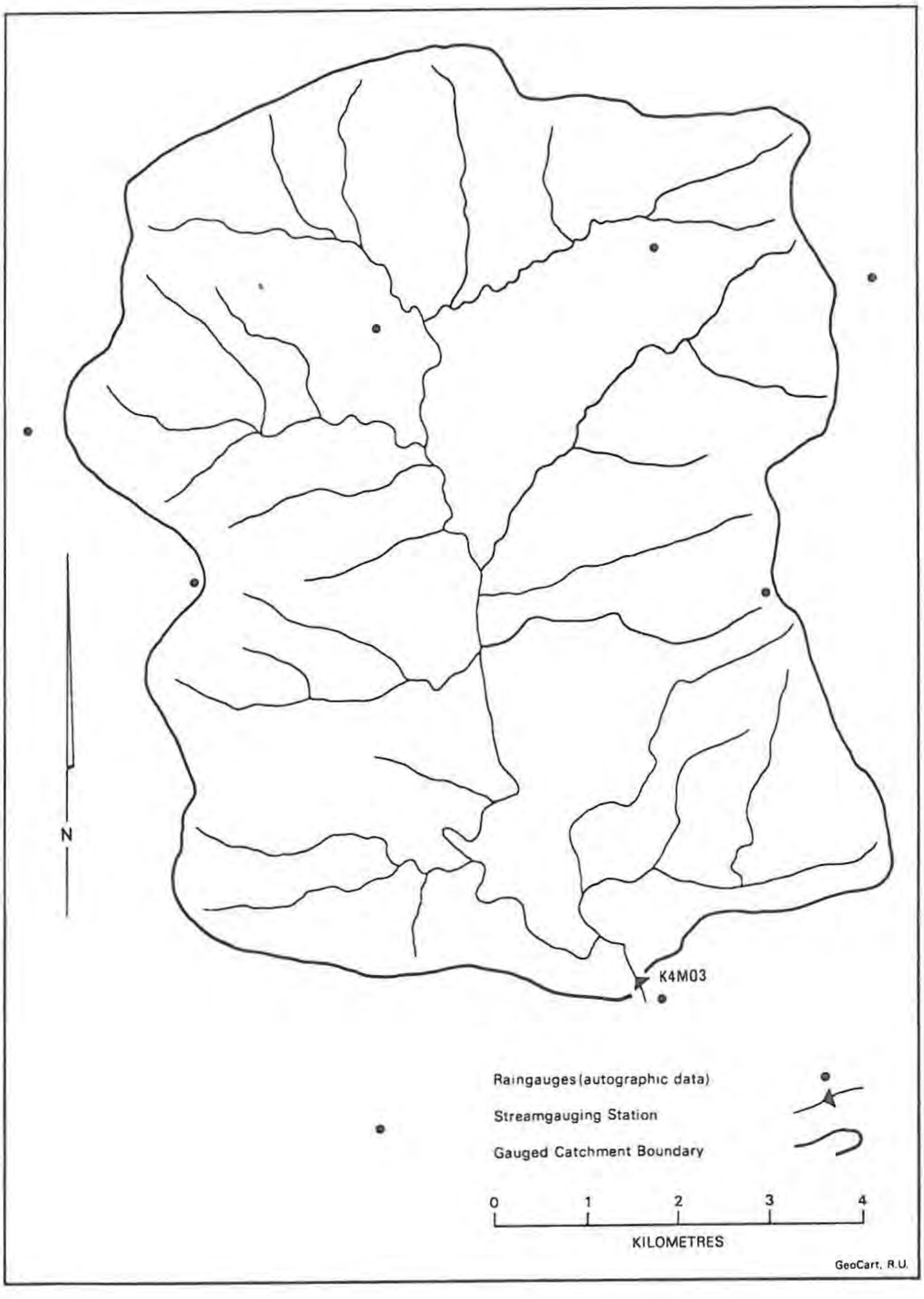


Figure 5.13 Diep (K4M03) catchment and raingauge locations (total area of 35km^2; raingauge density, including those in or close to the boundary, is 1 gauge per 5.8km^2.

The majority of the storm events occurring within this region are caused by the passage of cold fronts or the advection of moist maritime air. Orographic influences are strong and it is thought that the inconsistent patterns of spatial variation in storm rainfall are a consequence of variations in these orographic influences during different weather patterns (Hughes and Wright, 1988). In general, storm events are characterised by low intensity, long duration rainfall. The occurrence of shorter duration cells of higher intensity rainfall during these events can result in complex multi-peaked hydrographs.

5.7 NORTH DANVILLE CATCHMENTS

The North Danville catchments are located in Caledonia County, Vermont State in the northeastern USA and are part of the Connecticut River basin. The information on their characteristics and the single event data have been taken from USDA (1955-1973), while figure 4.15 illustrates the gauging network and the sub-catchment division used for the semi-distributed models in this study.

The catchments are underlain by calcareous schists and calsilicate rocks interbedded with quartz-mica schists and micaceous quartzite. Hydrologically more important is an impervious boulder clay which overlies the solid geological formations. Soil types vary from rocky, fine sandy loams with rapid permeabilities to silty loams with moderate to slow permeabilities. Soil depth varies from 0,3 to 0,8m and the information given for the four catchments (ND1, 3, 4 and 5) indicates little variation in the soil characteristics at the catchment scale. Vegetation type is predominantly deciduous hardwood with some softwoods and approximately 30% of the area is under pasture or cultivation.

Mean annual precipitation is about 950mm and while relatively evenly distributed throughout the year, much of the winter precipitation occurs as snowfall. Mean daily temperatures during the summer months are in excess of $15^{o}C$ while five months of the year experience sub-zero mean daily temperatures and there appears to be a spring snowmelt runoff period in April and May. All of the storms used in model testing have therefore been drawn from the summer months when rainfall storm characteristics can vary between relatively high intensity and short duration events to longer duration (up to and over 12h) events with generally lower intensities. There are similarly large differences in the degree of spatial variability between events. The distribution of raingauges for which storm total data are available is fairly satisfactory, but intensity data are available for only a few of these (figure 5.14). The definition of spatial variability in input rainfall is not always possible.

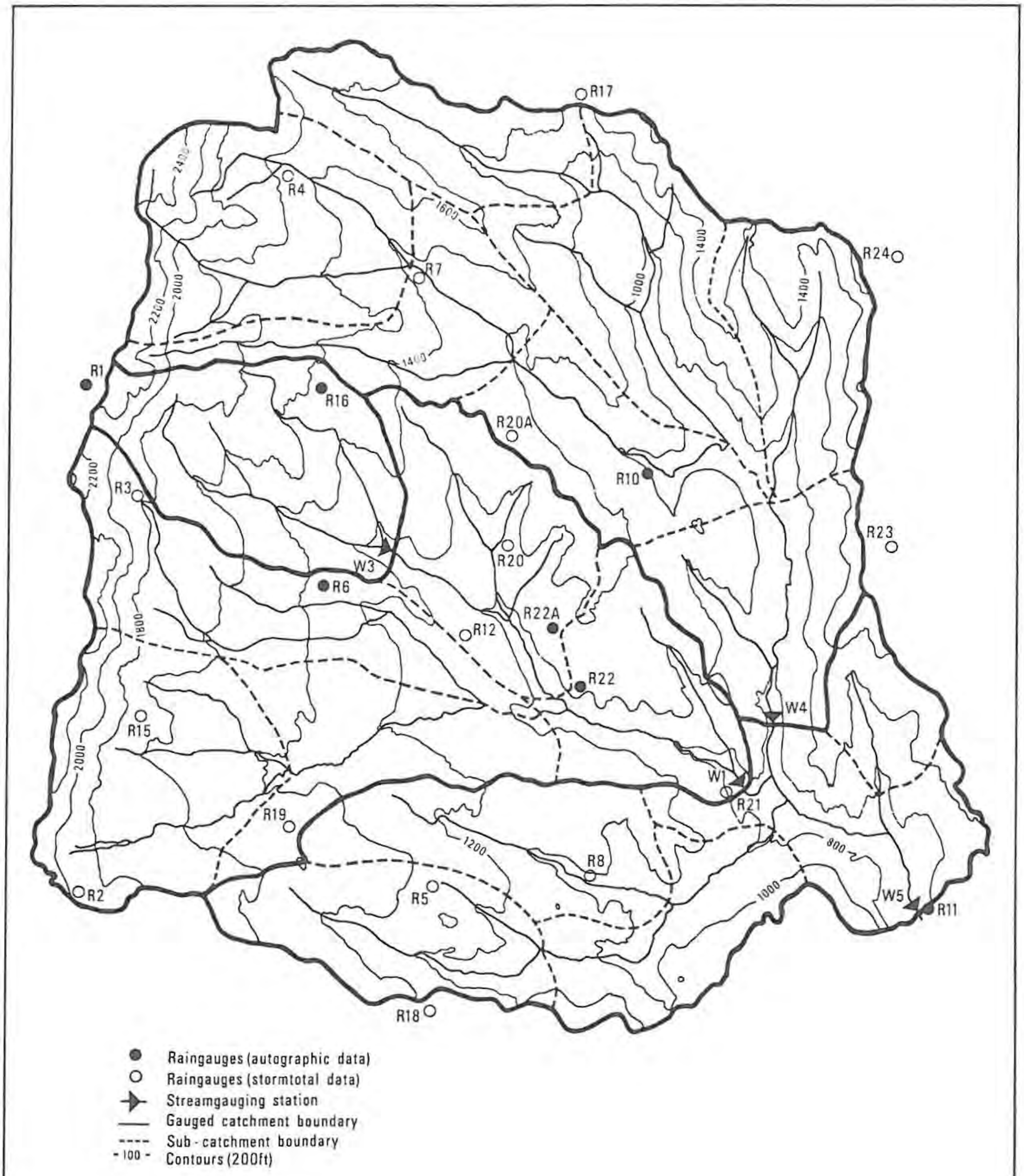


Figure 5.14 North Danville catchments, raingauge locations and sub-catchment boundaries (total area is 112km^2; overall raingauge density is 1 gauge per 4.9km^2; autographic gauge density is 1 gauge per 16km^2 and very uneven).

5.8 TOMBSTONE CATCHMENTS

The Tombstone catchments are within the USDA Walnut Gulch experimental watershed, a tributary area of the San Pedro River in Cochise County, Arizona. Within the main catchment there are a further five gauged sub-catchments (table 5.2 and figure 5.15). The catchments represent the arid to semi-arid desert grassland area of the south eastern Arizona basin. The slopes are moderate except in a few areas close to the catchment boundary where they are quite steep. The majority of the information on the Tombstone catchments is derived from USDA (1955-1973).

The major area of the catchment is underlain by interbedded sand and gravel alluvium which is very deep in the east but is shallowly underlain by granodiorite in the west. The granodiorites outcrop in the south west and are capped in places by limestones. Soils are gravelly or stony clay loams which are moderately permeable. Given that the alluvium is also permeable it can be assumed that the effective depth of the soil from a hydrological point of view is high. Vegetation cover is sparse and consists mainly of desert shrubs and grasses. Mean annual rainfall is about 300mm with a clear peak in July and August. There are no available data on evaporation rates but mean daily temperatures during the summer months exceed 26^{o}C.

All the storms used are summer thunderstorm events of short duration and high intensity, typically of small areal extent. Consequently, there is a high degree of spatial variation in rainfall with some parts of the whole catchment receiving up to 68mm while other parts receive less than 10mm. Figure 5.15 illustrates the distribution of raingauges for which storm profile data are available for some of the events. However, not all gauges are represented for all events. These data are supplemented by isohyetal maps of storm total rainfall (USDA, 1955-1973) which assist in defining the spatial variation of rainfall input. One advantage is that the gauges for which the detailed data exist are those closest to the storm centre for each event.

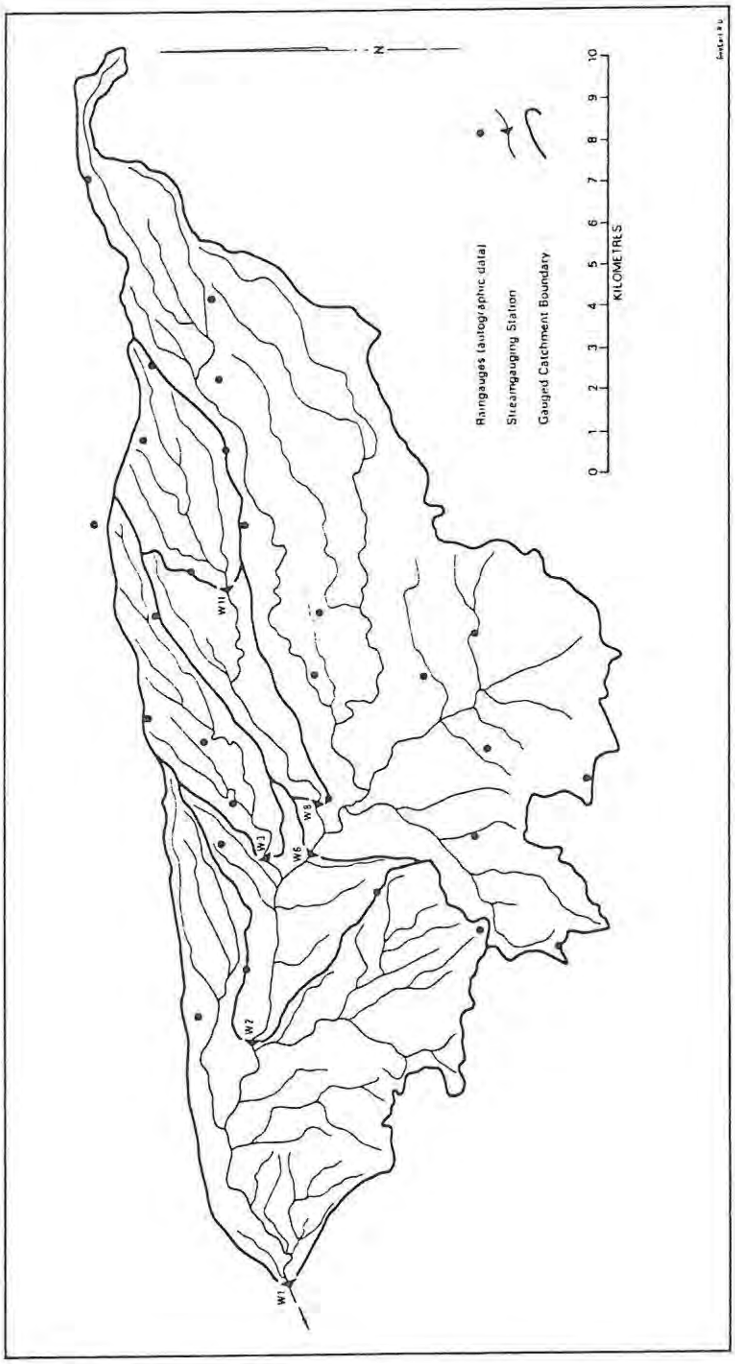


Figure 5.15 Gauged catchments and raingauge network in the Tombstone area (total area of 150km^2; raingauge density for the catchments ranges from 1 gauge per 1.6 and 5.5km^2).

The runoff response is extremely 'flashy', particularly from the smaller catchments (TM3, 8 and 11). Events on TM8, for example, rarely last more than 3h and the peak of the largest event reached $121m^3s^{-1}$ 35 mins after the onset of flow. One event in August 1971 progressed from zero flow at TM6 at 19h31 to over $70m^3s^{-1}$ at 19h35 reaching a peak of $107m^3s^{-1}$ at 19h47. Flows of over $50m^3s^{-1}$ were sustained for 1h, while 2h later the flow had reduced to below $1m^3s^{-1}$. While most of the other catchments were modelled using a 15 min time interval, it was considered necessary to reduce the interval to 5 min for the Tombstone events. Renard and Keppel (1966) as well as Burkham (1970) have documented the importance of channel loss processes in this region. For example when comparing the volumes and peaks at TM8 ($15km^2$) with the upstream volumes and peaks at the outlet of TM11 ($8km^2$) they are usually substantially less. It is unlikely that either of the models will be able to adequately account for this process.

5.9 OXFORD CATCHMENTS

The Oxford catchments cover a total area of over $300km^2$ in Marshall County, Mississippi State. There are numerous sub-catchments within this area of which 7 have been used in this study (table 5.2 and figure 5.16). Information on the catchment characteristics and the single event data have been extracted from the USDA (1955 to 1973) volumes. The area represents the eroded uplands in the transitional zone between the southern coastal plain and the southern Mississippi Valley uplands. The area is gently to moderately sloping and underlain by sandstones which have many clay lenses. The main river valleys are underlain by mixed alluvial material and are broad and flat with well developed floodplains. Soils are silty clay loams to fine sandy loams with moderate to rapid subsurface permeabilities. Soil depths are generally less than 1m but can be deeper. Some of the soil types have impeding layers at 400 - 500mm. Although there is no specific information on the spatial distribution of soil types, comparison of the soils descriptions given for the various catchments indicates only small variations between catchments.

Land use includes approximately 20% under cotton and corn cultivation, over 30% with poor to good cover of broomsedge and grasses, 10 - 15% pasture and up to 25% under woods having fair to good cover. An interesting feature of the vegetation cover is the great seasonal variation particularly in the cultivated areas. During winter the cover characteristics are poor to fair depending upon the stage of ground preparation for the next crop and the state of the residue from the previous crop. In spring and early summer the cover improves as the crop growth increases and in August and September the mature crops provide fair cover. Such variations can be expected to be hydrologically significant. To investigate the importance of these seasonal changes prior to model testing rainfall-runoff depth relationships were plotted for events in January, March, May/June and September. These are illustrated in figure 5.17 which demonstrates that the seasonal differences are marked. Despite the inevitable scatter in the relationships the decrease in runoff proportion from high values in the January to March period through spring to the low values in late summer is marked. These differences cannot be attributed to any changes in intensity between the seasons as summer intensities are generally similar or higher than winter intensities. This evidence for seasonal differences prompted the separation of all Oxford events into those occurring in the winter months (November through to April) those in the spring and early summer (May and June) and those in the later summer months (mainly July to September). The three groups have been modelled separately under the assumption that different sets of model parameter values will be applicable to each.

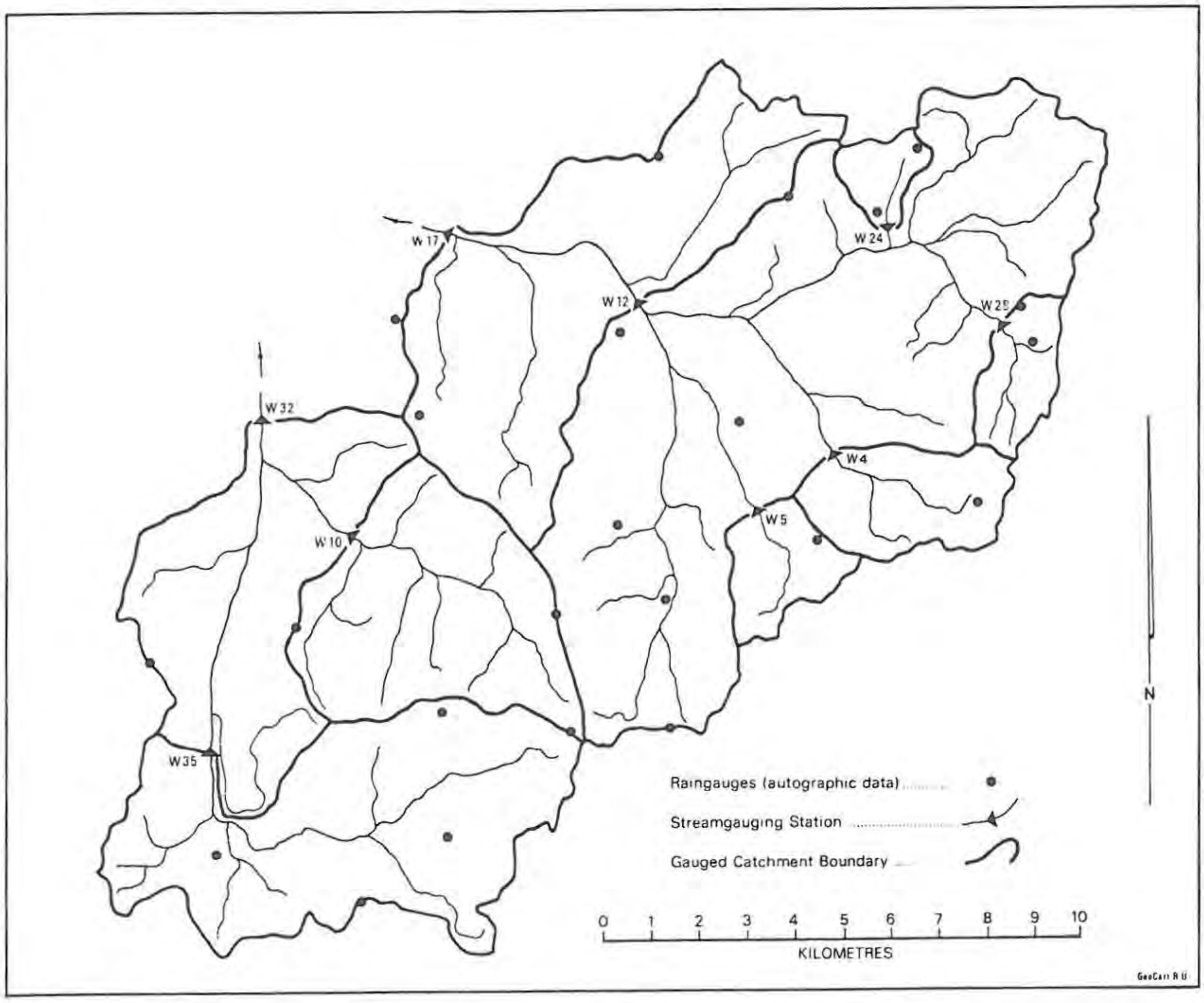


Figure 5.16 Oxford catchments and raingauge locations. The two main catchments of W17 ($130km^{2h}$) and W32 ($81km^2$) have raingauges densities of 1 gauge per 8.1 and $9.0km^2$ respectively.

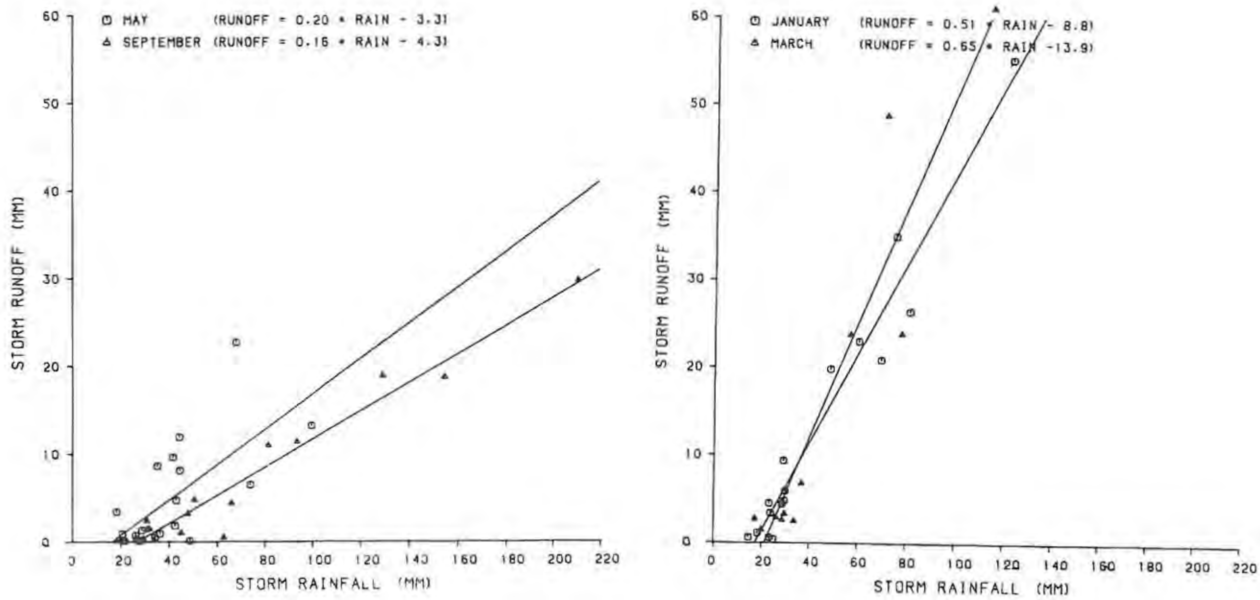


Figure 5.17 Relationship between total storm rainfall and runoff for a number of events taken from four seasons. The lines are least squares best fit lines and their equations are given in the annotation.

A further consideration with respect to runoff response is the number of small desilting and retention dams. Up to 25% of the catchment areas lie above such structures. Finally, large runoff events on the bigger catchments are likely to be affected by attenuation on the floodplains along the major rivers. There are no components in models OSE1 or 3 to account for such attenuation.

Mean annual rainfall is about 1350mm and there is little seasonality in the monthly distribution. There is no detailed information available on the temperature and evaporation regimes. Although the raingauge network density appears to be reasonably adequate from figure 5.16, there are some storms for which only total rainfall amount (no intensity distribution) at some of these stations exists. For some of the events on the large catchments, only one Thiessen weighted average intensity distribution is given in USDA (1955 - 1973). Therefore, while the data allow an adequate definition of the spatial variation in total storm depth, they do not always allow spatial variations in intensity distribution to be defined. From what little evidence there is, the degree of spatial variability in intensity distribution is very different for the range of events used.

5.10 CHICKASHA CATCHMENTS

The Chickasha catchments are tributary to the Washita River and located in various counties of Oklahoma state in the Southwestern U.S. prairies. Two of the catchments (CH111 and CH512) have been used in this study and their position within the whole area as well as their drainage pattern and the position of available raingauges is shown in figure 5.18. The single event data and descriptions of the catchments have been drawn from USDA (1955-1973).

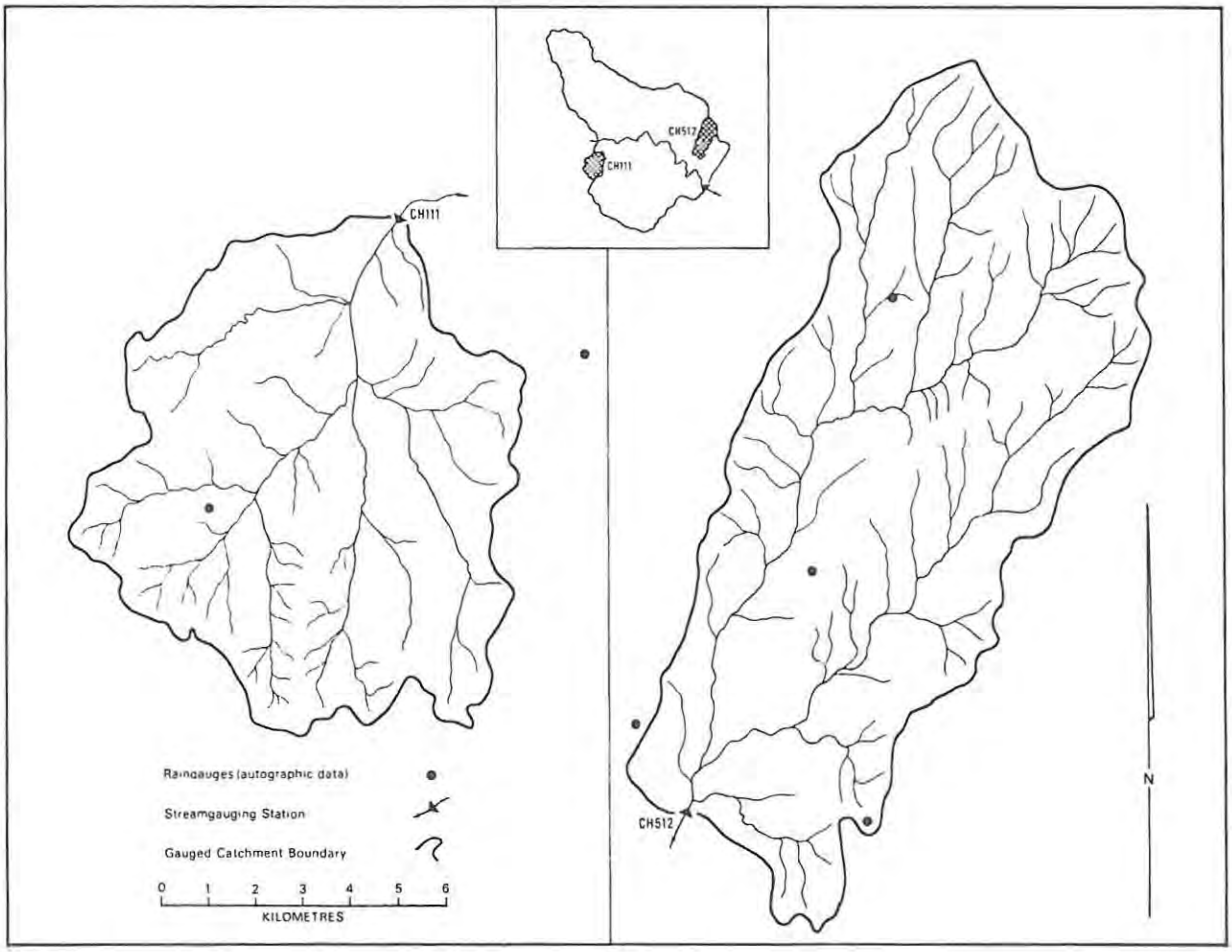


Figure 5.18 Chickasha catchments and raingauge locations (areas are $68km^2$ for CH111 and $92km^2$ for CH512; raingauge densities are 1 gauge per 34 and $23km^2$ respectively).

Catchment CH111 is underlain by fine grained, even-bedded sandstone formations while CH512 is underlain by a mixture of cross-bedded shales, siltstones, sandstones and conglomerates. Both have relatively small amounts of alluvium in the valley bottoms of the major streams. The soils developed on the sandstones are deep sandy to fine sandy loams with moderate permeabilities. CH512 soils appear to be of a finer texture (silt loams to loams), marginally shallower but still with moderate permeabilities. The USDA (1955-1973) reports present a relatively confusing impression of the landuse differences between the two catchments. There is a mixture of cultivation (rotation of grain, alfalfa and cotton) pasture and rangeland. The exact proportions of the different land-uses appear to be fairly dynamic and it is difficult to give representative values. Catchment CH512 has a greater number of soil conservation measures than CH111 although both have terraced land in the sloping areas.

Mean annual precipitation is about 700mm with a peak in spring and late summer. Mean daily temperatures are about 13^{o}C in early spring but reach up to 26^{o}C in mid-summer. The majority of the storms used for model testing are taken from the spring to summer months of the year and are characterised by high intensities and short durations. There is only one suitable raingauge in CH111 (figure 5.18), the nearest additional gauge for which intensity data are available being several kilometres outside the catchment. Comparisons between these gauges indicate that large differences in storm totals do occur but that the shape of the intensity profiles are usually similar. However, the additional gauge is of little use in defining patterns of spatial variability of rainfall. The situation is marginally better for CH512 but although more gauges are indicated in figure 5.18 to be within or close to the catchment, data are not always given for all gauges for individual events.

This chapter is designed to give an overview of the test data set rather than to fully describe each catchment. Reference can be made to the original sources for more complete descriptions where they are available, although in many cases the original descriptions are far from complete. This is particularly true of the descriptions of soil characteristics as very little quantitative information is available for comparative purposes. Consequently, a great deal of reliance has had to be placed upon the qualitative references to such as 'rapid' or 'moderate' permeability and 'deep' or 'shallow' soils. This lack of detailed quantitative information would be extremely limiting if strongly physically-based models were to be applied to the catchments without collecting more data than is available in the publications. The amount of field work involved in collecting additional data would be beyond the resources of most single research organisations and could only be achieved by many such organisations co-operating together. These factors serve to further illustrate the difficulties of assessing physically based models on a wide range of catchment types.

The summary information in each section of this chapter is also designed to illustrate the type of rainfall regime prevalent over the catchments during the seasons for which storms have been extracted. Of particular importance is the type of storm event in terms of intensity and duration as well as the degree of spatial variation in storm rainfall characteristics over the catchments. Coupled with this is the extent to which the available data are considered to adequately represent the spatial variation. Owing to the great differences in amount of available rainfall data, not only between catchments, but also between storms on some catchments, the ability of these data to satisfactorily represent the actual storm rainfall characteristics is highly variable. This will inevitably have some influence on the simulation results and must be taken into account when assessing these results. It has not been possible to standardise the way in which rainfall input to sub-catchments (in semi-distributed models) or whole catchments (in lumped models) have been defined, largely because of the differences in the type of rainfall data available. However, the maximum amount of information has been used in all cases. Where data for a number of gauges are present then the most appropriate gauge profile, or weighted combination of gauge profiles has been used. The choice of the most appropriate gauges has been based upon the relative positions of the gauges and the sub-catchments as well as a consideration of the spatial pattern of storm rainfall total. For some catchments there are few storm profiles but additional data in the form of storm totals at other gauge sites, or isohyetal diagrams of storm total, have been used to weight the available profiles. Weighting is carried out on the basis of storm total such that intensity variations within the storms will not always be adequately represented.

CHAPTER 6

MODEL CALIBRATION RESULTS (INDIVIDUAL CATCHMENTS)

This chapter discusses the results of and the degree of success with which the two models have been able to reproduce the observed hydrographs of most of the catchments referred to in chapter 5. As indicated in chapter 1 the calibration of both models is divided into two separate stages. The initial calibration is restricted to two sets of catchments with very different climatic and physiographic characteristics. The purpose of this stage was to identify any obvious deficiencies in the models' structures which could easily be corrected and to attempt to establish, for each model, a calibration procedure to follow before continuing with the larger data set incorporating far more catchments. The semi-arid, South African, Ecca catchments (section 5.1) and the temperate, forested, USA, North Danville catchments (section 5.7) were selected for initial calibration. The results are presented and discussed with respect to the curve fitting capabilities of the models, the parameter stability and the ease of model calibration. Comparisons between the individual model results are also discussed. The second stage consisted of applying the models to a further 8 sets of catchments (referred to in chapter 5 and listed in tables 5.1 and 5.2), using the most suitable calibration procedure(s) developed during the initial calibration. As explained in section 4.3.1 at least one parameter from each model varied between events on the same catchment, during calibration, but those parameters which could assume fixed values were calibrated on a subset of the available storm data followed by a validation on the remaining data set. The results of this stage of the calibration are interpreted with respect to the model types, different catchment types as well as the amount and quality of the available data with which to define the rainfall input.

To avoid breaking up the text with too many tables, most of the numerical results are presented in appendices. Appendix A consists of tables containing the parameter values and statistics of fit of the initial calibrations, for both models and for both the lumped and semi-distributed formats. Appendices B and C list the main calibration parameters and the statistics of correspondence between the observed and simulated values for all the individual storms for each model. The statistics used to describe whether the simulated fit is 'acceptable' are referred to in section 2.2.2 and include the percentage errors of simulated volume and peak as well as the coefficients of efficiency and determination. Although difficult to define, an 'acceptable' fit for this study, is one where the peak and volume estimations are within approximately 20% of the observed values and where the overall hydrograph shape is well simulated.

6.1 INITIAL CALIBRATION STAGE

There are several aspects associated with the results of fitting the two models to observed storm data. The following topics are discussed for each of the models.

a) Ability of the models to reproduce a range of hydrograph responses to a range of rainfall input types. This is the curve fitting ability of the model.

b) The extent to which a) can be achieved with a reasonable degree of parameter stability and with parameters that are intuitively acceptable. It may not be easy to determine what is an intuitively acceptable value. To a large extent this depends upon the model being operated in lumped or semi-distributed mode. The semi-distributed versions of the models have a large parameter 'space' and therefore a large number of values can be changed to vary the simulation result. For both models, intuitive ideas about the sub-catchment variation in response, have been used to determine sub-catchment parameter factors. In some cases sub-catchment factors have been calculated from relative differences in measurable physiographic factors. Therefore, to a certain extent the calibration results constitute a test of the applicability of these relationships. The sub-catchment factors have only been changed during calibration runs when changes in global parameter values have not been able to achieve a satisfactory result. In such cases, the characteristics of the sub-catchments have been re-examined to try and rationalise such changes to the original intuitive reasoning.

c) The ease or difficulty of achieving acceptable fits to the observed data. This is an important consideration if a model is to be of practical value.

During the discussion of these three topics, comparisons are made between the temperate and semi-arid catchments. Comparisons between the lumped and semi-distributed versions of each model are also made, to establish whether the more complex semi-distributed approach is warranted.

6.1.1 OSE1 - Simple antecedent moisture model

Curve fitting capabilities

The curve fitting capability of a model refers to its ability to fit a range of disparate rainfall-runoff responses regardless of the values that the parameters have to assume to achieve this. For the North Danville catchments the curve fitting capability of OSE1, over the range of storms, appeared adequate (Appendix A: tables A1, A2, A5 A7; Figure 6.1). However with respect to the lumped model there were some situations where acceptable fits were not obtained. These are associated with storms having a high degree of spatial variability in the rainfall input. This observation does not apply to all spatially variable events and in some cases the smoothing effect of the catchment is such that even the lumped model simulates the result satisfactorily. This is particularily true for events on ND5 (table A2), which is the larger catchment. Generally the semi-distributed model produces better results when the space/time pattern of input is well defined. However for some storms there is little improvement between the results for the lumped and semi-distributed formats, even if a fair amount of rainfall input is provided. The information available for storm 22.07.64, consists of 4 rainfall profiles (gauges 1, 11, 16 and 22 - figure 5.14) plus storm totals for most of the other gauges in the catchment. The storm totals as well as intensities are extremely variable and one possible reason for the unsatisfactory results is the inadequate definition of the time distribution of rainfall over some sub-catchments. Even less information is available about the spatial variation of the rainfall of other events, although there is enough to demonstrate a high degree of spatial variation but not enough to define it. Where the rainfall is more uniformly distributed in space there is very little difference in the modelling capabilities of the lumped and semi-distributed versions of the model.

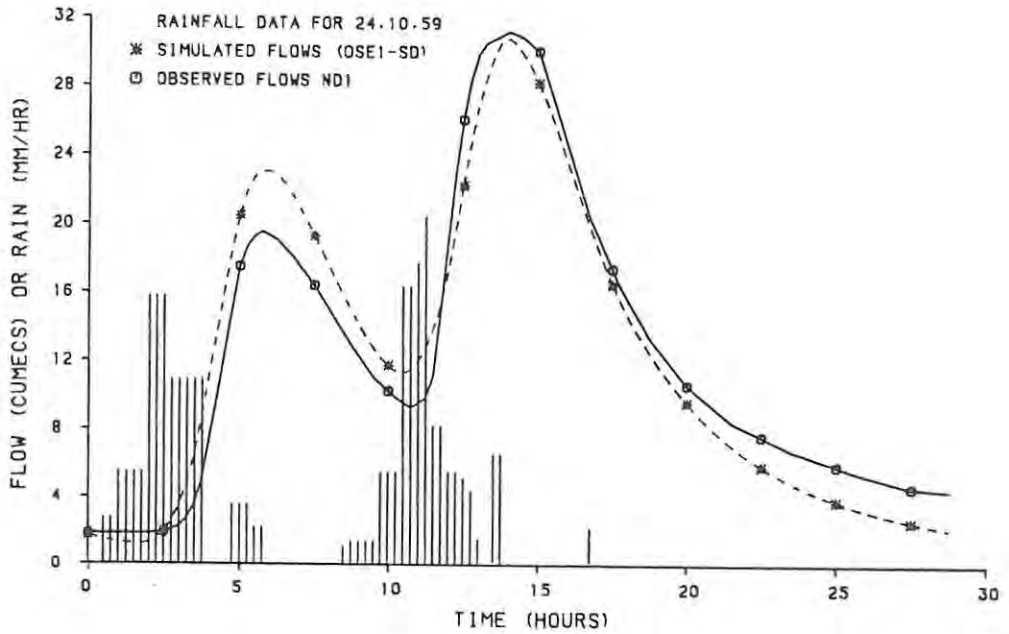


Figure 6.1 Adequate curve fitting capability - model OSE1 on ND1.

The curve fitting capability of OSE1 for the Ecca storms is less satisfactory (Appendix A: tables A3, A4, A9) and without the incorporation of the initial losses (IL) the fits would have been worse. Storms having a high degree of spatial variability in the rainfall input, are generally not well simulated, although the semi-distributed version can produce better results for spatially variable storms when the space/time pattern is well defined (figure 6.2). Simulation of the 'large' events is generally adequate, although neither version of the model can reproduce a large twin peaked event, suggesting the need for a variable runoff proportion. It was also found that simulations were generally better for the large catchment - Q9M20 (tables A3 and A4). The overall curve fitting capabilities of the lumped and semi-distributed formats are not significantly different (Appendix A: tables A4 and A9), however on an individual storm basis there are differences (figures 6.2). The model has distinctly poorer fitting capabilities on the 'small' events (convective storms - section 5.1).

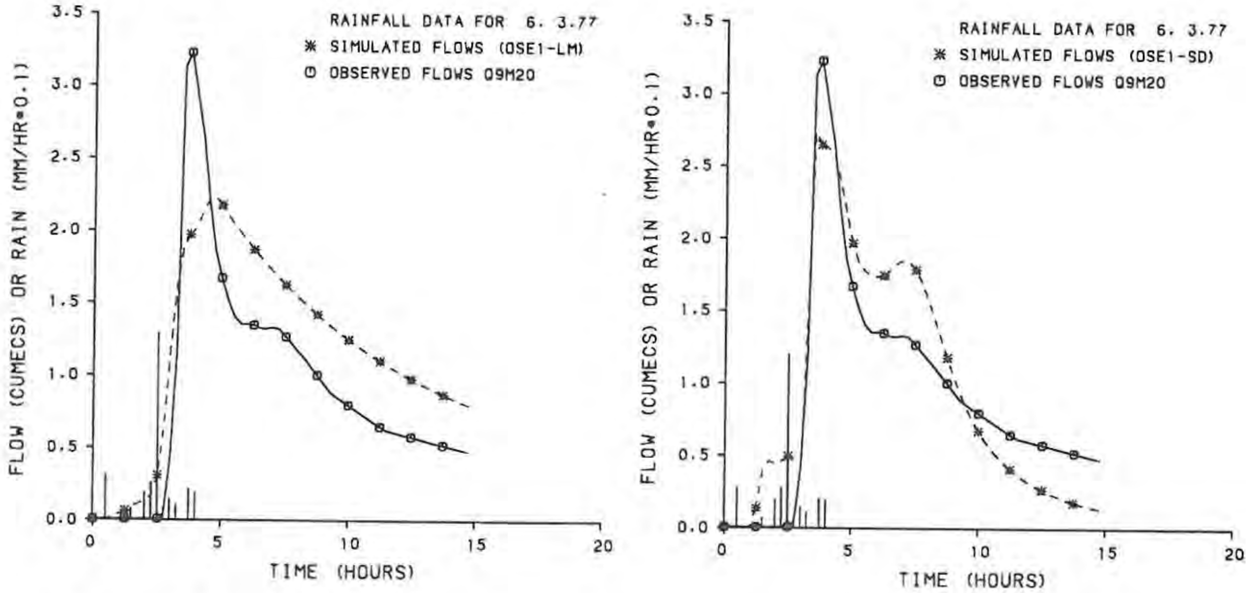


Figure 6.2 Better simulation of an event by the semi-distributed format of model OSE1 on Q9M20.

Parameter stability and acceptability

For the North Danville catchments it was possible to use constant non-linear routing and initial loss parameters. Basin delay was the only routing parameter which needed to be varied in both the lumped and semi-distributed versions of the model (tables A1, A2, A5, A6, A7, A8). Of the volume conversion parameters, SMAX was held constant but the shape of the S-curve had to be varied to get adequate fits. The APF parameter was varied according to the season in which the event occurred. The APF for winter (Oct-Mar) was set 0.10 higher than the APF for summer (Apr-Sept). It is noted that the summer season APF is automatically set 0.05 lower than the winter value by the model. This facility was included in the model to allow storms from different seasons to be calibrated together in a single model run, this is only possible if all the other parameters are stable. Generally this simple separation produced acceptable results, indicating that in summer there is higher evaporation and therefore a greater drying effect, while in winter evaporation is lower and the catchment remains wetter for longer periods given the same amount of antecedent rainfall.

The calibration results for the Ecca (tables A3, A4, A9) indicate how difficult it was to establish constant parameter values for the set of events. In particular the results for the 'small' events are extremely variable due possibly to the fact that most of these 'small' events can hardly be classed as floods. The four 'large' floods indicate less variation in parameters, particularily the semi-distributed model parameters (Appendix A; table A4). The problem with modelling the 'small' events is that only a limited area near the catchment outlet appears to be generating the runoff. Evidence for this feature is provided by the quick response of the catchment to the small events. The result is that the model needs very low A and K values to simulate the rapid response of the catchments (tables A3, A4 and A9).

Table 6.1 lists comparative parameter values for ND1, ND5 and Q9M20 for both versions of the model. Parameters for ND1 ($43km^2$) and ND5 ($112km^2$) are similar and as would be expected the channel delay on ND1 is generally less than ND5. The lumped results indicate that a greater degree of delay and attenuation occurs in the semi-arid Ecca catchment. The fact that initial losses (a kind of delay) is greater than those applied to ND1 and ND5 is additional evidence.

Table 6.1 Comparison between parameter values for OSE1 on ND1, ND5 and Q9M20.

Parameter	ND1		ND5		Q9M20*	
	lumped	semi-dist.	lumped	semi-dist.	lumped	semi-dist.
1. K	5.5	6.0	6.0	6.0	9.0-11.5	5.4-11.5
2. N	0.7	0.7	0.7	0.7	0.7	0.7
3. CDEL	-	0,0-1.25	-	0.0-2.25	-	0.75-5.25
4. KC	-	0.4-0.8	-	0.31-1.15	-	0.40-1.04
5. DEL	0.0-1.5	-	0.0-3.0	-	1.5	-
6. A	4.0	-	5.5	-	4.5-7.0	-
7. B	0.15	-	0.15	-	0.15	-
8. SMAX	150	150	150	150	200	200
9. DA	0.42-0.88	0.43-0.68	0.50-0.60	0.55-0.63	0.26-0.94	0.20-0.90
10. C	0.10-0.75	0.056-0.32	0.06-0.42	0.05-0.26	0.03-0.58	0.03-0.58
14. APF	0.80/0.90	0.80/0.90	0.80/0.90	0.85/0.90	0.85/0.95	0.85/0.95
15. IL	0.0	0.0	0.0	0.0	1.0-50.0	1.0-45.0

The catchments listed under semi-distributed represent the range over the sub-catchments.
* Parameters for 'large' events only.

SMAX values for the North Danville catchments and the Ecca are different as is the general shape of the S-curves. The North Danville S-curves imply greater runoff proportions at lower moisture values than Q9M20. This is logical in view of the fact that the main moisture storage in the Ecca is in the valley bottom alluvial soils and on some of the flatter hilltops. A greater proportion of the total storage must therefore be satisfied before relatively high runoff proportions can be achieved. The soil depth distribution in the North Danville catchments is more uniform suggesting that the valley bottom soils will become saturated more quickly and hence generate runoff at lower catchment moisture values. The soils are also more permeable therefore sub-surface flow plays a larger role and it is possible to get runoff before surface saturation occurs. There is a great deal of variation in the S-curve parameters which is not easily explicable in terms of physical catchment or storm characteristics. The APF parameter differs between catchments and is generally higher on the Ecca. The values suggest that the Ecca dries out more slowly for a given antecedent rainfall input than North Danville. The parameter has to represent the combined effects of evapotranspiration and drainage. The Ecca however experiences higher potential evaporation effects due to high temperatures. Higher unsaturated lateral permeabilities and more dense vegetation cover in the North Danville catchments may be accounting for the greater drying effect. As mentioned previously the component of the model controlled by this parameter has many weaknesses and this parameter is less stable than the others. However, the effect of changing this parameter is closely associated with changes in the S-curve parameters. These associations require further investigations to find out whether a stable set of S-curve parameters can be used together with more variable APF values. The initial losses parameter was included once modelling on North Danville had been completed and had been assumed to be 0. For the Ecca, initial losses (IL) improved the calibration results quite significantly, particularly for events with 'dry' antecedent conditions. The improvement occurs because even at low moisture status, the S-curve will generate runoff. Without the IL parameter, flow would occur in the period prior to actual catchment response. The IL parameter allows the catchment moisture requirement to be satisfied prior to producing runoff.

The method used to set initial values for the North Danville sub-catchment factors was largely based upon the ideas expressed in section 4.2.1. During calibration these were only modified if an improved fit could not be obtained by changing the global parameter values or if the characteristics of the generated flow from gauged sub-catchments did not approximately match the observed data. It was generally necessary to adjust the channel delays on both sets of catchments but few other adjustments were necessary.

For the North Danville catchments the sub-catchment CDEL factors were initially calculated from TC values (section 4.4) using the length from the outlet to the sub-catchment centre and the average slope over that length. It was then found necessary to reduce these values by approximately 0.75 to obtain CDEL values (tables A6 and A8) that produce acceptable fits. KC (channel routing) factor values were fixed by determining the relative channel distances from the sub-catchment node to the next downstream node.

A similar procedure was followed for determining the initial values of the sub-catchment factors for running the semi-distributed model on the Ecca catchments. There is little published information on the soils and geology of this area, therefore personal observations and experience of the area, by Dr Hughes was relied upon in determining sub-catchment values. The K factors (table A10) were determined largely through a consideration of both sub-catchment areas and slopes. Thus the relatively small (6% of total area) and steep sub-catchment 9 has the lowest K value, while the larger, more rounded or flatter sub-catchments have the highest values (figure 5.4). The CDEL and KC factors were determined as described for the North Danville catchments, but consideration of the observed flows at the three gauging stations within Q9M20 (figure 5.3) also aided the estimation of these values.

Sub-catchment factors for SMAX, DA, C, APF and K (in the case of the North Danville catchments), were found to be very difficult to fix. All these factors were set at constant values. This was due in part to modelling inexperience and at this stage no attempt to assign sub-catchment values to these parameters was made. This calibration aspect required further investigation once more catchments had been calibrated.

Ease of calibration

In some respects OSE1 was easier to calibrate on the temperate North Danville catchments than the semi-arid Ecca catchments. A great deal of effort was required to achieve the fits on the Ecca catchment storms. This was particularily true when attempting to obtain acceptable fits for both the 'large' and 'small' events using a similar parameter set. As the tables in appendix A illustrate, this was not achieved and different parameter sets were eventually used. The semi-arid catchment appears to have more complex response characteristics than the temperate catchment.

6.1.2 OSE3 - Augmented hydrograph model

Curve fitting capabilities

The curve fitting capabilities of the model on the North Danville catchments are considered to be adequate in both the lumped and semi-distributed formats, for the range of storms used (Appendix A, tables A11, A12, A15 and A17; figure 6.3). There are several situations, however, where acceptable fits are not possible, this is particularly true of the lumped results for the smaller catchment (ND1). As with OSE1 this feature is associated with the degree of spatial variability in the rainfall input. The semi-distributed format of the model did not produce significantly better results for the spatially variable events. For the storms of 1963 (ND1 and ND5) and 1969 (ND1) there was not sufficient information to define the distribution of rainfall over the sub-catchments, therefore adequate simulation was not possible. However, it is also possible that the flexibility of the semi-distributed format has not been adequately exploited. Figure 6.4 illustrates a situation where the semi-distributed fit is an improvement on the fit obtained using the lumped format.

The curve fitting capabilities of OSE3 on the Ecca catchments are generally less adequate and without the inclusion of initial losses would have been worse. To facilitate modelling, storm events on the Ecca were divided into 'large' and 'small' runoff events. The 'larger' events are reproduced adequately, especially those events with 'wet' antecedent moisture conditions. The 'small' storms were generally less satisfactorily reproduced as were events with a high degree of spatial variation of the rainfall input. For most events the curve fitting capabilities of the semi-distributed format were better than the lumped model (table A19). The sub-catchment factors determined for initial losses improved the response of the model (table A20). However, even in the semi-distributed format the model was not capable of reproducing multi-peaked events on the Ecca catchments (figures 6.5), suggesting that a constant ROP is inadequate in this semi-arid area.

Parameter stability and acceptability

Both the lumped and semi-distributed calibration results for OSE3 are given in tables A11 to A19 of Appendix A. For the temperate North Danville catchments it was possible to simulate observed flows acceptably with constant routing and initial losses parameters. Although the catchment delay of the time-area routing function was allowed to vary, this is not considered a serious problem and only effects the timing of the hydrographs to a limited extent. As expected, the volume reduction parameter (ROP), does vary between events (see section 3.2.1). The variation in the ROP parameter is similar for the same events on ND1 and ND5. At this stage it was difficult to evaluate the suitability of the ROP's achieved, although it is possible to establish intuitively a degree of acceptability. For example the 24.10.59 storm is a large event, the rainfall is fairly intense and the catchment is 'wet' prior to the event occurring, therefore a high ROP (0.438, table A15) is not unexpected. The storm of 30.07.60 is a long duration, low intensity rainfall event with 'dry' antecedent conditions, therefore a low ROP (0.09, table A15) is acceptable. The general stability of parameters on the North Danville catchments appears to suggest that catchment characteristics are not very variable, thus making it possible to model events with reasonable success even in the lumped format.

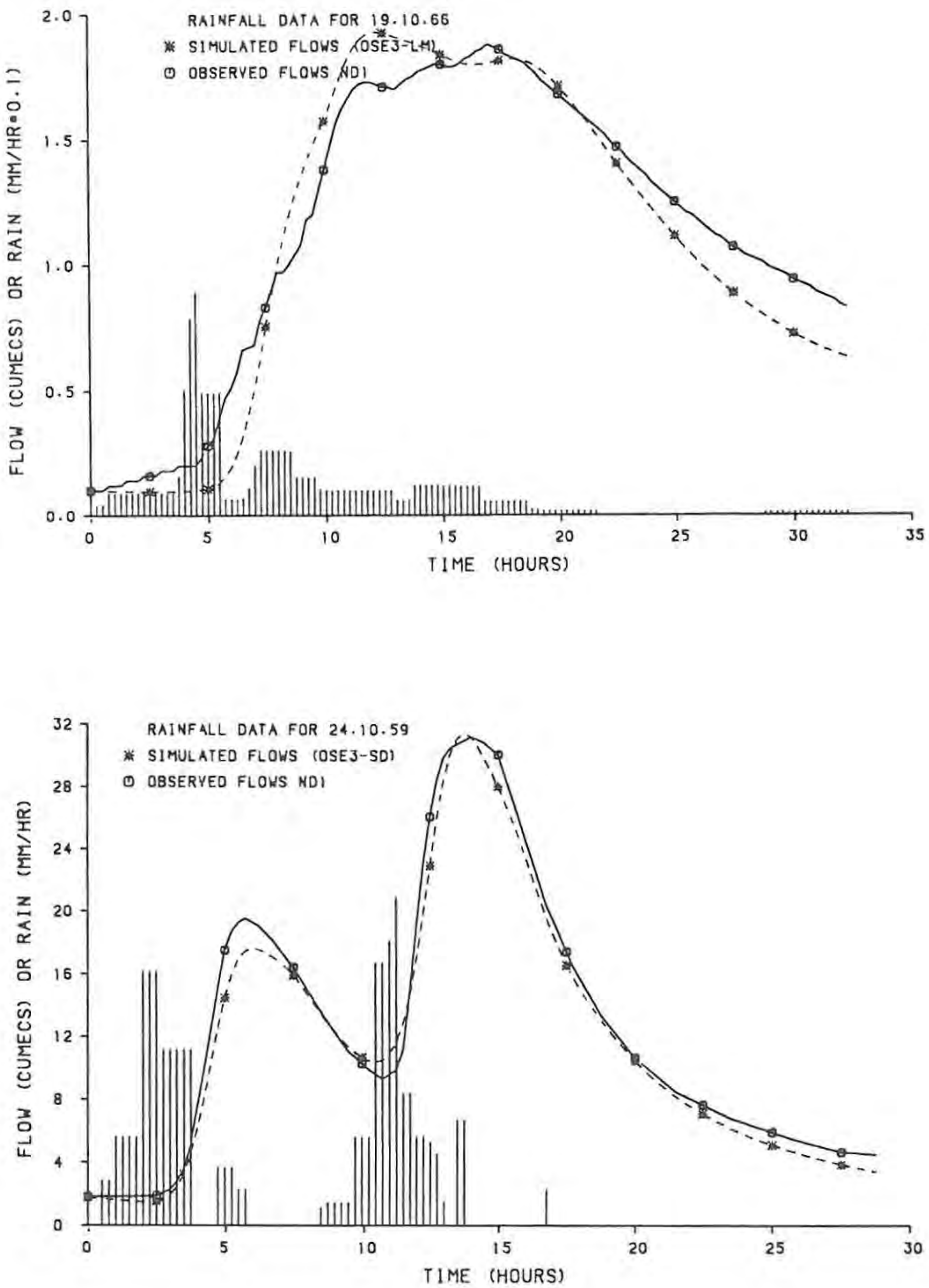


Figure 6.3 Adequate reproduction of events for both formats of OSE3.

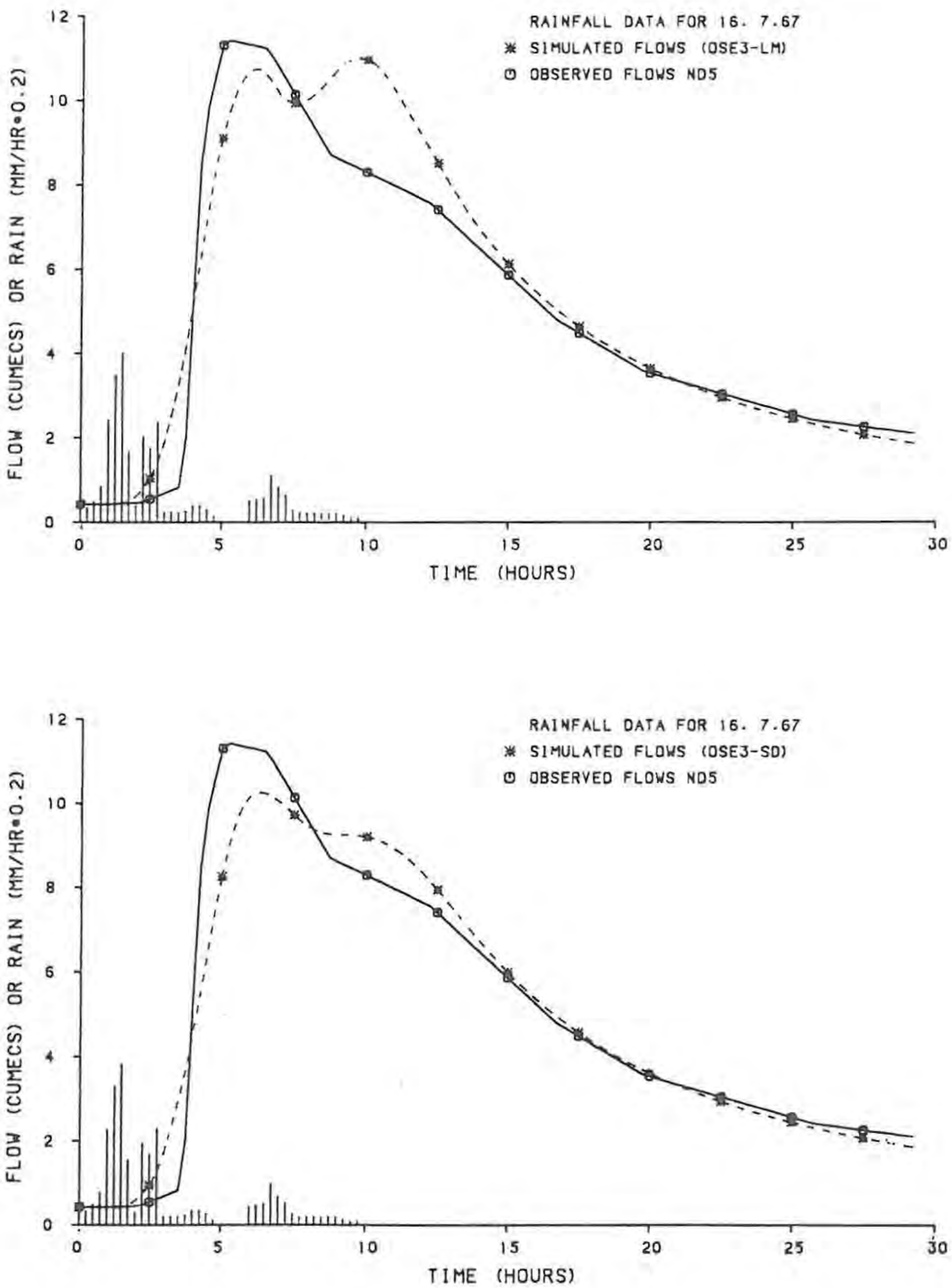


Figure 6.4 Improved fit for an event using semi-distributed version of OSE3.

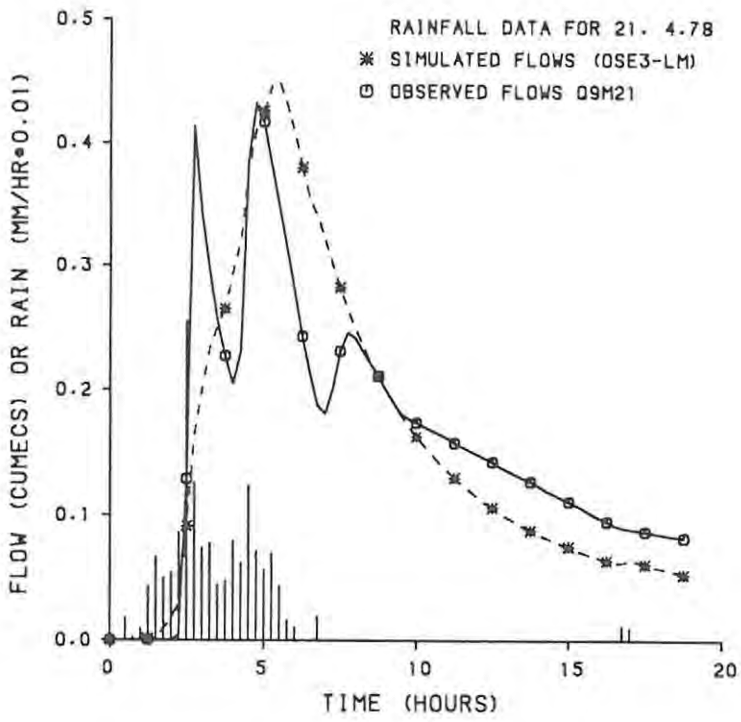


Figure 6.5 Inadequate simulation of a multi-peaked events - model OSE3.

For the semi-arid Ecca catchments, parameter stability appears to be dependent on the size of the event and the format of the model. There is little stability when the model is in lumped format (tables A13 and A14) and when the 'small' events are calibrated. In the semi-distributed version the channel routing parameters are constant (table A19) and the range of basin routing parameter (K) for the large storms is small. The poor results achieved for the 'small' events is possibly due to the fact that these events can hardly be classed as floods and that the 'large' events reflect the true flood conditions for the semi-arid Ecca. The general lack of stability of parameters in the lumped format suggests that in the semi-arid situation, catchment and storm characteristics are very variable. It is therefore extremely difficult to determine a single average value for a parameter that is suitable for all events.

Table 6.2 lists comparative values for ND1, ND5 and Q9M20 (the large events only), for both versions of model. As intuitively expected, ND1 (smaller catchment) has lower delays than ND5 in the semi-distributed format and a smaller time-area base (A) in the lumped version of the model. For ND5 and Q9M20 the table indicates that a greater degree of delay and attenuation occurs in the Ecca catchment. For the lumped version, basin routing K and A are generally higher for Q9M20. In the semi-distributed version of the model, K can be lower (less attenuation on some sub-catchments) for Q9M20, but initial losses (which can include channel losses) for the Ecca are higher than for ND5. The methods used to set initial values for the sub-catchment parameter factors are similar to those described in section 6.1.1 for OSE1.

Table 6.2 Comparison between parameter values for OSE3 on ND1, ND5 and Q9M20.

Parameter	ND1		ND5		Q9M20*	
	lumped	semi-dist.	lumped	semi-dist.	lumped	semi-dist.
1. CDEL	-	0.0-1.25	-	0.0-2.25	-	0.75-5.25
2. KC	-	0.4-0.8	-	0.13-0.85	-	0.43-1.10
3. ROP	0.09-0.43	0.09-0.44	0.10-0.37	0.10-0.38	0.19-0.54	0.31-0.58
4. N	0.5	0.5	0.5	0.5	0.5	0.5
5. DEL	0.0-1.75	-	0.0-1.75	-	0.0-1.5	-
6. A	4.0	-	5.0	-	4.5-8.0	-
7. B	0.15	-	0.15	-	0.15	-
8. K	15	15	15	15	15-24	9.7-25.2
9. IL	2.5	2.5	2.5	2.5	0-65	0-98

The values listed under semi-distributed represent the range over the sub-catchments.
* Only 'large' events considered.

Ease of calibration

It was generally easier to calibrate both forms of the Augmented hydrograph model on the North Danville catchments. This is due possibly to the greater degree of parameter stability obtained on the North Danville catchments. With respect to the North Danville catchments the semi-distributed version did not achieve significantly better results than the lumped model, whereas for the Ecca catchments the semi-distributed format is better able to reproduce storm hydrographs. Multi-peaked and spatially variable rainfall events were not well modelled on any of the catchments.

6.1.3 Model comparisons

The mean values for the fitting criterion are compared in table 6.3. Comparisons are made between the models as well as between the two groups of catchments. The table suggests that both models reproduce the observed hydrographs accurately, however both the models have a certain amount of parameter variability which at this stage has no apparent relationship with storm characteristics. This is particularily true when modelling the Ecca storms.

Table 6.3 Comparison of model fit statistics.

		Mean values			
		% Vol.	% Peak	C.Eff.	C.Det.
All catchments					
OSE1	lumped	5.5	7.1	0.868	0.891
	semi-dist.	6.3	7.8	0.889	0.901
OSE3	lumped	4.1	4.6	0.884	0.910
	semi-dist.	3.8	4.5	0.851	0.903
All models					
Ecca		8.5	9.1	0.754	0.832
North Danville		9.4	10.9	0.812	0,915

The tables in Appendix A present the differences between the lumped and semi-distributed modelling and the differences between temperate and semi-arid catchments. The patterns are similar regardless of the actual model type. Some storms are modelled more successfully with the lumped versions while others favour the semi-distributed approach. Both versions of the models have difficulty reproducing the 'small' storms on the Ecca catchments. This is believed to be due to the scale of operation of the hydrological processes during these storms, which is smaller than the distribution scale of the models. It is suggested that the streamflow during these events is generated in the lower parts of the catchment and only in areas close to river channels. The rapid and very small responses of the observed hydrographs support this view and suggests that surface runoff generated elsewhere in the catchment is reabsorbed into the soils or valley bottom alluvium. The incorporation of initial losses proved very useful with respect to modelling some of the smaller storms. However it was still necessary to reduce the time area base parameter (A) to achieve a faster response in the lumped models.

The values for the basin routing (K) parameter are lower for model OSE1 than for OSE3. This might be expected as gross rainfall is routed in OSE3 while only excess rainfall is routed in OSE1. The other routing parameters (KC, A, B and CDEL), have very similar values. Both models have difficulty reproducing multi-peaked events and only a model with a variable runoff proportion (model OSE2) (Hughes and Beater, 1987) could satisfactorily reproduce multi-peaked events. This appears to be one of the more serious shortcomings of both models, although both models can reproduce, if not the shape of these events, at least the volume and peak of such events fairly satisfactorily (e.g. storm 24.10.59 on ND1).

The main calibration problem was encountered with the volume reduction parameters of model OSE1. These difficulties were experienced due to the strong interaction between the five parameters that have an effect on the proportion of rainfall that contributes to runoff. These five are initial losses (IL), antecedent precipitation factor (APF) and the three parameters of the S-curve (DA, C and SMAX). The initial modelling attempts produced the realisation that a general calibration procedure needed to be established, whereby all the parameters, except one (possibly DA or C) would be kept constant for a particular catchment and this parameter along with the seasonally adjusted APF parameter would account for the variations in catchment response to rainfall events. Due to these calibration problems it was often felt that the best results was rarely achieved with model OSE1, whereas with model OSE3 it was generally possible to recognise the best result.

It is difficult to draw firm conclusions at this stage but it would appear that inadequate definition of the spatial variation in the rainfall input contributes to some of the poor modelling results, particularily on the North Danville catchments. This factor makes it more difficult to compare the relative success of the lumped and semi-distributed approaches. Further model calibration tests, in catchments with more complete data, are required to investigate this problem further. Storm events on the large catchments (Ecca, Q9M20 and North Danville, ND5) were generally modelled more successfully. Both models were easier to calibrate on the temperate North Danville catchments then the semi-arid Ecca catchments.

6.2 RESULTS OF THE MAIN MODEL CALIBRATION FOR INDIVIDUAL CATCHMENTS

Listings of the model parameters and the statistics of correspondence between simulated and observed values for individual catchments are given in Appendices B and C respectively. Various aspects of the calibration results for each model are discussed, followed by a section providing some answers to the questions raised in section 4.3.3.

6.2.1 Model OSE1

Problems associated with the initial calibration were referred to earlier in this chapter. The difficulties mainly involved calibrating the volume reduction parameters. That is, initial losses (IL), antecedent precipitation factor (APF) and the three parameters of the S-curve (SMAX, DA and C). After the initial calibration attempts, a general calibration procedure was established whereby all the parameters except C and APF were kept constant for a particular catchment (section 4.3.1).

Therefore variations in C and APF accounted for the different responses to rainfall events. This made calibration less complicated and did not appear to have an adverse effect on the overall results. Appendix C lists the results of the recalibration of the Ecca and North Danville catchments plus a further eight sets of catchments. Calibration of these catchments revealed that the initial losses parameters (IL) does not appear to be generally important and its inclusion was only necessary for the Ecca catchments which experience long duration, relatively low intensity storms occurring on very dry catchments. Under such conditions up to 30mm of the first part of a storm has been observed to generate no runoff at all. For those catchments with a highly seasonal regime, with frequent rainfall events in the previous 30 days, antecedent precipitation values are relatively high and the resulting initial moisture values are very sensitive to the APF parameter. The southern Cape and Ecca catchments have a non-seasonal and more irregular rainfall regime which often gives rise to low initial moisture values. Under these conditions, changes to APF or SMAX have relatively minor effects on the simulation, unless the amount of runoff is very small compared to the rainfall. The latter type of storm is represented in both the Ecca and Tombstone data sets and any small parameter change can affect the simulations dramatically.

The effects of the power parameters in the routing components of both the lumped (N and B) and semi-distributed (N) versions are difficult to separate from the effects of the relevant scale parameters, that is K and A in the lumped and K and KC in the semi-distributed model. Therefore the N (catchment routing power) and B (time area relation power) values were fixed at 0.7 and 0.1 respectively for all the catchments. In terms of the shapes of the simulated hydrographs, the most important parameters are A and K in the lumped model and K, together with variations in the sub-area channel delays (CDEL), in the semi-distributed model.

The lumped channel delay parameter (DEL) merely represents a time shift of the complete hydrograph. The simulations were found to be not very sensitive to changes in KC, assuming such changes were constrained to lie in the range suggested by the physical interpretation of this parameter (channel storage factor). The relative importance of the two semi-distributed routing parameters K and KC indicates that attenuation over or under the surface of the catchment (K) is more important than the attenuation in the channel segments (KC). This would seem to be an acceptable conclusion given the size of the sub-catchments involved. However, if the catchment is considered as a whole, the relative time of arrival at the outlet of flow derived from different parts of the catchment is also important. This is reflected in the lumped model by parameter A and in the semi-distributed model by the sub-area CDEL's, both important parameters.

All parameters were fixed for any one catchment except for C and APF. The number of different C or APF (which only varied seasonally) values were kept to a minimum. The graphical fitting procedure explained in section 4.3.1 and illustrated in figure 4.2 was used to identify groups of storms requiring the same C values. This calibration procedure generally produced acceptable results (tables 6.4 and 6.5) for many of the catchments, although it was noted that changes to the routing parameters would have improved the fits for some storms on certain catchments. The summary statistics given in tables 6.4 and 6.5 suggest that the Ecca results are amongst the best. However, this was one situation where the routing parameters were allowed to vary. This was because two groups of events are represented in the Ecca data set, namely very 'small' runoff events resulting from high intensity, short duration storms and 'large' runoff events from long duration, low intensity rainfall. The timing characteristics of these different types of events is such that a single set of routing parameters would produce, overall, very poor results.

The results of simulating storms from the Oxford catchments also need to be highlighted. During the calibration stage for these catchments, the usual procedure of only varying C and APF was adopted. However, it became evident that the runoff response characteristics were extremely variable and closer examination of the observed responses and the results revealed a strong seasonal grouping of events. Winter (November - April), spring (May - June) and summer (July - October) groupings were identified from the model results as being distinct from each other in terms of response characteristics. A close examination of the physical characteristics of the catchment revealed that there are major seasonal differences in vegetation cover characteristics that are consistent with the seasonal parameter value differences. The seasonality in vegetation is discussed in section 5.9 and figure 5.17 graphically illustrates the effect on runoff response. At this stage the need for seasonal changes to parameters was acknowledged but only applied when validating the parameter estimation relationships (chapter 7).

Generally it was found that relatively long duration, multi-peaked events occurring on catchments with low initial moisture status are not modelled successfully by OSE1. This is assumed to be the result of large temporal variations in the proportion of rainfall that becomes runoff as the catchment moisture status increases during the event. Multi-peaked events on wetter catchments are likely to have lower temporal variations in runoff proportions which can be more closely simulated by a model which has a constant runoff proportion for each storm, such as OSE1.

Table 6.4 Comparison of mean absolute percentage errors for both models for each area.

	OSE1				OSE3			
	LM		SD		LM		SD	
Area	Vol.	Pk.	Vol.	Pk.	Vol.	Pk.	Vol.	Pk.
Tombstone	12	16	13	24	7	19	4	24
	(14)	(17)	(11)	(21)	(6)	(19)	(5)	(22)
Ecca	12	10	13	9	5	6	6	6
	(12)	(13)	(15)	(11)	(6)	(6)	(7)	(5)
Bethlehem	16	20	13	18	11	18	7	11
	(15)	(23)	(8)	(14)	(7)	(17)	(5)	(6)
De Hoek	20	40	21	42	9	30	9	29
	(14)	(29)	(14)	(30)	(6)	(25)	(8)	(23)
Cedara	11	23	15	38	7	27	10	7
	(6)	(13)	(8)	(34)	(6)	(24)	(6)	(9)
Zululand	11	14	13	16	5	18	8	17
	(7)	(13)	(6)	(21)	(5)	(12)	(6)	(13)
Oxford	14	34	11	29	8	22	6	22
	(21)	(31)	(12)	(30)	(8)	(19)	(7)	(17)
Kaaimans	11	20	9	12	5	14	6	13
	(9)	(28)	(6)	(6)	(3)	(14)	(4)	(14)
Malgas	8	16	11	11	9	13	8	15
	(6)	(18)	(6)	(9)	(4)	(12)	(3)	(12)
N. Danville	8	10	10	14	4	4	3	5
	(7)	(8)	(17)	(18)	(2)	(2)	(3)	(4)

Figures in parenthesis are standard deviations
Eff. = Coefficient of efficiency * 100
Det. = Coefficient of determination * 100.

Table 6.5 Comparison of mean coefficients of efficiency and determination for both models for each area.

	OSE1				OSE3			
	LM		SD		LM		SD	
Area	Eff.	Det.	Eff.	Det.	Eff.	Det.	Eff.	Det.
Tombstone	59	63	30	55	76	82	39	59
	(32)	(33)	(65)	(30)	(17)	(13)	(57)	(29)
Ecca	76	84	52	72	83	87	70	81
	(24)	(12)	(46)	(20)	(16)	(10)	(42)	(26)
Bethlehem	34	55	59	66	55	67	54	68
	(59)	(35)	(36)	(31)	(46)	(36)	(55)	(31)
De Hoek	22	60	27	63	34	58	49	60
	(79)	(35)	(64)	(34)	(59)	(29)	(45)	(31)
Cedara	48	72	15	67	-2	41	53	72
	(54)	(23)	(121)	(24)	(62)	(18)	(34)	(17)
Zululand	65	78	67	80	71	77	74	79
	(26)	(20)	(27)	(14)	(21)	(19)	(18)	(18)
Oxford	58	77	66	79	70	78	76	81
	(60)	(18)	(30)	(18)	(28)	(21)	(24)	(17)
Kaaimans	11	51	41	63	45	58	64	75
	(89)	(28)	(59)	(25)	(39)	(25)	(30)	(20)
Malgas	37	60	38	63	51	67	46	66
	(56)	(34)	(66)	(33)	(55)	(29)	(58)	(30)
N. Danville	68	83	76	87	92	94	90	92
	(49)	(22)	(38)	(12)	(14)	(9)	(20)	(13)

Figures in parenthesis are standard deviations.
Eff. = Coefficient of efficiency * 100
Det. = Coefficient of determination * 100.

6.2.2 Model OSE3

Like model OSE1, OSE3 has a fixed runoff proportion (ROP) that has to be calibrated for each event on a catchment. ROP is calculated as the ratio of observed runoff depth to average catchment rainfall depth. Initially no variations in ROP between sub-areas in the semi-distributed model were allowed. An attempt was then made, on some of the catchments to include sub-area variations based upon perceived physical differences that were considered to effect runoff response. However, these changes did not improve the simulations and they made modelling more complicated. This lack of success might be attributable to poor correspondence between the perceived and real sub-catchment differences in the context of their effects on runoff response.

The routing components of OSE3 are much the same as OSE1 except for the order in which they occur within the model structure. This does not appear to affect their importance or the sensitivity of the simulation results to changes in their values. Consequently, the comments made about these parameters during the discussion of OSE1 are equally valid for this model. Very few differences in the calibration performance of the two models (tables 6.4 and 6.5) could be detected and the routing K values could be kept constant for each catchment for both models. Mandeville (1983) suggested that the change in the order of the components should lead to greater stability in the value of the routing parameter. Given that a single value of K is acceptable for each catchment in OSE1, an improvement is not possible. The OSE3 calibration of the Oxford catchments also revealed seasonal differences in runoff response. Multi-peaked events also presented a problem for this constant runoff proportion model. An assessment of the differences in the usefulness of the two models can only be made, after attempts are made to develop relationships for the estimation of parameters values. This topic will be discussed in chapter 7.

6.3 MODEL EVALUATION AND COMPARISON

Section 4.3.3 presented a number of questions, which when answered should provide the basis for a comparative evaluation of the two models about the calibration stage of the study. Each question is discussed separately.

6.3.1 Parameter sensitivity

Identifying the relationship between changes in the values of model parameters and the effects of these changes on certain aspects of the simulated flow is an important component in hydrological modelling. Knowledge concerning parameter sensitivity is useful to a model user as it gives some indication of how much the values of parameters should be altered to achieve a desired result. It also provides an indication of how far an estimate of a parameter can vary from its 'real' value before the simulation results deteriorate beyond acceptable limits. However, the usefulness of this information becomes limited without some information about what the 'real' value should be. This point is central to the problem of estimating parameter values for situations where complete calibration is not possible. It is also relevant to the debate about the comparative worth of physically based and conceptual models. Abbott *et al.* (1986) suggest that the closer the direct association that exists between parameters and physical characteristics, the easier it is to achieve an accurate estimate of the 'real' parameter value.

The calibrations revealed that some of the parameters of both models are only of minor importance assuming that there values are kept within certain limits. This may be because other parameters can achieve much the same effect on the simulations or because the parameters control a relatively unimportant component of the model (for example, initial losses parameter (IL) in both models). Perhaps more importantly, most of the effects of varying parameter values are highly dependent upon some characteristic of the storm or antecedent rainfall input. This makes it extremely difficult to make general statements about parameter sensitivities. Parameter N, in the storage routing equation used in both models, can be considered constant (OSE1 - 0.7 and OSE3 - 0.5) for the catchments modelled. Only limited improvements were obtained by varying this value. Varying K between catchments represents a more straightforward method of accounting for the land phase routing differences. The channel routing KC also has secondary importance compared to K and CDEL (channel delays) in the semi-distributed versions of OSE1 and OSE3.

The sensitivity of the simulations to changes in APF (model OSE1) depends upon the rainfall pattern 30 days prior to the event. Frequent occurrences of relatively high rainfalls, and particularily rainfall in the few days before the event, means that model output is very sensitive to APF values. This type of antecedent rainfall regime is associated with those catchments experiencing frequent heavy convective storms during the summer season. The effects of changes in the S-curve (OSE1) and ROP (OSE3) parameters are very difficult to generalise due to strong interaction between the parameters and the influence of storm characteristics.

6.3.2 Stability of parameters

It was never expected that the main volume conversion parameters would be able to remain constant for all storms on the same catchment. For OSE1 it was necessary only to vary one of the volume conversion parameters and the best results were generally obtained when the S-curve C parameter was varied. The APF parameter was varied seasonally and was relatively successful. Similar conclusions are applicable to model OSE3 for which storm dependent variations can generally be accounted for by differences in ROP. Therefore the question of parameter stability refers mainly to the routing parameters. The routing parameters were kept constant for all the catchments reasonably successfully, except for the Ecca and Oxford catchments (see section 6.2.1). For both models, two catchments emerged with the poorest results using the semi-distributed format, namely Tombstone and Malgas. The problems of high channel losses in the Tombstone catchments has already been mentioned (section 5.8). The Malgas catchment has no raingauges within its boundary. A study by Hughes and Wright (1988) indicates that the timing of the input may be reasonably accurately estimated from adjacent gauges but total storm amounts may be difficult to estimate. The semi-distributed results for the Kaaimans (adjacent to and physically similar to the Malgas) are somewhat better than for the Malgas. The input rainfall definition for the Kaaimans is superior, being based upon gauges that are better situated with respect to the catchment boundary. It therefore seems reasonable to suggest that at least part of the cause of the poor simulations on the Malgas is due to data inadequacies.

Tables 6.4 and 6.5 indicate that the mean absolute percentage errors in peak and volume estimation are frequently close to or below 20% and that the mean coefficients of efficiency are often greater than 0.5. On some catchments the coefficients of efficiency are very low (Cedara, for example) but the coefficients of determination are usually quite high, indicating a systematic error. It should be noted that these mean values are in most cases strongly affected by poor simulations for only one or two storms. Perfect definition of the spatial pattern of input rainfall is rarely possible and for a lot of storms the input data falls short of perfect. Consequently, it is usually not possible to attribute simulation errors to any particular cause. They may be related to input data inadequacies or the structure of the model with respect to the specific rainfall-runoff processes prevailing. They may also be associated with the fact that model calibration may have been stopped short of identifying the optimum parameter set. Given these potential sources of error, the results for most catchments are as good as might be expected.

6.3.3 Patterns of variability in the parameters of OSE1 and OSE3

This refers to the possibility of patterns of variation in the volume conversion parameters of OSE1 and OSE3 being related to storm characteristics. For OSE3 the relevant characteristics could include antecedent precipitation, whereas in OSE1 the antecedent moisture estimation is a component of the model.

During the calibration of OSE1 some relatively vague and imprecise associations were noted. On some catchments, intensity variations appeared to determine the C parameter value, while on others the C parameter value was influenced by the duration and amount of rainfall. These somewhat casual observations indicate that determining quantitative relationships would not be an easy task and that it would be difficult to generalise and fix the form of a relationship applicable to a range of different catchments. The observations suggested that different combinations of storm variables would be most appropriate to different catchments. Despite this, attempts were made to develop useful relationships after all calibrations had been completed. These attempts are discussed in the following chapter. For model OSE3 there is no component to account for antecedent catchment moisture status and therefore it was expected that the variations in ROP would have to account for this factor as well as the storm characteristics. This additional dimension made it difficult to assess the likelihood of success of trying to establish quantitative relationships.

6.3.4 Comparative model performance relative to specific storm or catchment types

The most noticeable difference was observed for complex, multi-peaked events. Both models were not capable of reproducing storm events characterised by short, high intensity bursts of rainfall superimposed upon longer duration, low intensity rain. This was particularily true for events with relatively low initial moisture status. Simulations were generally better for the multi-peaked events starting with wet antecedent conditions. Further general conclusions about the comparative results after the calibration stage are difficult to make.

6.3.5 Comparisons between the lumped and semi-distributed model versions

Tables 6.4 and 6.5 indicate that the lumped models do not generally perform less satisfactorily than the semi-distributed versions. In fact in some cases the lumped results appear to be better (for example the Tombstone catchments). There are many examples of individual events where the rainfall is spatially variable and the semi-distributed results for both models show improved simulations over the lumped. One of the possible reasons why the differences are not clearer could be related to the variety of storm types represented by the computer data set. Storm type in this context refers to not only the degree of spatial variation but also the extent to which the spatial variation is satisfactorily defined by the available data. The events were therefore divided up into three groups. A-type events are those where the available data demonstrates that the degree of spatial variation in total rainfall and intensity is small. B-type events are defined as having a relatively high degree of spatial variability due to either the small size of the storm area, or spatially variable orographic effects (the Southern Cape, for example). To be classified as a B-type event there must also be a reasonable amount of available data with which to define the variability. Inevitably, the greater the degree of variability, the more data are required to define it. However, few of the spatially variable events are very well defined by a dense gauge network. C-type events are those where the available data indicate variability but are not considered sufficient to define it. An example of a C-type situation would be where only one gauge exists within the catchment boundary and or another gauge, outside the catchment, which records dissimilar rainfall characteristics. The table of goodness of fit statistics for all individual events, for both models, given in appendix C also includes a column specifying the storm type. Clearly the rather loose definitions used for the different storm types will result in fairly ill-defined boundaries between the groups. However it is felt that most of the storms classified as belonging to one of the groups are different enough from those storms in the other groups. Tables 6.6 and 6.7 list the means of goodness of fit statistics for the simulation results grouped under storm and model type headings. Figure 6.9, consisting of 4 pages of computer plots, illustrates the same results using histograms of the distributions of the goodness of fit statistics for the storms falling into the three categories. Figure 6.9 indicates that due to the skewed nature of the distributions the mean values given in tables 6.6 and 6.7, are not always a satisfactory index for comparison.

Table 6.6 Comparison of mean absolute percentage errors for different models for both storm types.

	Storm Type					
	A		B		C	
Model	Volume	Peak	Volume	Peak	Volume	Peak
OSE1	14	25	13	20	10	20
Lumped	(19)	(24)	(11)	(18)	(11)	(29)
OSE1	13	25	16	26	14	24
Semi-dist.	(13)	(26)	(15)	(26)	(16)	(27)
OSE3	7	19	8	19	6	14
Lumped	(6)	(19)	(8)	(17)	(5)	(15)
OSE3	7	17	6	22	5	15
Semi-dist.	(6)	(15)	(7)	(21)	(5)	(15)

Table 6.7 Comparison of mean coefficients of efficiency and determination for both models for different storm types.

	Storm Type					
	A		B		C	
Model	Eff.	Det.	Eff.	Det.	Eff.	Det.
OSE1	59	80	45	65	54	66
Lumped	(59)	(18)	(65)	(30)	(41)	(29)
OSE1	58	80	48	68	39	65
Semi-dist.	(55)	(19)	(49)	(26)	(60)	(29)
OSE3	68	77	61	72	68	77
Lumped	(37)	(23)	(38)	(25)	(37)	(21)
OSE3	73	81	64	72	68	77
Semi-dist.	(29)	(19)	(32)	(24)	(53)	(28)

Figures in parenthesis are standard deviations.

Eff. = Coefficient of efficiency * 100

Det. = Coefficient of determination * 100.

There is very little difference between the lumped and semi-distributed versions of either model for the A events. This is also true of B and C events, which for the B events is surprising as the semi-distributed models were expected to produce better results for these spatially variable events. It is not surprising that both models do not show large differences in results between storm groups because the main volume conversion parameter is calibrated for each event. It may be concluded therefore that the variation in the values of these parameters is influenced by the spatial patterns of the rainfall as well as other storm characteristics.

The fact that the semi-distributed versions do not overall, produce demonstrably better simulations than the lumped models, even for the B-type events, is due to a number of possible reasons.

a) Many of the B-type storms are less than adequately defined by the available data. This is the group where the semi-distributed versions would be expected to show the greatest improvements over the lumped. The fact that they generally do not, suggests that input data errors might be dominating any further factors.

b) The channel routing function of the semi-distributed versions of the models is inferior to the time-area in the lumped versions. This is unlikely to be a major reason as the dominant parameter in the channel routing component is the channel delay and the distribution of these delays over the sub-area performs very much the same function as the time-area diagram in the lumped models.

c) The larger dimension of the calibration problem inherent in the semi-distributed models makes it more difficult to determine whether the final result is close to the optimum, i.e. the best result.

d) Neither version of the models are completely satisfactory conceptualisations of the processes of runoff generation and are therefore likely to produce some bad results. The models have demonstrated that they are capable of simulating a wide range of individual events successfully. The fact that some storms are not well simulated illustrates that there are inadequacies in their structure with respect to their application to certain situations. Such inadequacies are inevitable in these relatively simple models.

The above discussion indicates that a) and c) are most likely to be responsible for the similarity in the overall calibration results between the lumped and semi-distributed versions.

During the calibration of a catchment the semi-distributed models were calibrated and then initial estimates of some of the lumped parameters were obtained from sub-area weighted averages of the semi-distributed parameter values. The lumped routing parameters A and DEL were inferred from the distribution of channel delays used for the semi-distributed versions. In general this procedure was satisfactory and little adjustment of the parameter values was necessary to obtain overall results similar to the semi-distributed version. Further adjustments did not generally improve the overall results for the group of events used on each catchment. As mentioned previously, there were several events with highly spatially variable rainfall input that the lumped versions were unable to model satisfactorily.

The calibration results have been able to provide some of the answers to the questions posed in section 4.3.3, although not all of them have been answered unequivocally. This uncertainty is due to a number of different factors. This includes uncertainty in defining parameter sensitivity and is related to variations between catchments and storm types such that general statements on sensitivity are difficult to make. The capabilities of both models need to be evaluated further so that comparison about their performance can be made. The uncertainties about the comparative performance of the lumped and semi-distributed model versions appear to be at least partly a result of uncertainties in the accuracy of the input rainfall data. The impossibility of satisfactorily defining spatially distributed rainfall input for many of the storm events does present a serious limitation to a comparison of some of the model results. This is however not uncommon when attempting to assess modelling approaches using real data.

Figure 6.6 Distributions of goodness of fit statistics for the lumped and semi-distributed versions of models OSE1 and OSE3, grouped by storm type (A, B and C).

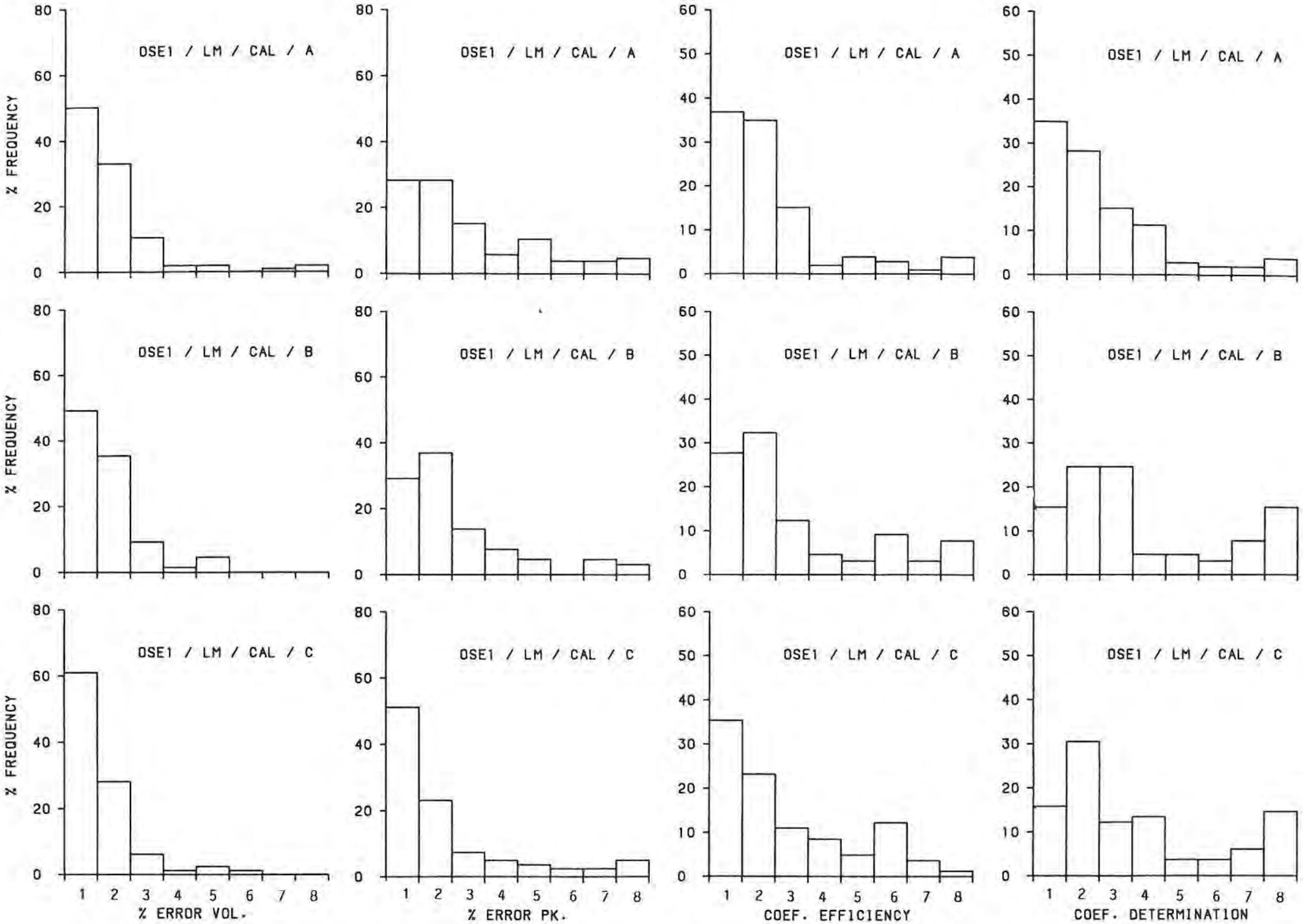
Key to following 4 pages of computer plots.

Each histogram is labelled with a four part code

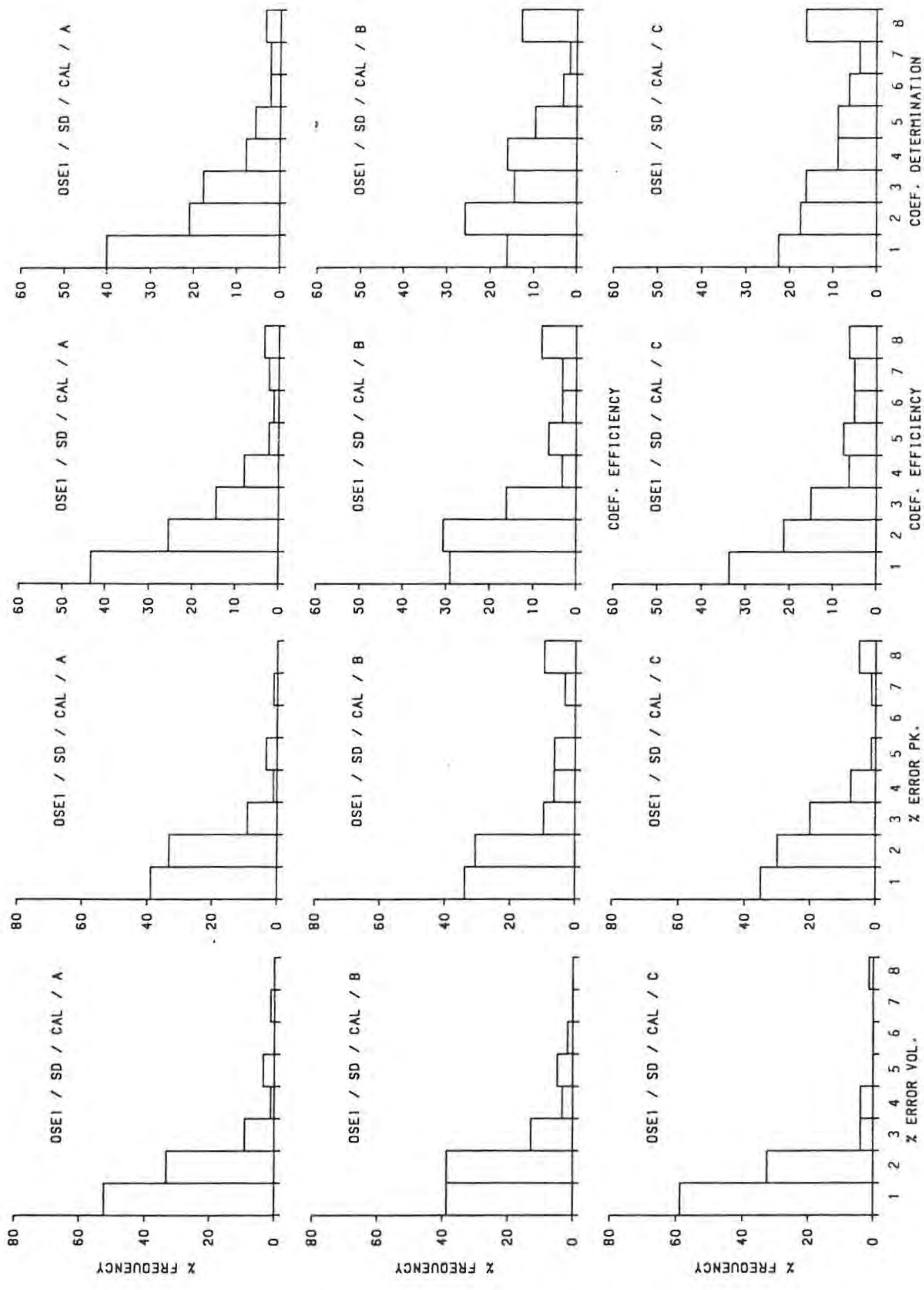
Model name/ Lumped or semi-dist./ Calibration or validation/ Storm type.

The eight histogram categories are as follows.

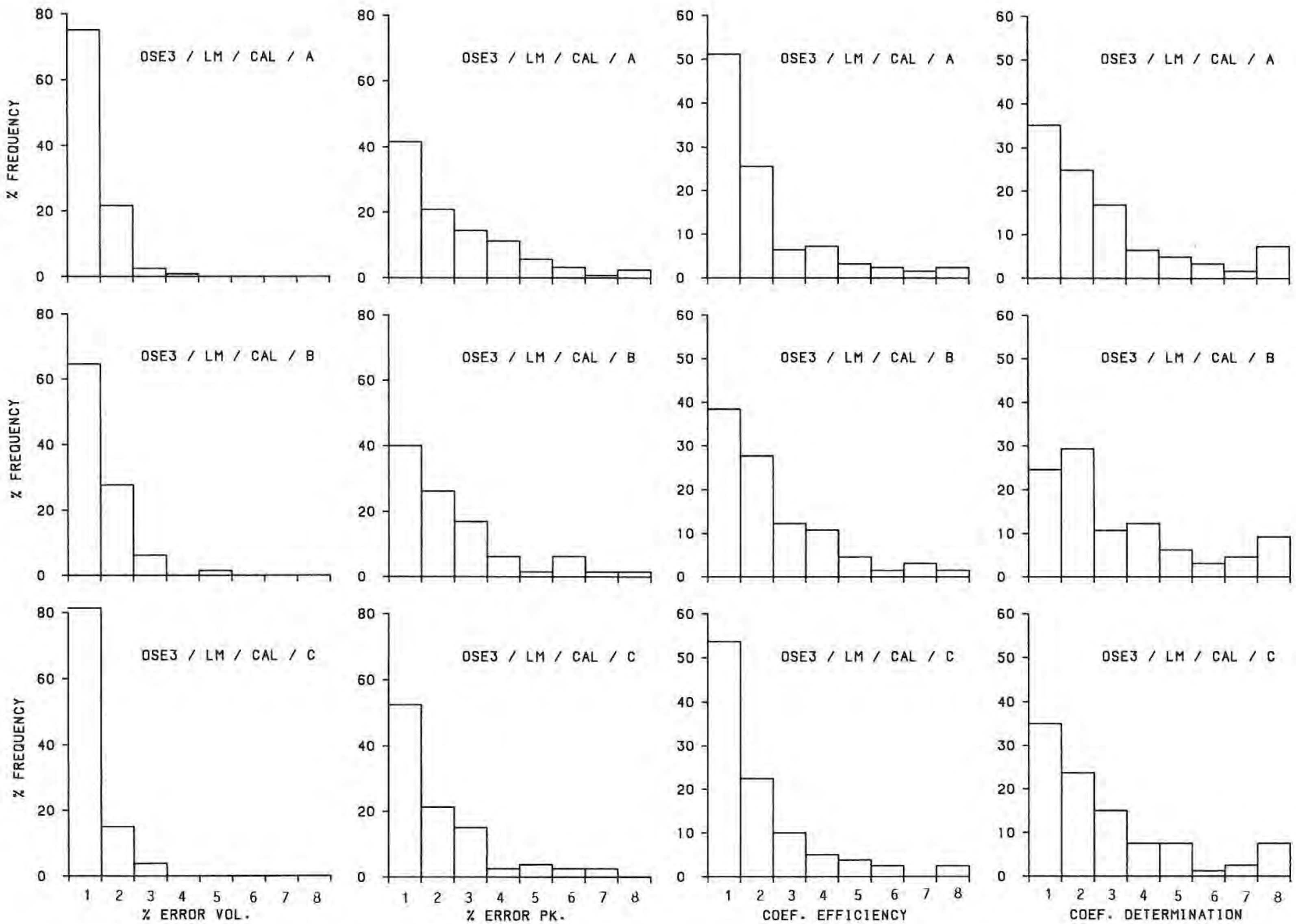
HISTOGRAM	GOODNESS OF FIT STATISTIC		
CATEGORY	ABSOLUTE % ERRORS IN	COEFFICIENTS OF	
	VOLUME AND PEAK	EFFICIENCY	DETERMINATION
1	0 to 10	1.0 to 0.8	1.0 to 0.9
2	10 to 20	0.8 to 0.6	0.9 to 0.8
3	20 to 30	0.6 to 0.4	0.8 to 0.7
4	30 to 40	0.4 to 0.2	0.7 to 0.6
5	40 to 50	0.2 to 0.0	0.6 to 0.5
6	50 to 60	0.0 to -0.2	0.5 to 0.4
7	60 to 70	-0.2 to -0.4	0.4 to 0.3
8	>70	<-0.4	<0.3



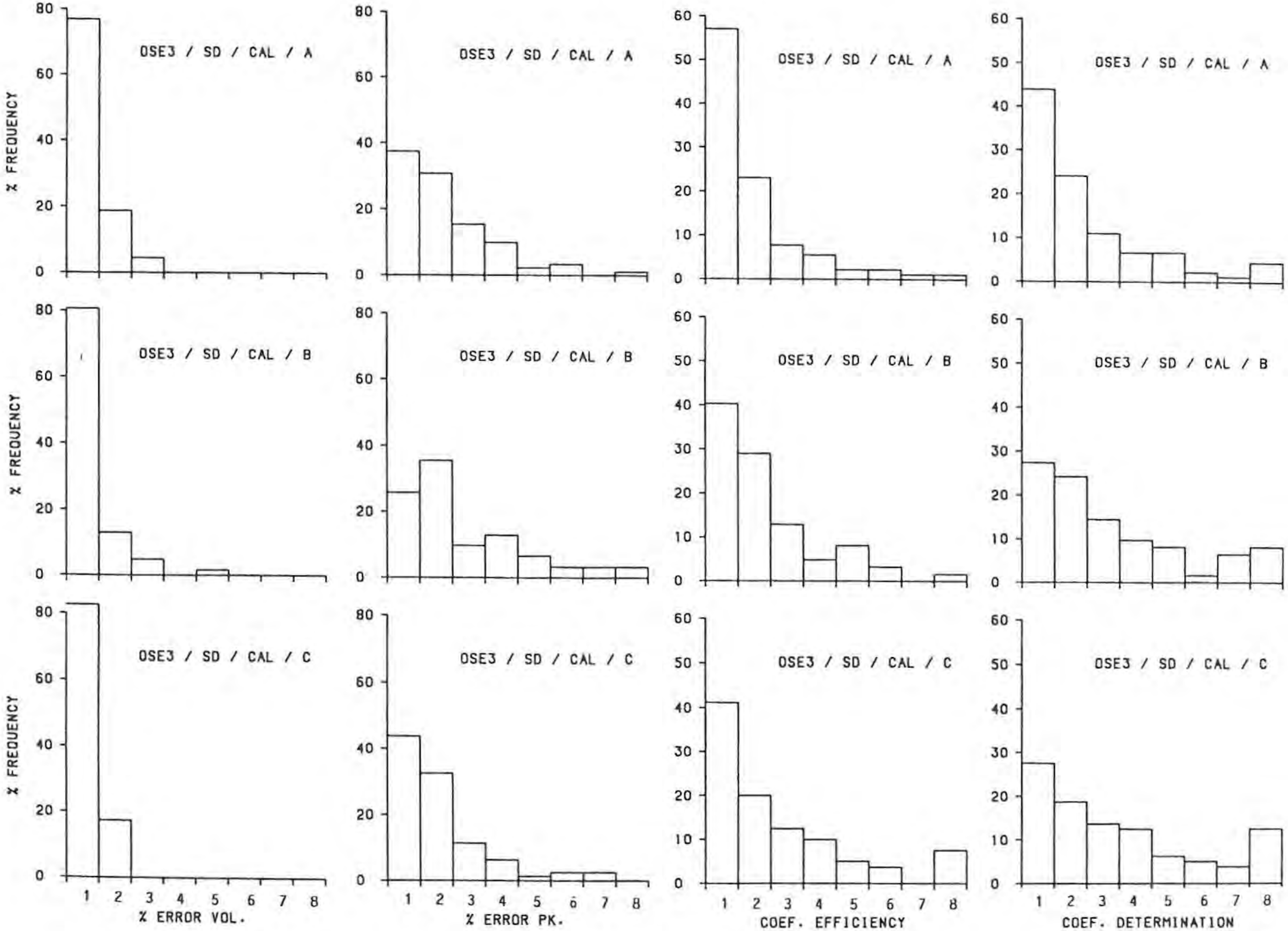
OSE1 Lumped calibration results.



OSE1 Semi-distributed calibration results.



OSE3 Lumped calibration results.



OSE3 Semi-distributed calibration results.

CHAPTER 7

RELATIONSHIPS BETWEEN PARAMETER VALUES AND CATCHMENT OR STORM CHARACTERISTICS

The discussion that follows summarises the results of attempts to derive relationships between the calibrated model parameters on individual catchments and physical properties of the catchments. This is followed by a discussion of the final stages of the model testing which involved assessing the degree of success that is likely to be obtained if the models were to be applied to situations where calibration is not possible.

7.1 THE DEVELOPMENT OF RELATIONSHIPS

The background discussion to this part of the study is covered in section 4.4 and includes the way in which the physical catchment characteristics were quantified. This part of the study is confined to using the calibration results of the semi-distributed versions of both the models. Estimated values of the physical characteristic variables of the sub-catchments of each catchment are given in appendix D while the equivalent parameter values are given in appendix B (i.e. the validation parameters). The values of parameters that could not be fixed for all storms on the same sub-catchments and the derivation of relationships between the storm dependent parameter weightings (that is C - OSE1; ROP - OSE3) and the storm characteristics (appendix E) are discussed later in this section.

Early in this investigation it was decided that developing relationships by a multiple regression approach whereby variables are included or excluded on the basis of some statistical criterion would not produce the best results. This is partly due to the type of equations that would be produced by such a technique, partly by the time taken to explore a wide variety of possible variable transformations (involving both single and combined variables) and partly by the problem of outliers obscuring otherwise strong general trends in the relationships. The latter prompted the use of a technique dominated by the visual assessment of graphical plots backed up by the calculation of the square of the least squares regression coefficient (R^2 = coefficient of determination) for different sub-sets of the data. A micro-computer program was developed in which it was possible to interactively set the form of the equation, plot the resulting relationship on the screen and optionally calculate the R^2 value and the parameters of the equation. Once the form of the equation is set, different sub-sets of the data can be viewed separately. Similarly, the program allows the form of the equation to be changed easily and rapidly and the new results plotted. The format of the equations allowed in the program is:

$$Y = A * X + B$$

where Y = transformed or untransformed model parameter

X = single physical variable or combination of variables with or without transformations.

B = constant.

Once the form of X and Y are determined, the equation becomes a simple linear regression equation for which the calculation of R^2 and the parameters A and B is possible. The advantage is that individual variables used to create the X values can be given different transformations or weights and can be combined in many different ways. A further advantage is that if the graphical plot indicates a non-linear trend then additional transformations of either X or Y can be imposed. The main advantage of this technique is that a large number of possible variable combinations can be assessed rapidly with a minimum of effort in terms of data file editing. This is an important advantage given the very large number of possible combinations of variables and transformations that could produce useful relationships. In practice, the number of combinations tested were limited by including only those variables that were perceived to be conceptually associated with the parameters. The results are discussed for each model and illustrated using graphical plots and summary tables.

7.1.1 Parameters of model OSE1

Figures 7.1 to 7.3 graphically illustrate the relationships for 8 of the semi-distributed parameters of OSE1 while table 7.1 lists the formats of the transformation variables and a few summary comments on the nature of the relationships.

Parameter CDEL

Initially this parameter was plotted against the single variable TC (time of concentration). A set of approximately straight line relationships for different areas resulted, but with no single trend present. An attempt was made to correct TC to account for the different conditions present in the data. One such attempt (TC * VEG/ ENERGY) represented a form of aridity correction and is shown in figure 7.1. While the number of trends is reduced, there is still no general relationship that could be considered applicable to all areas. A consideration of the channel conditions prevailing in the various catchments suggested the later addition of a further physical variable to account for channel roughness. In this context, roughness includes all those factors which prohibit the rapid movement of a body of water through a channel reach. It can therefore include the effects of farm dams, conservation structures, in-channel and riparian vegetation as well as the more conventional channel roughness factors such as the short distance variations in width and depth and the degree of channel meandering. Similar to many other physical variables, values of channel roughness have been assigned to each catchment on an ordinal scale of measurement between 1 and 10. The Tombstone catchments, which have well defined channels and not much restrictive vegetation have been assigned a value of 2 (Appendix D). At the other end of the scale, the Ecca channels are less well defined with great variations in width and depth over short lengths and even at moderate flow levels are restricted by in-channel bushes and trees, were given a value of 8. Catchments like Bethlehem and De Hoek have been assigned relatively high values due to the incidence of conservation structures, farm dams and shallow natural ponds or vleis. The values of ROUGH for all the catchments are given in appendix D and it should be noted that no attempt was made to adjust this variable for sub-catchments due to a lack of available detailed information on channel characteristics. The relationship between CDEL and TC*ROUGH is illustrated in Figure 7.1 and the coefficient of determination is 0,92.

Parameter KC

This parameter represents the degree of attenuation in the channel reach between sub-catchment nodes or centres. It is logical that KC should be related to the length of that channel reach (CDIST) as well as the dimensions of the channel. A surrogate measure of channel dimension has been used and that is the channel order (Shreve order - variable ORD1). The combination of variables giving the best overall trend for all the data is CDIST + LOG(ORD1) and is illustrated in figure 7.1. Some of the scatter in the relationship may be related to some of the effects referred to in the previous section that will have an influence on the attenuation as well as the speed of movement of a flood wave. The model results are relatively insensitive to adjustments in KC within the range of values used and therefore the degree of scatter present in the relationship may not be seriously restrictive with respect to its use as a prediction tool.

Table 7.1 Derived equations relating model OSE1 parameters with catchment and storm characteristics.

Model Parameter	Format of the transformation variable and comments on the initial relationships.
CDEL	TC - Good relationship for individual areas but no generally applicable relationship.
CDEL	TC * VEG/ENERGY - Reduces the number of trends but still no generally applicable relationship.
CDEL	TC * ROUGH - Very good relationship with an R^2 of 0.92.
KC	CDIST + Log (ORD1) - Moderate degree of scatter but all catchments conform to a general trend.
K	VEG^2 * INFIL/(ENERGY * SLOPE) - High degree of scatter. Oxford and Cedara have low values lying off the general trend.
SMAX	DEPTH * WHCAP - Relatively small amount of scatter. Good relationship.
DA	Log (SLOPE * PERMC * SL/V) - A general trend is present but the scatter is very great.
SCA*1	Log ((SLOPE * PERMC * SL/V)/(INFIL * VEG)) - A general trend is present but with a moderately high degree of scatter. Values plotted are based on average C values for all storms on the catchment.
APF	ENERGY * PERMC - High degree of scatter caused partly by variations in sub-catchment parameters but little or no variations in sub-catchment physical variable values.
C (Storm	Log (TOTR * MAXI/DUR) - Applicable to Tombstone catchments.
Weights)	Log (TOTR * MAXI/DUR) - Applicable to Ecca, De Hoek, Zululand, Oxford, southern Cape and North Danville catchments. - No relationship possible for Bethlehem & Cedara.

SCA*1 = S-curve area approximation = (1 + DA - C)/2
TOTR = Total storm rainfall (mm)
MAXI = Maximum intensity over model time interval (mm hr^{-1})
DUR = Total rainfall duration (hr)

Parameter K

This parameter controls the degree of attenuation in the land phase of the flow routing component. The importance of different physical variables depends largely upon the dominant runoff generation mechanism prevailing in each catchment. In some catchments surface runoff processes are assumed to dominate and in others sub-surface processes. To try and account for these processes in one general equation is difficult. The equation given in table 7.1 and the resulting plot figure 7.1) is the attempt that gave the best overall trend. The inclusion of SLOPE is self explanatory, while vegetation cover is also likely to be important if surface runoff (in any form) prevails. Low infiltration rates, exacerbated by sparse vegetation and the possibility of surface crusting (Berndtsson and Larson, 1987) could be indicative of surface runoff and low attenuation. The inclusion of the ENERGY variable was found to be useful and possibly reflects the occurrence of high intensity rainfalls promoting greater proportions of surface runoff and decreasing attenuation. The division by PERMC is possibly a reflection of lower attenuation for sub-surface flow environments with high soil permeability characteristics. There is a great deal of scatter in the relationship and in particular the Oxford and Cedara values appear to be anomalous.

Parameter SMAX

The simplest variable combination designed to account for variations in the maximum soil moisture capacity parameter is DEPTH * WHCAP. Figure 7.2 illustrates that further variables or transformations appear to be unnecessary as there is a strong relationship. Some of the vertical line trends can be ascribed to the fact that the values of these two physical variables were only approximately estimated and therefore there is little variation in sub-catchment values.

Parameter DA

The derivation of relationships for the two S-curve parameters DA and C proved to be more complicated. This is partly related to the difficulty of defining the association of these parameters with physical characteristics. Higher values of DA, for a given value of C represents a more rapid rate of increase in the conceptual source area at low relative moisture state. Variables which effect the spatial location of areas of surface saturation might be expected to be important. However, it is not that easy to identify which of the variables described in section 4.4 should be involved. The variable SL/V was specifically evaluated for this purpose, while SLOPE and PERMC of the equation reflects the conditions that catchments with higher slopes and poor drainage (LOW PERMC) will have more rapidly expanding source areas. There is a high degree of scatter in the relationship (figure 7.2), due partly to the little variation allowed in the values of this parameter for different sub-catchments on the same catchment during calibration stage.

S-curve area approximation (SCA)

No acceptable relationship could be derived for parameter C and therefore a new variable was created which represents a single approximation of the area under the S-curve. The variable SCA (S-curve area approximation) is defined by the areas of two triangles (co-ordinates 0,0: C,DA and C,DA: 1,DA: 1,1) and one rectangle (co-ordinates C,0: 1,0: 1,DA: C,DA) lying below the S-curve. The areas of these three components are;

lower triangle : (C * DA)/2
upper triangle : (1 - C) * (1 - DA)/2
rectangle : (1 - 3) * DA

Combining these areas gives the equation for SCA as;

SCA = (1 + DA) - C)/2.

If DA and SCA can be estimated then a value for C can also be obtained. These values are plotted and are average values for each sub-catchment in figure 7.2 and the format of the selected equation is given in table 7.1. The relationship between the individual event weighting factors and storm characteristics will be presented and discussed in a following section.

APF parameter

Within the model, the nominal APF value is reduced by 0.05 for summer (October to March in the southern hemisphere) events. The values used to derive a relationship for this parameter reflects the dominant flood event season for each catchment. For example, all the Tombstone and Bethlehem storms are summer events while the majority of the large events in the southern Cape are in the winter period. The two variables referred to in table 7.1 and figure 7.2 were chosen to represent an evapotranspiration component and a drainage component. The general trend of decreasing APF values with increases in the value of the combined variable is marred by the Cedara and Tombstone results. The Tombstone simulations are primarily affected by rainfall intensity therefore the antecedent moisture status, reflected by APF, is likely to have a relatively minor effect.

C parameter versus storm characteristics

Some of the relationships between the individual event weighting factors of parameter C and storm characteristics are illustrated in figure 7.3. Table 7.1 lists the equations relevant to the different catchment areas. The most noticeable characteristic of figure 7.3 is the high degree of scatter present in all the relationships. It is in fact difficult to recognise trends in the plots for all the separate catchments. The solid lines drawn on the plots are least squares best fit lines and no lines have been drawn for Bethlehem and Cedara because the calculated best fits are positive. This implies increasing C (therefore decreasing runoff proportion) with increasing total rainfall and duration which makes no hydrological sense. Some of the other relationships are hardly an improvement and are unlikely to be of great value from the point of view of predicting C values for other storms. The use of different storm indices did not produce better results. The Tombstone catchments were the only ones for which the inclusion of the maximum intensity variable reduced the degree of scatter. The figures indicate that the majority of the relationships, apart from being very weak are also unique to the individual catchments. It is therefore difficult to imagine how such results can be extrapolated to ungauged catchments with any success. This point is discussed in section 7.2.

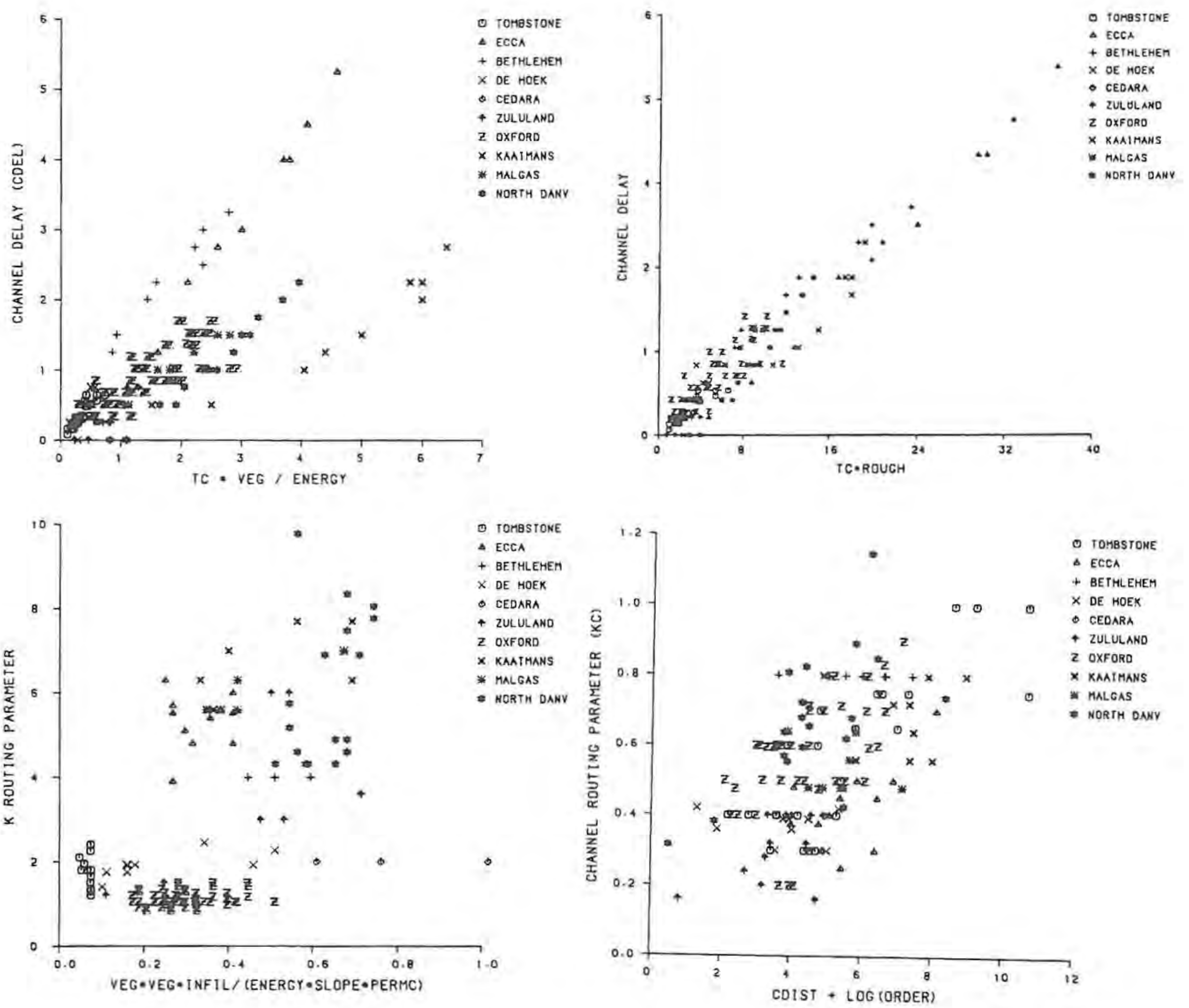


Figure 7.1 Plots of parameter - catchment variable relationships for CDEL, KC and K parameters of OSE1.

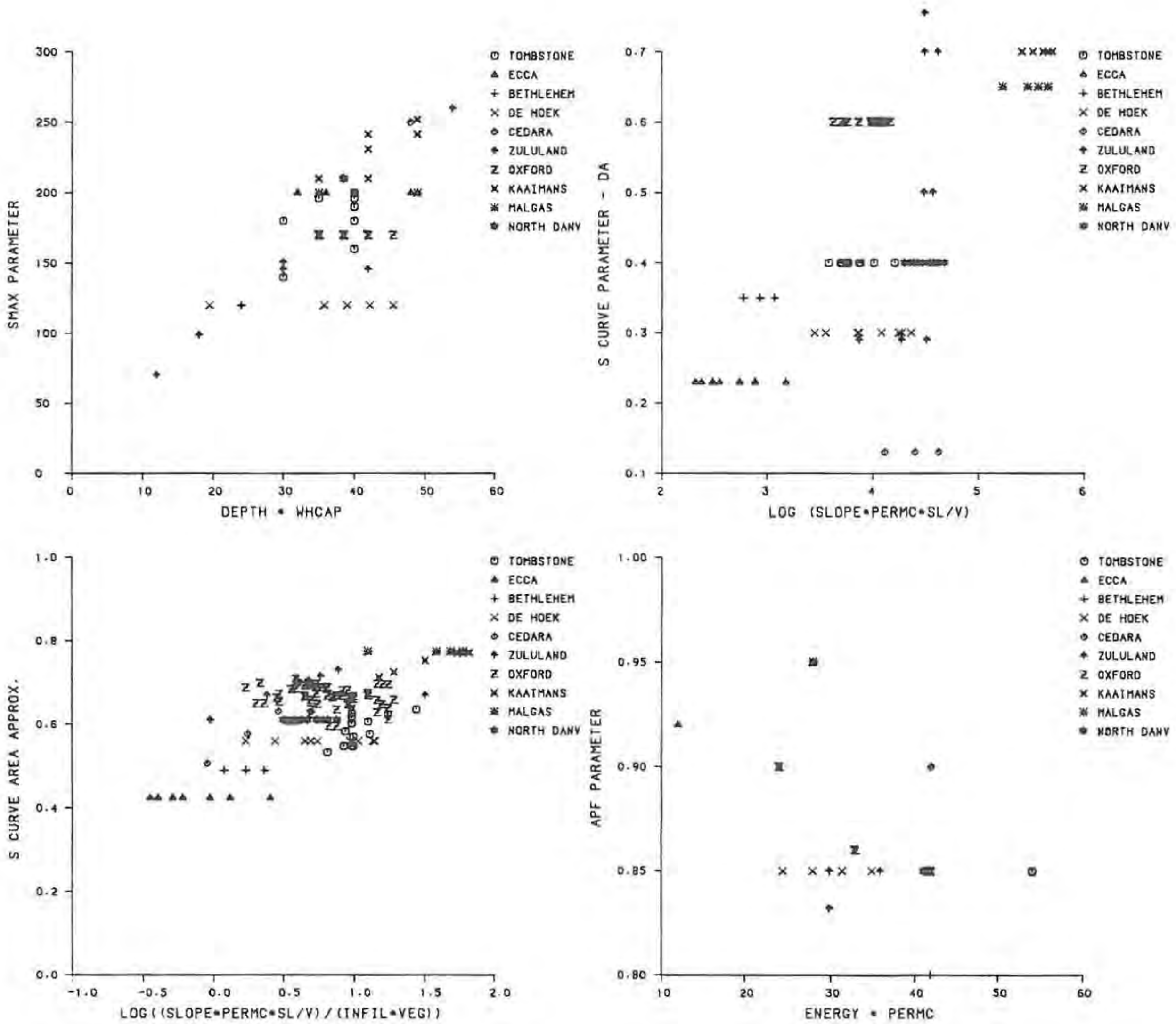


Figure 7.2 Plots of parameter - catchment variable relationships for for SMAX, DA, SCA and APF.

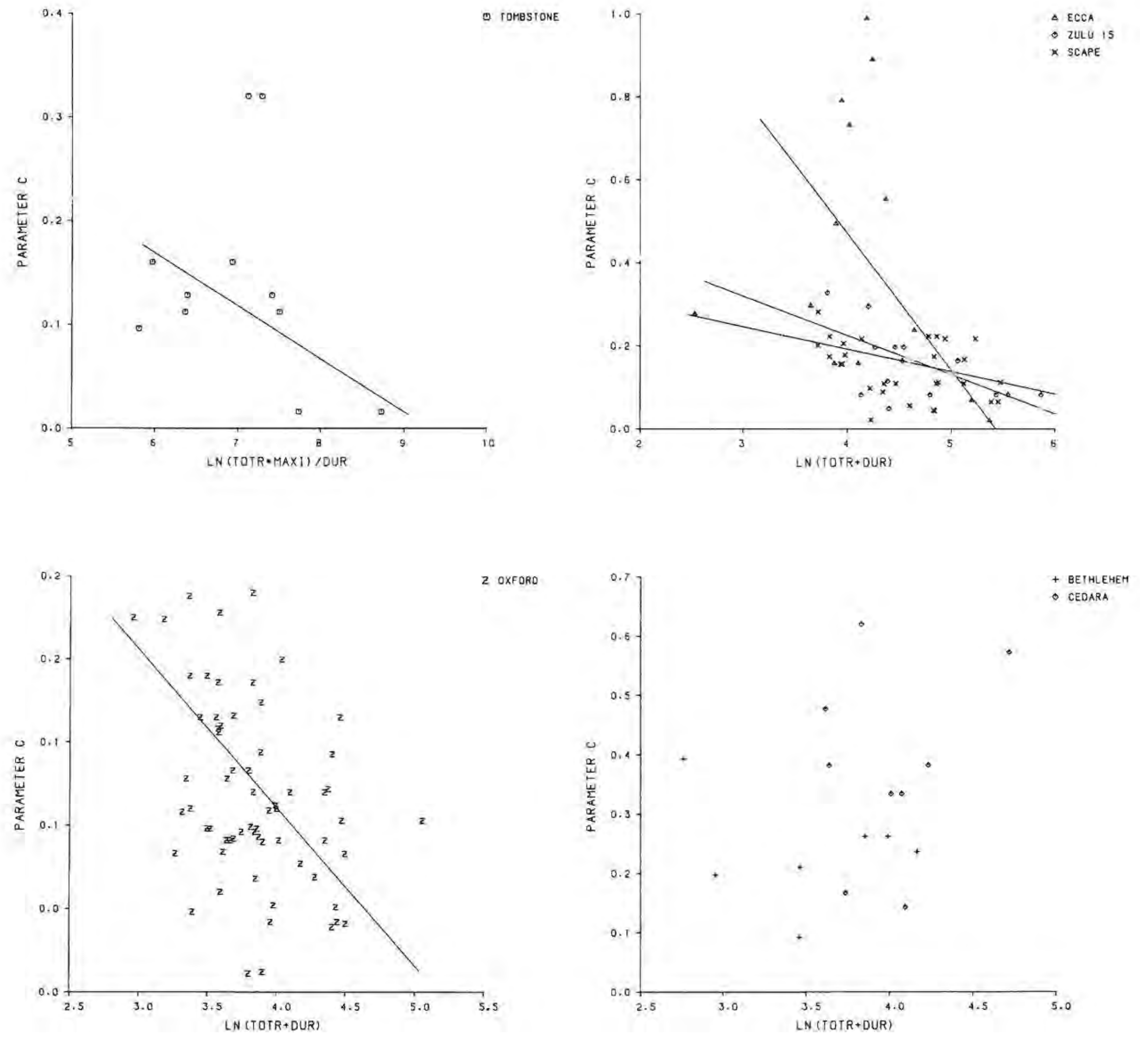


Figure 7.3 Plots of parameter - storm variables for the individual event weighting factors for parameter C of OSE1.

7.1.2 Parameters of model OSE3

Several of the relationships between OSE3 parameters and catchment characteristics are identical or very similar to those developed for OSE1. Table 7.3 lists the formats of the transformations combining the catchment and storm characteristics that have been used in the relationships.

Table 7.2 Derived equations relating model OSE3 parameters with catchment and storm characteristics.

Model Parameter	Format of the transformation variable and comments on the initial relationships.
CDEL	TC * ROUGH - Similar to OSE1.
KC	CDIST + log (ORD1) - Great deal of scatter.
K	Veg^2 * INFIL/(ENERGY * SLOPE * PERMC) - Similar general trend to OSE1 but more scatter.
ROP	TOTR * (MAXI)$^{0.5}$ + 30 day API - Applicable to Tombstone and Bethlehem catchments.
ROP	TOTR * 2QT/100 + 30 day / API - Applicable to southern Cape catchments.
ROP	TOTR + 30 day API - Applicable to Ecca, De Hoek, Cedara, Zululand, Oxford and North Danville catchments. There is a great variation in the degree of scatter as well as the slope of the relationship for ROP.

TOTR = Total storm rainfall (mm)
MAXI = Maximum intensity over model time interval (mm hr^{-1}).
2QT = Percentage of total rain falling in the first half of the storm duration.

Routing parameters (CDEL, K and KC)

The relationships for these parameters have been derived using the same combinations of variables in OSE1. The CDEL values are identical for both models (figure 7.1) whereas figure 7.4 illustrates that the amount of scatter in the relationships for K and KC is somewhat greater than for OSE1.

Runoff proportion (ROP) parameter

Unlike OSE1, no combination of physical catchment variables produced a relationship for which even a general trend could be identified. Consequently, the relationships for ROP are totally based upon storm characteristics. As the storm characteristic values were only calculated on a total catchment basis, no sub-catchment variations in ROP were allowed for in the model. This effectively reduces OSE3 to a lumped volume conversion model with a semi-distributed routing component.

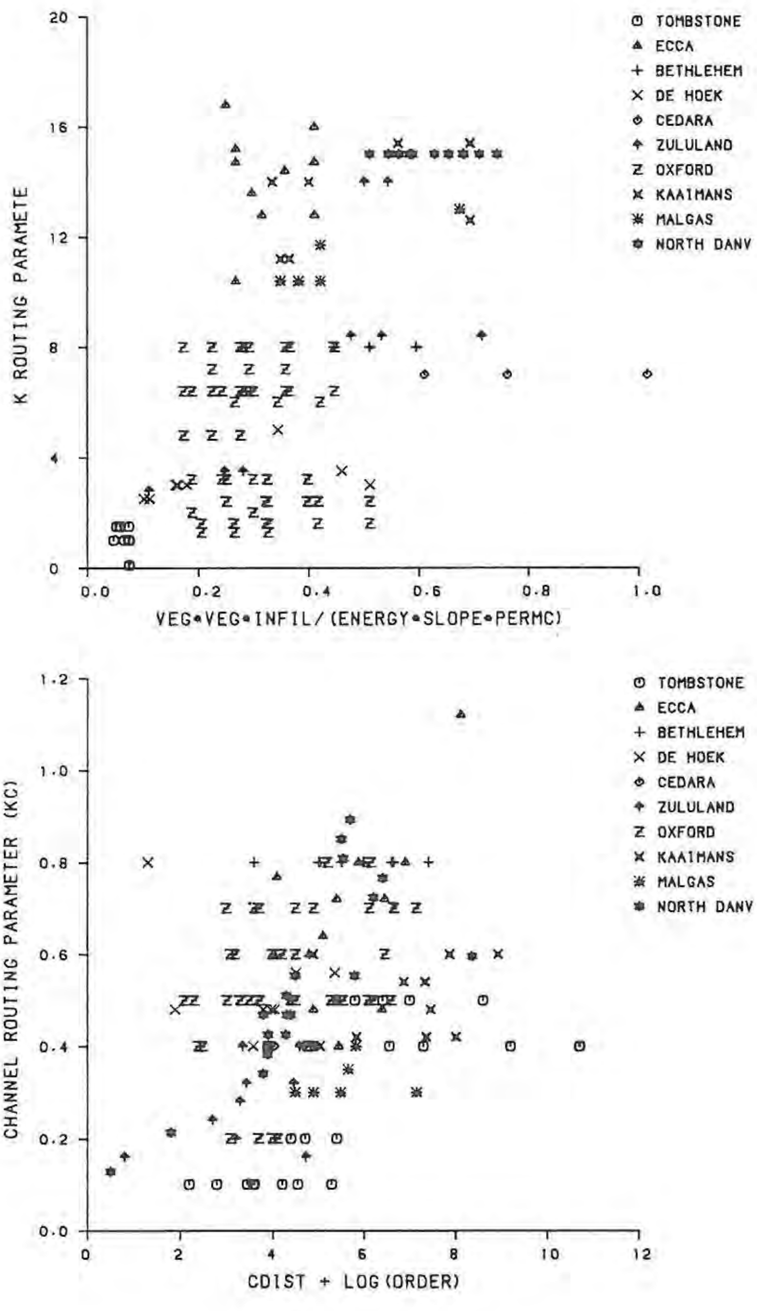
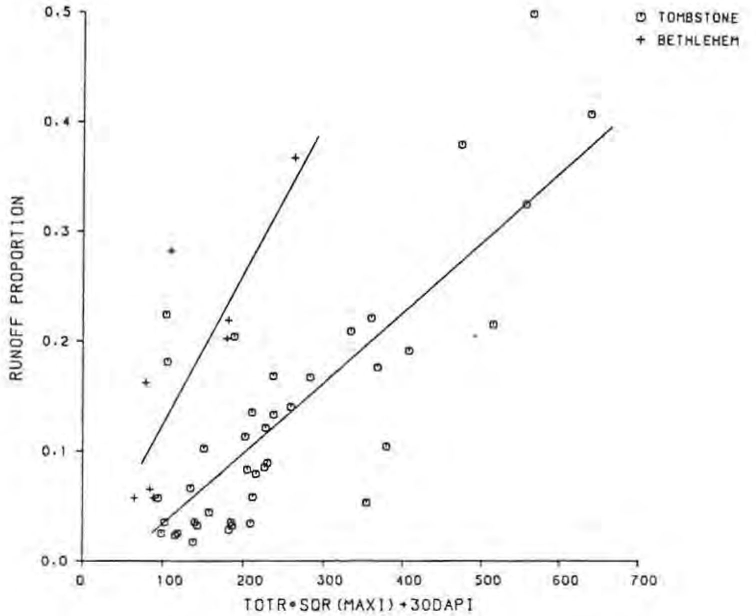


Figure 7.4 Plots of parameter - catchment variable relationships for K and KC of OSE3.

The relationships are illustrated in figures 7.5 and 7.6 where it can be seen that not only are different combinations of storm variables applicable to different catchments but also the slope of the relationships are highly variable. Linear least squares best fit lines have been included in the figures more to highlight the general trends (and the differences between catchments) than for any other reason. The inclusion of the maximum intensity variable for the Tombstone and Bethlehem catchments reflects the importance of intensity variations between events when the prevailing storms are of short duration. Its inclusion for the other catchments did not reduce the degree of scatter in the relationships. The use of the amount of rain falling during the first half of the storm duration (TOTR * 2QT/100) for the southern Cape, possibly reflects the fact that these storms are of long duration. For most flood events with high rainfall amounts, the proportion falling at the end of the storm on a wet catchment might be expected to have less influence on the overall runoff proportion than the quantity of rain falling during the earlier part of the storm. The linear trends suggested by the solid lines in figure 7.5 are probably misleading (note the intercept on the ROP axis at storm variable = 0, for the southern Cape catchments). A curvilinear relationship, horizontally asymptotic at a runoff proportion close to 0.9 is probably more realistic. It should be noted that for all the relationships, extrapolation of the trend lines beyond the data points is not recommended. For the remainder of the catchments a combination variable defined by TOTR + 30 day API (using a fixed decay constant of 0.9) appears to be more applicable (figure 7.6). Some of the relationships exhibit a relatively low degree of scatter (De Hoek, Cedara and North Danville) while others, such as the winter Oxford events, are very scattered. The De Hoek and Zululand relationships appear to be very similar and it is only the three high rainfall events on Zululand that prevent the slopes of the least squares best fit lines being similar. Once again a curvilinear relationship through the De Hoek and Zululand data points and horizontally asymptotic to an ROP of 0.7 to 0.8 is probably more realistic. The Oxford catchments have been divided up by season into winter Oxford (W), spring (SP) and summer (S). The visual trends of the three groups of data are similar to the seasonal differences found between observed total storm rainfall and runoff (figure 5.16), which are discussed earlier in section 5.9 and attributed to variations in landuse and vegetation. The least squares fit line through the winter data has a similar slope to the least squares best fit for spring. This seems to mainly be a result of the wide scatter in the winter relationship.



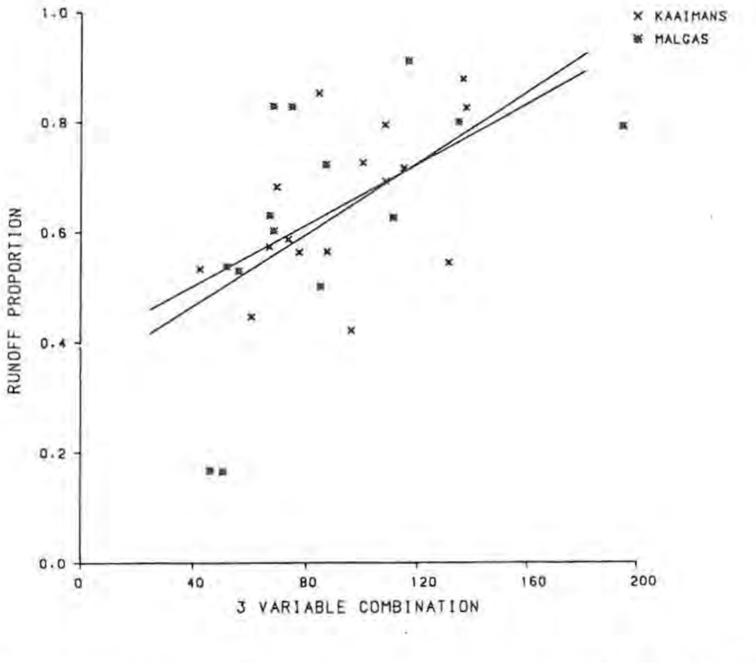


Figure 7.5 Plots of parameter - storm variable relationships for ROP of OSE3 (Tombstone, Bethlehem, Kaaimans and Malgas). Solid lines represent least squares best fit lines for the different data sets.

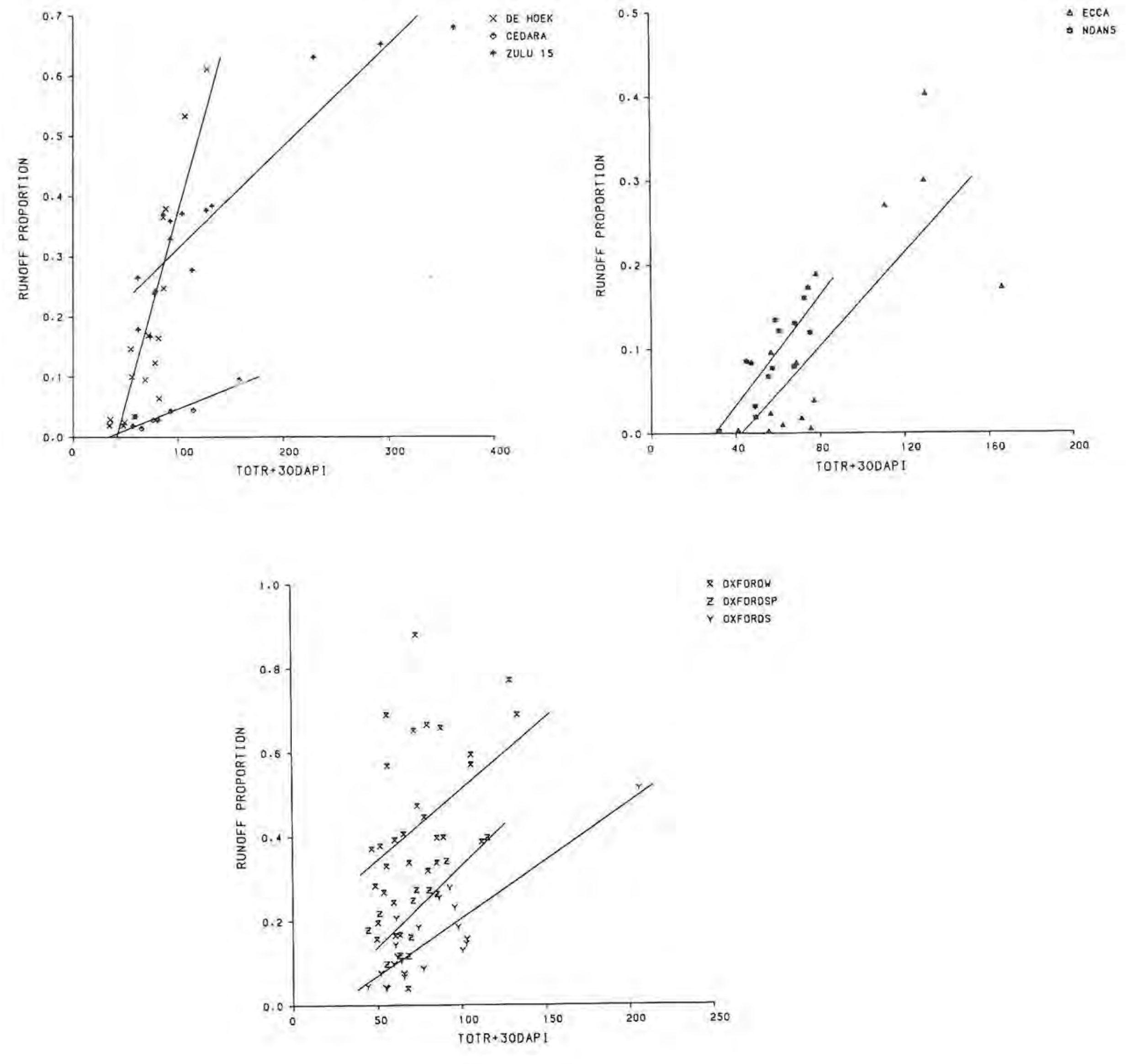


Figure 7.6 Plots of parameter - storm variable relationships for ROP of OSE3 (De Hoek, Cedara, Zululand, Ecca, North Danville and Oxford). Solid lines represent least squares best fit lines for the different data sets.

Until now no statistics have been provided to quantify the strengths or significance of the derived relationships. This is because the following section provides quantitative information which is of greater value with respect to the application of the models and the estimation of parameter values. This section discusses the results of the next stage of the study in which the linear trend lines (fitted by eye and ignoring outliers) are used to re-estimate new parameter values for the sub-areas of the catchments. The new parameter values are then used to simulate the storms again (for each catchment) and these validation results are compared with the original calibration results. Validation in this context refers to the validation of the derived trend lines which relate parameter values to physical catchment and storm characteristics.

7.2 VALIDATION OF THE DERIVED RELATIONSHIPS AND EXTENSION TO FURTHER CATCHMENTS

The majority of applied modelling problems involve ungauged catchments or situations where some change to the physical characteristics of the catchment, means that existing data are unlikely to produce satisfactory model calibrations that are applicable to the changed conditions. Under these circumstances the parameters have to be estimated by whatever means are available. The following section discusses the results of using the relationships derived in section 7.1 to estimate the parameter values of the sub-catchments already used, as well as a further four (two in the southern Cape and two in Oklahoma State, USA). The validation results are compared with the original calibration results and conclusions are reached about the relative usefulness of the models. Figure 7.7 uses histogram plots of distributions of the goodness of fit statistics to illustrate and compare the calibration and validation results for the semi-distributed versions of both models. The data are grouped by storm type (A, B and C) and are plotted in the same way as figure 6.1. The semi-distributed calibration plots are included in figure 7.7 to facilitate comparison with the validation plots. Appendix C lists the individual storm calibration and validation statistics.

7.2.1 Model OSE1

Table 7.3 repeats the formats of the combination variables (that is the transformed combinations (X) of physical variables) and the linear equations ($Y = AX + B$) to estimate the model parameter values (Y). The values for the slopes (A) and intercepts (B) are also included. To estimate C it is necessary to estimate SCA and DA from the relationships with catchment characteristics and calculate a catchment C value ($1 + DA - 2 * SCA$). The storm weights for C are then estimated from the relationships with storm characteristics. Table 7.3 compares the mean values for the four goodness of fit statistics for the original calibration simulations with the validation simulations for all the catchments.

Table 7.3 Format of the equations for estimation of model OSE1 (semi-distributed) parameters.

MODEL PARAMETER	FORMAT OF TRANSFORMED COMBINATION OF PHYSICAL VARIABLES		LINEAR EQUATION PARAMETERS A	B
CDEL	TC * ROUGH		0.132	0.055
K	VEG^2 * INFIL/(ENERGY * SLOPE * PERMC)		8.04	-0.280
KC	CDIST + Log (ORD1)		0.125	0.018
SMAX	DEPTH * WHC		4.65	10.5
DA	Log (SLOPE * PERMC * SL/V)		0.138	-0.099
SCA	Log (SLOPE * PERMC * SL/V/(INFIL * VEG))		0.153	0.503
APF	ENERGY * PERMC		-0.003	0.949
C(storm weights)	Log (TOTR * MAXI/DUR)	- Tombstone	-0.051	0.475
		- De Hoek	-0.130	0.811
	Log (TOTR + DUR)	- Ecca	-0.330	1.79
		- Zululand	-0.095	0.603
		- Oxford	-0.095	0.491
		- S. Cape	-0.054	0.408
		- N. Danville	-0.266	1.212

For parameter c: (1+DA-2*SCA) * C(storm weight)
model parameter values = A * combination variable + B.

It is obvious from table 7.4 that the validation results for OSE1 are poor. In fact validation was not even possible for two catchments (Bethlehem and Cedara) because sensible relationships for the C parameter (storm characteristics) could not be established (section 7.1.1). Only in the cases of the Zululand and Oxford catchments are mean coefficients of efficiency greater than zero. Many individual storms are simulated quite satisfactorily (Appendix C) but the effect of very poor simulations on other storms is seen quite clearly in the histograms of figure 7.7 as well as the high standard deviations of table 7.4. In many cases it only requires two extremely badly simulated storms on a catchment (coefficients of efficiency of -10.0 and less), to make the resulting mean highly negative. The rest of the storms could have reasonably good coefficients of efficiency. For some catchments (Ecca, Malgas and Kaaimans) the simulation results were generally better for the large events.

Table 7.4 Comparison of original and validation goodness of fit statistics for model OSE1.

Catchment	No. of Storms	Original fit statistics % Errors Vol.	Pk.	Coefficients Eff.	Det.	Validation fit statistics % Errors Vol.	Pk.	Coefficients Eff.	Det.
Tombstone	11	16	38	0.30	0.62	72	68	-0.36	0.63
TM11		(19)	(33)	(0.64)	(0.27)	(59)	(45)	(2.05)	(0.33)
Tombstone	9	11	25	0.16	0.48	127	60	-2.09	0.33
TM8		(11)	(17)	(0.85)	(0.31)	(120)	(75)	(5.49)	(0.18)
Tombstone	8	13	18	0.27	0.49	79	57	-0.29	0.62
TM3		(14)	(11)	(0.62)	(0.35)	(69)	(32)	(1.60)	(0.19)
Ecca	13	13	9	0.49	0.72	125	134	-8.4	0.40
Q9M20		(15)	(11)	(0.48)	(0.20)	(154)	(162)	(17.4)	(0.22)
De Hoek	16	21	42	0.27	0.63	71	63	-3.34	0.64
V1M19		(14)	(30)	(0.64)	(0.34)	(89)	(86)	(9.57)	(0.29)
Zululand	15	16	22	0.61	0.77	36	46	0.21	0.76
W1M15		(13)	(17)	(0.17)	(0.14)	(31)	(38)	(0.68)	(0.15)
Oxford	12	10	21	0.71	0.78	52	57	-0.01	0.70
W10		(9)	(18)	(0.23)	(0.19)	(48)	(49)	(1.02)	(0.23)
Oxford	11	6	24	0.69	0.75	42	60	0.22	0.76
W12		(4)	(11)	(0.24)	(0.25)	(26)	(47)	(0.61)	(0.27)
Oxford	13	15	31	0.64	0.73	34	53	0.44	0.68
W17		(7)	(38)	(0.25)	(0.18)	(24)	(37)	(0.31)	(0.28)
Oxford	14	11	28	0.72	0.79	36	47	0.36	0.52
W32		(8)	(17)	(0.24)	(0.20)	(18)	(30)	(0.50)	(0.36)
Oxford	12	9	29	0.61	0.74	33	48	0.49	0.68
W35		(8)	(25)	(0.24)	(0.19)	(21)	(24)	(0.33)	(0.30)
Kaaimans	16	9	12	0.41	0.63	36	51	-0.41	0.53
K3M01		(6)	(6)	(0.59)	(0.25)	(29)	(42)	(1.62)	(0.29)
Malgas	16	11	11	0.38	0.63	45	47	-0.22	0.55
K3M04		(6)	(9)	(0.66)	(0.33)	(31)	(33)	(0.80)	(0.30)
Diep	13			no result		47	60	-1.20	0.58
K4M03						(29)	(44)	(2.21)	(0.27)
Karatara	7			no result		62	50	-0.25	0.59
K4M02						(23)	(27)	(0.40)	(0.24)
N.Danville	11	6	9	0.87	0.90	62	82	-2.01	0.85
ND5		(5)	(5)	(0.08)	(0.09)	(47)	(75)	(5.43)	(0.08)
Chickasha	5			no result		98	75	-2.42	0.31
CH111						(66)	(41)	(3.45)	(0.35)
Chickasha	8			no result		81	55	-1.25	0.47
CH512						(87)	(66)	(3.24)	(0.39)

Figures in parenthesis are standard deviations.

% Errors in volume and peak are means of the absolute values.

Coefficients of efficiency and determination are mean values.

The four catchments for which there are no results for the original simulations were not included in the analysis until the validation stage.

The storm weights for Diep and Karatara catchments are estimated using the relationships derived for the southern Cape catchments. The Diep simulations are generally over predicted while those for the Karatara are under-predicted. The Karatara is a steep headwater catchment (having relatively high runoff proportions) while the Diep has gentler slopes and denser vegetation resulting in a corresponding lower runoff response. The two calibrated catchments (Malgas and Kaaimans) have characteristics lying between the extremes of the Karatara and Diep. One possible reason for the over and under prediction on the Diep and Karatara is that the storm characteristic based equations for the C weights also include some effects of catchment characteristics. Ideally these effects should have already been accounted for through the catchment characteristic equation for SCA and DA. A further possible reason that may explain the simulation differences between the Karatara and Diep is related to the difficulties of estimating the storm rainfall input to these catchments. The Chickasha catchment simulations are based upon using the Tombstone equations for the C storm weights. It was decided to use the Tombstone equation because the Chickasha storms are also high intensity, relatively short duration events. However, the results suggest that the direct transfer of storm weight relationships to other catchments is unlikely to meet with much success. This conclusion is reinforced by the differences found in the form of C storm weight equations, derived for the calibrated catchments.

7.2.2 Model OSE3

The equations for the parameters of model OSE3 are given in table 7.5 and the values for the goodness of fit statistics from the validation compared to those from the calibration are given in table 7.6.

Many of the conclusions reached about the validation exercise for OSE1 are also applicable to model OSE3. They confirm the main conclusion made for OSE1, that the validation results (table 7.6) are poor. Some of the results for OSE3 are better (Tombstone and Zululand), while other are worse (Malgas and Chickasha).

The main validation problems, were encountered with the transfer of relationships developed for parameter ROP. The Chickasha results in particular illustrate the problems of trying to apply relationships for ROP developed for one group of catchments to a very different group of catchments. The Tombstone equation for estimating ROP is used for the Chickasha catchments and results in extreme over prediction of most of the events. The Chickasha total storm rainfalls are usually higher than for Tombstone which means that the values for TOTR * $MAXI^{0.5}$ + 30DAPI are usually outside the range used to develop this relationship. The Tombstone relationship is therefore demonstrated to be inapplicable to the Chickasha catchments. However, none of the alternative equations (using TOTR and 30DAPI) are applicable either. These problems are possibly a result of the volume reduction component of OSE3 being represented by one component. The equation for this parameter must include the effects of the rainfall event and the antecedent moisture status of the catchment. The antecedent moisture status determination is acknowledged as being oversimplified (chapter 3) and could possibly adversely effect the equation used to determine ROP.

Table 7.5 Format of the equations for estimation of model OSE3 (semi-distributed) parameters.

MODEL PARAMETER	FORMAT OF TRANSFORMED COMBINATION OF PHYSICAL VARIABLES		LINEAR EQUATION PARAMETERS A	B
CDEL	TC * ROUGH		0.132	0.055
K	VEG^2 * INFIL/(ENERGY * SLOPE * PERMC)		16.2	-0.096
KC	CDIST + Log (ORD1)		0.125	0.019
ROP	TOTR * $MAXI^{0.5}$ + 30DAPI	- Tombstone	0.0006	-0.030
		- Bethlehem	0.0014	-0.013
	TOTR + 30DAPI	- Ecca	0.0028	-0.118
		- De Hoek	0.0063	-0.261
		- Cedara	0.0007	-0.024
		- Zululand	0.0017	0.142
		- Oxford W	0.0034	0.175
		- Oxford P	0.0039	-0.056
		- Oxford S	0.0027	-0.067
		- Kaaimans	0.0028	0.391
		- Malgas	0.0032	0.336
		- N. Danville	0.0033	-0.099

Model parameter values = A * combination variable + B

Table 7.6 Comparison of original fit statistics and validation goodness of fit statistics for model OSE3.

Catchment	No. of Storms	Original fit statistics				Validation fit statistics			
		% Errors		Coefficients		% Errors		*Coefficents	
		Vol.	Pk.	Eff.	Det.	Vol.	Pk.	Eff.	Det.
Tombstone	11	4	24	0.58	0.66	27	39	0.50	0.60
TM11		(6)	(19)	(0.44)	(0.26)	(21)	(29)	(0.32)	(0.33)
Tombstone	9	3	23	0.22	0.50	46	66	0.12	0.30
TM8		(4)	(20)	(0.74)	(0.30)	(40)	(23)	(0.32)	(0.30)
Tombstone	8	5	25	0.16	0.51	60	32	0.11	0.56
TM3		(7)	(36)	(0.62)	(0.32)	(65)	(24)	(0.97)	(0.23)
Ecca	13	6	6	0.75	0.87	178	136	-6.32	0.56
Q9M20		(7)	(5)	(0.38)	(0.11)	(243)	(159)	(10.60)	(0.26)
Bethlehem	7	6	11	0.52	0.66	27	34	0.27	0.58
C8M25		(4)	(7)	(0.59)	(0.33)	(26)	(32)	(0.59)	(0.39)
De Hoek	14	9	29	0.49	0.60	46	64	-2.21	0.63
V1M19		(8)	(23)	(0.45)	(0.32)	(51)	(89)	(9.23)	(0.29)
Cedara	10	10	17	0.53	0.72	32	51	0.34	0.58
U2M16		(6)	(9)	(0.34)	(0.17)	(23)	(28)	(0.45)	(0.29)
Zululand	15	5	14	0.77	0.81	17	22	0.61	0.76
W1M15		(4)	(10)	(0.17)	(0.16)	(13)	(10)	(0.22)	(0.15)
Oxford	12	6	21	0.63	0.76	27	41	0.46	0.76
W10		(12)	(20)	(0.37)	(0.22)	(37)	(38)	(0.68)	(0.19)
Oxford	11	7	23	0.82	0.84	31	41	0.56	0.88
W12		(8)	(15)	(0.18)	(0.15)	(32)	(30)	(0.55)	(0.13)
Oxford	13	11	23	0.82	0.87	22	58	0.53	0.80
W17		(5)	(15)	(0.10)	(0.09)	(16)	(55)	(0.33)	(0.16)
Oxford	13	1	25	0.75	0.79	32	54	0.37	0.54
W32		(2)	(16)	(0.25)	(0.21)	(14)	(21)	(0.46)	(0.309)
Oxford	12	5	23	0.71	0.78	58	39	0.08	0.75
W35		(5)	(23)	(0.22)	(0.20)	(62)	(25)	(1.15)	(0.24)
Kaaimans	16	6	13	0.64	0.75	16	39	-0.20	0.56
K3M01		(4)	(14)	(0.30)	(0.20)	(14)	(56)	(1.29)	(0.25)
Malgas	16	8	15	0.46	0.66	36	71	-1.8	0.56
K3M04		(3)	(12)	(0.56)	(0.30)	(50)	(85)	(6.38)	(0.36)
Diep	13	no result				269	343	-27.0	0.60
K4M03						(337)	(380)	(40)	(0.25)
Karatara	7	no result				24	73	-0.77	0.51
K4M02						(16)	(70)	(1.48)	(0.28)
N.Danville	12	3	3	0.94	0.95	25	29	0.60	0.91
ND5		(2)	(3)	(0.05)	(0.05)	(17)	(15)	(0.34)	(0.07)
Chickasha	5	no result				275	176	-15.58	0.39
CH111						(166)	(167)	(16.18)	(0.40)
Chickasha	8	no result				138	119	-7.77	0.56
CH512						(146)	(123)	(17.07)	(0.29)

Figures in parenthesis are standard deviations.

% Errors in volume and peak are means of the absolute values.

Coefficients of efficiency and determination are mean values.

The four catchments for which there are no results for the original simulations were not included in the analysis until the validation stage.

7.3 COMPARISONS BETWEEN MODELS AND STORM TYPES (A, B AND C)

Table 7.7 lists the mean values for the goodness of fit statistics grouped according to storm type (A, B and C) as defined in section 6.3.5 As the histogram plots of figure 7.7 demonstrate the mean values do not always represent a satisfactory measure of central tendency when the distributions are skewed. Table 7.7 gives an immediate and easy to read impression of the relative performance of both models after validation. The A-type events have similar means for both models. However for the B- and C-type events the results do not deteriorate as would be expected for events with worse rainfall input definition. This is particularily true for model OSE3, where the results are better for the C-type events then for the more well defined A-type events. This result is difficult to explain and is possibly a reflection of the erratic nature of the validation simulations for both models.

Table 7.7 Validation results - mean goodness of fit statistics grouped by model and storm type.

STORM TYPE		OSE1	OSE3
	% error Vol.	49 (70)	50 (102)
A	% error Pk.	62 (86)	55 (68)
	Coeff. Eff.	-1.20 (8.40)	-1.11 (6.54)
	Coeff. Det.	0.73 (0.26)	0.74 (0.24)
	% error Vol.	64 (72)	42 (55)
B	% error Pk.	65 (57)	43 (31)
	Coeff. Eff.	-1.46 (5.97)	-0.02 (2.00)
	Coeff. Det.	0.54 (0.30)	0.63 (0.28)
	% error Vol.	62 (67)	30 (37)
C	% error Pk.	63 (63)	47 (51)
	Coeff. Eff.	-0.94 (3.38)	-0.23 (3.14)
	Coeff. Det.	0.57 (0.28)	0.58 (0.32)

Figures in parenthesis are standard deviations.
% Errors in volume and peak are means of the absolute values.
Coefficients of efficiency and determination are mean values.

Figure 7.7 Distributions of goodness of fit statistics for the semi-distributed calibration and validation results of models OSE1 and OSE3, grouped by storm type (A,B and C).

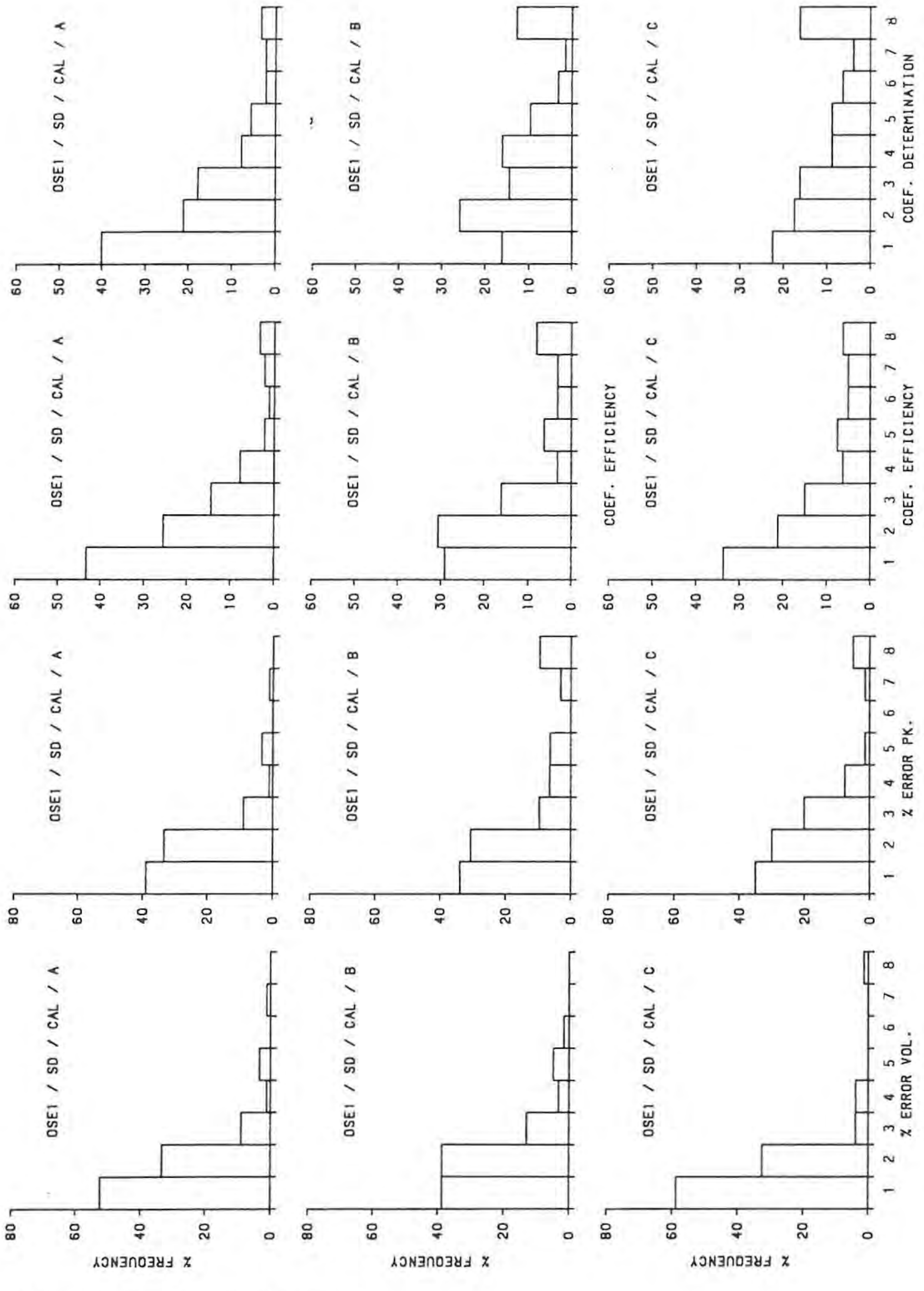
Key to following 4 pages of computer plots.

Each histogram is labelled with a four part code

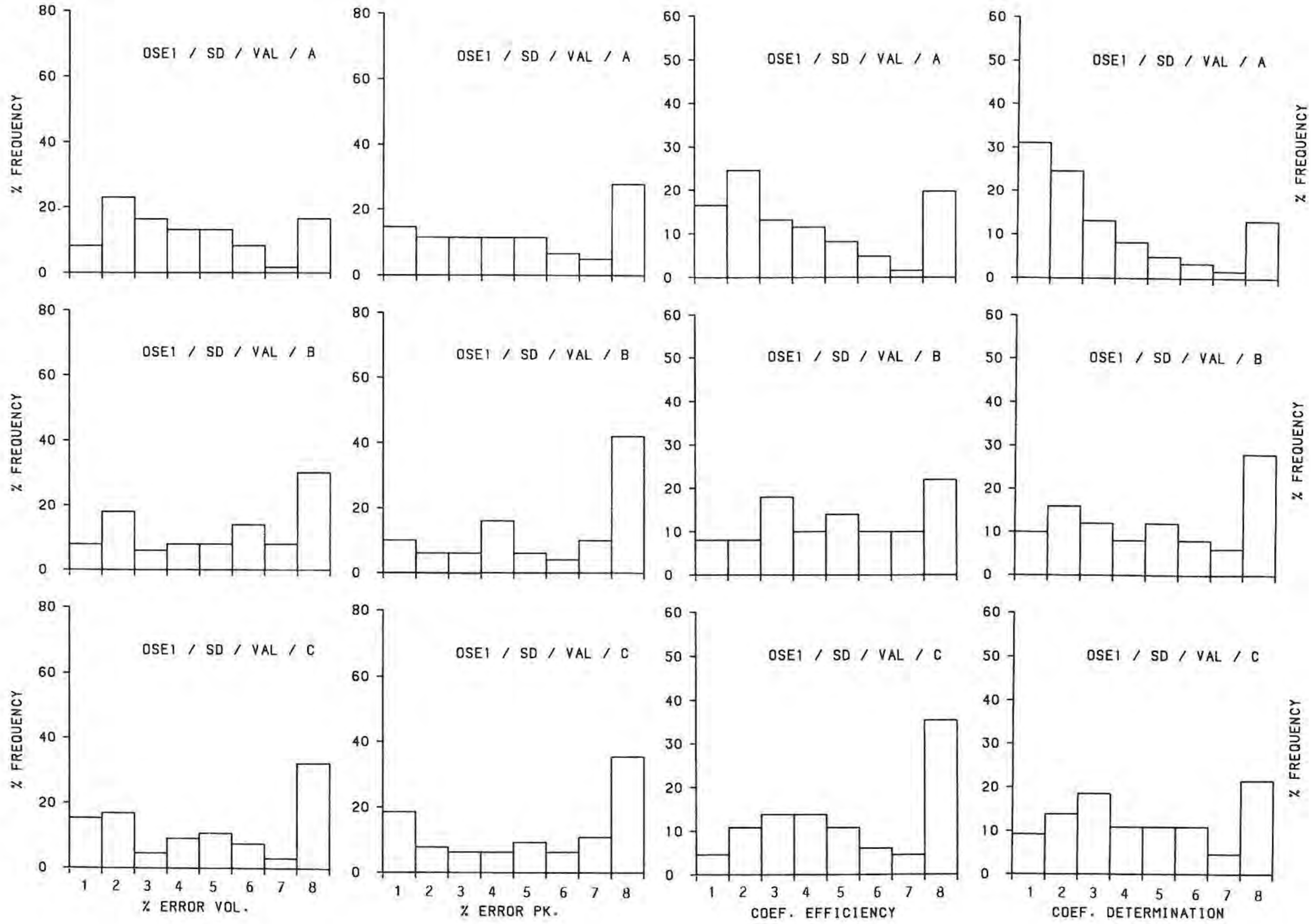
Model name/ Lumped or semi-dist./ Calibration or validation/ Storm type.

The eight histogram categories are as follows.

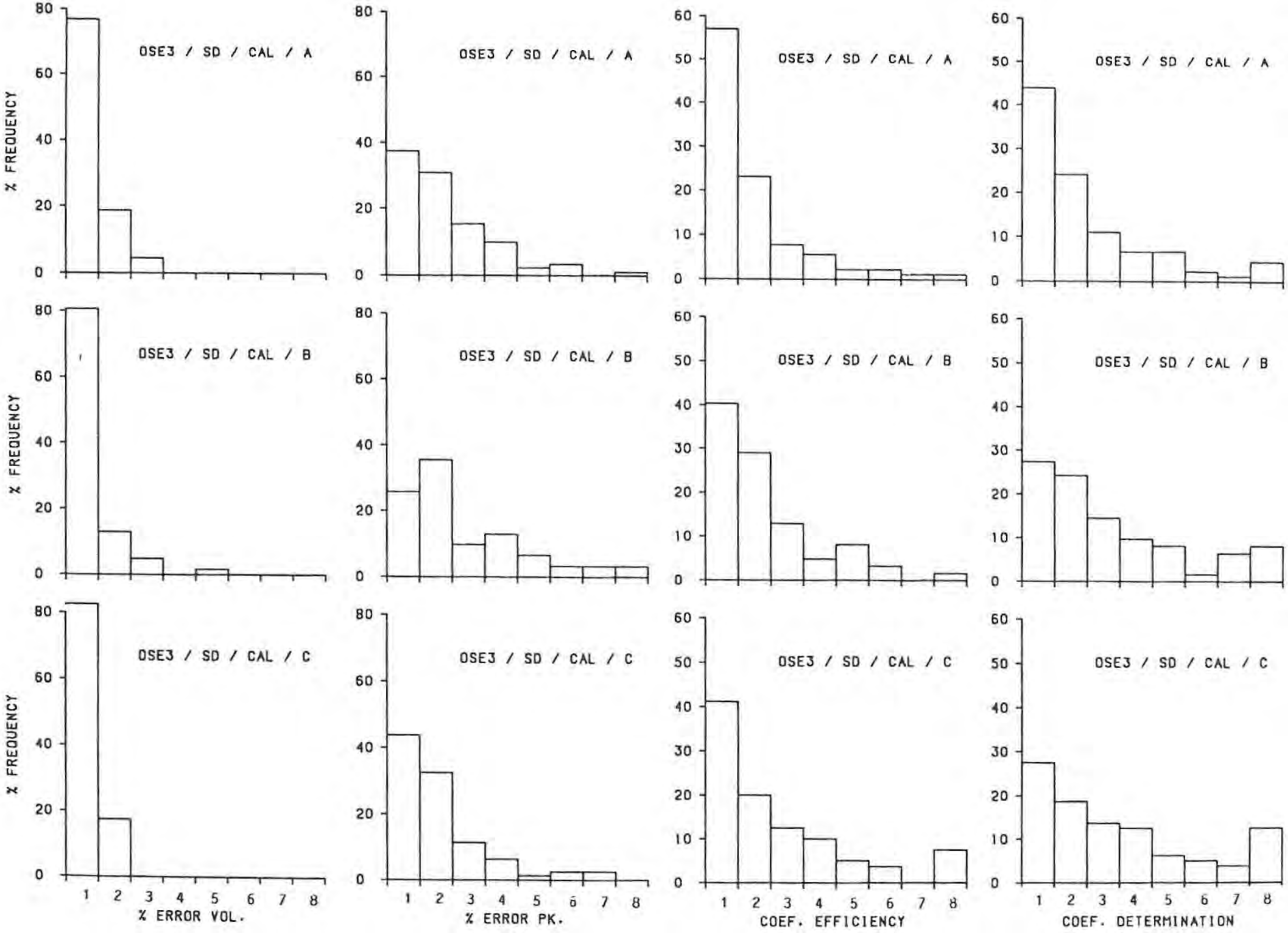
HISTOGRAM	GOODNESS OF FIT STATISTIC		
CATEGORY	ABSOLUTE % ERRORS IN	COEFFICIENTS OF	
	VOLUME AND PEAK	EFFICIENCY	DETERMINATION
1	0 to 10	1.0 to 0.8	1.0 to 0.9
2	10 to 20	0.8 to 0.6	0.9 to 0.8
3	20 to 30	0.6 to 0.4	0.8 to 0.7
4	30 to 40	0.4 to 0.2	0.7 to 0.6
5	40 to 50	0.2 to 0.0	0.6 to 0.5
6	50 to 60	0.0 to -0.2	0.5 to 0.4
7	60 to 70	-0.2 to -0.4	0.4 to 0.3
8	>70	<-0.4	<0.3



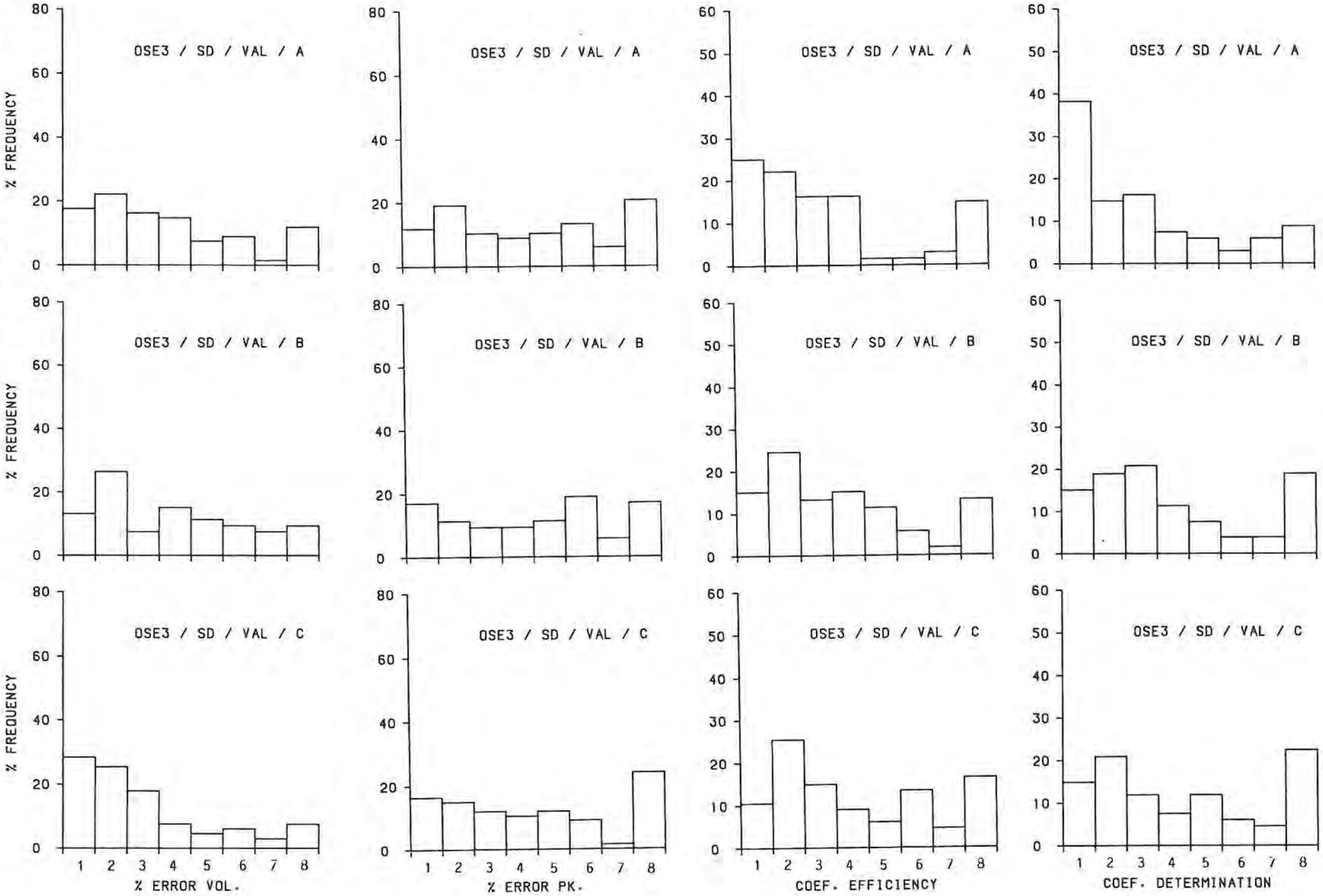
OSE1 Semi-distributed calibration results.



OSE1 Semi-distributed validation results.



OSE3 Semi-distributed calibration results.



OSE3 Semi-distributed validation results.

CHAPTER 8

CONCLUSIONS

The purpose of this chapter is to summarise the main findings of the research (discussed in the previous two chapters) and relate them to the research objectives (section 4.1). This includes a comparison of the performance of OSE1 and OSE3 and is followed by a discussion of their suitability for estimating floods.

8.1 CONCLUSIONS OF THE RESEARCH

The following conclusions pertain to the main objectives of the study (section 4.1).

a) With respect to their ability to reproduce observed hydrographs (aim a, objective 1), regardless of the values of the parameters, both versions of the models adequately reproduce most events. This is particularly true when the spatial distribution of the input rainfall is relatively uniform and well defined. Both models have problems simulating complex multi-peaked events, especially when the input rainfall is poorly defined and the antecedent catchment moisture status is low. These results confirm hypothesis a and its corollary and suggest the need for a variable runoff proportion. The variable runoff proportion model (OSE2) discussed in Hughes and Beater (1987) did not simulate most events any better than the models referred to in this study. However, the multi-peaked events were generally better simulated by OSE2. A further observation about the calibration results is that they are similar for both models. This is not unexpected because they have very similar components, only the order in which the components are applied is different. However, for the models to be of any practical value it is necessary to establish whether the calibrated parameter sets can be applied to other events, that is there is a need to assess the multi-storm stability of parameters (aim b, objective 1).

b) During calibration it was generally possible to keep the routing parameters of both models stable on most individual catchments. Exceptions occurred in the cases of the Oxford and Ecca catchments. For the Ecca catchments the routing parameter (K) had to be varied because two types of storm event occur to which the catchment response is very different (section 6.2). For the Oxford catchments the calibration results indicate the need for different routing parameters to cope with differences associated with catchment characteristics. The USDA (1955-1975) publications indicate that soil erosion is higher during winter. The data indicate that this is unlikely to be due to seasonal differences in rainfall intensity, thus suggesting seasonal differences in runoff response characteristics. These differences result from seasonal variation in landuse, with decreased vegetation cover during the winter months. The consequently higher runoff proportions and more rapid runoff support the need for variation in parameter values on a seasonal basis (section, 6.2). The calibration results for the Oxford catchments indicated the need for variations in parameters, while the actual variations were applied only during the validation stage of the research after the parameters had been related to catchment characteristics. Both models have at least one volume reduction parameter which must be calibrated for each individual event to achieve acceptable results. Therefore it was difficult to access the success of the calibrations at this stage. Any real comparisons of the models could only be made after an assessment of the success of attempts to develop relationships between parameter values and measurable physical characteristics of either the catchment, the storms or both.

c) Before discussing the results of the attempt to derive relationships between physical variables and the sub-catchment parameters (aim c, objective 1), it is noted that this exercise was hampered by the fact that it was often difficult to obtain adequate information with which to quantify physical catchment characteristics. This is particularly true of soil characteristics, where the available information is often limited, very generalised and not always of relevance to hydrological processes. This meant that indices were used which are based upon an ordinal measurement scale, and involve a certain degree of subjective interpretation of qualitative descriptions contained within the various sources. The results of the validation of parameter relationships must be seen in the light of these limitations.

The general trends exhibited by many of the relationships are encouraging. Combinations of variables could be found which demonstrate approximate linear trends for the routing parameters of both models as well as for most of the volume conversion parameters of OSE1 (chapter 7). Furthermore, the format of the combinations of physical variables do make sense with respect to the original parameter conceptualisations (chapter 3), confirming hypothesis c. The degree of scatter of some of the relationships is not unexpected given the imprecision with which the some of the physical variables have been quantified and the usual uncertainties associated with calibrating models of this type. However, very poor relationships were obtained for the volume conversion parameters (parameter C in model OSE1 and parameter ROP in model OSE3) which are allowed to vary between events. The main limitation is that the nature of the relationships (and particularily the slopes) is different for individual catchments or groups of catchment. The degree of scatter and the between catchment variation in the form of the relationships present major drawbacks to the application of the models, when calibration is not possible. Model OSE1 has the additional problem that no relationship could be derived for the event based weights of parameter C for two of the catchments, namely Bethlehem and Cedara.

Given the above conclusion it is not surprising that the validation results are poor for both models. Although the histograms of the validation results for model OSE3 (chap 7) indicate that the relationships used to predict parameter ROP are useful, this is only the case if some calibration data are available to determine the form of the relationship for a specific catchment. As a consequence, transferring the relationships derived for Kaaimans and Malgas to similar catchments in the same area produced very poor results, particularly for the Diep. Transferring relationships derived from the Tombstone catchments to the Chickasha (totally different area) catchments was a total failure, with errors in peak and volume well in excess of 100 per cent for both models.

d) Another objective of this research was to establish whether the semi-distributed versions of both models performed consistently better than the lumped versions. The following conclusions apply to both models. There are events for which the semi-distributed versions perform more satisfactorily than the lumped versions. Generally these are events with very spatially variable rainfall input, which confirms hypothesis b, section 4.1. However, this conclusion is not generally applicable to all events with a high degree of spatial variation in the storm rainfall characteristics. For some of these events even the semi-distributed versions give poor results. This is partly related to the lack of sufficient data with which to define the variability. Therefore the quality of the input rainfall will have an effect on the reliability of the modelling results regardless of the sophistication of the model. The study has shown that the lumped versions perform as well as the semi-distributed versions when there is little spatial variation in the input rainfall. This is an important conclusion from the applied point of view because the lumped models are simpler to use and require much less computer time. However, for many of the catchments used in this study, there are major differences in the physical characteristics of the sub-catchments. For example the Zululand catchments have areas with relatively deep soils and other areas which have thin soils with a high proportion of bare rock. These differences in soil depth result in differences in the runoff response of different areas of the catchments and consequently the lumped versions of both models will not necessarily be able to simulate the catchment runoff regime. For the semi-distributed model to perform better the model user must be able to recognise the differences and assign values to the sub-catchment parameters that have an effect on the runoff simulations that truly reflect these runoff differences.

e) The above conclusions are used to compare the performances of OSE1 and OSE3. Conclusion (a) notes that the calibration results are very similar for the models. Although this is not unexpected, this result does indicate how similar these two constant runoff proportion models are. Conclusion (b), that both models have stable routing parameters and at least one volume reduction parameter that varies between events, reinforces the similarity and does not substantiate Mandeville's (1983) contention that the Augmented Hydrograph model should have stable parameters (hypothesis d) and model OSE1 should have more variability amongst its parameters. The models are also similar in terms of the relationships derived for the parameters and the validation results.

While in general OSE3 was easier to calibrate, the main problem with this model was that the attempt to establish relationships between parameter ROP and catchment and storm characteristics was not successful. This means that the volume reduction component of this model was determined in a lumped way and that storms were required to calibrate the model before it could be used.

8.2 DESIGN FLOOD SUITABILITY

If models OSE1 and OSE3 are going to be used for design flood purposes there are a number of implications arising from the conclusions. These implications include uncertainties in extrapolating outside the observed range of data and a lack of transferability to other catchments. The catchment average volume and peak errors from the validation exercise were rarely within 20 per cent of the observed values and average coefficients of efficiency were usually well below 0.7. However, even some of the worst results for both models can be favourably compared with the results reported in Campbell, Ward and Middleton (1987) for several models currently in common use for deriving design floods.

Despite the poor results of the validation, the attempt to develop relationships between parameters and catchment or storm characteristics produced promising results. An effort to further develop these relationships and attempt to regionlise parameters is considered to be possible. Parameter relationships for model OSE3, in particular parameter ROP, could be improved. It was possible to establish fairly good relationships with storm characteristics for ROP for all the calibrated catchments. If these relationships could be modified to include catchment characteristics then

ROP could possibly be determined in a semi-distributed way. For model OSE1, difficulties are expected when trying to improve the existing relationships with storm characteristics, for parameter C. The possible introduction of a variable runoff proportion could improve both the results and the parameter relationships. For example, the S-curve model (OSE2), which has a variable runoff proportion produced consistently better validation results for the same set of catchments (Hughes and Beater, 1989). This result indicates that both models seem to be limited by the simple constant runoff proportion component of their structure and the introduction of a variable runoff proportion could be a way of improving results and the stability of parameters for both models.

An effort to regionalise parameter relationships would mean that data would be required to provide:-

a) more information about the physical characteristics of the existing catchments to strengthen the parameter relationships and

b) additional catchments would be required for calibrating the models so that a wider range of runoff generation regimes could be represented.

These data requirements, particularly for historical rainfall-runoff data, could be a major barrier to further model development or testing. This is because the collection and acquisition of more data, which may not be readily available, would be expensive and time consuming. Even if the additional data are available, there is no guarantee that an attempt to regionalise parameter relationships of these relatively simple conceptual models, will be sufficiently successful to justify the additional work involved. Whereas a distributed, physically based model which also requires a lot of data, particularly physical catchment data would be more likely to produce parameter relationships which could be extrapolated and transferred successfully to the ungauged situation (Abbott *et al.*, 1986).

The current school of thought is that relatively simple conceptual models have less rigorous data requirements then complex physically based models and in many cases produce similar results therefore it is better to use the simple model (Naef, 1981; Pilgrim and McDermott, 1982; Loage and Freeze, 1985). However, the results of this study seem to indicate that the data requirements for the simple models are significant and may rival the requirements of more complex models. Therefore the selection of a model could be based on the calibration requirements which in the case of a simple conceptual model relies on the availability of catchment rainfall-runoff data which may not be available. More complex physically based models rely on measureable physical catchment data which also may not be available but which can be obtained more easily then historical hydrological data. It is possible that a compromise between these two extremes will represent the best approach.

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APPENDIX A

Model calibration results : tables

The tables are arranged in the following way:

Model name	Model Type	Catchment ND1	ND5	Q9M21	Q9M20
OSE1	Lumped	A1	A2	A3	A4
	S.distributed	A5	A7		A9
	sub-area factors	A6	A8		A10
OSE3	Lumped	A11	A12	A13	A14
	S.distributed	A15	A17		A19
	sub-area factors	A16	A18		A20

Notes: a) Parameter values that change between storms on the same catchment are listed in the tables, others are given below the tables.

b) Coefficient of efficiency : Eff. = $1 - \dfrac{(\text{Observed-Simulated})^2}{(\text{Observed-Observed mean})^2}$

Coefficient of Determination : Det. = $(\text{corr.coefficient})^2$

Table A1 Calibration results

Catchment North Danville, ND1 — Area 42,96km*km
Model Simple antecedent moisture model-OSE1 — Type Lumped

Storm No.	Date	Parameters DEL (5)	DA (9)	C (10)	APF (14)	% errors Volume	Peak	Coefficients Eff.	Det.
1	24.10.60	0,25	0,420	0,280	0,90	-2,5	3,2	0,914	0,928
2	30.07.60	0,50	0,710	0,115	0,80	6,3	-25,7	0,831	0,850
3	2.06.61	No acceptable fit (rainfall spatially variable)							
4	31.07.62	0,25	0,830	0,110	0,80	4,7	-13,9	0,863	0,891
5	30.07.63	No acceptable fit (rainfall spatially variable)							
6	22.07.64	No acceptable fit (rainfall spatially variable)							
7	7.06.65	1,50	0,885	0,103	0,80	3,4	-3,8	0,910	0,942
8	19.10.66	1,25	0,620	0,260	0,90	-7,8	6,9	0,875	0,942
9	16.07.67	0,00	0,697	0,204	0,80	-6,0	6,2	0,803	0,875
10	11.09.68	0,00	0,705	0,163	0,80	3,3	-10,2	0,977	0,980
11	7.09.69	1,00	0,650	0,750	0,80	-5,5	-4,7	0,810	0,881
12	23.08.71	0,00	0,420	0,256	0,80	-2,3	-5,2	0,974	0,977
13	3.07.72	1,00	0,590	0,245	0,80	-8,3	3,2	0,921	0,946
14	10.07.72	0,00	0,506	0,255	0,80	-3,4	-2,2	0,945	0,952
15	17.09.73	0,25	0,528	0,233	0,80	3,5	-5,8	0,936	0,936
Mean						4,7	7,6	0,896	0,925
St. dev.						2,0	6,6	0,060	0,041

Other parameters: K(1) = 5,5 N(2) = 0,7 A(6) = 4,0 B(7) = 0,15
SMAX(8) = 150,0 IL(15) = 0,0

Table A2 Calibration results

Catchment North Danville, ND5 — Area 111,60km*km
Model Simple antecedent moisture model - OSE1 — Type Lumped

Storm No.	Date	Parameters DEL (5)	DA (9)	C (10)	APF (14)	% errors Volume	Peak	Coefficients Eff.	Det.
1	30.07.60	1,00	0,585	0,088	0,80	5,0	-21,5	0,882	0,892
2	2.06.61	0,00	0,585	0,060	0,80	-12,8	6,1	0,913	0,970
3	31.07.62	0,25	0,585	0,098	0,80	2,0	-3,9	0,965	0,972
4	30.07.63	No acceptable fit (rainfall spatially variable)							
5	22.07.64	0,00	0,600	0,230	0,80	3,0	-1,1	0,772	0,797
6	7.06.65	3,00	0,575	0,063	0,80	-9,1	10,9	0,924	0,970
7	19.10.66	0,25	0,620	0,240	0,90	-5,0	5,4	0,956	0,978
8	16.07.67	0,00	0,550	0,160	0,80	2,5	-0,2	0,859	0,884
9	11.09.68	0,00	0,575	0,126	0,80	1,9	-0,6	0,963	0,966
10	7.09.69	0,75	0,575	0,423	0,80	0,6	-0,8	0,936	0,963
11	23.08.71	0,00	0,605	0,281	0,80	-3,9	1,8	0,974	0,984
12	10.07.72	0,00	0,640	0,150	0,80	-4,9	-1,4	0,933	0,943
13	20.07.72	0,00	0,500	0,135	0,80	2,3	-2,0	0,893	0,909
14	14.07.73	No acceptable fit possible							
15	17.09.73	0,25	0,585	0,218	0,80	0,9	-8,9	0,938	0,938
Mean						4,1	5,1	0,916	0,936
St. dev.						3,4	5,9	0,055	0,053

Other parameters: K(1) = 6,0 N(2) = 0,7 DEL(5) = 0,5 A(6) = 5,5
B(7) = 0,15 SMAX(8) = 150,0 IL(15) = 0,1

Table A3 Calibration results

Catchment Ecca, Q9M21 Area 9,1km^2
Model Simple antecedent moisture model - OSE1 Type Lumped

Storm No.	Date	K (1)	A (6)	DA (9)	C (10)	APF (14)	IL (15)	% errors Volume	% errors Peak	Coefficients Eff.	Coefficients Det.
1	28.02.77	0,5	0,5	0,170	0,880	0,90	1,0	9,0	-19,9	0,806	0,815
2	6.03.77	No acceptable fit (rainfall spatially variable)									
3	7.05.77	2,5	1,5	0,700	0,100	0,85	40,0	-18,4	-21,5	0,836	0,836
4	19.04.78	Not modelled (suspect data)									
5	21.04.78	3,0	0,5	0,160	0,560	0,95	10,0	-0,9	-0,4	0,660	0,779
* 6	20.07.79	7,5	0,5	0,950	0,028	0,95	58,0	-15,4	-4,9	0,773	0,794
* 7	23.07.79	10,0	1,5	0,190	0,510	0,95	0,1	-4,3	-3,8	0,952	0,975
* 8	19.08.79	17,0	5,0	0,600	0,095	0,90	25,0	1,7	-0,7	0,897	0,912
9	26.03.81	2,0	1,0	0,120	0,690	0,90	1,0	13,6	-14,4	0,409	0,524
10	22.10.81	Not modelled (zero flow)									
11	23.12.81	1,0	1,5	0,400	0,120	0,85	15,0	2,1	-21,5	0,710	0,729
*12	2.11.85	11,5	1,5	0,490	0,560	0,90	1,0	-6,9	-9,3	0,927	0,957
13	25.11.85	Not modelled (missing data)									
14	1.12.85	3,5	1,5	0,250	0,500	0,90	1,0	-0,1	1,3	0,977	0,984
15	3.12.85	Not modelled (data errors)									
Mean								7,2	9,8	0,795	0,831
St. dev.								6,6	8,8	0,171	0,140

Other parameters: N(2) = 0,7 DEL(5) = 0,0 SMAX(8) = 200,0
* 'Large' storm events.

Table A4 Calibration results

Catchment Ecca, Q9M20 Area 73,9km*km
Model Simple antecedent moisture model - OSE1 Type Lumped

Storm No.	Date	DEL (5)	K (1)	A (6)	DA (9)	C (10)	APF (14)	IL (15)	% errors Vol.	% errors Peak	Coefficients Eff.	Coefficients Det.
1	28.02.77	0,0	3,0	2,0	0,147	0,600	0,90	1,0	-4,6	1,2	0,915	0,923
2	6.03.77	No acceptable fit (rainfall spatially variable)										
3	7.05.77	0,0	2,5	3,0	0,260	0,420	0,90	25,0	-4,0	1,4	0,735	0,742
4	19.04.78	0,0	2,5	2,5	0,250	0,380	0,90	22,0	-7,5	-4,3	0,845	0,847
5	21.04.78	0,0	6,0	1,0	0,170	0,495	0,95	1,0	-3,6	0,8	0,790	0,878
* 6	20.07.79	1,5	9,0	4,5	0,940	0,030	0,95	50,0	-15,6	15,1	0,744	0,770
* 7	23.07.79	1,5	10,0	6,5	0,265	0,500	0,95	1,0	-3,9	-5,8	0,949	0,962
* 8	19.08.79	1,5	10,0	7,0	0,660	0,095	0,90	30,0	-10,8	-1,6	0,861	0,887
9	26.03.81	0,0	5,0	1,5	0,095	0,600	0,90	1,0	15,8	-11,6	0,923	0,955
10	22.10.81	0,0	5,5	2,0	0,450	0,130	0,85	1,0	-1,6	-4,4	0,871	0,884
11	23.12.81	0,0	1,5	2,0	0,350	0,180	0,85	16,0	5,3	-12,2	0,957	0,959
*12	2.08.85	1,5	11,5	5,5	0,610	0,580	0,90	1,0	-1,7	-6,6	0,934	0,943
13	25.08.85	Not modelled										
14	1.12.85	1,0	4,5	4,0	0,350	0,380	0,90	1,0	2,2	-18,7	0,819	0,832
15	3.12.85	Not modelled (data errors)										
Mean									6,4	7,0	0,862	0,882
St. dev.									5,1	6,0	0,077	0,073

Other parameters: N(2) = 0,7 B(7) = 0,15 SMAX = 200,0
* 'Large' events

Table A5 Calibration results

Catchment North Danville, ND1 Area 42,96km*km
Model Simple antecedent moisture model - OSE1 Type Semi-distributed

Storm No.	Date	Parameters CDEL (3)	DA (9)	C (10)	APF (14)	% errors Volume	Peak	Coefficients Eff.	Det.
1	24.10.60	1,50	0,560	0,310	0,90	-1,1	0,4	0,929	0,936
2	30.07.60	1,75	0,613	0,090	0,80	26,2	-14,2	0,732	0,816
3	2.06.61	1,75	0,545	0,056	0,80	-11,9	9,6	0,867	0,943
4	31.07.62	1,75	0,650	0,095	0,80	2,6	-21,7	0,884	
5	30.07.63	No acceptable fit (rainfall spatially variable)							
6	22.07.64	No acceptable fit (rainfall spatially variable)							
7	7.06.65	2,50	0,490	0,068	0,80	3,9	-5,2	0,862	0,894
8	19.10.66	4,00	0,570	0,237	0,90	-4,7	4,5	0,935	0,967
9	16.07.67	1,25	0,580	0,173	0,80	-7,2	7,3	0,857	
10	11.09.68	1,50	0,680	0,150	0,80	5,4	-12,8	0,972	0,978
11	7.09.69	No acceptable fit (rainfall spatially variable)							
12	23.08.71	1,25	0,630	0,328	0,80	-1,7	-7,4	0,992	0,993
13	3.07.72	2,50	0,435	0,200	0,80	-1,8	0,8	0,825	0,853
14	10.07.72	1,25	0,620	0,153	0,80	-2,0	-0,9	0,952	0,962
15	17.09.73	1,50	0,613	0,280	0,80	2,0	7,2	0,921	0,921
Mean						5,9	7,7	0,894	0,922
St. dev.						7,1	6,3	0,072	0,052

Other parameters: K(1) = 6,0 N(2) = 0,7 KC(4) = 0,80 SMAX(8) = 150,0 IL(15) = 0,0

Table A6 Sub-catchment parameter weighting factors

Catchment North Danville, ND1 Area 42,96km*km
Model Simple antecedent moisture model - OSE1 Type Semi-distributed

Sub-catchment No.	Area (%)	Parameters 3 CDEL	4 KC
1	19,5	1,00	0,50
2	13,4	0,50	0,75
3	18,0	0,75	0,90
4	19,6	1,25	0,65
5	16,9	0,50	0,70
6	12,6	0,00	1,00

Other parameters: K(1), N(2), SMAX(8), DA(9), C(10), APF(14), IL(15) all = 1,00.

Table A7 Calibration results

Catchment North Danville, ND5 | Area 111,60km*km
Model Simple antecedent moisture model - OSE1 | Type Semi-distributed

Storm No.	Date	Parameters CDEL (3)	DA (9)	C (10)	APF (14)	% errors Volume	Peak	Coefficients Eff.	Det.
1	30.07.60	1,75	0,620	0,090	0,80	9,0	-20,0	0,844	0,857
2	2.06.61	1,50	0,550	0,056	0,80	-10,7	10,7	0,889	0,970
3	31.07.62	1,25	0,585	0,100	0,80	-5,3	-11,7	0,960	0,968
4	30.07.63	No acceptable fit (rainfall spatially variable)							
5	22.07.64	1,00	0,630	0,263	0,80	-0,7	-1,9	0,926	0,931
6	7.06.65	2,00	0,585	0,095	0,80	2,2	-6,6	0,902	0,909
7	19.10.66	1,25	0,585	0,225	0,90	-4,6	1,0	0,960	0,976
8	16.07.67	1,25	0,585	0,160	0,80	-2,4	-4,2	0,930	0,937
9	11.09.68	1,25	0,585	0,125	0,80	1,7	0,5	0,954	0,960
10	7.09.69	No acceptable fit (rainfall spatially variable)							
11	23.08.71	1,25	0,560	0,267	0,80	-4,7	3,9	0,957	0,985
12	10.07.72	1,25	0,585	0,140	0,80	-8,7	4,5	0,924	0,954
13	20.07.72	1,50	0,585	0,148	0,80	1,9	-1,7	0,869	0,869
14	14.07.73	1,00	0,565	0,135	0,80	-5,6	2,9	0,971	0,994
15	17.09.73	1,50	0,585	0,215	0,80	-0,1	-8,6	0,917	0,918
Mean						4,4	6,0	0,923	0,941
St. dev.						3,4	5,5	0,042	0,043

Other parameters: K(1) = 6,0 N(2) = 0,7 KC(4) = 0,85 SMAX(8) = 150,0
L(15) = 0,0

Table A8 Sub-catchment parameter weighting factors

Catchment North Danville, ND5 | Area 111,60km*km
Model Simple antecedent moisture model - OSE1 | Type Semi-distributed

Sub-catchment No.	Area (%)	Parameters 3 CDEL	4 KC
1	7,5	1,50	0,80
2	5,2	1,00	0,87
3	6,9	1,25	1,35
4	7,5	1,55	0,85
5	6,5	1,00	0,77
6	4,8	0,50	0,73
7	5,2	1,00	0,97
8	5,6	0,75	0,45
9	4,3	0,50	0,67
10	7,7	2,25	0,65
11	4,9	2,00	0,70
12	4,9	1,50	1,00
13	4,4	2,25	0,95
14	7,5	1,75	1,05
15	4,6	1,25	0,75
16	5,4	0,75	0,80
17	2,0	0,00	0,37
18	5,1	0,00	0,50

Other parameters: K(1), N(2), SMAX(8), DA(9), C(10), APF(14),
IL(15) all = 1,00

Table A9 Calibration results

Catchment Ecca, Q9M20 Area 73,9km*km
Model Simple antecedent moisture model - OSE1 Type Semi-distributed

Storm No.	Date	Parameters K (1)	DA (9)	C (10)	APF (14)	IL (15)	% errors Volume	Peak	Coefficients Eff.	Det.
1	28.02.77	0,5	0,150	0,610	0,90	1,0	6,6	-4,8	0,944	0,960
2	6.03.77	0,5	0,200	0,330	0,90	1,0	5,7	-15,3	0,819	0,846
3	7.05.77	No acceptable fit								
4	19.04.78	0,5	0,250	0,360	0,90	30,0	1,1	-6,4	0,950	0,961
**5	21.04.78	1,0	0,130	0,510	0,95	1,0	-15,1	10,7	-0,367	-0,321
* 6	20.07.79	6,0	0,930	0,034	0,95	45,0	-23,4	-23,5	0,654	0,779
* 7	23.07.79	11,0	0,200	0,510	0,95	1,0	-1,9	-5,8	0,960	0,970
* 8	19.08.79	10,0	0,700	0,090	0,90	34,0	-8,1	-4,0	0,869	0,970
9	26.03.81	0,5	0,080	0,800	0,90	1,0	7,9	-7,4	0,795	0,825
10	22.10.81	2,0	0,370	0,160	0,85	1,0	-3,2	1,1	0,648	0,774
11	23.12.81	0,5	0,300	0,200	0,85	15,0	-14,8	-32,1	0,751	0,795
*12	2.08.85	11,0	0,610	0,580	0,90	1,0	-2,2	-4,0	0,962	0,972
13	25.11.85	Not modelled								
14	1.12.85	2,0	0,350	0,380	0,90	5,0	-16,6	4,1	0,670	0,881
15	3.12.85	Not modelled (data errors)								
Mean							13,7	9,5	0,508	0,714
St. dev.							14,4	11,5	0,452	0,201

Other parameters: N(2) = 0,7 CDEL(3) = 1,0 KC(4) = 0,8 SMAX(8) = 200,0
** Not included in mean and st. dev. calculations.
* 'Large' storm events.

Table A10 Sub-catchment parameter weighting factors

Catchment Ecca, Q9M20 Area 73,9km.sq
Model Simple antecedent moisture model - OSE1 Type Semi-distributed

Sub-catchment No.	Area (%)	Parameters 1 K	3 CDEL	4 KC	15 IL
1	13,5	1,00	5,25	0,80	1,50
2	5,9	0,92	4,50	0,90	1,50
3	5,6	0,92	4,50	0,90	1,50
4	7,0	0,92	4,00	1,00	1,50
5	6,4	0,90	4,00	0,75	1,50
6	7,0	0,90	4,00	0,75	1,50
7	11,4	0,85	3,00	0,50	1,30
8	7,9	0,80	2,75	0,60	1,20
9	6,0	0,65	2,25	0,96	1,10
10	9,7	0,95	1,25	1,40	0,95
11	12,9	1,05	0,75	1,00	0,90
12	7,4	0,80	0,75	0,60	0,85

Parameters: N(2), SMAX(8), DA(9), C(10), APF(14) all weights = 1,00
weights = 1,00

Table **A11** Calibration results

Catchment North Danville, **ND1** Area 42,94km^2
Model Augmented Hydrograph - **OSE3** Type **Lumped**

Storm No.	Date	Parameters ROP (3)	DEL (5)	% errors Volume	Peak	Coefficients Eff.	Det.
1	24.10.59	0,435	0,25	-0,9	7,1	0,991	0,991
2	30.07.60	0,090	1,00	7,3	-8,8	0,900	0,908
3	2.06.61	0,385	0,25	-1,8	0,1	0,974	0,975
4	31.07.62	0,238	0,50	6,6	-3,8	0,958	0,967
5	30.07.63	No acceptable fit (rainfall spatially variable)					
6	22.07.64	0,068	0,25	-2,0	5,9	0,284	0,511
7	7.06.65	0,165	1,75	5,3	0,3	0,945	0,958
8	19.10.66	0,135	0,75	-4,1	2,5	0,930	0,961
9	16.07.67	0,160	0,00	-2,4	-2,2	0,856	0,888
10	11.09.68	0,090	1,00	-3,2	-1,9	0,981	0,982
11	7.09.69	No acceptable fit (rainfall spatially variable)					
12	23.08.71	0,110	0,50	2,3	-1,5	0,963	0,970
13	3.07.72	0,240	1,25	3,0	0,1	0,967	0,969
14	10.07.72	0,140	0,50	-1,8	0,7	0,969	0,971
15	17.09.73	0,170	0,75	4,4	-6,8	0,977	0,980
Mean				3,5	3,2	0,899	0,925
St. dev.				2,0	3,0	0,189	0,128

Other parameters: N(3) = 0,5 A(6) = 4,0 B(7) = 0,15 K(8) = 15,0
IL(9) = 2,5

Table **A12** Calibration results

Catchment North Danville, **ND5** Area 111,60km}
Model Augmented hydrograph - **OSE3** Type **Lumped**

Storm No.	Date	Parameters ROP (3)	DEL (5)	% errors Volume	Peak	Coefficients Eff.	Det.
1	30.07.60	0,100	1,75	4,8	-2,4	0,925	0,929
2	2.06.61	0,370	0,25	-4,2	0,3	0,961	0,965
3	31.07.62	0,195	0,50	-0,9	8,2	0,986	0,988
4	30.07.61	No acceptable fit					
5	22.07.64	0,135	0,00	1,6	0,6	0,923	0,925
6	7.06.65	0,110	2,00	-0,6	-0,2	0,945	0,950
7	19.10.66	0,125	0,00	-1,2	4,9	0,945	0,957
8	16.07.67	0,190	0,00	5,7	-3,7	0,900	0,916
9	11.09.68	0,093	1,25	-9,0	8,4	0,968	0,983
10	7.09.69	0,215	1,00	1,8	-8,5	0,887	0,894
11	23.08.71	0,125	0,75	-2,5	4,6	0,985	0,993
12	10.07.72	0,160	0,75	-3,9	5,1	0,963	0,969
13	20.07.72	0,235	0,50	-0,7	0,8	0,966	0,967
14	14.07.73	0,300	0,00	4,4	-2,1	0,931	0,937
15	17.09.73	0,185	0,50	6,3	-2,6	0,950	0,958
Mean				3,4	2,9	0,945	0,952
St. dev.				2,5	2,6	0,029	0,029

Other parameters: N(4) = 0,5 A(6) = 5,0 B(7) = 0,15 K(8) = 15,0
IL(9) = 2,5

Table A13 Calibration results

Catchment Ecca, Q9M21 Area 9,1km²
Model Augmented Hydrograph - OSE3 Type Lumped

Storm No.	Date	Parameters ROP (3)	A (6)	K (8)	IL (9)	% errors Volume	Peak	Coefficients Eff.	Det.
1	28.02.77	0,018	1,0	3,0	1,0	9,5	-10,6	0,848	0,872
2	6.03.77	0,045	1,0	2,5	10,0	5,3	-6,8	0,866	0,868
3	7.05.77	0,190	2,0	6,0	40,0	-12,9	-18,9	0,870	0,892
4	19.04.78	Not modelled (suspect data)							
5	21.04.78	0,041	0,5	13,0	1,0	-1,6	3,9	0,664	0,771
* 6	20.07.79	0,310	1,5	23,0	50,0	1,2	2,9	0,832	0,841
* 7	23.07.79	0,435	1,5	16,0	1,0	-1,8	2,6	0,960	0,978
* 8	19.08.79	0,480	2,0	25,0	32,0	-5,6	9,4	0,938	0,967
9	26.03.81	0,014	1,0	6,5	1,0	-5,1	4,6	0,598	0,656
10	22.10.81	Not modelled (zero flow)							
*11	23.12.81	0,026	5,0	1,0	15,0	-2,7	-16,4	0,760	0,783
*12	2.11.85	0,305	1,5	20,0	1,0	-4,1	1,9	0,896	0,956
13	25.11.85	Not modelled (missing data)							
14	1.12.85	0,049	2,5	6,4	3,0	-0,0	-0,2	0,967	0,968
15	3.12.85	Not modelled (data errors)							
Mean						4,5	7,1	0,836	0,868
St. dev.						3,8	6,1	0,119	0,101

Other parameters: N(4) = 0,5 DEL(5) = 0,001 B(7) = 0,15
* 'Large' storm events.

Table A14 Calibration results

Catchment Ecca, Q9M20 Area 73,9km²
Model Augmented Hydrograph - OSE3 Type Lumped

Storm No.	Date	Parameters ROP (3)	DEL (5)	A (6)	K (8)	IL (9)	% errors Volume	Peak	Coefficients Eff.	Det.
1	28.02.77	0,029	0,00	2,5	13,5	0,0	-1,9	2,6	0,938	0,942
2	6.03.77	0,110	0,00	2,0	4,0	0,0	-0,2	3,0	0,737	0,830
3	7.05.77	0,022	0,00	6,0	9,0	30,0	-21,3	5,4	0,735	0,775
4	19.04.78	0,006	0,25	5,5	8,0	22,0	-0,3	-2,9	0,960	0,961
5	21.04.78	0,064	0,00	1,0	21,0	0,0	-4,2	-0,4	0,828	0,888
* 6	20.07.79	0,320	1,50	4,5	24,0	65,0	-1,0	2,1	0,876	0,879
* 7	23.07.79	0,470	1,25	7,0	15,0	0,0	-0,6	-0,7	0,950	0,900
* 8	19.08.79	0,540	1,50	8,0	16,0	32,0	-6,5	1,8	0,917	0,936
9	26.03.81	0,008	0,00	4,0	8,5	0,0	2,2	-1,2	0,938	0,939
10	22.10.81	0,030	0,00	5,0	10,0	0,0	-16,7	14,4	0,356	0,694
11	23.12.81	0,007	0,50	5,5	6,0	11,0	0,3	-3,5	0,979	0,980
*12	2.11.85	0,300	1,25	7,5	16,5	0,0	-6,8	2,5	0,928	0,962
13	25.11.85	Not modelled								
14	1.12.85	0,130	1,00	5,5	9,0	0,0	-3,9	-23,8	0,821	0,825
15	3.12.85	Not modelled (data errors)								
Mean		0,159					5,1	4,9	0,843	0,885
St. dev.		0,180					6,6	6,7	0,167	0,084

Other parameters: N(4) = 0,5 B(7) = 0,15
* 'Large' storm events.

Table A15 Calibration results

Catchment North Danville, ND1 Area $42,94km^2$
Model Augmented Hydrograph - OSE3 Type Semi-distributed

Storm No.	Date	Parameters ROP (3)	% errors Volume	Peak	Coefficients Eff.	Det.
1	24.10.59	0,438	-3,8	2,5	0,987	0,991
2	30.07.60	0,090	11,6	-10,8	0,869	0,886
3	2.06.61	0,405	0,9	3,7	0,983	0,989
4	31.07.62	0,230	2,4	-10,5	0,972	0,973
5	30.07.63	No acceptable fit (rainfall spatially variable)				
*6	22.07.64	0,100	-1,4	-0,9	0,043	0,378
7	7.06.65	0,190	7,5	-6,6	0,906	0,915
8	19.10.66	0,148	-2,1	-0,3	0,967	0,986
9	16.07.67	0,198	-5,3	-12,3	0,871	0,883
10	11.09.68	0,095	1,7	-2,7	0,996	0,997
11	7.09.69	No acceptable fit (rainfall spatially variable)				
12	23.08.71	0,091	-1,3	-1,3	0,972	0,984
13	3.07.72	0,242	-1,3	-12,6	0,797	0,779
14	10.07.72	0,168	2,7	-0,6	0,957	0,966
15	17.09.73	0,165	1,9	-7,0	0,972	0,972
Mean			3,4	5,5	0,934	0,943
St. dev.			3,1	4,7	0,062	0,066

Other parameters: CDEL(1) = 1,0 KC(2) = 0,80 N(4) = 0,5 K(8) = 15,0
IL(9) = 2,5

*Does not include the result for storm 6.

Table A16 Sub-catchment parameter weighting factors

Catchment North Danville, ND1 Area $42,94km^2$
Model Augmented Hydrograph - OSE3 Type Semi-distributed

Sub-catchment No.	Area %	Parameters 1 CDEL	2 KC
1	19,5	1,00	0,50
2	13,4	0,50	0,75
3	18,0	0,75	0,90
4	19,6	1,25	0,65
5	16,9	0,50	0,70
6	12,6	0,00	1,00

Parameters: ROP(3), N(4), K(8), IL(9) all weights = 1,00.

Table A17 Calibration results

Catchment North Danville, ND5 Area 111,60km}
Model Augmented hydrograph - OSE3 Type Semi-distributed

Storm No.	Date	Parameters ROP (3)	% errors Volume	Peak	Coefficients Eff.	Det.
1	30.07.60	0,100	6,8	-6,8	0,838	0,859
2	2.06.61	0,385	1,2	10,1	0,938	0,960
3	31.07.62	0,205	-0,1	0,9	0,994	0,995
4	30.07.61	No acceptable fit				
5	22.07.64	0,101	-1,5	2,7	0,901	0,914
6	7.06.65	0,120	-0,9	-9,6	0,911	0,912
7	19.10.66	0,125	-1,6	3,9	0,965	0,968
8	16.07.67	0,170	0,3	3,2	0,947	0,958
9	11.09.68	0,100	-6,8	0,0	0,981	0,988
10	7.09.69	0,080	0,2	-0,1	0,718	0,773
11	23.08.71	0,125	-1,2	1,0	0,976	0,983
12	10.07.72	0,205	2,6	2,8	0,978	0,985
13	20.07.72	0,238	1,4	3,6	0,937	0,949
14	14.07.73	0,270	2,8	1,7	0,871	0,881
15	17.09.73	0,195	1,7	-2,9	0,978	0,980
Mean			2,1	3,5	0,924	0,936
St. dev.			2,1	3,2	0,075	0,063

Other parameters: CDEL(1) = 1,0 KC(2) = 0,85 N(4) = 0,5 K(8) = 15,0
IL(9) = 2,5

Table A18 Sub-catchment parameter weighting factors

Catchment North Danville, ND5 Area 73,9km}
Model Augmented Hydrograph - OSE3 Type Semi-distributed

Sub-catchment No.	Area (%)	Parameters 1 CDEL	2 KC
1	7,5	1,50	0,50
2	5,2	1,00	0,70
3	6,9	1,25	0,85
4	7,5	1,55	0,60
5	6,5	1,00	0,65
6	4,8	0,50	0,95
7	5,2	1,00	0,55
8	5,6	0,75	0,25
9	4,3	0,50	0,55
10	7,7	2,25	0,45
11	4,9	2,00	0,55
12	4,9	1,50	0,90
13	4,4	2,25	0,50
14	7,5	1,75	0,65
15	4,6	1,25	0,40
16	5,4	0,75	1,05
17	2,0	0,00	0,15
18	5,1	0,00	1,00

Parameters: ROP(3), N(4), K(8), IL(9) all weights = 1,0.

Table A19 Calibration results

Catchment Ecca, Q9M20 Area 73,9km^2
Model Augmented Hydrograph - OSE3 Type Semi-distributed

Storm No.	Date	Parameters CDEL (1)	ROP (3)	K (8)	IL (9)	% errors: Volume	Peak	Coefficients Eff.	Det.
1	28.02.77	0,5	0,022	5,0	20,0	-3,8	3,5	0,889	0,909
2	6.03.77	1,0	0,095	3,5	6,0	-6,5	-3,4	0,744	0,846
3	7.05.77	0,5	0,062	7,5	30,0	-3,4	0,3	0,807	0,819
4	19.04.78	0,5	0,010	4,5	22,0	12,1	-7,5	0,944	0,949
**5	21.04.78	0,5	0,030	5,0	1,0	-25,1	9,4	-0,438	0,587
* 6	20.07.79	1,0	0,350	16,0	65,0	-0,7	-13,8	0,910	0,915
* 7	23.07.79	1,0	0,410	16,0	0,0	0,2	1,9	0,966	0,933
* 8	19.08.79	1,0	0,580	17,0	32,0	-6,7	-1,2	0,953	0,966
9	26.03.81	0,5	0,008	3,0	0,0	9,8	-12,3	0,950	0,962
10	22.10.81	0,5	0,028	9,0	10,0	-2,8	11,1	0,493	0,736
11	23.12.81	0,5	0,007	1,0	13,0	4,0	-11,2	0,747	0,783
*12	2.11.85	1,0	0,310	18,0	0,0	-3,4	0,8	0,949	0,972
13	25.11.85	Not modelled							
14	1.12.85	0,5	0,130	9,5	4,0	-0,5	-3,7	0,898	0,925
15	3.12.85	Not modelled (data errors)							
Mean			0,157			6,1	6,2	0,854	0,868
St. dev.			0,190			6,7	4,9	0,138	
0,113									

Other parameters: KC(2) = 0,8 N(4) = 0,5
** Does not include the result for storm 5.
* 'Large' storm events.

Table A20 Sub-catchment parameter weighting factors

Catchment Ecca, Q9M20 Area 73,9km^2
Model Augmented Hydrograph - OSE3 Type Semi-distributed

Sub-catchment No.	Area (%)	Parameters 1 CDEL	2 KC	8 K	9 IL
1	13,0	5,25	0,80	1,00	1,50
2	5,9	4,50	0,90	0,92	1,50
3	5,6	4,50	0,90	0,92	1,50
4	7,0	4,00	1,00	0,92	1,50
5	6,4	4,00	0,75	0,90	1,50
6	7,0	4,00	0,75	0,90	1,50
7	11,4	3,00	0,50	0,85	1,30
8	7,9	2,75	0,60	0,80	1,20
9	6,0	2,25	0,96	0,65	1,10
10	9,7	1,25	1,40	0,95	0,95
11	12,9	0,75	1,00	1,05	0,90
12	7,4	0,75	0,60	0,80	0,85

Parameters ROP(3), N(4) all weights = 1,00

APPENDIX B

Computer listing of the semi-distributed model parameters used in calibration and validation (derived from relationships with physical characteristics) runs.

Model OSE1	Calibration parameters
	Validation parameters
Model OSE3	Calibration parameters
	Validation parameters

OSE1-CALIBRATION PARAMETERS

Area	ID	1 K	2 N	3 CDEL	4 KC	5 SMAX	6 DA	7 C	8 APF	9 IL
TM11	1	0.100	0.700	0.240	0.100	200.000	0.400	0.191	0.900	0.000
TM11	2	0.100	0.700	0.240	0.100	200.000	0.400	0.191	0.900	0.000
TM11	3	0.100	0.700	0.160	0.100	200.000	0.400	0.191	0.900	0.000
TM8	4	0.100	0.700	0.240	0.100	200.000	0.400	0.350	0.900	0.000
TM8	5	0.100	0.700	0.240	0.100	200.000	0.400	0.350	0.900	0.000
TM8	6	0.100	0.700	0.160	0.100	200.000	0.400	0.350	0.900	0.000
TM8	7	0.100	0.700	0.080	0.100	200.000	0.400	0.350	0.900	0.000
TM3	1	0.100	0.700	0.320	0.100	200.000	0.400	0.413	0.900	0.000
TM3	2	0.100	0.700	0.240	0.100	200.000	0.400	0.413	0.900	0.000
TM3	3	0.100	0.700	0.160	0.100	200.000	0.400	0.413	0.900	0.000
TM3	4	0.100	0.700	0.160	0.100	200.000	0.400	0.413	0.900	0.000
TM6	1	0.100	0.700	0.640	0.400	190.000	0.400	0.319	0.900	0.000
TM6	2	0.100	0.700	0.480	0.400	200.000	0.400	0.319	0.900	0.000
TM6	3	0.100	0.700	0.560	0.400	180.000	0.400	0.319	0.900	0.000
TM6	4	0.100	0.700	0.640	0.400	196.000	0.400	0.319	0.900	0.000
TM6	5	0.100	0.700	0.480	0.400	190.000	0.400	0.319	0.900	0.000
TM6	6	0.100	0.700	0.320	0.400	196.000	0.400	0.319	0.900	0.000
TM6	7	0.100	0.700	0.320	0.400	180.000	0.400	0.319	0.900	0.000
TM6	8	0.100	0.700	0.240	0.400	196.000	0.400	0.319	0.900	0.000
TM2	10	0.200	0.700	0.320	0.500	180.000	0.400	0.319	0.900	0.000
TM1	11	0.200	0.700	0.640	0.500	140.000	0.400	0.319	0.900	0.000
TM1	12	0.200	0.700	0.560	0.500	190.000	0.400	0.319	0.900	0.000
TM1	13	0.200	0.700	0.320	0.500	160.000	0.400	0.319	0.900	0.000
ECCA	1	6.000	0.700	5.250	0.640	200.000	0.230	0.400	0.920	1.000
ECCA	2	6.000	0.700	4.500	0.720	200.000	0.230	0.400	0.920	1.000
ECCA	3	6.000	0.700	4.500	0.720	200.000	0.230	0.400	0.920	1.000
ECCA	4	6.000	0.700	4.000	0.800	200.000	0.230	0.400	0.920	1.000
ECCA	5	6.000	0.700	4.000	0.600	200.000	0.230	0.400	0.920	1.000
ECCA	6	6.000	0.700	4.000	0.600	200.000	0.230	0.400	0.920	1.000
ECCA	7	6.000	0.700	3.000	0.400	200.000	0.230	0.400	0.920	1.000
ECCA	8	6.000	0.700	2.750	0.480	200.000	0.230	0.400	0.920	1.000
ECCA	9	6.000	0.700	2.250	0.768	200.000	0.230	0.400	0.920	1.000
ECCA	10	6.000	0.700	1.250	0.800	200.000	0.230	0.400	0.920	1.000
ECCA	11	6.000	0.700	0.750	0.480	200.000	0.230	0.400	0.920	1.000
ECCA	12	6.000	0.700	0.750	0.480	200.000	0.230	0.400	0.920	1.000
BETH	1	4.000	0.700	3.250	0.800	120.000	0.350	0.400	0.800	0.000
BETH	2	4.000	0.700	2.750	0.800	120.000	0.350	0.400	0.800	0.000
BETH	3	4.000	0.700	3.000	0.800	120.000	0.350	0.400	0.800	0.000
BETH	4	4.000	0.700	2.500	0.800	120.000	0.350	0.400	0.800	0.000
BETH	5	4.000	0.700	2.000	0.800	120.000	0.350	0.400	0.800	0.000
BETH	6	4.000	0.700	2.250	0.800	120.000	0.350	0.400	0.800	0.000
BETH	7	4.000	0.700	1.500	0.800	120.000	0.350	0.400	0.800	0.000
BETH	8	4.000	0.700	1.250	0.800	120.000	0.350	0.400	0.800	0.000
BETH	9	4.000	0.700	0.500	0.800	120.000	0.350	0.400	0.800	0.000
HOEK	1	1.800	0.700	0.750	0.720	120.000	0.300	0.400	0.850	0.000
HOEK	2	1.000	0.700	0.500	0.400	120.000	0.300	0.400	0.850	0.000
HOEK	3	1.200	0.700	0.750	0.400	120.000	0.300	0.400	0.850	0.000
HOEK	4	1.200	0.700	0.750	0.480	120.000	0.300	0.400	0.850	0.000
HOEK	5	1.200	0.700	0.750	0.480	120.000	0.300	0.400	0.850	0.000
HOEK	6	1.400	0.700	0.500	0.560	120.000	0.300	0.400	0.850	0.000
HOEK	7	1.000	0.700	0.000	0.560	120.000	0.300	0.400	0.850	0.000
HOEK	8	1.200	0.700	0.250	0.480	120.000	0.300	0.400	0.850	0.000
HOEK	9	1.200	0.700	0.250	0.480	120.000	0.300	0.400	0.850	0.000
CED	1	1.500	0.700	0.500	0.400	250.000	0.130	0.300	0.900	0.000
CED	2	1.500	0.700	0.500	0.400	250.000	0.130	0.300	0.900	0.000
CED	3	1.500	0.700	0.250	0.400	250.000	0.130	0.300	0.900	0.000

Area ID	1 K	2 N	3 CDEL	4 KC	5 SMAX	6 DA	7 C	8 APF	9 IL
ZULU 1	6.000	0.700	0.750	0.400	260.000	0.500	0.125	0.850	0.000
ZULU 2	6.000	0.700	0.500	0.400	260.000	0.500	0.125	0.850	0.000
ZULU 3	3.600	0.700	0.250	0.320	145.600	0.290	0.200	0.850	0.000
ZULU 4	3.600	0.700	0.250	0.160	145.600	0.290	0.200	0.832	0.000
ZULU 5	1.200	0.700	0.250	0.200	70.200	0.755	0.001	0.832	0.000
ZULU 6	1.500	0.700	0.250	0.240	98.800	0.700	0.250	0.832	0.000
ZULU 7	1.500	0.700	0.250	0.280	98.800	0.700	0.250	0.832	0.000
ZULU 8	3.600	0.700	0.000	0.160	150.800	0.290	0.200	0.850	0.000
ZULU 9	3.600	0.700	0.000	0.320	150.800	0.290	0.200	0.850	0.000
ZULU 10	3.600	0.700	0.250	0.400	150.800	0.290	0.200	0.850	0.000
OX4W 1	0.900	0.700	0.850	0.500	170.000	0.600	0.225	0.900	0.000
OX4W 2	1.000	0.700	0.510	0.500	170.000	0.600	0.225	0.900	0.000
OX4S 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX4S 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX12W 1	1.200	0.700	1.530	0.700	170.000	0.600	0.300	0.900	0.000
OX12W 2	1.200	0.700	1.530	0.700	170.000	0.600	0.300	0.900	0.000
OX12W 3	1.050	0.790	1.700	0.500	170.000	0.600	0.400	0.900	0.000
OX12W 4	1.350	0.700	1.530	0.600	170.000	0.600	0.250	0.900	0.000
OX12W 5	1.500	0.700	0.850	0.700	170.000	0.600	0.250	0.900	0.000
OX12W 7	1.500	0.700	1.190	0.800	170.000	0.600	0.230	0.900	0.000
OX12W 8	1.350	0.700	1.700	0.600	170.000	0.600	0.300	0.900	0.000
OX12W 9	1.050	0.700	1.190	0.600	170.000	0.600	0.250	0.900	0.000
OX12W 10	1.425	0.700	0.680	0.700	170.000	0.600	0.230	0.900	0.000
OX12W 11	1.050	0.700	1.360	0.500	170.000	0.600	0.200	0.900	0.000
OX12W 12	1.500	0.700	1.020	0.800	170.000	0.600	0.230	0.900	0.000
OX12P 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX12P 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX12P 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX12P 4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX12P 5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX12P 7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX12P 8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX12P 9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX12P 10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX12P 11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX12P 12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX12S 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX12S 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX12S 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX12S 4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX12S 5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX12S 7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX12S 8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX12S 9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX12S 10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX12S 11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX12S 12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX10W 1	1.125	0.700	0.680	0.600	170.000	0.600	2.200	0.900	0.000
OX10W 2	1.125	0.700	0.680	0.200	170.000	0.600	2.200	0.900	0.000
OX10W 3	1.050	0.700	0.510	0.200	170.000	0.600	2.200	0.900	0.000
OX10W 4	1.050	0.700	0.340	0.400	170.000	0.600	2.200	0.900	0.000
OX10W 5	1.005	0.700	0.340	0.200	170.000	0.600	2.200	0.900	0.000
OX10P 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX10P 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX10P 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX10P 4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX10P 5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX10S 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX10S 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000

Area ID	1 K	2 N	3 CDEL	4 KC	5 SMAX	6 DA	7 C	8 APF	9 IL
OX10S 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX10S 4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX10S 5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX35W 1	1.050	0.700	1.190	0.500	170.000	0.600	0.180	0.900	0.000
OX35W 2	1.125	0.700	1.020	0.500	170.000	0.600	0.180	0.900	0.000
OX35W 3	1.005	0.700	1.020	0.400	170.000	0.600	0.180	0.900	0.000
OX35W 4	1.050	0.700	0.850	0.500	170.000	0.600	0.180	0.900	0.000
OX35W 5	1.050	0.700	0.850	0.400	170.000	0.600	0.180	0.900	0.000
OX35W 6	1.125	0.700	0.680	0.500	170.000	0.600	0.180	0.900	0.000
OX35W 7	1.050	0.700	0.510	0.500	170.000	0.600	0.180	0.900	0.000
OX35W 8	1.050	0.700	0.340	0.500	170.000	0.600	0.180	0.900	0.000
OX35P 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX35P 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX35P 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX35P 4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX35P 5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX35P 6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX35P 7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX35P 8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX35S 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX35S 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX35S 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX35S 4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX35S 5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX35S 6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX35S 7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX35S 8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX17W 11	1.200	0.700	1.360	0.600	170.000	0.600	0.200	0.900	0.000
OX17W 12	1.200	0.700	0.850	0.600	170.000	0.600	0.180	0.900	0.000
OX17W 13	1.200	0.700	0.340	0.700	170.000	0.600	0.180	0.900	0.000
OX17W 14	1.200	0.700	1.020	0.700	170.000	0.600	0.200	0.900	0.000
OX17W 15	1.350	0.700	0.510	0.700	170.000	0.600	0.180	0.900	0.000
OX17W 16	1.200	0.700	0.510	0.600	170.000	0.600	0.180	0.900	0.000
OX17P 11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX17P 12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX17P 13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX17P 14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX17P 15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX17P 16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX17S 11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX17S 12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX17S 13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX17S 14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX17S 15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX17S 16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX32W 9	1.050	0.700	1.360	0.500	170.000	0.600	0.160	0.900	0.000
OX32W 10	1.050	0.700	1.020	0.500	170.000	0.600	0.160	0.900	0.000
OX32W 11	1.050	0.700	0.680	0.500	170.000	0.600	0.160	0.900	0.000
OX32W 12	1.050	0.700	0.340	0.500	170.000	0.600	0.160	0.900	0.000
OX32W 18	1.050	0.700	0.340	0.500	170.000	0.600	0.160	0.900	0.000
OX32P 9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX32P 10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX32P 11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX32P 12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX32P 18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.000
OX32S 9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX32S 10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX32S 11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX32S 12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000
OX32S 18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.850	0.000

Area ID	1 K	2 N	3 CDEL	4 KC	5 SMAX	6 DA	7 C	8 APF	9 IL
KAAI 1	5.600	0.700	2.750	0.420	210.000	0.700	0.200	0.950	0.000
KAAI 2	5.600	0.700	2.000	0.420	210.000	0.700	0.200	0.950	0.000
KAAI 3	5.600	0.700	2.250	0.420	210.000	0.700	0.200	0.950	0.000
KAAI 4	5.600	0.700	2.250	0.480	210.000	0.700	0.200	0.950	0.000
KAAI 5	6.300	0.700	1.500	0.540	210.000	0.700	0.200	0.950	0.000
KAAI 6	7.000	0.700	1.250	0.540	231.000	0.700	0.220	0.950	0.000
KAAI 7	7.700	0.700	1.000	0.600	241.500	0.700	0.230	0.950	0.000
KAAI 8	7.700	0.700	0.500	0.600	241.500	0.700	0.230	0.950	0.000
KAAI 9	6.300	0.700	0.500	0.600	252.000	0.700	0.230	0.950	0.000
MALG 1	4.800	0.700	1.500	0.480	200.000	0.650	0.150	0.950	0.000
MALG 2	4.800	0.700	1.500	0.480	200.000	0.650	0.150	0.950	0.000
MALG 3	4.800	0.700	1.250	0.480	200.000	0.650	0.150	0.950	0.000
MALG 4	4.800	0.700	1.000	0.480	200.000	0.650	0.150	0.950	0.000
MALG 5	4.800	0.700	1.000	0.480	200.000	0.650	0.150	0.950	0.000
MALG 6	5.400	0.700	1.000	0.560	200.000	0.650	0.150	0.950	0.000
MALG 7	6.000	0.700	0.500	0.640	200.000	0.650	0.150	0.950	0.000
MALG 8	6.000	0.700	0.500	0.640	200.000	0.650	0.150	0.950	0.000
NDAN5 1	6.000	0.700	1.500	0.680	210.000	0.400	0.200	0.850	0.000
NDAN5 2	6.000	0.700	1.000	0.740	210.000	0.400	0.200	0.850	0.000
NDAN5 3	6.000	0.700	1.250	1.148	210.000	0.400	0.200	0.850	0.000
NDAN5 4	6.000	0.700	1.550	0.723	210.000	0.400	0.200	0.850	0.000
NDAN5 5	6.000	0.700	1.000	0.655	210.000	0.400	0.200	0.850	0.000
NDAN5 6	6.000	0.700	0.500	0.620	210.000	0.400	0.200	0.850	0.000
NDAN5 7	6.000	0.700	1.000	0.825	210.000	0.400	0.200	0.850	0.000
NDAN5 8	6.000	0.700	0.750	0.382	210.000	0.400	0.200	0.850	0.000
NDAN5 9	6.000	0.700	0.500	0.570	210.000	0.400	0.200	0.850	0.000
NDAN5 9	6.000	0.700	0.500	0.570	210.000	0.400	0.200	0.850	0.000
NDAN5 10	6.000	0.700	2.250	0.553	210.000	0.400	0.200	0.850	0.000
NDAN5 11	6.000	0.700	2.000	0.595	210.000	0.400	0.200	0.850	0.000
NDAN5 13	6.000	0.700	2.250	0.808	210.000	0.400	0.200	0.850	0.000
NDAN5 14	6.000	0.700	1.750	0.892	210.000	0.400	0.200	0.850	0.000
NDAN5 15	6.000	0.700	1.250	0.638	210.000	0.400	0.200	0.900	0.000
NDAN5 16	6.000	0.700	0.750	0.680	210.000	0.400	0.200	0.900	0.000
NDAN5 17	6.000	0.700	0.000	0.315	210.000	0.400	0.200	0.900	0.000
NDAN5 18	6.000	0.700	0.000	0.425	210.000	0.400	0.200	0.900	0.000

OSE1-VALIDATION PARAMETERS

AREA	ID	1 K	2 N	3 CDEL	4 KC	5 SMAX	6 DA	7 C	8 APF	9 IL
TM11	1	0.100	0.700	0.240	0.530	193.000	0.400	0.146	0.820	0.000
TM11	2	0.100	0.700	0.240	0.650	193.000	0.400	0.146	0.820	0.000
TM11	3	0.100	0.700	0.160	0.590	193.000	0.400	0.146	0.820	0.000
TM8	4	0.100	0.700	0.240	0.360	193.000	0.400	0.197	0.820	0.000
TM8	5	0.100	0.700	0.240	0.430	193.000	0.400	0.197	0.820	0.000
TM8	6	0.100	0.700	0.160	0.430	193.000	0.400	0.197	0.820	0.000
TM8	7	0.100	0.700	0.080	0.570	193.000	0.400	0.197	0.820	0.000
TM3	1	0.100	0.700	0.320	0.520	193.000	0.400	0.166	0.820	0.000
TM3	2	0.100	0.700	0.240	0.630	193.000	0.400	0.166	0.820	0.000
TM3	3	0.100	0.700	0.160	0.270	193.000	0.400	0.166	0.820	0.000
TM3	4	0.100	0.700	0.160	0.430	193.000	0.400	0.166	0.820	0.000
TM6	1	0.100	0.700	0.640	1.290	193.000	0.430	0.276	0.820	0.000
TM6	2	0.100	0.700	0.480	0.910	193.000	0.400	0.304	0.820	0.000
TM6	3	0.100	0.700	0.560	1.100	193.000	0.400	0.304	0.820	0.000
TM6	4	0.100	0.700	0.640	1.290	165.100	0.400	0.304	0.820	0.000
TM6	5	0.100	0.700	0.480	0.480	193.000	0.400	0.304	0.820	0.000
TM6	6	0.100	0.700	0.320	0.590	193.000	0.400	0.304	0.820	0.000
TM6	7	0.100	0.700	0.320	0.600	146.100	0.490	0.219	0.820	0.000
TM6	8	0.100	0.700	0.240	0.760	193.000	0.400	0.333	0.820	0.000
TM2	10	0.200	0.700	0.320	1.060	193.000	0.430	0.269	0.820	0.000
TM1	11	0.200	0.700	0.640	0.710	146.100	0.440	0.228	0.820	0.000
TM1	12	0.200	0.700	0.560	0.820	193.000	0.430	0.265	0.820	0.000
TM1	13	0.200	0.700	0.320	0.880	193.000	0.470	0.243	0.820	0.000
ECCA	1	3.200	0.700	5.250	0.620	235.000	0.280	0.432	0.940	1.000
ECCA	2	3.200	0.700	4.500	0.820	178.400	0.280	0.432	0.940	1.000
ECCA	3	3.200	0.700	4.500	0.690	178.400	0.280	0.432	0.940	1.000
ECCA	4	2.300	0.700	4.000	0.770	159.400	0.340	0.240	0.940	1.000
ECCA	5	2.600	0.700	4.000	0.650	159.400	0.300	0.336	0.940	1.000
ECCA	6	2.600	0.700	4.000	0.540	159.400	0.300	0.336	0.940	1.000
ECCA	7	2.300	0.700	3.000	0.690	159.400	0.240	0.624	0.940	1.000
ECCA	8	2.300	0.700	2.750	0.620	159.400	0.240	0.672	0.940	1.000
ECCA	9	2.000	0.700	2.250	0.540	159.400	0.260	0.576	0.940	1.000
ECCA	10	2.300	0.700	1.250	1.000	200.000	0.260	0.576	0.940	1.000
ECCA	11	2.000	0.700	0.750	0.870	159.400	0.270	0.600	0.940	1.000
ECCA	12	3.200	0.700	0.750	0.820	200.000	0.280	0.432	0.940	1.000
BETH	1	4.000	0.700	3.250	0.740	125.200	0.300	0.300	0.830	0.000
BETH	2	3.780	0.700	2.750	0.800	125.200	0.300	0.300	0.830	0.000
BETH	3	4.630	0.700	3.000	0.800	125.200	0.280	0.300	0.830	0.000
BETH	4	4.630	0.700	2.500	0.860	125.200	0.280	0.300	0.830	0.000
BETH	5	3.400	0.700	2.000	0.860	125.200	0.321	0.214	0.830	0.000
BETH	6	3.780	0.700	2.250	0.990	125.200	0.300	0.300	0.830	0.000
BETH	7	3.780	0.700	1.500	0.448	125.200	0.300	0.300	0.830	0.000
BETH	8	3.400	0.700	1.250	0.680	125.200	0.321	0.214	0.830	0.000
BETH	9	4.630	0.700	0.500	0.680	125.200	0.280	0.300	0.830	0.000
HOEK	1	2.700	0.700	0.750	0.170	206.900	0.490	0.350	0.807	0.000
HOEK	2	0.520	0.700	0.500	0.440	105.000	0.440	0.297	0.850	0.000
HOEK	3	1.200	0.700	0.750	0.680	175.000	0.490	0.181	0.859	0.000
HOEK	4	1.200	0.700	0.750	0.530	195.000	0.500	0.181	0.859	0.000
HOEK	5	1.200	0.700	0.750	0.250	175.000	0.450	0.194	0.859	0.000
HOEK	6	3.500	0.700	0.500	0.560	222.000	0.400	0.334	0.867	0.000
HOEK	7	0.520	0.700	0.000	0.648	105.000	0.440	0.271	0.859	0.000
HOEK	8	3.840	0.700	0.250	0.480	195.000	0.370	0.388	0.867	0.000
HOEK	9	1.230	0.700	0.250	0.480	175.000	0.490	0.220	0.859	0.000
CED	1	4.630	0.700	0.500	0.510	235.000	0.540	0.279	0.820	0.000
CED	2	5.760	0.700	0.500	0.510	235.000	0.500	0.347	0.820	0.000
CED	3	7.000	0.700	0.250	0.510	235.000	0.465	0.453	0.820	0.000

Area ID	1 K	2 N	3 CDEL	4 KC	5 SMAX	6 DA	7 C	8 APF	9 IL
ZULU 1	2.930	0.700	0.750	0.440	260.000	0.560	0.150	0.840	0.000
ZULU 2	3.220	0.700	0.500	0.580	260.000	0.500	0.100	0.840	0.000
ZULU 3	3.500	0.700	0.250	0.440	208.000	0.530	0.130	0.840	0.000
ZULU 4	3.210	0.700	0.250	0.072	150.000	0.490	0.150	0.840	0.000
ZULU 5	0.380	0.700	0.250	0.440	70.200	0.530	0.190	0.840	0.000
ZULU 6	1.520	0.700	0.250	0.340	98.800	0.560	0.130	0.840	0.000
ZULU 7	1.500	0.700	0.250	0.440	98.800	0.560	0.100	0.840	0.000
ZULU 8	4.630	0.700	0.000	0.580	150.800	0.450	0.230	0.840	0.000
ZULU 9	4.630	0.700	0.000	0.620	150.800	0.450	0.230	0.840	0.000
ZULU 10	4.630	0.700	0.250	0.640	150.800	0.450	0.230	0.840	0.000
OX4W 1	1.000	0.700	0.850	0.250	170.000	0.450	0.195	0.880	0.000
OX4W 2	1.000	0.700	0.510	0.380	170.000	0.450	0.195	0.880	0.000
OX4S 1	1.950	0.700	0.850	0.250	170.000	0.450	0.115	0.830	0.000
OX4S 2	1.950	0.700	0.510	0.380	170.000	0.450	0.115	0.830	0.000
OX12W 1	1.200	0.700	1.530	0.780	170.000	0.490	0.211	0.880	0.000
OX12W 2	1.200	0.700	1.530	0.860	170.000	0.490	0.211	0.880	0.000
OX12W 3	1.050	0.790	1.700	0.500	170.000	0.490	0.173	0.880	0.000
OX12W 4	1.350	0.700	1.530	0.830	187.000	0.490	0.173	0.880	0.000
OX12W 5	1.920	0.700	0.850	0.860	187.000	0.440	0.173	0.880	0.000
OX12W 7	1.920	0.700	1.190	0.800	187.000	0.440	0.134	0.880	0.000
OX12W 8	1.350	0.700	1.700	0.500	170.000	0.450	0.134	0.880	0.000
OX12W 9	1.050	0.700	1.190	0.600	187.000	0.490	0.269	0.880	0.000
OX12W 10	1.920	0.700	0.680	0.620	187.000	0.440	0.115	0.880	0.000
OX12W 11	1.900	0.700	1.360	0.300	170.000	0.420	0.230	0.880	0.000
OX12W 12	1.920	0.700	1.020	0.680	187.000	0.420	0.230	0.880	0.000
OX12P 1	1.550	0.700	1.530	0.780	170.000	0.490	0.196	0.840	0.000
OX12P 2	1.550	0.700	1.530	0.860	170.000	0.490	0.196	0.840	0.000
OX12P 3	1.550	0.700	1.700	0.500	170.000	0.490	0.156	0.840	0.000
OX12P 4	1.550	0.700	1.530	0.830	187.000	0.490	0.168	0.840	0.000
OX12P 5	2.510	0.700	0.850	0.860	187.000	0.440	0.168	0.840	0.000
OX12P 7	2.510	0.700	1.190	0.800	187.000	0.440	0.192	0.840	0.000
OX12P 8	1.550	0.700	1.700	0.500	170.000	0.450	0.180	0.840	0.000
OX12P 9	1.550	0.700	1.190	0.600	187.000	0.490	0.168	0.840	0.000
OX12P 10	2.510	0.700	0.680	0.620	187.000	0.440	0.192	0.840	0.000
OX12P 11	2.510	0.700	1.360	0.300	170.000	0.420	0.204	0.840	0.000
OX12P 12	2.510	0.700	1.020	0.680	187.000	0.420	0.204	0.840	0.000
OX12S 1	1.950	0.700	1.530	0.780	170.000	0.490	0.114	0.830	0.000
OX12S 2	1.950	0.700	1.530	0.860	170.000	0.490	0.114	0.830	0.000
OX12S 3	1.950	0.700	1.700	0.500	170.000	0.490	0.114	0.830	0.000
OX12S 4	1.950	0.700	1.530	0.830	187.000	0.490	0.114	0.830	0.000
OX12S 5	3.100	0.700	0.850	0.860	187.000	0.440	0.132	0.830	0.000
OX12S 7	3.100	0.700	1.190	0.800	187.000	0.440	0.132	0.830	0.000
OX12S 8	1.950	0.700	1.700	0.500	170.000	0.450	0.120	0.830	0.000
OX12S 9	1.950	0.700	1.190	0.600	187.000	0.490	0.144	0.830	0.000
OX12S 10	3.100	0.700	0.680	0.620	187.000	0.440	0.132	0.830	0.000
OX12S 11	3.100	0.700	1.360	0.300	170.000	0.420	0.120	0.830	0.000
OX12S 12	3.100	0.700	1.020	0.680	187.000	0.420	0.120	0.830	0.000
OX10W 1	1.380	0.700	0.680	0.410	170.000	0.455	0.160	0.880	0.000
OX10W 2	1.380	0.700	0.680	0.550	187.000	0.455	0.160	0.880	0.000
OX10W 3	1.380	0.700	0.510	0.550	187.000	0.455	0.160	0.880	0.000
OX10W 4	1.380	0.700	0.340	0.300	170.000	0.455	0.160	0.880	0.000
OX10W 5	1.380	0.700	0.340	0.480	187.000	0.455	0.160	0.880	0.000
OX10P 1	2.000	0.700	0.680	0.410	170.000	0.455	0.120	0.840	0.000
OX10P 2	2.000	0.700	0.680	0.550	187.000	0.455	0.120	0.840	0.000
OX10P 3	2.000	0.700	0.510	0.550	187.000	0.455	0.120	0.840	0.000
OX10P 4	2.000	0.700	0.340	0.300	170.000	0.455	0.120	0.840	0.000
OX10P 5	2.000	0.700	0.340	0.480	187.000	0.455	0.120	0.840	0.000
OX10S 1	2.400	0.700	0.680	0.410	170.000	0.455	0.060	0.830	0.000
OX10S 2	2.400	0.700	0.680	0.550	187.000	0.455	0.060	0.830	0.000

Area ID	1 K	2 N	3 CDEL	4 KC	5 SMAX	6 DA	7 C	8 APF	9 IL
OX10S 3	2.400	0.700	0.510	0.550	187.000	0.455	0.060	0.830	0.000
OX10S 4	2.400	0.700	0.340	0.300	170.000	0.455	0.060	0.830	0.000
OX10S 5	2.400	0.700	0.340	0.480	187.000	0.455	0.060	0.830	0.000
OX35W 1	1.950	0.700	1.190	0.410	170.000	0.448	0.110	0.880	0.000
OX35W 2	1.950	0.700	1.020	0.620	170.000	0.448	0.110	0.880	0.000
OX35W 3	1.950	0.700	1.020	0.300	170.000	0.448	0.110	0.880	0.000
OX35W 4	1.950	0.700	0.850	0.480	170.000	0.448	0.110	0.880	0.000
OX35W 5	1.950	0.700	0.850	0.630	170.000	0.448	0.110	0.880	0.000
OX35W 6	1.950	0.700	0.680	0.890	170.000	0.448	0.110	0.880	0.000
OX35W 7	1.950	0.700	0.510	0.720	170.000	0.448	0.110	0.880	0.000
OX35W 8	1.950	0.700	0.340	0.820	170.000	0.448	0.110	0.880	0.000
OX35P 1	2.380	0.700	1.190	0.410	170.000	0.448	0.070	0.840	0.000
OX35P 2	2.380	0.700	1.020	0.620	170.000	0.448	0.070	0.840	0.000
OX35P 3	2.380	0.700	1.020	0.300	170.000	0.448	0.070	0.840	0.000
OX35P 4	2.380	0.700	0.850	0.480	170.000	0.448	0.070	0.840	0.000
OX35P 5	2.380	0.700	0.850	0.630	170.000	0.448	0.070	0.840	0.000
OX35P 6	2.380	0.700	0.680	0.890	170.000	0.448	0.070	0.840	0.000
OX35P 7	2.380	0.700	0.510	0.720	170.000	0.448	0.070	0.840	0.000
OX35P 8	2.380	0.700	0.340	0.820	170.000	0.448	0.070	0.840	0.000
OX35S 1	3.150	0.700	1.190	0.410	170.000	0.448	0.030	0.830	0.000
OX35S 2	3.150	0.700	1.020	0.620	170.000	0.448	0.030	0.830	0.000
OX35S 3	3.150	0.700	1.020	0.300	170.000	0.448	0.030	0.830	0.000
OX35S 4	3.150	0.700	0.850	0.480	170.000	0.448	0.030	0.830	0.000
OX35S 5	3.150	0.700	0.850	0.630	170.000	0.448	0.030	0.830	0.000
OX35S 6	3.150	0.700	0.680	0.890	170.000	0.448	0.030	0.830	0.000
OX35S 7	3.150	0.700	0.510	0.720	170.000	0.448	0.030	0.830	0.000
OX35S 8	3.150	0.700	0.340	0.820	170.000	0.448	0.030	0.830	0.000
OX17W 11	1.200	0.700	1.360	0.410	170.000	0.470	0.077	0.880	0.000
OX17W 12	1.620	0.700	0.850	0.600	187.000	0.460	0.110	0.880	0.000
OX17W 13	1.620	0.700	0.340	0.960	212.500	0.470	0.077	0.880	0.000
OX17W 14	1.200	0.700	1.020	0.480	170.000	0.480	0.088	0.880	0.000
OX17W 15	2.000	0.700	0.510	0.480	222.000	0.440	0.121	0.880	0.000
OX17W 16	1.620	0.700	0.510	0.410	212.500	0.460	0.110	0.880	0.000
OX17P 11	1.620	0.700	1.360	0.410	170.000	0.470	0.132	0.840	0.000
OX17P 12	2.000	0.700	0.850	0.600	187.000	0.460	0.124	0.840	0.000
OX17P 13	2.000	0.700	0.340	0.960	212.500	0.470	0.109	0.840	0.000
OX17P 14	1.620	0.700	1.020	0.480	170.000	0.480	0.116	0.840	0.000
OX17P 15	2.380	0.700	0.510	0.480	222.000	0.440	0.124	0.840	0.000
OX17P 16	2.000	0.700	0.510	0.410	212.500	0.460	0.124	0.840	0.000
OX17S 11	2.000	0.700	1.360	0.410	170.000	0.470	0.085	0.830	0.000
OX17S 12	2.380	0.700	0.850	0.600	187.000	0.460	0.090	0.830	0.000
OX17S 13	2.000	0.700	0.340	0.960	212.500	0.470	0.081	0.830	0.000
OX17S 14	2.380	0.700	1.020	0.480	170.000	0.480	0.085	0.830	0.000
OX17S 15	3.140	0.700	0.510	0.480	222.000	0.440	0.094	0.830	0.000
OX17S 16	2.380	0.700	0.510	0.410	212.500	0.460	0.089	0.830	0.000
OX32W 9	2.380	0.700	1.360	0.560	187.000	0.406	0.110	0.880	0.000
OX32W 10	2.380	0.700	1.020	0.760	212.500	0.427	0.100	0.880	0.000
OX32W 11	2.380	0.700	0.680	0.500	212.500	0.427	0.100	0.880	0.000
OX32W 12	2.380	0.700	0.340	0.760	212.500	0.427	0.100	0.880	0.000
OX32W 18	2.380	0.700	0.340	0.820	212.500	0.406	0.110	0.880	0.000
OX32P 9	3.140	0.700	1.360	0.560	187.000	0.406	0.080	0.840	0.000
OX32P 10	3.140	0.700	1.020	0.760	212.500	0.427	0.060	0.840	0.000
OX32P 11	3.140	0.700	0.680	0.500	212.500	0.427	0.060	0.840	0.000
OX32P 12	3.140	0.700	0.340	0.760	212.500	0.427	0.060	0.840	0.000
OX32P 18	3.140	0.700	0.340	0.820	212.500	0.406	0.080	0.840	0.000
OX32S 9	3.900	0.700	1.360	0.560	187.000	0.406	0.030	0.830	0.000
OX32S 10	3.900	0.700	1.020	0.760	212.500	0.427	0.030	0.830	0.000
OX32S 11	3.900	0.700	0.680	0.500	212.500	0.427	0.030	0.830	0.000
OX32S 12	3.900	0.700	0.340	0.760	212.500	0.427	0.030	0.830	0.000
OX32S 18	3.900	0.700	0.340	0.820	212.500	0.406	0.030	0.830	0.000

Area ID	1 K	2 N	3 CDEL	4 KC	5 SMAX	6 DA	7 C	8 APF	9 IL
KAAI 1	1.970	0.700	2.750	0.670	184.000	0.680	0.139	0.860	0.000
KAAI 2	1.970	0.700	2.000	0.920	184.000	0.680	0.139	0.860	0.000
KAAI 3	1.800	0.700	2.250	1.000	184.000	0.680	0.139	0.860	0.000
KAAI 4	1.970	0.700	2.250	0.920	184.000	0.680	0.139	0.860	0.000
KAAI 5	1.750	0.700	1.500	0.860	212.000	0.690	0.147	0.860	0.000
KAAI 6	2.900	0.700	1.250	0.920	212.000	0.660	0.154	0.860	0.000
KAAI 7	3.900	0.700	1.000	1.100	212.000	0.650	0.201	0.860	0.000
KAAI 8	5.040	0.700	0.500	1.000	240.000	0.650	0.224	0.860	0.000
KAAI 9	5.040	0.700	0.500	0.620	240.000	0.650	0.224	0.860	0.000
MALG 1	1.800	0.700	1.500	0.680	184.000	0.690	0.124	0.860	0.000
MALG 2	1.800	0.700	1.500	0.620	184.000	0.690	0.124	0.860	0.000
MALG 3	2.080	0.700	1.250	0.560	184.000	0.680	0.131	0.860	0.000
MALG 4	2.080	0.700	1.000	0.890	184.000	0.680	0.131	0.860	0.000
MALG 5	2.360	0.700	1.000	0.680	184.000	0.650	0.137	0.860	0.000
MALG 6	2.360	0.700	1.000	0.710	184.000	0.650	0.137	0.860	0.000
MALG 7	5.190	0.700	0.500	0.740	240.000	0.620	0.189	0.860	0.000
MALG 8	5.190	0.700	0.500	0.500	240.000	0.620	0.189	0.860	0.000
NDAN5 1	4.900	0.700	1.500	0.560	194.000	0.510	0.204	0.835	0.000
NDAN5 2	5.700	0.700	1.000	1.050	194.000	0.500	0.224	0.835	0.000
NDAN5 3	5.200	0.700	1.250	0.820	194.000	0.485	0.198	0.835	0.000
NDAN5 4	4.500	0.700	1.500	0.560	194.000	0.520	0.191	0.835	0.000
NDAN5 5	4.900	0.700	1.000	0.550	194.000	0.500	0.204	0.835	0.000
NDAN5 6	4.900	0.700	0.500	0.700	194.000	0.510	0.204	0.835	0.000
NDAN5 7	5.480	0.700	1.000	0.560	194.000	0.500	0.218	0.835	0.000
NDAN5 8	5.760	0.700	0.750	0.240	194.000	0.500	0.224	0.835	0.000
NDAN5 9	5.250	0.700	0.500	0.500	194.000	0.485	0.198	0.835	0.000
NDAN5 10	4.500	0.700	2.250	0.500	194.000	0.520	0.191	0.835	0.000
NDAN5 11	5.200	0.700	2.000	0.550	194.000	0.530	0.224	0.835	0.000
NDAN5 12	5.250	0.700	1.500	0.830	194.000	0.530	0.224	0.835	0.000
NDAN5 13	4.700	0.700	2.250	0.500	194.000	0.530	0.211	0.835	0.000
NDAN5 14	4.060	0.700	1.750	0.740	194.000	0.550	0.198	0.835	0.000
NDAN5 15	4.000	0.700	1.250	0.500	194.000	0.540	0.178	0.835	0.000
NDAN5 16	4.100	0.700	0.750	0.700	194.000	0.540	0.191	0.835	0.000
NDAN5 17	4.300	0.700	0.000	0.072	194.000	0.540	0.198	0.835	0.000
NDAN5 18	4.300	0.700	0.000	0.730	194.000	0.540	0.198	0.835	0.000

OSE3-CALIBRATION PARAMETERS

Area	ID	1 CDEL	2 KC	3 ROP	4 N	5 K	6 IL
TM11	1	0.240	0.200	0.200	0.500	0.100	0.000
TM11	2	0.240	0.200	0.200	0.500	0.100	0.000
TM11	3	0.160	0.200	0.200	0.500	0.100	0.000
TM8	4	0.240	0.100	0.120	0.500	0.100	0.000
TM8	5	0.240	0.100	0.120	0.500	0.100	0.000
TM8	6	0.160	0.100	0.120	0.500	0.100	0.000
TM8	7	0.080	0.100	0.120	0.500	0.100	0.000
TM3	1	0.320	0.100	0.190	0.500	0.100	0.000
TM3	2	0.240	0.100	0.190	0.500	0.100	0.000
TM3	3	0.160	0.100	0.190	0.500	0.100	0.000
TM3	4	0.160	0.100	0.190	0.500	0.100	0.000
TM6	1	0.640	0.400	0.060	0.500	1.000	0.000
TM6	2	0.480	0.400	0.060	0.500	1.000	0.000
TM6	3	0.560	0.400	0.060	0.500	1.000	0.000
TM6	4	0.640	0.400	0.060	0.500	1.000	0.000
TM6	5	0.480	0.400	0.060	0.500	1.000	0.000
TM6	6	0.320	0.400	0.060	0.500	1.000	0.000
TM6	7	0.320	0.400	0.060	0.500	1.000	0.000
TM6	8	0.240	0.400	0.060	0.500	1.000	0.000
TM2	10	0.320	0.500	0.110	0.500	1.000	0.000
TM1	11	0.640	0.500	0.110	0.500	1.500	0.000
TM1	12	0.560	0.500	0.110	0.500	1.500	0.000
TM1	13	0.320	0.500	0.110	0.500	1.500	0.000
ECCA	1	5.250	0.640	0.330	0.500	16.000	15.000
ECCA	2	4.500	0.720	0.330	0.500	14.720	15.000
ECCA	3	4.500	0.720	0.330	0.500	14.720	15.000
ECCA	4	4.000	0.800	0.330	0.500	14.720	15.000
ECCA	5	4.000	0.600	0.330	0.500	14.400	15.000
ECCA	6	4.000	0.600	0.330	0.500	14.400	15.000
ECCA	7	3.000	0.400	0.330	0.500	13.600	13.000
ECCA	8	2.750	0.480	0.330	0.500	12.800	12.000
ECCA	9	2.250	0.768	0.330	0.500	10.400	11.000
ECCA	10	1.250	1.120	0.330	0.500	15.200	9.500
ECCA	11	0.750	0.800	0.330	0.500	16.800	9.000
ECCA	12	0.750	0.480	0.330	0.500	12.800	8.500
BETH	1	3.250	0.800	0.250	0.500	8.000	0.000
BETH	2	2.750	0.800	0.250	0.500	8.000	0.000
BETH	3	3.000	0.800	0.250	0.500	8.000	0.000
BETH	4	2.500	0.800	0.250	0.500	8.000	0.000
BETH	5	2.000	0.800	0.250	0.500	8.000	0.000
BETH	6	2.250	0.800	0.250	0.500	8.000	0.000
BETH	7	1.500	0.800	0.250	0.500	8.000	0.000
BETH	8	1.250	0.800	0.250	0.500	8.000	0.000
BETH	9	0.500	0.800	0.250	0.500	8.000	0.000
HOEK	1	0.750	0.800	0.230	0.500	5.000	0.000
HOEK	2	0.500	0.400	0.230	0.500	2.500	0.000
HOEK	3	0.750	0.400	0.230	0.500	3.000	0.000
HOEK	4	0.750	0.480	0.230	0.500	3.000	0.000
HOEK	5	0.750	0.480	0.230	0.500	3.000	0.000
HOEK	6	0.500	0.560	0.230	0.500	3.500	0.000
HOEK	7	0.000	0.560	0.230	0.500	2.500	0.000
HOEK	8	0.250	0.480	0.230	0.500	3.000	0.000
HOEK	9	0.250	0.480	0.230	0.500	3.000	0.000
CED	1	0.500	0.400	0.040	0.500	7.000	0.000
CED	2	0.500	0.400	0.040	0.500	7.000	0.000
CED	3	0.250	0.400	0.040	0.500	7.000	0.000
ZULU	1	0.750	0.400	0.380	0.500	14.000	0.000
ZULU	2	0.500	0.400	0.380	0.500	14.000	0.000
ZULU	3	0.250	0.320	0.380	0.500	8.400	0.000
ZULU	4	0.250	0.160	0.380	0.500	8.400	0.000
ZULU	5	0.250	0.200	0.380	0.500	2.800	0.000

Area ID	1 CDEL	2 KC	3 ROP	4 N	5 K	6 IL
ZULU 6	0.250	0.240	0.380	0.500	3.500	0.000
ZULU 7	0.250	0.280	0.380	0.500	3.500	0.000
ZULU 8	0.000	0.160	0.380	0.500	8.400	0.000
ZULU 9	0.000	0.320	0.380	0.500	8.400	0.000
ZULU 10	0.250	0.400	0.380	0.500	8.400	0.000
OX4W 1	0.850	0.500	0.170	0.500	2.000	0.000
OX4W 2	0.510	0.500	0.170	0.500	2.000	0.000
OX4S 1	0.000	0.000	0.000	0.000	0.000	0.000
OX4S 2	0.000	0.000	0.000	0.000	0.000	0.000
OX12W 1	1.530	0.700	0.270	0.500	4.800	0.000
OX12W 2	1.530	0.700	0.270	0.500	4.800	0.000
OX12W 3	1.700	0.500	0.270	0.500	3.200	0.000
OX12W 4	1.530	0.600	0.270	0.500	6.400	0.000
OX12W 5	0.850	0.700	0.270	0.500	8.000	0.000
OX12W 7	1.190	0.800	0.270	0.500	8.000	0.000
OX12W 8	1.700	0.600	0.270	0.500	6.400	0.000
OX12W 9	1.190	0.600	0.270	0.500	8.000	0.000
OX12W 10	0.680	0.700	0.270	0.500	8.000	0.000
OX12W 11	1.360	0.500	0.270	0.500	6.000	0.000
OX12W 12	1.020	0.800	0.270	0.500	8.000	0.000
OX12P 1	0.000	0.000	0.000	0.000	0.000	0.000
OX12P 2	0.000	0.000	0.000	0.000	0.000	0.000
OX12P 3	0.000	0.000	0.000	0.000	0.000	0.000
OX12P 4	0.000	0.000	0.000	0.000	0.000	0.000
OX12P 5	0.000	0.000	0.000	0.000	0.000	0.000
OX12P 7	0.000	0.000	0.000	0.000	0.000	0.000
OX12P 8	0.000	0.000	0.000	0.000	0.000	0.000
OX12P 9	0.000	0.000	0.000	0.000	0.000	0.000
OX12P 10	0.000	0.000	0.000	0.000	0.000	0.000
OX12P 11	0.000	0.000	0.000	0.000	0.000	0.000
OX12P 12	0.000	0.000	0.000	0.000	0.000	0.000
OX12S 1	0.000	0.000	0.000	0.000	0.000	0.000
OX12S 2	0.000	0.000	0.000	0.000	0.000	0.000
OX12S 3	0.000	0.000	0.000	0.000	0.000	0.000
OX12S 4	0.000	0.000	0.000	0.000	0.000	0.000
OX12S 5	0.000	0.000	0.000	0.000	0.000	0.000
OX12S 7	0.000	0.000	0.000	0.000	0.000	0.000
OX12S 8	0.000	0.000	0.000	0.000	0.000	0.000
OX12S 9	0.000	0.000	0.000	0.000	0.000	0.000
OX12S 10	0.000	0.000	0.000	0.000	0.000	0.000
OX12S 11	0.000	0.000	0.000	0.000	0.000	0.000
OX12S 12	0.000	0.000	0.000	0.000	0.000	0.000
OX10W 1	0.680	0.600	0.250	0.500	1.600	0.000
OX10W 2	0.680	0.200	0.250	0.500	1.600	0.000
OX10W 3	0.510	0.200	0.250	0.500	1.600	0.000
OX10W 4	0.340	0.400	0.250	0.500	1.280	0.000
OX10W 5	0.340	0.200	0.250	0.500	1.280	0.000
OX10P 1	0.000	0.000	0.000	0.000	0.000	0.000
OX10P 2	0.000	0.000	0.000	0.000	0.000	0.000
OX10P 3	0.000	0.000	0.000	0.000	0.000	0.000
OX10P 4	0.000	0.000	0.000	0.000	0.000	0.000
OX10P 5	0.000	0.000	0.000	0.000	0.000	0.000
OX10S 1	0.000	0.000	0.000	0.000	0.000	0.000
OX10S 2	0.000	0.000	0.000	0.000	0.000	0.000
OX10S 3	0.000	0.000	0.000	0.000	0.000	0.000
OX10S 4	0.000	0.000	0.000	0.000	0.000	0.000
OX10S 5	0.000	0.000	0.000	0.000	0.000	0.000
OX35W 1	1.190	0.500	0.360	0.500	2.400	0.000
OX35W 2	1.020	0.500	0.360	0.500	3.200	0.000
OX35W 3	1.020	0.400	0.360	0.500	2.400	0.000
OX35W 4	0.850	0.500	0.360	0.500	2.400	0.000
OX35W 5	0.850	0.400	0.360	0.500	3.200	0.000
OX35W 6	0.680	0.500	0.360	0.500	3.200	0.000

Area ID	1 CDEL	2 KC	3 ROP	4 N	5 K	6 IL
OX35W 7	0.510	0.500	0.360	0.500	2.400	0.000
OX35W 8	0.340	0.500	0.360	0.500	2.400	0.000
OX35P 1	0.000	0.000	0.000	0.000	0.000	0.000
OX35P 2	0.000	0.000	0.000	0.000	0.000	0.000
OX35P 3	0.000	0.000	0.000	0.000	0.000	0.000
OX35P 4	0.000	0.000	0.000	0.000	0.000	0.000
OX35P 5	0.000	0.000	0.000	0.000	0.000	0.000
OX35P 6	0.000	0.000	0.000	0.000	0.000	0.000
OX35P 7	0.000	0.000	0.000	0.000	0.000	0.000
OX35P 8	0.000	0.000	0.000	0.000	0.000	0.000
OX35S 1	0.000	0.000	0.000	0.000	0.000	0.000
OX35S 2	0.000	0.000	0.000	0.000	0.000	0.000
OX35S 3	0.000	0.000	0.000	0.000	0.000	0.000
OX35S 4	0.000	0.000	0.000	0.000	0.000	0.000
OX35S 5	0.000	0.000	0.000	0.000	0.000	0.000
OX35S 6	0.000	0.000	0.000	0.000	0.000	0.000
OX35S 7	0.000	0.000	0.000	0.000	0.000	0.000
OX35S 8	0.000	0.000	0.000	0.000	0.000	0.000
OX17W 11	1.360	0.600	0.290	0.500	6.400	0.000
OX17W 12	0.850	0.600	0.290	0.500	6.400	0.000
OX17W 13	0.340	0.700	0.290	0.500	8.000	0.000
OX17W 14	1.020	0.700	0.290	0.500	6.400	0.000
OX17W 15	0.510	0.700	0.290	0.500	6.400	0.000
OX17W 16	0.510	0.700	0.290	0.500	7.200	0.000
OX17P 11	0.000	0.000	0.000	0.000	0.000	0.000
OX17P 12	0.000	0.000	0.000	0.000	0.000	0.000
OX17P 13	0.000	0.000	0.000	0.000	0.000	0.000
OX17P 14	0.000	0.000	0.000	0.000	0.000	0.000
OX17P 15	0.000	0.000	0.000	0.000	0.000	0.000
OX17P 16	0.000	0.000	0.000	0.000	0.000	0.000
OX17S 11	0.000	0.000	0.000	0.000	0.000	0.000
OX17S 12	0.000	0.000	0.000	0.000	0.000	0.000
OX17S 13	0.000	0.000	0.000	0.000	0.000	0.000
OX17S 14	0.000	0.000	0.000	0.000	0.000	0.000
OX17S 15	0.000	0.000	0.000	0.000	0.000	0.000
OX17S 16	0.000	0.000	0.000	0.000	0.000	0.000
OX32W 9	1.360	0.500	0.350	0.500	2.400	0.000
OX32W 10	1.020	0.500	0.350	0.500	2.400	0.000
OX32W 11	0.680	0.500	0.350	0.500	2.400	0.000
OX32W 12	0.340	0.500	0.350	0.500	2.400	0.000
OX32W 18	0.340	0.500	0.350	0.500	1.600	0.000
OX32P 9	0.000	0.000	0.000	0.000	0.000	0.000
OX32P 10	0.000	0.000	0.000	0.000	0.000	0.000
OX32P 11	0.000	0.000	0.000	0.000	0.000	0.000
OX32P 12	0.000	0.000	0.000	0.000	0.000	0.000
OX32P 18	0.000	0.000	0.000	0.000	0.000	0.000
OX32S 9	0.000	0.000	0.000	0.000	0.000	0.000
OX32S 10	0.000	0.000	0.000	0.000	0.000	0.000
OX32S 11	0.000	0.000	0.000	0.000	0.000	0.000
OX32S 12	0.000	0.000	0.000	0.000	0.000	0.000
OX32S 18	0.000	0.000	0.000	0.000	0.000	0.000
KAAI 1	2.750	0.420	0.600	0.500	11.200	0.000
KAAI 2	2.000	0.420	0.600	0.500	11.200	0.000
KAAI 3	2.250	0.420	0.600	0.500	11.200	0.000
KAAI 4	2.250	0.480	0.600	0.500	11.200	0.000
KAAI 5	1.500	0.540	0.600	0.500	14.000	0.000
KAAI 6	1.250	0.540	0.600	0.500	14.000	0.000
KAAI 7	1.000	0.600	0.600	0.500	15.400	0.000
KAAI 8	0.500	0.600	0.600	0.500	15.400	0.000
KAAI 9	0.500	0.600	0.600	0.500	12.600	0.000
MALG 1	1.500	0.300	0.600	0.500	10.400	0.000
MALG 2	1.500	0.300	0.600	0.500	10.400	0.000
MALG 3	1.250	0.300	0.600	0.500	10.400	0.000

Area ID	1 CDEL	2 KC	3 ROP	4 N	5 K	6 IL
MALG 4	1.000	0.300	0.600	0.500	10.400	0.000
MALG 5	0.600	0.500	0.600	0.400	10.400	0.000
MALG 6	1.000	0.350	0.600	0.500	11.700	0.000
MALG 7	0.500	0.400	0.600	0.500	13.000	0.000
MALG 8	0.500	0.400	0.600	0.500	13.000	0.000
NDAN5 1	1.500	0.425	0.200	0.500	15.000	2.500
NDAN5 2	1.000	0.595	0.200	0.500	15.000	2.500
NDAN5 3	1.250	0.723	0.200	0.500	15.000	2.500
NDAN5 4	1.550	0.510	0.200	0.500	15.000	2.500
NDAN5 5	1.000	0.553	0.200	0.500	15.000	2.500
NDAN5 6	0.500	0.808	0.200	0.500	15.000	2.500
NDAN5 7	1.000	0.468	0.200	0.500	15.000	2.500
NDAN5 8	0.750	0.213	0.200	0.500	15.000	2.500
NDAN5 9	0.500	0.468	0.200	0.500	15.000	2.500
NDAN5 10	2.250	0.382	0.200	0.500	15.000	2.500
NDAN5 11	2.000	0.468	0.200	0.500	15.000	2.500
NDAN5 12	1.500	0.765	0.200	0.500	15.000	2.500
NDAN5 13	2.250	0.425	0.200	0.500	15.000	2.500
NDAN5 14	1.750	0.553	0.200	0.500	15.000	2.500
NDAN5 15	1.250	0.340	0.200	0.500	15.000	2.500
NDAN5 16	0.750	0.892	0.200	0.500	15.000	2.500
NDAN5 17	0.000	0.128	0.200	0.500	15.000	2.500
NDAN5 18	0.000	0.850	0.200	0.500	15.000	2.500

OSE3-VALIDATION PARAMETERS

Area	ID	1 CDEL	2 KC	3 ROP	4 N	5 K	6 IL
TM11	1	0.240	0.530	0.200	0.500	0.100	0.000
TM11	2	0.240	0.650	0.200	0.500	0.100	0.000
TM11	3	0.160	0.590	0.200	0.500	0.100	0.000
TM8	4	0.240	0.360	0.120	0.500	0.100	0.000
TM8	5	0.240	0.430	0.120	0.500	0.100	0.000
TM8	6	0.160	0.430	0.120	0.500	0.100	0.000
TM8	7	0.080	0.570	0.120	0.500	0.100	0.000
TM3	1	0.320	0.520	0.190	0.500	0.100	0.000
TM3	2	0.240	0.630	0.190	0.500	0.100	0.000
TM3	3	0.160	0.270	0.190	0.500	0.100	0.000
TM3	4	0.160	0.430	0.190	0.500	0.100	0.000
TM6	1	0.640	1.290	0.060	0.500	1.000	0.000
TM6	2	0.480	0.910	0.060	0.500	1.000	0.000
TM6	3	0.560	1.100	0.060	0.500	1.000	0.000
TM6	4	0.640	1.290	0.060	0.500	1.000	0.000
TM6	5	0.480	0.480	0.060	0.500	1.000	0.000
TM6	6	0.320	0.590	0.060	0.500	1.000	0.000
TM6	7	0.320	0.600	0.060	0.500	1.000	0.000
TM6	8	0.240	0.760	0.060	0.500	1.000	0.000
TM2	10	0.320	1.060	0.110	0.500	1.000	0.000
TM1	11	0.640	0.710	0.110	0.500	1.500	0.000
TM1	12	0.560	0.820	0.110	0.500	1.500	0.000
TM1	13	0.320	0.880	0.110	0.500	1.500	0.000
ECCA	1	5.250	0.620	0.330	0.500	6.540	15.000
ECCA	2	4.500	0.820	0.330	0.500	6.540	15.000
ECCA	3	4.500	0.690	0.330	0.500	6.540	15.000
ECCA	4	4.000	0.770	0.330	0.500	4.290	15.000
ECCA	5	4.000	0.650	0.330	0.500	5.700	15.000
ECCA	6	4.000	0.540	0.330	0.500	5.700	15.000
ECCA	7	3.000	0.690	0.330	0.500	4.750	13.000
ECCA	8	2.750	0.620	0.330	0.500	5.030	12.000
ECCA	9	2.250	0.540	0.330	0.500	4.290	11.000
ECCA	10	1.250	1.000	0.330	0.500	4.290	9.500
ECCA	11	0.750	0.870	0.330	0.500	4.010	9.000
ECCA	12	0.750	0.820	0.330	0.500	6.540	8.500
BETH	1	3.250	0.740	0.250	0.500	8.100	0.000
BETH	2	2.750	0.800	0.250	0.500	8.100	0.000
BETH	3	3.000	0.800	0.250	0.500	9.450	0.000
BETH	4	2.500	0.860	0.250	0.500	9.450	0.000
BETH	5	2.000	0.860	0.250	0.500	7.110	0.000
BETH	6	2.250	0.990	0.250	0.500	8.100	0.000
BETH	7	1.500	0.448	0.250	0.500	8.100	0.000
BETH	8	1.250	0.680	0.250	0.500	7.110	0.000
BETH	9	0.500	0.680	0.250	0.500	9.450	0.000
HOEK	1	0.750	0.170	0.230	0.500	5.500	0.000
HOEK	2	0.500	0.440	0.230	0.500	1.850	0.000
HOEK	3	0.750	0.680	0.230	0.500	2.600	0.000
HOEK	4	0.750	0.530	0.230	0.500	2.330	0.000
HOEK	5	0.750	0.250	0.230	0.500	2.640	0.000
HOEK	6	0.500	0.560	0.230	0.500	7.310	0.000
HOEK	7	0.000	0.648	0.230	0.500	1.700	0.000
HOEK	8	0.250	0.480	0.230	0.500	8.120	0.000
HOEK	9	0.250	0.480	0.230	0.500	2.900	0.000
CED	1	0.500	0.510	0.040	0.500	9.690	0.000
CED	2	0.500	0.510	0.040	0.500	12.080	0.000
CED	3	0.250	0.510	0.040	0.500	16.000	0.000
ZULU	1	0.750	0.440	0.380	0.500	6.860	0.000
ZULU	2	0.500	0.580	0.380	0.500	7.440	0.000
ZULU	3	0.250	0.440	0.380	0.500	7.270	0.000
ZULU	4	0.250	0.072	0.380	0.500	6.510	0.000
ZULU	5	0.250	0.440	0.380	0.500	1.590	0.000

Area ID	1 CDEL	2 KC	3 ROP	4 N	5 K	6 IL
ZULU 6	0.250	0.340	0.380	0.500	3.870	0.000
ZULU 7	0.250	0.440	0.380	0.500	3.330	0.000
ZULU 8	0.000	0.580	0.380	0.500	9.740	0.000
ZULU 9	0.000	0.620	0.380	0.500	9.740	0.000
ZULU 10	0.250	0.640	0.380	0.500	9.740	0.000
OX4W 1	0.850	0.250	0.170	0.500	3.050	0.000
OX4W 2	0.510	0.380	0.170	0.500	3.050	0.000
OX4S 1	0.000	0.250	0.000	0.000	4.780	0.000
OX4S 2	0.000	0.380	0.000	0.000	4.780	0.000
OX12W 1	1.530	0.780	0.270	0.500	2.820	0.000
OX12W 2	1.530	0.860	0.270	0.500	2.820	0.000
OX12W 3	1.700	0.500	0.270	0.500	3.050	0.000
OX12W 4	1.530	0.830	0.270	0.500	3.050	0.000
OX12W 5	0.850	0.860	0.270	0.500	4.510	0.000
OX12W 7	1.190	0.800	0.270	0.500	4.510	0.000
OX12W 8	1.700	0.500	0.270	0.500	3.050	0.000
OX12W 9	1.190	0.600	0.270	0.500	2.820	0.000
OX12W 10	0.680	0.620	0.270	0.500	4.510	0.000
OX12W 11	1.360	0.300	0.270	0.500	4.260	0.000
OX12W 12	1.020	0.680	0.270	0.500	4.510	0.000
OX12P 1	5.250	0.780	0.044	0.500	3.620	0.000
OX12P 2	4.500	0.860	0.044	0.500	3.620	0.000
OX12P 3	4.500	0.500	0.044	0.500	3.900	0.000
OX12P 4	4.000	0.830	0.044	0.500	3.900	0.000
OX12P 5	4.000	0.860	0.044	0.500	5.820	0.000
OX12P 7	4.000	0.800	0.044	0.500	5.820	0.000
OX12P 8	3.000	0.500	0.044	0.500	3.900	0.000
OX12P 9	2.750	0.600	0.044	0.500	3.620	0.000
OX12P 10	2.250	0.620	0.044	0.500	5.820	0.000
OX12P 11	1.250	0.300	0.044	0.500	5.470	0.000
OX12P 12	0.750	0.680	0.044	0.500	5.820	0.000
OX12P 1	0.750	0.780	0.044	0.500	4.420	0.000
OX12S 2	0.000	0.860	0.000	0.000	4.420	0.000
OX12S 3	0.000	0.500	0.000	0.000	4.780	0.000
OX12S 4	0.000	0.830	0.000	0.000	4.780	0.000
OX12S 5	0.000	0.860	0.000	0.000	7.110	0.000
OX12S 7	0.000	0.800	0.000	0.000	7.110	0.000
OX12S 8	0.000	0.500	0.000	0.000	4.780	0.000
OX12S 9	0.000	0.600	0.000	0.000	4.420	0.000
OX12S 10	0.000	0.620	0.000	0.000	7.110	0.000
OX12S 11	0.000	0.300	0.000	0.000	6.700	0.000
OX12S 12	0.000	0.680	0.000	0.000	7.110	0.000
OX10W 1	0.680	0.410	0.250	0.500	3.320	0.000
OX10W 2	0.680	0.550	0.250	0.500	3.320	0.000
OX10W 3	0.510	0.550	0.250	0.500	3.320	0.000
OX10W 4	0.340	0.300	0.250	0.500	3.320	0.000
OX10W 5	0.340	0.480	0.250	0.500	3.320	0.000
OX10P 1	0.000	0.410	0.000	0.000	5.170	0.000
OX10P 2	0.000	0.550	0.000	0.000	5.170	0.000
OX10P 3	0.000	0.550	0.000	0.000	5.170	0.000
OX10P 4	0.000	0.300	0.000	0.000	5.170	0.000
OX10P 5	0.000	0.480	0.000	0.000	5.170	0.000
OX10S 1	0.000	0.410	0.000	0.000	6.340	0.000
OX10S 2	0.000	0.550	0.000	0.000	6.340	0.000
OX10S 3	0.000	0.550	0.000	0.000	6.340	0.000
OX10S 4	0.000	0.300	0.000	0.000	6.340	0.000
OX10S 5	0.000	0.480	0.000	0.000	6.340	0.000
OX35W 1	1.190	0.410	0.360	0.500	4.030	0.000
OX35W 2	1.020	0.620	0.360	0.500	4.030	0.000
OX35W 3	1.020	0.300	0.360	0.500	4.030	0.000
OX35W 4	0.850	0.480	0.360	0.500	4.030	0.000
OX35W 5	0.850	0.630	0.360	0.500	4.030	0.000
OX35W 6	0.680	0.890	0.360	0.500	4.030	0.000

Area ID	1 CDEL	2 KC	3 ROP	4 N	5 K	6 IL
OX35W 7	0.510	0.720	0.360	0.500	4.030	0.000
OX35W 8	0.340	0.820	0.360	0.500	4.030	0.000
OX35P 1	0.000	0.410	0.000	0.000	5.170	0.000
OX35P 2	0.000	0.620	0.000	0.000	5.170	0.000
OX35P 3	0.000	0.300	0.000	0.000	5.170	0.000
OX35P 4	0.000	0.480	0.000	0.000	5.170	0.000
OX35P 5	0.000	0.630	0.000	0.000	5.170	0.000
OX35P 6	0.000	0.890	0.000	0.000	5.170	0.000
OX35P 7	0.000	0.720	0.000	0.000	5.170	0.000
OX35P 8	0.000	0.820	0.000	0.000	5.170	0.000
OX35S 1	0.000	0.410	0.000	0.000	6.340	0.000
OX35S 2	0.000	0.620	0.000	0.000	6.340	0.000
OX35S 3	0.000	0.300	0.000	0.000	6.340	0.000
OX35S 4	0.000	0.480	0.000	0.000	6.340	0.000
OX35S 5	0.000	0.630	0.000	0.000	6.340	0.000
OX35S 6	0.000	0.890	0.000	0.000	6.340	0.000
OX35S 7	0.000	0.720	0.000	0.000	6.340	0.000
OX35S 8	0.000	0.820	0.000	0.000	6.340	0.000
OX17W 11	1.360	0.410	0.290	0.500	3.050	0.000
OX17W 12	0.850	0.600	0.290	0.500	3.630	0.000
OX17W 13	0.340	0.960	0.290	0.500	3.630	0.000
OX17W 14	1.020	0.480	0.290	0.500	2.820	0.000
OX17W 15	0.510	0.480	0.290	0.500	4.510	0.000
OX17W 16	0.510	0.410	0.290	0.500	3.630	0.000
OX17P 11	0.000	0.410	0.000	0.000	3.900	0.000
OX17P 12	0.000	0.600	0.000	0.000	4.670	0.000
OX17P 13	0.000	0.960	0.000	0.000	4.670	0.000
OX17P 14	0.000	0.480	0.000	0.000	3.620	0.000
OX17P 15	0.000	0.480	0.000	0.000	5.820	0.000
OX17P 16	0.000	0.410	0.000	0.000	4.670	0.000
OX17S 11	0.000	0.410	0.000	0.000	4.780	0.000
OX17S 12	0.000	0.600	0.000	0.000	5.710	0.000
OX17S 13	0.000	0.960	0.000	0.000	5.710	0.000
OX17S 14	0.000	0.480	0.000	0.000	4.420	0.000
OX17S 15	0.000	0.480	0.000	0.000	7.110	0.000
OX17S 16	0.000	0.410	0.000	0.000	5.710	0.000
OX32W 9	1.360	0.560	0.350	0.500	5.140	0.000
OX32W 10	1.020	0.760	0.350	0.500	5.140	0.000
OX32W 11	0.680	0.500	0.350	0.500	5.140	0.000
OX32W 12	0.340	0.760	0.350	0.500	5.140	0.000
OX32W 18	0.340	0.820	0.350	0.500	5.140	0.000
OX32P 9	0.000	0.560	0.000	0.000	6.640	0.000
OX32P 10	0.000	0.760	0.000	0.000	6.640	0.000
OX32P 11	0.000	0.500	0.000	0.000	6.640	0.000
OX32P 12	0.000	0.760	0.000	0.000	6.640	0.000
OX32P 18	0.000	0.820	0.000	0.000	6.640	0.000
OX32S 9	0.000	0.560	0.000	0.000	8.120	0.000
OX32S 10	0.000	0.760	0.000	0.000	8.120	0.000
OX32S 11	0.000	0.500	0.000	0.000	8.120	0.000
OX32S 12	0.000	0.760	0.000	0.000	8.120	0.000
OX32S 18	0.000	0.820	0.000	0.000	8.120	0.000
KAAI 1	2.750	0.670	0.600	0.500	4.470	0.000
KAAI 2	2.000	0.920	0.600	0.500	4.470	0.000
KAAI 3	2.250	1.000	0.600	0.500	4.280	0.000
KAAI 4	2.250	0.920	0.600	0.500	4.470	0.000
KAAI 5	1.500	0.860	0.600	0.500	4.110	0.000
KAAI 6	1.250	0.920	0.600	0.500	6.390	0.000
KAAI 7	1.000	1.100	0.600	0.500	8.950	0.000
KAAI 8	0.500	1.000	0.600	0.500	11.010	0.000
KAAI 9	0.500	0.620	0.600	0.500	11.010	0.000
MALG 1	1.500	0.680	0.600	0.500	4.280	0.000
MALG 2	1.500	0.620	0.600	0.500	4.280	0.000
MALG 3	1.250	0.560	0.600	0.500	4.690	0.000

Area ID	1 CDEL	2 KC	3 ROP	4 N	5 K	6 IL
MALG 4	1.000	0.890	0.600	0.500	4.690	0.000
MALG 5	0.600	0.680	0.600	0.400	5.160	0.000
MALG 6	1.000	0.710	0.600	0.500	5.160	0.000
MALG 7	0.500	0.740	0.600	0.500	10.710	0.000
MALG 8	0.500	0.500	0.600	0.500	10.710	0.000
NDAN5 1	1.500	0.560	0.200	0.500	10.400	0.000
NDAN5 2	1.000	1.050	0.200	0.500	11.800	0.000
NDAN5 3	1.250	0.820	0.200	0.500	10.820	0.000
NDAN5 4	1.550	0.560	0.200	0.500	9.360	0.000
NDAN5 5	1.000	0.550	0.200	0.500	11.800	0.000
NDAN5 6	0.500	0.700	0.200	0.500	10.400	0.000
NDAN5 7	1.000	0.560	0.200	0.500	11.280	0.000
NDAN5 8	0.750	0.240	0.200	0.500	11.780	0.000
NDAN5 9	0.500	0.500	0.200	0.500	10.820	0.000
NDAN5 10	2.250	0.500	0.200	0.500	9.280	0.000
NDAN5 11	2.000	0.550	0.200	0.500	10.820	0.000
NDAN5 12	1.500	0.830	0.200	0.500	10.820	0.000
NDAN5 13	2.250	0.500	0.200	0.500	9.990	0.000
NDAN5 14	1.750	0.740	0.200	0.500	8.670	0.000
NDAN5 15	1.250	0.500	0.200	0.500	8.130	0.000
NDAN5 16	0.750	0.700	0.200	0.500	8.670	0.000
NDAN5 17	0.000	0.072	0.200	0.500	8.970	0.000
NDAN5 18	0.000	0.730	0.200	0.500	8.970	0.000

APPENDIX C

Individual storm simulation statistics.

Model OSE1 Lumped calibration
Semi-distributed calibration
Semi-distributed validation

Model OSE3 Lumped calibration
Semi-distributed calibration
Semi-distributed validation

MODEL OSE1 Lumped calibration results

Catch name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Peak	Coefficient Eff.	Det.
TM	1	1	26.07.59	B	-10.5	-15.3	0.666	0.724
TM	1	2	4.09.65	C	24.6	-18.2	0.365	0.624
TM	2	1	26.07.59	B	-12.4	-19.8	0.791	0.799
TM	2	2	17.08.61	C	SUSPECT DATA			
TM	2	3	4.09.65	B	-5.9	-8.3	0.772	0.822
TM	2	4	25.08.68	C	SUSPECT DATA			
TM	2	5	31.08.68	C	-11.8	-20.9	0.804	0.815
TM	3	1	19.07.55	C	SUSPECT DATA			
TM	3	2	14.08.58	B	-8.3	-23.9	0.903	0.906
TM	3	3	16.08.58	C	-1.0	-32.2	0.679	0.703
TM	3	4	17.08.61	B	SUSPECT DATA			
TM	3	5	25.07.62	C	7.2	-30.2	0.841	0.843
TM	3	7	25.08.68	C	38.0	-29.1	0.653	0.688
TM	3	8	31.08.68	C	20.8	-25.7	0.782	0.800
TM	3	11	27.07.73	C	19.9	-14.1	0.649	0.686
TM	6	1	4.09.65	B	-3.4	-3.0	0.700	0.756
TM	6	2	31.08.68	B	9.8	-10.7	0.421	0.576
TM	8	1	19.08.63	C	-11.4	3.7	0.870	0.900
TM	8	2	22.07.64	C	-49.2	-75.6	0.465	0.708
TM	8	3	9.09.64	C	-5.6	-7.9	0.872	0.873
TM	8	5	11.09.64	C	59.0	-45.3	0.577	0.619
TM	8	6	17.07.65	C	-10.3	-1.1	0.828	0.842
TM	8	7	4.09.65	B	-8.5	0.2	0.763	0.847
TM	8	8	30.07.66	C	-11.6	-15.1	0.791	0.804
TM	8	10	31.08.68	C	16.7	-2.6	0.853	0.940
TM	8	11	24.07.72	C	42.0	-39.9	0.256	0.362
TM	11	1	19.08.63	C	14.4	-8.3	0.899	0.834
TM	11	2	22.07.64	B	SUSPECT DATA			
TM	11	3	9.09.64	C	-8.1	8.3	0.840	0.843
TM	11	4	11.09.64	B	-12.0	-5.4	0.883	0.887
TM	11	5	17.07.65	C	4.1	-48.2	0.692	0.694
TM	11	6	4.09.65	B	7.9	-18.0	0.930	0.931
TM	11	7	30.07.66	C	0.7	-17.5	0.943	0.949
TM	11	9	31.08.68	C	SUSPECT DATA			
TM	11	10	13.08.69	B	8.2	8.3	0.612	0.719
TM	11	11	15.09.69	C	-13.1	-24.5	0.783	0.799
TM	11	12	21.08.73	B	SUSPECT DATA			
EC	1	1	28.02.77	A	3.0	3.5	0.936	0.942
EC	1	2	6.03.77	B	-3.7	-6.2	0.671	0.771
EC	1	3	7.05.77	B	-3.6	7.0	0.792	0.803
EC	1	4	19.04.78	A	-5.0	-8.2	0.927	0.928
EC	1	5	21.04.78	A	-17.6	9.2	0.360	0.770
EC	1	6	20.07.79	A	-61.5	-60.8	-0.053	0.676
EC	1	7	23.07.79	A	-7.3	2.1	0.923	0.973
EC	1	8	19.08.79	A	-8.8	1.0	0.834	0.872
EC	1	9	26.03.81	A	11.7	-12.7	0.932	0.956
EC	1	10	22.10.81	B	-19.6	-10.0	0.530	0.745
EC	1	11	23.12.81	A	14.2	-12.0	0.906	0.917
EC	1	12	2.11.85	A	-12.3	2.2	0.887	0.958
EC	1	13	25.11.85	B	-16.2	2.2	0.608	0.685
EC	1	14	1.12.85	B	-7.4	1.1	0.885	0.940
EC	2	1	28.02.77	A	9.0	-19.9	0.806	0.815
EC	2	2	6.03.77	B	26.3	-17.2	0.794	0.794
EC	2	3	7.05.77	B	-18.4	-21.5	0.836	0.836
EC	2	5	21.04.78	A	-0.9	-0.4	0.660	0.779
EC	2	6	20.07.79	A	-15.4	-4.9	0.773	0.794
EC	2	7	23.07.79	A	-4.3	-3.8	0.952	0.975
EC	2	8	19.08.79	A	1.7	-0.7	0.897	0.912
EC	2	9	26.03.81	A	13.6	-14.4	0.409	0.524

Catch name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Peak	Coefficient Eff.	Det.
EC	2	11	23.12.81	A	2.1	-21.5	0.710	0.729
EC	2	12	2.11.85	A	-6.9	-9.3	0.927	0.957
EC	2	14	1.12.85	B	-0.1	1.3	0.977	0.984
BETH		1	1.11.80	C	SUSPECT DATA			
BETH		2	15.12.80	B	6.2	12.2	0.787	0.890
BETH		5	05.02.81	B	-49.7	-73.6	-0.817	0.296
BETH		6	10.02.81	B	-7.3	-15.0	0.945	0.952
BETH		7	14.02.81	B	18.6	-15.1	0.704	0.800
BETH		8	17.02.81	B	-18.6	-21.5	0.759	0.780
BETH		9	27.02.81	C	11.0	-23.3	0.263	0.380
BETH		10	22.03.81	C	-16.9	-1.0	0.072	0.310
HOEK		1	2.03.79	A	13.4	101.3	0.618	0.835
HOEK		2	4.05.79	B	-44.0	-70.5	-0.372	0.026
HOEK		3	16.02.80	A	-41.8	-44.9	0.645	0.945
HOEK		4	17.02.80	B	16.1	-30.1	0.848	0.875
HOEK		5	17.12.80	B	-8.1	-6.5	0.716	0.748
HOEK		6	8.01.81	B	-43.2	-62.1	-0.924	0.124
HOEK		7	1.02.81	A	14.6	-1.6	0.704	0.918
HOEK		8	19.02.81	B	3.7	33.7	0.549	0.794
HOEK		9	21.02.81	B	-5.8	-11.9	0.796	0.810
HOEK		10	24.02.81	B	27.4	30.0	0.129	0.629
HOEK		11	21.03.82	A	23.1	70.4	-1.732	0.061
HOEK		12	8.04.82	B	-11.1	-62.1	-0.924	0.124
HOEK		13	26.11.83	B	2.5	-19.4	0.566	0.566
HOEK		14	28.11.83	B	36.2	-10.5	0.767	0.870
HOEK		15	17.12.83	B	-15.7	-69.5	0.273	0.304
HOEK		16	24.12.83	B	18.6	20.2	0.841	0.928
CED		1	11.11.78	A	-4.2	-26.5	0.858	0.892
CED		2	9.12.78	A	9.0	29.3	0.654	0.837
CED		3	28.12.78	A	-11.4	-22.2	0.788	0.804
CED		4	2.01.79	A	-1.8	41.9	-0.856	0.238
CED		5	25.02.79	A	15.4	2.9	0.735	0.864
CED		6	2.12.84	A	-11.2	36.6	0.760	0.852
CED		7	9.02.85	A	7.7	8.5	0.566	0.674
CED		8	24.02.85	C	23.1	6.7	0.805	0.895
CED		9	11.03.85	A	-12.2	30.8	-0.057	0.375
CED		10	14.03.86	C	-11.7	22.6	0.559	0.777
ZL	15	1	29.01.77	B	-14.6	8.9	0.779	0.870
ZL	15	2	6.02.77	B	4.2	-16.4	0.418	0.495
ZL	15	3	14.02.77	B	18.1	11.1	0.485	0.733
ZL	15	4	14.03.77	B	SUSPECT DATA			
ZL	15	5	9.10.77	A	-0.5	9.4	0.870	0.921
ZL	15	6	9.11.77	B	10.2	-14.1	0.950	0.958
ZL	15	7	19.12.77	B	20.0	-7.5	0.836	0.890
ZL	15	8	19.01.78	C	5.3	-3.5	0.844	0.940
ZL	15	9	21.01.78	A	-6.3	-22.1	0.950	0.957
ZL	15	10	21.02.78	B	0.8	-15.0	0.827	0.832
ZL	15	11	1.03.78	A	6.5	17.9	0.525	0.894
ZL	15	12	9.03.78	B	14.6	50.0	-0.136	0.717
ZL	15	13	27.03.78	B	-10.2	13.2	0.512	0.750
ZL	15	14	8.09.78	A	1.7	-12.4	0.684	0.690
ZL	15	15	18.10.78	A	27.5	18.2	0.665	0.889
ZL	16	1	29.01.77	A	-5.6	17.6	0.779	0.870
ZL	16	3	14.02.77	A	18.1	11.1	0.485	0.733
ZL	16	5	9.10.77	A	-12.2	3.7	0.848	0.880
ZL	16	6	9.11.77	A	7.2	4.5	0.778	0.802
ZL	16	7	19.12.77	A	-15.8	-7.0	0.680	0.722
ZL	16	8	19.01.78	A	-6.5	-3.8	0.790	0.840
ZL	16	9	21.01.78	A	-6.4	-3.4	0.936	0.943
ZL	16	10	21.02.78	A	-24.4	-10.8	0.810	0.906
ZL	16	11	1.03.78	A	-21.0	9.7	0.701	0.839

Catch name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Peak	Coefficient Eff.	Det.
ZL	16	12	9.03.78	A	-10.3	28.8	0.455	0.723
ZL	16	13	27.03.78	A	-16.6	-53.7	0.461	0.485
ZL	16	14	8.09.78	A	10.3	0.3	0.690	0.710
ZL	16	15	18.10.78	A	16.2	15.8	0.561	0.789
OX	4	1	3.04.58	A	1.8	45.1	0.720	0.964
OX	4	2	17.01.60	A	23.9	24.5	0.475	0.691
OX	4	3	31.08.61	A	-27.2	-56.3	0.619	0.852
OX	4	4	4.09.62	A	-8.3	-45.4	0.785	0.815
OX	4	5	29.08.63	A	-3.7	-17.1	0.955	0.972
OX	10	1	22.05.59	B	-7.3	48.6	0.681	0.757
OX	10	2	17.01.60	A	-0.4	6.5	0.511	0.646
OX	10	3	31.08.61	B	-28.0	-22.9	0.798	0.877
OX	10	4	4.09.62	A	-15.0	-41.0	0.819	0.946
OX	10	5	29.08.63	A	-2.7	-10.3	0.956	0.968
OX	10	6	4.03.64	A	-21.0	-9.7	0.947	0.977
OX	10	7	1.03.65	A	-18.5	14.0	0.438	0.633
OX	10	8	27.12.66	C	9.7	-3.6	0.523	0.571
OX	10	9	31.05.67	A	-7.5	-14.0	0.831	0.837
OX	10	10	1.02.68	A	-6.7	16.4	0.400	0.525
OX	10	11	17.04.69	A	-2.6	16.8	0.913	0.914
OX	10	12	26.08.71	C	-1.1	-17.5	0.859	0.875
OX	12	1	2.03.60	A	1.3	-13.2	0.840	0.920
OX	12	2	31.08.61	B	16.1	-11.1	0.542	0.600
OX	12	3	4.09.62	B	11.0	-34.9	0.840	0.877
OX	12	4	29.08.63	A	-0.7	-11.0	0.965	0.982
OX	12	5	4.03.64	A	5.5	44.5	0.865	0.929
OX	12	6	1.03.65	A	17.9	31.4	0.746	0.920
OX	12	7	24.05.66	A	9.7	24.5	0.933	0.989
OX	12	8	31.05.67	A	5.7	-18.1	0.890	0.897
OX	12	9	1.02.68	A	26.3	3.6	0.783	0.831
OX	12	10	17.04.69	A	14.4	41.7	0.850	0.980
OX	12	11	21.02.71	C	5.2	51.8	0.542	0.655
OX	17	1	2.03.60	A	-23.7	-14.3	0.709	0.823
OX	17	2	31.08.61	B	-4.4	-20.1	0.363	0.385
OX	17	3	4.09.62	B	8.9	-28.9	0.710	0.645
OX	17	4	29.08.63	A	1.6	9.2	0.788	0.791
OX	17	5	4.03.64	A	-0.3	45.6	0.697	0.785
OX	17	6	1.03.65	A	-5.5	-16.1	0.923	0.927
OX	17	7	24.05.66	A	-31.8	-19.4	0.596	0.667
OX	17	8	31.05.67	A	-11.8	-30.3	0.708	0.729
OX	17	9	1.02.68	A	-3.5	2.7	0.976	0.977
OX	17	10	17.04.69	A	-12.5	21.4	0.912	0.938
OX	17	11	21.02.71	C	2.0	59.3	0.552	0.658
OX	17	12	2.07.72	C	-4.4	107.5	0.269	0.513
OX	17	13	19.04.73	C	-4.1	183.2	-0.277	0.598
OX	28	1	17.01.60	A	4.5	-49.3	0.750	0.796
OX	28	2	4.09.62	A	-28.5	-58.3	0.511	0.687
OX	28	3	29.08.63	A	-17.5	-41.8	0.776	0.919
OX	28	4	4.03.64	A	-36.7	-49.3	0.716	0.948
OX	28	5	1.03.65	A	116.3	50.3	-1.207	0.774
OX	28	6	24.05.66	A	132.2	89.6	-3.631	0.671
OX	28	7	31.05.67	A	-48.9	-69.9	0.095	0.169
OX	32	1	22.05.59	B	20.1	-14.6	0.876	0.891
OX	32	2	2.03.60	A	-7.8	27.9	0.305	0.698
OX	32	3	31.08.61	B	4.5	-9.2	0.202	0.342
OX	32	4	4.09.62	A	-19.2	-20.2	0.690	0.727
OX	32	5	29.08.63	A	-14.7	-36.1	0.457	0.466
OX	32	6	4.03.64	A	1.9	10.3	0.965	0.983
OX	32	7	1.03.65	A	-0.4	-21.5	0.868	0.870
OX	32	8	24.05.66	A	-13.8	3.7	0.799	0.807
OX	32	9	31.05.67	A	-14.9	-25.7	0.783	0.834

Catch name	Storm No.	Storm date	Storm type	Calibration % Error Vol.	Peak	Coefficient Eff.	Det.
OX 32	10	1.02.68	A	17.1	19.7	0.754	0.803
OX 32	11	17.04.69	A	0.1	67.6	0.749	0.889
OX 32	12	18.06.71	C	-1.9	-12.6	0.724	0.737
OX 32	13	25.06.72	C	0.6	20.0	0.880	0.931
OX 32	14	19.04.73	C	-11.4	62.1	0.740	0.846
OX 35	1	22.05.59	B	6.6	16.8	0.935	0.940
OX 35	2	2.03.60	A	0.5	90.1	-0.059	0.821
OX 35	3	31.08.61	B	-12.6	-38.1	0.643	0.706
OX 35	4	4.09.62	A	7.3	-25.4	0.187	0.329
OX 35	5	29.08.63	A	11.5	-20.8	0.194	0.281
OX 35	6	4.03.64	A	-22.2	0.7	0.707	0.738
OX 35	7	1.03.65	A	-1.0	27.9	0.402	0.669
OX 35	8	24.05.66	A	4.2	31.0	0.924	0.931
OX 35	9	31.05.67	A	7.8	64.0	0.729	0.871
OX 35	10	1.02.68	A	3.5	13.1	0.482	0.556
OX 35	11	17.04.69	A	0.4	140.6	0.092	0.656
OX 35	12	26.08.71	C	9.6	2.5	0.729	0.771
KAAI	1	25.03.81	C	-16.2	0.7	0.863	0.880
KAAI	2	26.04.81	C	-14.0	-19.2	0.845	0.860
KAAI	3	5.05.81	C	18.2	6.9	-0.359	0.210
KAAI	4	28.05.81	C	-7.7	-19.9	0.881	0.890
KAAI	6	24.08.81	C	-29.0	-33.2	0.581	0.690
KAAI	7	27.08.81	C	-2.5	13.3	0.143	0.459
KAAI	8	30.08.81	C	-6.7	-8.0	-0.025	0.417
KAAI	9	18.02.82	C	-4.3	-12.2	0.156	0.360
KAAI	10	3.03.82	C	18.2	-2.7	0.278	0.440
KAAI	11	12.09.82	C	-20.2	118.5	-0.207	0.130
KAAI	12	12.06.83	C	0.8	-3.9	0.658	0.780
KAAI	13	2.10.83	C	-0.9	-18.4	0.543	0.630
KAAI	14	28.10.85	C	-2.1	-7.7	0.648	0.660
KAAI	15	2.11.85	B	16.5	26.3	-2.823	0.001
KAAI	16	8.11.85	B	-22.2	14.5	-0.237	0.320
KAAI	17	2.12.85	B	-0.5	-18.2	-0.198	0.370
MALGAS	1	25.03.81	C	-7.1	-3.1	0.824	0.829
MALGAS	2	26.04.81	C	-3.8	4.7	0.876	0.881
MALGAS	3	5.05.81	C	1.4	49.0	0.202	0.813
MALGAS	4	28.05.81	C	-9.6	14.3	0.916	0.934
MALGAS	6	24.08.81	C	-4.8	19.9	-1.131	0.030
MALGAS	7	27.08.81	C	19.4	61.3	-0.159	0.623
MALGAS	8	30.08.81	C	3.7	7.2	0.592	0.808
MALGAS	9	15.10.81	C	-4.1	-2.7	0.703	0.816
MALGAS	10	15.01.82	C	12.8	-13.6	0.163	0.288
MALGAS	11	18.02.82	C	1.1	-9.9	0.787	0.809
MALGAS	12	3.03.82	C	-12.8	16.0	0.925	0.964
MALGAS	13	1.09.82	C	SUSPECT DATA			
MALGAS	14	11.06.83	C	-11.2	-8.9	-0.038	0.215
MALGAS	15	22.09.83	C	-18.0	1.7	0.202	0.396
MALGAS	16	15.10.85	B	-12.0	-10.1	0.917	0.928
MALGAS	17	21.01.86	B	-0.8	-41.1	0.173	0.239
ND 1	1	24.10.59	A	-18.0	-14.5	0.837	0.909
ND 1	2	30.07.60	A	19.4	-15.2	-0.245	0.846
ND 1	4	31.07.62	B	5.9	-11.5	0.802	0.865
ND 1	6	22.07.64	B	27.6	38.3	-1.110	0.420
ND 1	7	7.06.65	C	SUSPECT DATA			
ND 1	8	19.10.66	C	-13.4	0.9	0.725	0.830
ND 1	9	16.07.67	C	-8.9	8.9	0.700	0.820
ND 1	10	11.09.68	C	-6.3	-16.6	0.962	0.980
ND 1	12	23.08.71	C	4.3	6.7	0.916	0.960
ND 1	13	3.07.72	C	-9.7	7.2	0.649	0.739
ND 1	14	10.07.72	C	-11.2	-6.1	0.909	0.930
ND 1	15	17.09.73	A	3.2	-3.1	0.904	0.910

Catch name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Calibration % Error Peak	Calibration Coefficient Eff.	Calibration Coefficient Det.
ND	5	1	30.07.60	A	15.6	-14.1	0.808	0.840
ND	5	3	31.07.62	B	-10.0	-17.2	0.941	0.960
ND	5	6	7.06.65	C	-2.8	-11.6	0.879	0.880
ND	5	7	19.10.66	C	-2.0	7.9	0.938	0.980
ND	5	8	16.07.67	C	1.1	-1.2	0.739	0.780
ND	5	9	11.09.68	C	0.0	-3.2	0.944	0.950
ND	5	11	23.08.71	C	3.3	11.8	0.886	0.941
ND	5	12	10.07.72	C	-7.2	-3.0	0.922	0.940
ND	5	13	20.07.72	C	3.2	-1.4	0.864	0.890
ND	5	14	14.07.73	C	-4.3	9.9	0.779	0.850
ND	5	15	17.09.73	A	0.1	-10.9	0.934	0.940

MODEL OSE1 Semi-distributed calibration and validation results

Catch name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Calibration % Error Peak	Calibration Coefficient Eff.	Calibration Coefficient Det.	Validation % Error Vol.	Validation % Error Peak	Validation Coefficient Eff.	Validation Coefficient Det.
TM	1	1	26.07.59	B	-11.7	-13.0	0.568	0.602	NOT MODELLED			
TM	1	2	4.09.65	C	22.1	-20.9	0.606	0.705	NOT MODELLED			
TM	2	1	26.07.59	B	-19.6	19.2	0.840	0.870	NOT MODELLED			
TM	2	2	17.08.61	C	9.2	-15.1	0.487	0.597	NOT MODELLED			
TM	2	3	4.09.65	B	-14.6	-1.3	0.840	0.870	NOT MODELLED			
TM	2	4	25.08.68	C	37.0	-41.0	0.670	0.710	NOT MODELLED			
TM	2	5	31.08.68	C	-19.1	-11.1	-0.390	0.062	NOT MODELLED			
TM	3	1	19.07.55	C	-3.0	-33.4	0.843	0.851	14.5	-36.2	0.776	0.784
TM	3	2	14.08.58	B	-2.1	0.2	0.721	0.792	-51.7	-68.1	0.392	0.718
TM	3	3	16.08.58	C	2.4	-5.8	0.739	0.829	222.3	97.4	-4.184	0.711
TM	3	4	17.08.61	B	-43.6	15.1	0.599	0.679	-88.6	-91.1	-0.094	0.835
TM	3	5	25.07.62	C	-2.4	-21.6	-0.949	0.002	7.6	-63.2	0.283	0.285
TM	3	7	25.08.68	C	16.1	-24.5	0.076	0.195	104.6	-9.7	0.209	0.537
TM	3	8	31.08.68	C	19.3	-19.6	-0.240	0.116	97.6	-21.8	0.090	0.452
TM	3	11	27.07.73	C	-18.2	-22.3	0.376	0.416	-44.8	-69.6	0.234	0.616
TM	6	1	4.09.65	B	0.4	13.8	0.814	0.837	NOT MODELLED			
TM	6	2	31.08.68	B	17.1	6.8	-0.559	0.129	NOT MODELLED			
TM	8	1	19.08.63	C	-38.0	-24.5	0.106	0.247	-84.9	-93.9	-0.375	0.101
TM	8	2	22.07.64	C	9.3	-26.3	0.876	0.884	109.0	-23.3	-0.080	0.400
TM	8	3	9.09.64	C	-4.6	7.0	0.750	0.751	1.2	-58.5	0.214	0.215
TM	8	5	11.09.64	C	3.7	-60.8	0.453	0.467	248.8	-13.0	-1.162	0.319
TM	8	6	17.07.65	C	10.8	15.8	0.505	0.628	118.6	2.8	-0.255	0.485
TM	8	7	4.09.65	B	-3.4	-9.2	0.657	0.728	19.2	-40.9	0.497	0.530
TM	8	8	30.07.66	C	-2.0	32.2	-1.920	0.008	355.7	243.2	-16.661	0.185
TM	8	10	31.08.68	C	12.3	10.5	0.237	0.478	11.7	-63.8	0.131	0.154
TM	8	11	24.07.72	C	13.9	-39.6	-0.187	0.080	197.0	4.6	-1.100	0.581
TM	11	1	19.08.63	C	18.1	39.0	-0.372	0.223	-90.2	-93.4	-0.070	0.753
TM	11	2	22.07.64	B	10.1	-17.9	0.648	0.662	-12.1	-37.1	0.864	0.931
TM	11	3	9.09.64	C	3.2	77.4	0.599	0.714	-55.3	-59.5	0.416	0.707
TM	11	4	11.09.64	B	2.8	40.1	0.773	0.853	67.3	81.7	0.195	0.894
TM	11	5	17.07.65	C	7.6	25.5	0.507	0.574	126.3	1.3	-0.106	0.680
TM	11	6	4.09.65	B	-6.8	3.0	0.807	0.818	85.9	28.1	0.374	0.916
TM	11	7	30.07.66	C	0.8	17.5	-1.194	0.000	206.2	170.9	-6.435	0.084
TM	11	9	31.08.68	C	31.3	4.2	0.802	0.849	0.2	-71.5	0.102	0.104
TM	11	10	13.08.69	B	13.1	108.4	-0.184	0.591	-15.5	-37.7	0.823	0.927
TM	11	11	15.09.69	C	-9.6	19.8	0.736	0.763	-50.6	-73.8	0.037	0.234
TM	11	12	21.08.73	B	-32.9	-31.5	0.569	0.650	-86.3	-92.6	-0.167	0.718
EC	1	1	28.02.77	A	12.5	-2.0	0.743	0.831	127.5	183.0	-11.194	0.278
EC	1	2	6.03.77	B	8.5	-16.5	0.790	0.815	-86.9	-94.2	-1.032	0.018
EC	1	3	7.05.77	B	7.1	-12.0	0.640	0.678	393.0	190.3	-16.118	0.272
EC	1	4	19.04.78	A	9.5	-5.3	0.907	0.913	327.9	222.4	-5.776	0.757
EC	1	6	20.07.79	A	-61.9	-46.0	-0.123	0.431	-17.0	-8.5	0.323	0.389
EC	1	7	23.07.79	A	-7.9	6.1	0.839	0.948	58.0	143.5	-5.687	0.546

Catch name	Storm No.	Storm date	Storm type	Calibration % Error Vol.	Calibration % Error Peak	Calibration Coefficient Eff.	Calibration Coefficient Det.	Validation % Error Vol.	Validation % Error Peak	Validation Coefficient Eff.	Validation Coefficient Det.
EC 1	8	19.08.79	A	-7.0	-3.1	0.713	0.787	23.9	4.9	-0.859	0.166
EC 1	9	26.03.81	A	10.3	-2.3	0.704	0.771	438.9	609.6	-63.869	0.476
EC 1	10	22.10.81	B	-9.2	1.5	0.603	0.737	-60.0	-61.4	-2.003	0.344
EC 1	11	23.12.81	A	12.9	-9.8	0.804	0.812	-18.4	-41.7	0.600	0.703
EC 1	12	2.11.85	A	-0.1	7.8	0.909	0.972	42.8	133.4	-3.512	0.555
EC 1	13	25.11.85	B	-12.5	-6.5	0.451	0.588	-23.2	-37.1	0.200	0.520
EC 1	14	1.12.85	B	-17.4	5.4	-0.450	0.272	-11.3	6.7	-0.629	0.173
BETH	2	15.12.80	B	6.1	-2.3	0.836	0.880	NOT MODELLED			
BETH	5	05.02.81	B	-23.9	-46.6	-0.045	0.123	NOT MODELLED			
BETH	6	10.02.81	B	-13.1	-16.8	0.956	0.980	NOT MODELLED			
BETH	7	14.02.81	B	16.6	-17.3	0.717	0.784	NOT MODELLED			
BETH	8	17.02.81	B	-19.3	-13.2	0.815	0.854	NOT MODELLED			
BETH	9	27.02.81	C	-1.0	-20.6	0.602	0.630	NOT MODELLED			
BETH	10	22.03.81	C	-12.5	-7.9	0.232	0.371	NOT MODELLED			
HOEK	1	2.03.79	A	14.9	93.1	-0.214	0.873	-32.2	-2.9	0.816	0.919
HOEK	2	4.05.79	B	-43.1	-77.8	-0.229	0.109	50.7	-39.7	0.017	0.496
HOEK	3	16.02.80	A	-40.3	-57.1	0.596	0.906	86.4	89.3	-1.026	0.897
HOEK	4	17.02.80	B	-15.7	-32.0	0.910	0.940	2.5	-16.6	0.934	0.935
HOEK	5	17.12.80	B	-7.4	-13.9	0.692	0.814	245.0	366.5	-23.477	0.685
HOEK	6	8.01.81	B	-44.7	-71.1	0.192	0.635	66.5	34.5	-0.038	0.783
HOEK	7	1.02.81	A	14.7	27.7	0.688	0.979	-11.0	-7.6	0.958	0.978
HOEK	8	19.02.81	B	4.6	3.3	0.756	0.864	12.2	2.7	0.554	0.742
HOEK	9	21.02.81	B	-5.0	-21.4	0.449	0.509	-12.9	34.8	0.466	0.484
HOEK	10	24.02.81	B	26.7	24.1	0.103	0.691	-45.9	-62.5	0.294	0.548
HOEK	11	21.03.82	A	20.6	70.7	-1.541	0.123	30.0	81.4	-2.044	0.106
HOEK	12	8.04.82	B	-12.2	-64.1	-0.442	0.001	311.2	102.5	-31.511	0.075
HOEK	13	26.11.83	B	5.0	-28.4	0.590	0.594	79.2	31.5	-0.204	0.555
HOEK	14	28.11.83	B	36.8	-6.6	0.799	0.904	-20.1	-50.4	0.750	0.864
HOEK	15	17.12.83	B	-16.2	-72.8	0.137	0.157	113.8	-29.6	-0.837	0.292
HOEK	16	24.12.83	B	20.9	2.2	0.858	0.937	-24.3	-48.4	0.778	0.884
CED	1	11.11.78	A	-3.1	-41.6	0.835	0.885	NOT MODELLED			
CED	2	9.12.78	A	25.2	128.2	-2.896	0.389	NOT MODELLED			
CED	3	28.12.78	A	-9.4	-33.7	0.848	0.865	NOT MODELLED			
CED	4	2.01.79	A	-5.9	20.1	0.145	0.513	NOT MODELLED			
CED	5	25.02.79	A	17.1	-18.4	0.680	0.764	NOT MODELLED			
CED	6	2.12.84	A	-15.6	-16.6	0.893	0.961	NOT MODELLED			
CED	7	9.02.85	A	10.4	57.2	-0.954	0.218	NOT MODELLED			
CED	8	24.02.85	C	21.1	-23.8	0.721	0.754	NOT MODELLED			
CED	9	11.03.85	A	-14.0	-16.1	0.501	0.569	NOT MODELLED			
CED	10	14.03.86	C	25.9	-27.5	0.723	0.798	NOT MODELLED			
ZL 15	1	29.01.77	B	14.5	106.4	-0.481	0.451	63.1	115.7	-1.758	0.672
ZL 15	2	6.02.77	B	-1.0	-23.7	0.387	0.438	8.9	-17.4	0.337	0.476
ZL 15	3	14.02.77	B	16.7	3.7	0.521	0.738	13.2	-33.5	0.595	0.637
ZL 15	4	14.03.77	B	-2.0	-16.5	0.632	0.655	0.5	4.5	0.411	0.553
ZL 15	5	9.10.77	A	-16.8	-8.7	0.888	0.950	14.3	27.7	0.701	0.919
ZL 15	6	9.11.77	B	5.3	-9.1	0.704	0.719	78.8	-89.4	-0.152	0.546
ZL 15	7	19.12.77	B	-16.7	-19.1	0.729	0.750	-46.8	-63.0	0.433	0.810
ZL 15	8	19.01.78	C	-8.3	-8.3	0.873	0.942	-64.4	-78.7	0.250	0.887
ZL 15	9	21.01.78	A	-11.9	-26.6	0.916	0.944	16.3	-4.2	0.913	0.944
ZL 15	10	21.02.78	B	-20.4	-6.6	0.881	0.942	19.3	-30.0	0.807	0.851
ZL 15	11	1.03.78	A	18.3	22.8	0.411	0.784	21.4	47.9	-0.143	0.869
ZL 15	12	9.03.78	B	-12.9	22.8	0.636	0.826	-14.5	7.4	0.555	0.760
ZL 15	13	27.03.78	B	7.6	-4.6	0.707	0.806	-86.8	-92.9	-0.336	0.798
ZL 15	14	8.09.78	A	7.6	-4.6	0.707	0.806	-73.1	-76.6	-0.304	0.859
ZL 15	15	18.10.78	A	12.2	-3.8	0.600	0.761	-4.6	-1.4	0.807	0.834
ZL 16	1	29.01.77	A	-9.5	16.0	0.826	0.914	NOT MODELLED			
ZL 16	3	14.02.77	A	16.7	3.7	0.521	0.738	NOT MODELLED			
ZL 16	5	9.10.77	A	-16.8	-8.7	0.888	0.951	NOT MODELLED			
ZL 16	6	9.11.77	A	5.3	-9.1	0.704	0.719	NOT MODELLED			
ZL 16	7	19.12.77	A	-16.7	-19.1	0.729	0.748	NOT MODELLED			
ZL 16	8	19.01.78	A	-8.3	-8.3	0.870	0.892	NOT MODELLED			
ZL 16	9	21.01.78	A	-8.2	-5.5	0.915	0.923	NOT MODELLED			

Catch name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Calibration % Error Peak	Calibration Coefficient Eff.	Calibration Coefficient Det.	Validation % Error Vol.	Validation % Error Peak	Validation Coefficient Eff.	Validation Coefficient Det.
ZL	16	10	21.02.78	A	-20.4	-6.6	0.881	0.942	NOT MODELLED			
ZL	16	11	1.03.78	A	-28.1	-4.3	0.691	0.932	NOT MODELLED			
ZL	16	12	9.03.78	A	-12.9	22.8	0.636	0.826	NOT MODELLED			
ZL	16	13	27.03.78	A	-18.2	-58.3	0.574	0.629	NOT MODELLED			
ZL	16	14	8.09.78	A	7.6	-4.6	0.707	0.806	NOT MODELLED			
ZL	16	15	18.10.78	A	12.2	-3.8	0.600	0.761	NOT MODELLED			
OX	4	1	3.04.58	A	-0.1	2.8	0.838	0.934	NOT MODELLED			
OX	4	2	17.01.60	A	20.5	12.3	0.661	0.791	NOT MODELLED			
OX	4	3	31.08.61	A	-30.4	-64.7	0.422	0.589	NOT MODELLED			
OX	4	4	4.09.62	A	-7.7	-46.3	0.823	0.870	NOT MODELLED			
OX	4	5	29.08.63	A	-3.6	-24.9	0.897	0.918	NOT MODELLED			
OX	10	1	22.05.59	B	-12.0	-60.6	0.573	0.688	-38.5	-83.1	0.109	0.266
OX	10	2	17.01.60	A	-0.4	-3.7	0.562	0.703	-29.0	12.0	0.925	0.982
OX	10	3	31.08.61	B	-28.0	-37.7	0.811	0.952	-59.1	-78.1	0.073	0.392
OX	10	4	4.09.62	A	-12.8	-40.5	0.832	0.949	-5.5	-57.6	0.520	0.604
OX	10	5	29.08.63	A	-3.8	-18.6	0.950	0.977	101.8	35.2	0.098	0.878
OX	10	6	4.03.64	A	-21.2	-17.5	0.931	0.962	10.7	12.0	0.925	0.982
OX	10	7	1.03.65	A	-18.4	-6.6	0.408	0.605	26.6	58.3	-0.185	0.725
OX	10	8	27.12.66	C	-9.8	-6.6	0.460	0.517	77.4	80.3	-1.050	0.582
OX	10	9	31.05.67	A	-7.6	-24.8	0.887	0.902	46.0	-6.2	0.291	0.590
OX	10	10	1.02.68	A	-6.6	8.6	0.317	0.463	-12.0	-8.8	0.617	0.642
OX	10	11	17.04.69	A	-2.4	1.1	0.967	0.968	173.1	180.5	-2.781	0.967
OX	10	12	26.08.71	C	-0.8	-23.1	0.760	0.771	-43.1	-70.8	0.345	0.790
OX	12	1	2.03.60	A	-46.0	-47.7	0.349	0.855	7.6	17.1	0.701	0.871
OX	12	2	31.08.61	B	-59.0	-75.7	0.032	0.366	-67.9	-84.6	-0.293	0.015
OX	12	3	4.09.62	B	4.5	-30.9	0.894	0.911	46.6	-17.5	0.548	0.680
OX	12	4	29.08.63	A	-10.7	-14.6	0.967	0.952	42.9	26.0	0.644	0.834
OX	12	5	4.03.64	A	-7.6	30.2	0.896	0.928	30.2	84.8	0.441	0.926
OX	12	6	1.03.65	A	-6.2	3.3	0.872	0.911	15.5	26.4	0.726	0.939
OX	12	7	24.05.66	A	-11.6	5.1	0.982	0.992	74.3	115.9	-0.448	0.975
OX	12	8	31.05.67	A	-3.0	-20.5	0.852	0.854	57.7	35.2	0.146	0.655
OX	12	9	1.02.68	A	6.7	-9.3	0.819	0.823	46.4	27.4	0.557	0.844
OX	12	10	17.04.69	A	-7.7	17.8	0.758	0.882	73.7	160.6	-1.169	0.956
OX	12	11	21.02.71	C	-15.5	19.3	0.622	0.658	3.9	58.9	0.573	0.698
OX	17	1	2.03.60	A	-14.0	-4.9	0.809	0.990	-44.2	-37.9	0.413	0.924
OX	17	2	31.08.61	B	8.7	-17.0	0.858	0.864	-80.0	-90.8	-0.270	0.056
OX	17	3	4.09.62	B	20.4	-6.2	0.832	0.850	-39.7	-66.7	0.160	0.248
OX	17	4	29.08.63	A	7.3	12.8	0.975	0.982	72.5	71.7	0.279	0.885
OX	17	5	4.03.64	A	1.7	56.6	0.335	0.635	-24.2	-18.5	0.690	0.731
OX	17	6	1.03.65	A	9.1	-1.1	0.699	0.771	-20.9	-29.3	0.828	0.864
OX	17	7	24.05.66	A	-29.8	-15.2	0.872	0.959	-23.6	-12.2	0.769	0.812
OX	17	8	31.05.67	A	3.2	-14.5	0.818	0.893	-2.8	-24.6	0.626	0.627
OX	17	9	1.02.68	A	-1.0	6.0	0.779	0.810	-54.1	-50.2	0.560	0.964
OX	17	10	17.04.69	A	45.7	113.6	-0.327	0.931	15.5	67.6	0.648	0.982
OX	17	11	21.02.71	C	-5.2	34.8	0.375	0.508	-33.8	2.5	0.516	0.599
OX	17	12	2.07.72	C	2.3	97.6	0.048	0.435	6.6	90.7	0.312	0.574
OX	17	13	19.04.73	C	-3.4	182.8	-0.391	0.581	-18.3	131.4	0.144	0.611
OX	32	1	22.05.59	B	-17.8	-49.9	0.554	0.600	-56.1	-83.8	-0.068	0.045
OX	32	2	2.03.60	A	-5.5	34.3	0.323	0.737	-52.2	-44.4	-0.865	0.180
OX	32	3	31.08.61	B	14.4	-17.9	0.758	0.785	-82.0	-94.6	-0.247	0.000
OX	32	4	4.09.62	A	-1.9	-51.5	0.689	0.698	-38.0	-81.7	0.166	0.286
OX	32	5	29.08.63	A	-9.5	-46.1	0.780	0.858	-30.3	-71.7	0.175	0.240
OX	32	6	4.03.64	A	2.2	12.8	0.949	0.969	-31.3	-38.1	0.745	0.859
OX	32	7	1.03.65	A	0.5	-49.7	0.182	0.236	-35.3	-71.6	0.193	0.277
OX	32	8	24.05.66	A	4.0	-3.3	0.973	0.976	-17.8	-46.4	0.661	0.703
OX	32	9	31.05.67	A	-12.4	-40.9	0.789	0.852	33.5	-21.6	0.348	0.427
OX	32	10	1.02.68	A	18.2	3.3	0.532	0.627	37.9	-56.2	0.599	0.910
OX	32	11	17.04.69	A	0.7	22.5	0.786	0.874	-26.8	-31.7	0.885	0.951
OX	32	12	18.06.71	C	0.4	-22.5	0.935	0.942	31.7	-14.6	0.419	0.498
OX	32	13	25.06.72	C	1.1	15.9	0.898	0.936	10.3	5.3	0.923	0.943
OX	32	14	19.04.73	C	-11.1	22.0	0.936	0.967	-15.4	-1.7	0.925	0.936
OX	35	1	22.05.59	B	22.6	20.4	0.904	0.956	-57.6	-80.6	0.070	0.347
OX	35	2	2.03.60	A	0.5	37.0	0.607	0.911	-13.1	1.3	0.702	0.800

Catch name	Storm No.	Storm date	Storm type	Calibration % Error Vol.	Calibration % Error Peak	Calibration Coefficient Eff.	Calibration Coefficient Det.	Validation % Error Vol.	Validation % Error Peak	Validation Coefficient Eff.	Validation Coefficient Det.
OX 35	3	31.08.61	B	-12.6	-49.4	0.672	0.808	-45.3	-77.3	0.018	0.137
OX 35	4	4.09.62	A	9.3	-32.3	0.544	0.590	-10.3	-68.8	0.000	0.060
OX 35	5	29.08.63	A	12.8	-23.1	0.355	0.391	29.8	-38.8	0.583	0.672
OX 35	6	4.03.64	A	-22.2	6.0	0.721	0.750	-44.2	-42.8	0.702	0.980
OX 35	7	1.03.65	A	-1.1	22.1	0.358	0.649	-40.9	-41.7	0.697	0.897
OX 35	8	24.05.66	A	3.4	11.0	0.953	0.954	16.8	-13.3	0.833	0.846
OX 35	9	31.05.67	A	2.7	31.9	0.915	0.953	57.1	49.7	0.378	0.780
OX 35	10	1.02.68	A	3.9	8.0	0.405	0.503	-61.1	-70.3	0.282	0.952
OX 35	11	17.04.69	A	0.8	95.8	0.247	0.686	-7.8	38.1	0.879	0.916
OX 35	12	26.08.71	C	10.1	4.6	0.675	0.718	-7.4	-47.0	0.729	0.861
KAAI	1	25.03.81	C	-11.6	4.1	0.841	0.850	-37.0	-10.5	0.722	0.835
KAAI	2	26.04.81	C	-9.0	-14.0	0.875	0.884	-12.6	-4.1	0.791	0.807
KAAI	3	5.05.81	C	-14.6	19.5	-0.089	0.390	35.1	142.7	-2.660	0.162
KAAI	4	28.05.81	C	-6.3	-20.9	0.869	0.868	-29.4	-36.6	0.745	0.856
KAAI	6	24.08.81	C	-8.4	-5.0	0.677	0.720	-17.3	-0.3	0.532	0.620
KAAI	7	27.08.81	C	-1.2	8.6	0.266	0.553	28.1	45.4	-0.404	0.453
KAAI	8	30.08.81	C	-5.7	-10.8	0.075	0.493	42.4	37.7	-1.018	0.346
KAAI	9	18.02.82	C	-11.4	-16.2	0.590	0.652	-17.3	-13.7	0.502	0.574
KAAI	10	3.03.82	C	15.6	8.4	0.540	0.660	-2.7	-95.5	-0.432	0.380
KAAI	11	11.06.83	C	SUSPECT DATA				122.8	330.8	-9.334	0.137
KAAI	12	12.06.83	C	-6.3	-11.2	0.772	0.850	-5.4	-7.1	0.661	0.791
KAAI	13	2.10.83	C	-4.3	-21.6	0.610	0.682	-79.7	-79.3	-0.684	0.013
KAAI	14	28.10.85	C	-4.6	-6.2	0.845	0.850	-74.0	-76.2	-0.286	0.606
KAAI	15	2.11.85	B	-1.1	5.2	-1.389	0.034	-52.0	-50.3	0.427	0.830
KAAI	16	8.11.85	B	-17.5	17.3	0.377	0.684	102.4	96.7	-5.440	0.001
KAAI	17	2.12.85	B	1.3	-3.1	0.776	0.799	7.6	90.2	-0.587	0.486
MALGAS	1	25.03.81	C	6.4	1.3	0.833	0.839	-19.6	6.6	0.849	0.884
MALGAS	2	26.04.81	C	-3.1	9.3	0.845	0.859	18.3	69.1	0.181	0.656
MALGAS	3	5.05.81	C	19.8	21.4	0.435	0.803	-14.3	56.9	-0.119	0.781
MALGAS	4	28.05.81	C	-9.2	-14.4	0.910	0.923	22.4	-20.1	0.790	0.864
MALGAS	6	24.08.81	C	-4.5	31.2	-1.497	0.015	-58.2	-30.5	-0.913	0.001
MALGAS	7	27.08.81	C	-13.3	12.3	0.436	0.621	2.8	83.7	-0.582	0.450
MALGAS	8	30.08.81	C	-4.7	4.9	0.580	0.779	-7.7	11.1	0.135	0.598
MALGAS	9	15.10.81	C	-9.7	0.1	0.888	0.929	-77.7	-74.3	-0.633	0.914
MALGAS	10	15.01.82	C	-10.3	-4.3	0.087	0.286	-30.9	-2.3	-0.580	0.108
MALGAS	11	18.02.82	C	1.1	-2.5	0.746	0.807	-51.5	-42.3	0.470	0.703
MALGAS	12	3.03.82	C	-19.2	18.1	0.900	0.958	-47.9	21.7	0.517	0.789
MALGAS	14	11.06.83	C	-10.5	2.1	-0.192	0.193	-88.1	-86.7	-1.084	0.233
MALGAS	15	22.09.83	C	-17.4	15.3	0.095	0.362	-88.2	-80.6	-1.508	0.408
MALGAS	16	15.10.85	B	-15.2	-5.3	0.927	0.946	-30.1	-7.1	0.740	0.830
MALGAS	17	21.01.86	B	20.9	-19.5	-0.266	0.160	-82.5	-87.3	-0.620	0.221
ND 1	1	24.10.59	A	-12.5	-12.8	0.880	0.921	NOT MODELLED			
ND 1	2	30.07.60	A	17.6	-20.2	0.740	0.783	NOT MODELLED			
ND 1	4	31.07.62	B	2.9	-18.3	0.847	0.863	NOT MODELLED			
ND 1	6	22.07.64	B	-1.8	-11.3	0.514	0.571	NOT MODELLED			
ND 1	7	7.06.65	C	-84.6	-90.1	-0.872	0.929	NOT MODELLED			
ND 1	8	19.10.66	C	-3.4	6.5	0.707	0.771	NOT MODELLED			
ND 1	9	16.07.67	C	-11.8	-4.4	0.883	0.931	NOT MODELLED			
ND 1	10	11.09.68	C	1.6	-18.8	0.956	0.971	NOT MODELLED			
ND 1	12	23.08.71	C	15.0	6.8	0.892	0.993	NOT MODELLED			
ND 1	13	3.07.72	C	-13.5	-12.0	0.500	0.566	NOT MODELLED			
ND 1	14	10.07.72	C	2.0	-1.1	0.936	0.951	NOT MODELLED			
ND 1	15	17.09.73	A	-2.8	-15.0	0.896	0.901	NOT MODELLED			
ND 5	1	30.07.60	A	9.5	-19.9	0.722	0.732	-43.6	-60.2	0.325	0.800
ND 5	3	31.07.62	B	0.8	-6.4	0.942	0.950	-38.0	-43.9	0.618	0.951
ND 5	6	7.06.65	C	-3.2	14.0	0.720	0.730	-61.2	-68.1	-0.448	0.881
ND 5	7	19.10.66	C	0.7	5.4	0.926	0.940	46.5	68.1	-0.797	0.745
ND 5	8	16.07.67	C	-5.5	-10.3	0.914	0.920	-43.9	-46.1	0.312	0.923
ND 5	9	11.09.68	C	-0.1	-7.7	0.937	0.941	32.1	44.3	0.378	0.856
ND 5	11	23.08.71	C	10.1	12.3	0.901	0.977	172.1	274.2	-17.385	0.751
ND 5	12	10.07.72	C	-8.2	-6.2	0.908	0.920	-44.2	-45.7	0.404	0.946
ND 5	13	20.07.72	C	-0.6	-6.5	0.893	0.900	131.5	169.3	-5.884	0.741
ND 5	14	14.07.73	C	9.6	10.1	0.937	0.990	-56.4	-65.0	-0.424	0.910
ND 5	15	17.09.73	A	11.9	0.4	0.803	0.925	-10.6	-16.4	0.798	0.815

MODEL OSE3 Lumped calibration results

Catch name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Calibration % Error Peak	Coefficient Eff.	Coefficient Det.
TM	1	1	26.07.59	B	-1.2	-3.3	0.550	0.675
TM	1	2	4.09.65	C	6.5	-14.1	0.740	0.830
TM	2	1	26.07.59	B	0.8	1.7	0.850	0.886
TM	2	2	17.08.61	C	-0.3	4.7	0.550	0.710
TM	2	3	4.09.65	B	-0.8	14.0	0.749	0.880
TM	2	4	25.08.68	C	-2.7	-53.2	0.670	0.710
TM	2	5	31.08.68	C	-1.9	7.0	0.627	0.740
TM	3	1	19.07.55	C	4.1	-26.9	0.883	0.885
TM	3	2	14.08.58	B	0.1	-5.7	0.855	0.886
TM	3	3	16.08.58	C	3.2	-19.2	0.786	0.830
TM	3	4	17.08.61	B	-4.4	85.2	0.390	0.840
TM	3	5	25.07.62	C	3.7	-17.0	0.920	0.940
TM	3	7	25.08.68	C	23.2	-23.1	0.778	0.793
TM	3	8	31.08.68	C	10.8	-9.5	0.841	0.847
TM	3	11	27.07.73	C	2.2	-8.6	0.925	0.928
TM	6	1	4.09.65	B	-2.1	1.3	0.936	0.952
TM	6	2	31.08.68	B	-1.5	-7.1	0.737	0.780
TM	8	1	19.08.63	C	-7.2	25.6	0.704	0.862
TM	8	2	22.07.64	C	0.1	-46.2	0.803	0.812
TM	8	3	9.09.64	C	1.4	9.6	0.845	0.866
TM	8	5	11.09.64	C	6.0	60.1	0.575	0.627
TM	8	6	17.07.65	C	-18.4	17.2	0.811	0.855
TM	8	7	4.09.65	B	-7.5	16.4	0.659	0.833
TM	8	8	30.07.66	C	0.5	15.6	0.660	0.806
TM	8	10	31.08.68	C	-0.3	4.2	0.804	0.906
TM	8	11	24.07.72	C	5.0	-43.9	0.138	0.205
TM	11	1	19.08.63	C	-4.1	-14.3	0.924	0.930
TM	11	2	22.07.64	B	-1.0	-28.6	0.906	0.916
TM	11	3	9.09.64	C	-4.0	18.5	0.840	0.850
TM	11	4	11.09.64	B	-9.3	2.1	0.870	0.874
TM	11	5	17.07.65	C	-1.7	-44.3	0.718	0.721
TM	11	6	4.09.65	B	21.1	1.5	0.930	0.975
TM	11	7	30.07.66	C	8.2	-0.3	0.953	0.957
TM	11	9	31.08.68	C	22.8	-21.6	0.750	0.770
TM	11	10	13.08.69	B	-6.0	14.5	0.799	0.832
TM	11	11	15.09.69	C	-5.1	6.4	0.865	0.905
TM	11	12	21.08.73	B	10.8	-14.3	0.941	0.946
EC	1	1	28.02.77	A	-1.9	2.6	0.938	0.942
EC	1	2	6.03.77	B	-0.2	3.0	0.737	0.830
EC	1	3	7.05.77	B	-21.3	5.4	0.735	0.775
EC	1	4	19.04.78	A	-0.3	-2.9	0.960	0.961
EC	1	5	21.04.78	A	-4.2	-0.4	0.828	0.888
EC	1	6	20.07.79	A	-1.0	2.1	0.876	0.879
EC	1	7	23.07.79	A	-0.6	-0.7	0.950	0.900
EC	1	8	19.08.79	A	-6.5	1.8	0.917	0.936
EC	1	9	26.03.81	A	2.2	-1.2	0.938	0.939
EC	1	10	22.10.81	B	-16.7	14.4	0.356	0.694
EC	1	11	23.12.81	A	0.3	-3.5	0.979	0.980
EC	1	12	2.11.85	A	-6.8	2.5	0.928	0.962
EC	1	13	25.11.85	B	-19.1	4.6	0.524	0.628
EC	1	14	1.12.85	B	-3.9	-23.8	0.821	0.825
EC	2	1	28.02.77	A	9.5	-10.6	0.848	0.872
EC	2	2	6.03.77	B	5.3	-6.8	0.866	0.868
EC	2	3	7.05.77	B	-12.9	-18.9	0.870	0.892
EC	2	5	21.04.78	A	-1.6	3.9	0.664	0.771
EC	2	6	20.07.79	A	1.2	2.9	0.832	0.841
EC	2	7	23.07.79	A	-1.8	2.6	0.960	0.978
EC	2	8	19.08.79	A	-5.6	9.4	0.938	0.967
EC	2	9	26.03.81	A	-5.1	4.6	0.598	0.656

Catch name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Calibration % Error Peak	Coefficient Eff.	Coefficient Det.
EC	2	11	23.12.81	A	-2.7	-16.4	0.760	0.783
EC	2	12	2.11.85	A	-4.1	1.9	0.896	0.956
EC	2	14	1.12.85	B	-0.0	-0.2	0.967	0.968
BETH		1	01.11.80	C	-10.8	-3.8	-0.058	0.231
BETH		2	15.12.80	B	-11.6	3.5	0.783	0.859
BETH		5	05.02.81	B	10.9	-51.1	-0.282	0.006
BETH		6	10.02.81	B	-3.3	6.1	0.933	0.956
BETH		7	14.02.81	B	6.2	-7.9	0.876	0.914
BETH		8	17.02.81	B	-5.3	16.2	0.884	0.926
BETH		9	27.02.81	C	23.2	-24.8	0.605	0.662
BETH		10	22.03.81	C	-17.3	30.6	0.664	0.774
HOEK		1	2.03.79	A	-5.0	95.6	0.215	0.780
HOEK		2	4.05.79	B	-16.5	-7.7	0.060	0.345
HOEK		3	16.02.80	A	-4.1	-56.1	0.178	0.569
HOEK		4	17.02.80	B	-6.7	-11.0	0.803	0.804
HOEK		5	17.12.80	B	-7.1	9.4	0.662	0.744
HOEK		6	8.01.81	B	-8.2	-27.1	0.028	0.141
HOEK		7	1.02.81	A	0.0	-23.5	0.925	0.939
HOEK		8	19.02.81	B	-9.2	-19.5	0.737	0.746
HOEK		9	21.02.81	B	-2.6	-13.3	0.783	0.789
HOEK		10	24.02.81	B	-11.3	-29.6	0.390	0.416
HOEK		11	21.03.82	A	-4.9	36.1	-0.706	0.066
HOEK		12	8.04.82	B	-22.6	-59.9	-1.210	0.168
HOEK		13	26.11.83	B	-13.8	-0.7	0.339	0.403
HOEK		14	28.11.83	B	-9.6	-35.9	0.852	0.883
HOEK		15	17.12.83	B	-17.0	-50.1	0.604	0.698
HOEK		16	24.12.83	B	-4.4	12.6	0.828	0.849
CED		1	11.11.78	A	-14.9	-8.0	0.384	0.429
CED		2	9.12.78	A	-6.7	18.7	0.499	0.625
CED		3	28.12.78	A	0.9	-1.0	0.274	0.472
CED		4	2.01.79	A	-0.3	39.7	-0.987	0.136
CED		5	25.02.79	A	-1.3	-5.8	0.433	0.524
CED		6	2.12.84	A	-16.9	60.9	-0.153	0.350
CED		7	9.02.85	A	-5.5	7.2	0.361	0.510
CED		8	24.02.85	C	8.5	-20.6	0.576	0.589
CED		9	11.03.85	A	-11.1	50.8	-0.917	0.097
CED		10	14.03.86	C	-5.8	61.4	-0.667	0.332
ZL	15	1	29.01.77	B	2.2	33.7	0.465	0.691
ZL	15	2	6.02.77	B	-1.0	-19.5	0.458	0.504
ZL	15	3	14.02.77	B	-0.7	-34.5	0.666	0.667
ZL	15	4	14.03.77	B	-0.9	-22.1	0.634	0.664
ZL	15	5	9.10.77	A	-3.4	10.8	0.919	0.942
ZL	15	6	9.11.77	B	-7.5	-17.3	0.948	0.960
ZL	15	7	19.12.77	B	-1.2	-1.9	0.977	0.985
ZL	15	8	19.01.78	C	-6.0	3.3	0.839	0.903
ZL	15	9	21.01.78	A	1.4	-10.1	0.978	0.978
ZL	15	10	21.02.78	B	-1.4	-8.8	0.804	0.894
ZL	15	11	1.03.78	A	-11.9	-4.5	0.776	0.900
ZL	15	12	9.03.78	B	-2.3	24.5	0.616	0.823
ZL	15	13	27.03.78	B	-2.0	1.3	0.552	0.609
ZL	15	14	8.09.78	A	-4.7	-9.8	0.690	0.694
ZL	15	15	18.10.78	A	-7.3	-24.8	0.857	0.870
ZL	16	1	29.01.77	A	-3.3	27.2	0.761	0.867
ZL	16	2	6.02.77	A	-1.3	-38.1	0.205	0.242
ZL	16	3	14.02.77	A	-3.1	-5.2	0.783	0.801
ZL	16	4	14.03.77	A	1.0	11.2	0.638	0.703
ZL	16	5	9.10.77	A	-15.4	2.0	0.867	0.925
ZL	16	6	9.11.77	A	-13.6	-5.1	0.776	0.793
ZL	16	7	19.12.77	A	-15.8	25.5	0.516	0.610
ZL	16	8	19.01.78	A	-7.8	14.2	0.592	0.735
ZL	16	9	21.01.78	A	-0.3	9.7	0.939	0.959
ZL	16	10	21.02.78	A	-6.2	22.1	0.915	0.935

Catch name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Peak	Coefficient Eff.	Det.
ZL	16	11	1.03.78	A	-4.7	33.4	0.843	0.878
ZL	16	12	9.03.78	A	-3.1	34.8	0.619	0.798
ZL	16	13	27.03.78	A	-5.0	-20.8	0.175	0.314
ZL	16	14	8.09.78	A	-13.7	-13.7	0.693	0.726
ZL	16	15	18.10.78	A	-13.0	-44.5	0.645	0.605
OX	4	1	3.04.58	A	-0.7	51.6	0.363	0.739
OX	4	2	17.01.60	A	-2.1	11.2	0.774	0.800
OX	4	3	31.08.61	A	-12.2	-8.4	0.950	0.975
OX	4	4	4.09.62	A	-3.0	-17.7	0.800	0.808
OX	4	5	29.08.63	A	-1.0	19.3	0.845	0.868
OX	5	1	3.04.58	A	-4.7	12.0	0.960	0.970
OX	5	2	17.01.60	A	-1.8	0.2	0.902	0.914
OX	5	3	31.08.61	A	-5.2	-9.3	0.939	0.961
OX	5	4	4.09.62	A	-7.1	-21.4	0.917	0.954
OX	5	5	29.08.63	A	-0.6	34.3	0.864	0.907
OX	5	6	4.03.64	A	7.2	19.7	0.922	0.941
OX	5	7	1.03.65	A	18.0	7.8	0.853	0.898
OX	5	8	24.05.66	A	-5.0	15.0	0.902	0.909
OX	5	9	31.05.67	A	1.5	13.8	0.892	0.919
OX	10	1	22.05.59	B	-45.9	-61.8	0.468	0.794
OX	10	2	17.01.60	A	-2.7	0.8	0.794	0.820
OX	10	3	31.08.61	B	-12.3	12.1	0.784	0.802
OX	10	4	4.09.62	A	-6.0	-18.8	0.943	0.973
OX	10	5	29.08.63	A	-2.7	-1.8	0.933	0.934
OX	10	6	4.03.64	A	1.1	11.0	0.948	0.960
OX	10	7	1.03.65	A	-4.1	23.0	0.772	0.875
OX	10	8	27.12.66	C	-3.9	4.1	0.693	0.721
OX	10	9	31.05.67	A	-12.1	0.3	0.685	0.722
OX	10	10	1.02.68	A	-5.0	24.3	0.627	0.701
OX	10	11	17.04.69	A	-4.1	30.6	0.823	0.840
OX	10	12	26.08.71	C	-3.5	-7.0	0.899	0.903
OX	12	1	2.03.60	A	-32.4	-42.7	0.368	0.585
OX	12	2	31.08.61	B	-10.9	-23.7	0.562	0.571
OX	12	3	4.09.62	B	4.1	-27.7	0.908	0.941
OX	12	4	29.08.63	A	-3.9	-6.4	0.953	0.968
OX	12	5	4.03.64	A	-10.4	7.4	0.870	0.881
OX	12	6	1.03.65	A	-10.0	-16.5	0.845	0.882
OX	12	7	24.05.66	A	2.9	-10.0	0.885	0.885
OX	12	8	31.05.67	A	-12.7	-33.7	0.767	0.829
OX	12	9	1.02.68	A	-11.6	-34.0	0.845	0.967
OX	12	10	17.04.69	A	-8.8	-24.3	0.858	0.911
OX	12	11	21.02.71	C	-1.0	18.8	0.890	0.891
OX	17	1	2.03.60	A	-14.5	-21.7	0.747	0.796
OX	17	2	31.08.61	B	-17.2	-20.5	0.737	0.787
OX	17	3	4.09.62	B	-20.3	-36.5	0.785	0.953
OX	17	4	29.08.63	A	-8.1	15.1	0.850	0.853
OX	17	5	4.03.64	A	-21.7	2.8	0.717	0.748
OX	17	6	1.03.65	A	-14.7	-27.8	0.889	0.973
OX	17	7	24.05.66	A	-10.2	-4.1	0.754	0.761
OX	17	8	31.05.67	A	-26.1	-34.3	0.796	0.950
OX	17	9	1.02.68	A	-15.3	-15.7	0.889	0.952
OX	17	10	17.04.69	A	-11.8	1.2	0.916	0.930
OX	17	11	21.02.71	C	-4.8	38.5	0.678	0.697
OX	24	1	17.01.60	A	-0.2	22.8	0.093	0.500
OX	24	2	31.08.61	A	-3.8	-49.6	0.535	0.549
OX	24	3	4.09.62	A	SUSPECT DATA			
OX	24	4	29.08.63	A	4.0	-19.4	0.897	0.912
OX	24	5	4.03.64	A	1.6	-7.7	0.941	0.943
OX	24	6	1.03.65	A	1.3	-26.5	0.620	0.628
OX	24	7	24.05.66	A	-13.1	16.6	0.779	0.867
OX	24	8	31.05.67	A	-0.1	-2.8	0.902	0.910

Catch name	Storm No.	Storm date	Storm type	Calibration % Error Vol.	Peak	Coefficient Eff.	Det.
OX 28	1	17.01.60	A	-2.2	-40.5	0.785	0.805
OX 28	2	4.09.62	A	-2.5	-10.0	0.882	0.888
OX 28	3	29.08.63	A	-1.3	15.8	0.887	0.892
OX 28	4	4.03.64	A	-1.3	1.8	0.817	0.838
OX 28	5	1.03.65	A	3.9	-22.4	0.746	0.758
OX 28	6	24.05.66	A	-0.6	41.5	0.209	0.569
OX 28	7	31.05.67	A	-2.8	16.3	-0.345	0.150
OX 32	1	22.05.59	B	-19.1	-55.7	0.627	0.841
OX 32	2	2.03.60	A	-20.7	-20.9	-0.027	0.272
OX 32	3	31.08.61	B	-14.0	-29.5	0.251	0.284
OX 32	4	4.09.62	A	-13.5	-41.1	0.711	0.752
OX 32	5	29.08.63	A	-11.6	-37.7	0.432	0.438
OX 32	6	4.03.64	A	-10.0	-23.2	0.808	0.850
OX 32	7	1.03.65	A	-18.1	-50.0	0.691	0.811
OX 32	8	24.05.66	A	-7.1	-6.3	0.670	0.672
OX 32	9	31.05.67	A	-18.0	-36.9	0.626	0.713
OX 32	10	1.02.68	A	-15.6	-31.3	0.823	0.971
OX 32	11	17.04.69	A	-8.2	10.5	0.887	0.890
OX 32	12	18.06.71	C	-14.3	-15.4	0.610	0.631
OX 32	13	25.06.72	C	-5.3	8.5	0.921	0.922
OX 32	14	19.04.73	C	-3.5	24.5	0.744	0.778
OX 35	1	22.05.59	B	-5.2	16.2	0.935	0.937
OX 35	2	2.03.60	A	-17.7	55.0	0.258	0.692
OX 35	3	31.08.61	B	-10.2	-2.8	0.277	0.360
OX 35	4	4.09.62	A	-5.9	-10.9	0.051	0.291
OX 35	5	29.08.63	A	-7.9	-5.6	-0.315	0.066
OX 35	6	4.03.64	A	-4.0	24.8	0.864	0.883
OX 35	7	1.03.65	A	-4.3	-4.1	0.868	0.901
OX 35	8	24.05.66	A	-4.1	37.5	0.881	0.887
OX 35	9	31.05.67	A	0.5	73.7	0.603	0.762
OX 35	10	1.02.68	A	-6.4	3.4	0.751	0.754
OX 35	11	17.04.69	A	-1.8	120.2	0.419	0.735
OX 35	12	26.08.71	C	-1.5	11.1	0.802	0.815
KAAI	1	25.03.81	C	-5.0	22.2	0.894	0.901
KAAI	2	26.04.81	C	-3.1	1.4	0.833	0.848
KAAI	3	5.05.81	C	-11.1	-8.2	0.470	0.558
KAAI	4	28.05.81	C	-1.9	-10.9	0.921	0.922
KAAI	6	24.08.81	C	-3.5	-1.9	0.678	0.714
KAAI	7	27.08.81	C	-3.6	13.9	0.270	0.516
KAAI	8	30.08.81	C	-0.2	-0.4	0.206	0.515
KAAI	9	18.02.82	C	-5.2	-17.2	0.292	0.378
KAAI	10	3.03.82	C	-10.2	4.1	0.481	0.551
KAAI	11	12.09.82	C	-1.8	57.0	-0.158	0.181
KAAI	12	12.06.83	C	-8.3	-14.3	0.870	0.893
KAAI	13	2.10.83	C	-4.5	-27.6	0.711	0.734
KAAI	14	28.10.85	C	-5.1	-3.6	0.587	0.613
KAAI	15	2.11.85	B	-5.1	-7.1	-0.355	0.070
KAAI	16	8.11.85	B	-2.3	20.2	-0.077	0.389
KAAI	17	2.12.85	B	-8.0	-19.9	0.496	0.539
MALGAS	1	25.03.81	C	-7.3	2.9	0.830	0.840
MALGAS	2	26.04.81	C	-4.1	15.6	0.826	0.845
MALGAS	3	5.05.81	C	-14.7	-0.3	0.533	0.669
MALGAS	4	28.05.81	C	-5.1	-6.1	0.946	0.950
MALGAS	6	24.08.81	C	5.1	23.1	-1.160	0.265
MALGAS	7	27.08.81	C	-6.2	24.5	0.602	0.758
MALGAS	8	30.08.81	C	4.0	2.2	0.825	0.900
MALGAS	9	15.10.81	C	-8.4	-0.3	0.921	0.945
MALGAS	10	15.01.82	C	-15.0	-10.1	0.038	0.220
MALGAS	11	18.02.82	C	-8.4	-24.8	0.856	0.887
MALGAS	12	3.03.82	C	-10.4	-4.5	0.953	0.969
MALGAS	13	1.09.82	C	-13.3	6.2	0.204	0.464

Catch name	Storm No.	Storm date	Storm type	Calibration % Error Vol.	Calibration % Error Peak	Calibration Coefficient Eff.	Calibration Coefficient Det.
MALGAS	14	11.06.83	C	-6.6	-14.6	0.162	0.300
MALGAS	15	22.09.83	C	-10.7	-7.8	0.484	0.551
MALGAS	16	15.10.85	B	-13.1	-19.8	0.908	0.945
MALGAS	17	21.01.86	B	-14.0	-46.7	0.149	0.215
ND 1	1	24.10.59	A	-0.9	7.1	0.991	0.991
ND 1	2	30.07.60	A	7.3	-8.8	0.900	0.908
ND 1	4	31.07.62	B	6.6	-3.8	0.958	0.967
ND 1	6	22.07.64	B	-2.0	5.9	0.284	0.511
ND 1	7	7.06.65	C	5.3	0.3	0.945	0.958
ND 1	8	19.10.66	C	-4.1	2.5	0.930	0.961
ND 1	9	16.07.67	C	-2.4	-2.2	0.856	0.888
ND 1	10	11.09.68	C	-3.2	-1.9	0.981	0.982
ND 1	12	23.08.71	C	2.3	-1.5	0.963	0.970
ND 1	13	3.07.72	C	3.0	0.1	0.967	0.969
ND 1	14	10.07.72	C	-1.8	0.7	0.969	0.971
ND 1	15	17.09.73	A	4.4	-6.8	0.977	0.980
ND 5	1	30.07.60	A	4.8	-2.4	0.925	0.929
ND 5	3	31.07.62	B	-0.9	8.2	0.986	0.988
ND 5	6	7.06.65	C	-0.6	-0.2	0.945	0.950
ND 5	7	19.10.66	C	-1.2	4.9	0.945	0.957
ND 5	8	16.07.67	C	5.7	-3.7	0.900	0.916
ND 5	9	11.09.68	C	-9.0	8.4	0.968	0.983
ND 5	11	23.08.71	C	-2.5	4.6	0.985	0.993
ND 5	12	10.07.72	C	-3.9	5.1	0.963	0.969
ND 5	13	20.07.72	C	-0.7	0.8	0.966	0.967
ND 5	14	14.07.73	C	4.4	-2.1	0.931	0.937
ND 5	15	17.09.73	A	6.3	-2.6	0.950	0.958

MODEL OSE3 Semi-distributed calibration and validation results

Catch. name	Storm No.	Storm date	Storm type	Calibration % Error Vol.	Calibration % Error Peak	Calibration Coefficient Eff.	Calibration Coefficient Det.	Validation % Error Vol.	Validation % Error Peak	Validation Coefficient Eff.	Validation Coefficient Det.
TM 1	1	26.07.59	B	-6.0	19.8	0.484	0.628	NOT MODELLED			
TM 1	2	4.09.65	C	15.3	-17.3	0.840	0.860	NOT MODELLED			
TM 2	1	26.07.59	B	2.9	45.2	0.680	0.820	NOT MODELLED			
TM 2	2	17.08.61	C	-0.9	-12.7	0.625	0.681	NOT MODELLED			
TM 2	3	4.09.65	B	1.4	16.4	0.850	0.923	NOT MODELLED			
TM 2	4	25.08.68	C	-8.6	-65.0	0.560	0.699	NOT MODELLED			
TM 2	5	31.08.68	C	-2.3	8.8	-0.557	0.080	NOT MODELLED			
TM 3	1	19.07.55	C	0.4	-30.3	0.757	0.757	-6.1	-48.2	0.612	0.630
TM 3	2	14.08.58	B	-0.9	10.8	0.745	0.837	-61.2	-74.3	0.207	0.520
TM 3	3	16.08.58	C	1.5	-4.2	0.391	0.599	8.6	-44.4	0.313	0.365
TM 3	4	17.08.61	B	0.0	110.4	0.021	0.783	-17.8	5.7	0.920	0.931
TM 3	5	25.07.62	C	2.7	-13.3	-1.160	0.003	173.0	21.3	-2.054	0.172
TM 3	7	25.08.68	C	17.3	-17.4	0.228	0.310	48.6	-34.7	0.595	0.662
TM 3	8	31.08.68	C	14.3	-15.1	-0.122	0.133	145.7	4.1	-0.444	0.482
TM 3	11	27.07.73	C	-3.4	0.1	0.404	0.635	18.5	-22.3	0.693	0.727
TM 6	1	4.09.65	B	4.8	-14.1	0.951	0.953	NOT MODELLED			
TM 6	2	31.08.68	B	3.6	-18.2	0.178	0.325	NOT MODELLED			
TM 8	1	19.08.63	C	-8.4	18.6	-0.114	0.275	-17.7	-53.0	0.610	0.749
TM 8	2	22.07.64	C	1.3	-34.8	0.858	0.859	29.1	-58.3	0.030	0.137
TM 8	3	9.09.64	C	1.4	10.5	0.708	0.717	-90.1	-97.2	-0.263	0.039
TM 8	5	11.09.64	C	0.5	-62.0	0.546	0.593	-23.1	-85.3	-0.060	0.001
TM 8	6	17.07.65	C	1.3	11.5	0.640	0.695	-50.6	-83.0	-0.025	0.069
TM 8	7	4.09.65	B	1.0	-1.6	0.620	0.734	-12.6	-59.1	0.391	0.398
TM 8	8	30.07.66	C	-10.5	18.2	-1.517	0.006	-22.5	-65.6	0.573	0.704
TM 8	10	31.08.68	C	-0.6	6.5	0.353	0.510	-37.3	-74.1	-0.014	0.101
TM 8	11	24.07.72	C	5.1	-40.9	-0.081	0.106	133.1	-19.9	-0.146	0.554
TM 11	1	19.08.63	C	0.6	10.6	0.521	0.580	-10.5	-43.6	0.782	0.878

Catch. name	Storm No.	Storm date	Storm type	Calibration % Error Vol.	Calibration % Error Peak	Calibration Coefficient Eff.	Calibration Coefficient Det.	Validation % Error Vol.	Validation % Error Peak	Validation Coefficient Eff.	Validation Coefficient Det.
TM 11	2	22.07.64	B	0.9	-12.5	0.915	0.918	-33.5	-53.2	0.687	0.874
TM 11	3	9.09.64	C	-0.2	59.9	0.554	0.647	-8.2	-0.3	0.619	0.621
TM 11	4	11.09.64	B	-5.1	23.2	0.833	0.862	-19.4	-18.4	0.764	0.783
TM 11	5	17.07.65	C	0.7	-38.3	0.779	0.779	-26.4	-71.2	0.366	0.439
TM 11	6	4.09.65	B	0.3	5.4	0.927	0.933	-9.9	-44.1	0.693	0.720
TM 11	7	30.07.66	C	0.2	12.4	-0.645	0.042	19.1	-5.2	0.174	0.322
TM 11	9	31.08.68	C	18.9	-20.1	0.360	0.412	-18.7	-75.5	0.021	0.042
TM 11	10	13.08.69	B	-3.8	51.5	0.656	0.588	18.1	2.5	0.781	0.809
TM 11	11	15.09.69	C	-3.6	16.3	0.588	0.638	-58.7	-76.5	-0.065	0.185
TM 11	12	21.08.73	B	-8.2	-5.9	0.862	0.871	71.3	38.8	0.670	0.961
EC 1	1	28.02.77	A	-3.8	3.5	0.889	0.909	195.8	167.8	-16.025	0.819
EC 1	2	6.03.77	B	-6.5	-3.4	0.744	0.846	65.4	-79.1	-0.385	0.253
EC 1	3	7.05.77	B	-3.4	0.3	0.807	0.819	361.7	123.3	-12.739	0.212
EC 1	4	19.04.78	A	12.1	-7.5	0.944	0.949	801.7	420.1	-35.137	0.819
EC 1	5	21.04.78	A	-25.1	9.4	-0.438	0.587	121.1	124.9	-14.210	0.549
EC 1	6	20.07.79	A	-0.7	-13.8	0.910	0.915	100.2	122.4	-2.554	0.319
EC 1	7	23.07.79	A	0.2	1.9	0.966	0.933	-30.8	-8.3	0.340	0.722
EC 1	8	19.08.79	A	-6.8	-1.2	0.953	0.966	-40.2	-50.7	-0.012	0.223
EC 1	9	26.03.81	A	9.8	-12.3	0.950	0.962	NOT MODELLED			
EC 1	10	22.10.81	B	-2.8	11.1	0.493	0.736	57.3	70.6	-2.304	0.741
EC 1	11	23.12.81	A	4.0	-11.2	0.747	0.783	-54.6	-72.5	0.280	0.785
EC 1	12	2.11.85	A	-3.4	0.8	0.949	0.972	-33.9	-14.9	0.215	0.655
EC 1	13	25.11.85	B	DATA SUSPECT				-11.2	56.7	0.451	0.771
EC 1	14	1.12.85	B	-0.5	-3.7	0.898	0.925	-24.2	-31.4	-0.105	0.200
BETH	1	01.11.80	C	4.6	-14.2	-0.759	0.004	1.3	-20.4	-0.606	0.009
BETH	2	15.12.80	B	-0.6	-10.6	0.831	0.855	-44.3	-50.7	0.186	0.797
BETH	5	05.02.81	B	-1.3	-17.0	0.688	0.689	-69.7	-83.8	-0.402	0.106
BETH	6	10.02.81	B	-7.6	1.7	0.972	0.987	-0.3	6.8	0.964	0.987
BETH	7	14.02.81	B	11.1	-19.6	0.720	0.753	-44.2	-63.3	0.435	0.739
BETH	8	17.02.81	B	-9.9	11.1	0.822	0.873	-12.4	3.0	0.867	0.894
BETH	9	27.02.81	C	14.7	-13.7	0.671	0.822	69.2	-80.5	-0.083	0.868
BETH	10	22.03.81	C	-9.0	3.1	0.371	0.491	-14.4	-8.4	0.430	0.520
HOEK	1	2.03.79		DATA SUSPECT				10.0	79.4	0.140	0.862
HOEK	2	4.05.79	B	-20.8	-59.1	0.432	0.519	NOT MODELLED			
HOEK	3	16.02.80	A	0.4	-0.6	0.965	0.986	-8.4	-12.5	0.960	0.965
HOEK	4	17.02.80	B	-5.6	-17.6	0.933	0.935	-9.9	-27.7	0.893	0.907
HOEK	5	17.12.80	B	-4.5	-3.2	0.504	0.641	77.5	90.5	-2.049	0.627
HOEK	6	8.01.81	B	-8.1	-41.6	0.723	0.792	60.1	16.4	0.330	0.847
HOEK	7	1.02.81	A	0.0	-1.1	0.780	0.861	-19.4	-27.7	0.833	0.847
HOEK	8	19.02.81	B	-5.2	-24.9	0.805	0.808	-33.5	-52.9	0.498	0.660
HOEK	9	21.02.81	B	-1.1	-21.0	0.252	0.366	-11.8	-31.2	0.254	0.319
HOEK	10	24.02.81	B	-7.3	-20.9	0.222	0.367	-26.7	-47.6	0.149	0.244
HOEK	11	21.03.82	A	-9.3	24.7	-0.276	0.206	207.7	360.5	-34.816	0.135
HOEK	12	8.04.82	B	-25.5	-68.2	-0.504	0.002	NOT MODELLED			
HOEK	13	26.11.83	B	-14.6	-31.8	0.520	0.542	58.6	37.4	-0.141	0.497
HOEK	14	28.11.83	B	-8.2	-35.6	0.823	0.846	40.0	-5.2	0.720	0.841
HOEK	15	17.12.83	B	-21.7	-73.3	0.191	0.227	32.5	-51.9	0.078	0.218
HOEK	16	24.12.83	B	-0.6	12.3	0.940	0.941	-42.1	-58.7	0.604	0.854
CED	1	11.11.78	A	DATA SUSPECT				-4.6	-45.3	0.733	0.747
CED	2	9.12.78	A	-14.9	16.4	0.587	0.779	-26.0	-5.2	0.549	0.872
CED	3	28.12.78	A	9.3	11.6	0.691	0.850	-18.6	-57.6	0.459	0.523
CED	4	2.01.79	A	-3.0	36.4	-0.109	0.481	-24.8	-31.1	0.769	0.930
CED	5	25.02.79	A	2.7	-11.0	0.811	0.859	-15.8	-64.8	0.243	0.263
CED	6	2.12.84	A	-13.3	15.6	0.819	0.890	-57.4	-69.1	-0.367	0.289
CED	7	9.02.85	A	-6.7	17.0	0.379	0.566	-19.6	-17.5	0.770	0.817
CED	8	24.02.85	C	13.7	-23.2	0.877	0.876	-70.0	-91.3	-0.168	0.063
CED	9	11.03.85	A	-6.7	19.8	0.109	0.476	-67.2	-81.1	-0.255	0.569
CED	10	14.03.86	C	-18.6	3.0	0.586	0.743	-20.3	-43.7	0.649	0.717
ZL 15	1	29.01.77	B	-0.8	11.2	0.660	0.766	-5.7	19.3	0.733	0.837
ZL 15	2	6.02.77	B	-1.0	-23.7	0.387	0.438	10.9	-13.8	0.264	0.418
ZL 15	3	14.02.77	B	-1.6	-42.3	0.654	0.655	-3.0	-42.1	0.577	0.580
ZL 15	4	14.03.77	B	-2.0	-16.5	0.632	0.655	-5.3	-22.4	0.572	0.621
ZL 15	5	9.10.77	A	-7.5	1.4	0.949	0.957	8.9	15.8	0.843	0.956

Catch. name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Peak	Coefficient Eff.	Det.	Validation % Error Vol.	Peak	Coefficient Eff.	Det.
ZL	15	6	9.11.77	B	-8.6	-18.4	0.913	0.932	-12.9	-29.8	0.694	0.703
ZL	15	7	19.12.77	B	-7.0	-10.5	0.959	0.962	51.4	33.2	0.110	0.806
ZL	15	8	19.01.78	C	-8.1	-3.2	0.956	0.973	12.1	11.9	0.739	0.938
ZL	15	9	21.01.78	A	0.0	-18.8	0.940	0.942	-17.1	-28.1	0.890	0.924
ZL	15	10	21.02.78	B	-4.6	-12.4	0.902	0.905	-18.7	-23.6	0.841	0.877
ZL	15	11	1.03.78	A	-16.5	-5.1	0.618	0.807	-22.9	-17.4	0.362	0.717
ZL	15	12	9.03.78	B	-3.4	17.3	0.721	0.858	-15.5	7.3	0.717	0.861
ZL	15	13	27.03.78	B	-3.2	-1.7	0.730	0.745	12.3	6.8	0.646	0.759
ZL	15	14	8.09.78	A	-6.9	-16.5	0.754	0.764	32.4	22.6	0.514	0.759
ZL	15	15	18.10.78	A	-7.5	-11.7	0.735	0.739	-28.4	-33.7	0.572	0.623
ZL	16	1	29.01.77	A	-9.5	16.0	0.826	0.914	NOT MODELLED			
ZL	16	2	6.02.77	A	-2.2	-40.7	0.222	0.253	NOT MODELLED			
ZL	16	3	14.02.77	A	-6.0	-14.0	0.720	0.748	NOT MODELLED			
ZL	16	4	14.03.77	A	-9.0	-12.7	0.697	0.752	NOT MODELLED			
ZL	16	5	9.10.77	A	-21.4	-11.6	0.818	0.931	NOT MODELLED			
ZL	16	6	9.11.77	A	-15.6	-22.3	0.580	0.601	NOT MODELLED			
ZL	16	7	19.12.77	A	-17.6	1.4	0.614	0.673	NOT MODELLED			
ZL	16	8	19.01.78	A	-9.9	5.5	0.772	0.853	NOT MODELLED			
ZL	16	9	21.01.78	A	-4.2	6.5	0.869	0.894	NOT MODELLED			
ZL	16	10	21.02.78	A	-11.0	14.3	0.944	0.968	NOT MODELLED			
ZL	16	11	1.03.78	A	-16.4	14.6	0.837	0.927	NOT MODELLED			
ZL	16	12	9.03.78	A	-7.7	28.5	0.799	0.919	NOT MODELLED			
ZL	16	13	27.03.78	A	-7.0	-38.6	0.588	0.600	NOT MODELLED			
ZL	16	14	8.09.78	A	-16.7	-18.5	0.811	0.876	NOT MODELLED			
ZL	16	15	18.10.78	A	-20.0	-51.4	0.463	0.531	NOT MODELLED			
OX	4	1	3.04.58	A	-3.4	19.5	0.888	0.957	NOT MODELLED			
OX	4	2	17.01.60	A	-4.5	-7.9	0.851	0.856	NOT MODELLED			
OX	4	3	31.08.61	A	19.6	-22.4	0.855	0.876	NOT MODELLED			
OX	4	4	4.09.62	A	13.7	-22.9	0.850	0.865	NOT MODELLED			
OX	4	5	29.08.63	A	-0.9	-13.8	0.937	0.938	NOT MODELLED			
OX	10	1	22.05.59	B	-40.1	-60.4	0.465	0.643	35.4	-46.3	0.525	0.583
OX	10	2	17.01.60	A	0.3	-2.8	0.708	0.775	16.8	7.1	0.887	0.953
OX	10	3	31.08.61	B	-9.2	-2.2	0.973	0.977	-40.3	-55.6	0.385	0.535
OX	10	4	4.09.62	A	0.9	-11.0	0.918	0.919	-10.3	-43.6	0.630	0.676
OX	10	5	29.08.63	A	-0.6	1.5	0.939	0.939	-24.5	-46.1	0.614	0.734
OX	10	6	4.03.64	A	4.3	27.8	0.871	0.951	-15.4	-14.8	0.909	0.928
OX	10	7	1.03.65	A	-0.1	55.2	-0.055	0.553	-0.3	19.1	0.827	0.922
OX	10	8	27.12.66	C	-0.6	13.3	0.215	0.424	34.2	35.8	0.446	0.783
OX	10	9	31.05.67	A	-4.6	-1.8	0.945	0.962	5.4	-19.9	0.287	0.383
OX	10	10	1.02.68	A	-1.0	30.3	0.047	0.397	4.6	19.9	0.694	0.775
OX	10	11	17.04.69	A	-0.1	28.2	0.875	0.908	135.3	149.9	-1.599	0.912
OX	10	12	26.08.71	C	-0.4	-11.9	0.676	0.682	-3.0	-28.9	0.883	0.959
OX	12	1	2.03.60	A	-27.4	-35.9	0.464	0.611	7.7	19.5	0.755	0.909
OX	12	2	31.08.61	B	-16.3	-44.3	0.490	0.520	-14.4	-42.9	0.622	0.665
OX	12	3	4.09.62	B	5.1	-36.9	0.971	0.918	54.7	6.3	0.704	0.928
OX	12	4	29.08.63	A	0.7	-3.6	0.981	0.989	51.2	50.4	0.670	0.989
OX	12	5	4.03.64	A	-0.4	27.9	0.898	0.910	10.4	61.5	0.697	0.893
OX	12	6	1.03.65	A	-5.6	-5.8	0.927	0.933	-7.7	2.4	0.960	0.970
OX	12	7	24.05.66	A	3.6	0.4	0.905	0.908	-0.3	14.3	0.977	0.986
OX	12	8	31.05.67	A	-5.1	-28.1	0.728	0.739	48.8	34.7	0.643	0.926
OX	12	9	1.02.68	A	-7.5	-28.5	0.898	0.971	106.7	98.9	-1.048	0.752
OX	12	10	17.04.69	A	-4.9	-9.8	0.902	0.913	29.8	76.5	0.548	0.962
OX	12	11	21.02.71	C	0.8	27.9	0.840	0.844	-7.7	39.4	0.591	0.650
OX	17	1	2.03.60	A	-5.3	-7.1	0.803	0.813	-0.8	11.8	0.945	0.983
OX	17	2	31.08.61	B	-10.9	-39.0	0.658	0.714	-37.1	-59.3	0.507	0.768
OX	17	3	4.09.62	B	-16.1	-34.4	0.724	0.802	27.6	3.9	0.872	0.907
OX	17	4	29.08.63	A	-5.3	3.6	0.935	0.943	30.2	46.3	0.843	0.962
OX	17	5	4.03.64	A	-20.2	5.7	0.790	0.814	-4.1	52.9	0.397	0.605
OX	17	6	1.03.65	A	-11.7	-24.8	0.939	0.981	11.5	0.8	0.786	0.851
OX	17	7	24.05.66	A	-8.8	-2.5	0.786	0.791	-19.0	-0.5	0.885	0.915
OX	17	8	31.05.67	A	-15.2	-31.2	0.777	0.830	57.2	53.4	0.446	0.943
OX	17	9	1.02.68	A	-12.4	-13.4	0.947	0.989	23.9	46.1	0.548	0.820
OX	17	10	17.04.69	A	-9.2	6.7	0.944	0.950	35.3	118.2	0.119	0.923

Catch. name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Calibration % Error Peak	Calibration Coefficient Eff.	Calibration Coefficient Det.	Validation % Error Vol.	Validation % Error Peak	Validation Coefficient Eff.	Validation Coefficient Det.
OX	17	11	21.02.71	C	-3.4	33.6	0.713	0.732	-11.0	42.2	0.413	0.513
OX	32	1	22.05.59	B	0.4	-36.2	0.593	0.593	-43.2	-74.1	0.061	0.132
OX	32	2	2.03.60	A	-5.5	33.5	0.276	0.641	-46.1	-35.6	-0.782	0.138
OX	32	3	31.08.61	B	-2.2	-26.6	0.842	0.842	-58.2	-80.3	0.023	0.177
OX	32	4	4.09.62	A	-0.5	-48.5	0.652	0.652	-25.6	-73.3	0.390	0.493
OX	32	5	29.08.63	A	-1.4	-32.8	0.876	0.908	-35.9	-68.1	0.291	0.444
OX	32	6	4.03.64	A	-0.5	4.6	0.984	0.987	-37.8	-44.9	0.647	0.807
OX	32	7	1.03.65	A	-2.3	-52.8	0.269	0.283	-40.2	-72.7	0.223	0.386
OX	32	8	24.05.66	A	-0.2	-1.6	0.975	0.975	-32.1	-51.1	0.609	0.746
OX	32	9	31.05.67	A	-1.7	-33.2	0.860	0.881	-21.7	-58.2	0.325	0.358
OX	32	10	1.02.68	A	-1.9	-15.2	0.711	0.711	-12.9	-36.0	0.860	0.957
OX	32	11	17.04.69	A	-0.1	23.6	0.859	0.918	-34.4	-38.3	0.831	0.948
OX	32	12	18.06.71	C	0.5	-9.7	0.948	0.952	-23.6	-56.7	0.436	0.509
OX	32	13	25.06.72	C	-1.0	12.2	0.932	0.951	-4.2	-6.6	0.939	0.940
OX	32	14	19.04.73	C	0.2	27.2	0.903	0.975	NOT MODELLED			
OX	35	1	22.05.59	B	12.9	15.5	0.951	0.966	-40.8	-61.6	0.391	0.610
OX	35	2	2.03.60	A	-16.7	11.7	0.743	0.879	-24.9	-7.7	0.485	0.683
OX	35	3	31.08.61	B	-8.5	-39.9	0.710	0.775	183.3	66.5	-1.784	0.772
OX	35	4	4.09.62	A	-0.1	-25.1	0.461	0.534	52.8	-26.4	-0.446	0.159
OX	35	5	29.08.63	A	-7.4	-28.2	0.220	0.266	187.5	85.1	-2.657	0.730
OX	35	6	4.03.64	A	-2.3	18.1	0.846	0.878	-54.1	-50.9	0.555	0.980
OX	35	7	1.03.65	A	-2.2	8.6	0.751	0.847	-49.8	-51.0	0.560	0.917
OX	35	8	24.05.66	A	-3.5	10.3	0.972	0.974	-10.8	-24.7	0.765	0.805
OX	35	9	31.05.67	A	-2.4	30.8	0.853	0.886	-37.4	-41.3	0.418	0.523
OX	35	10	1.02.68	A	-3.4	1.2	0.676	0.689	-17.0	-22.3	0.859	0.931
OX	35	11	17.04.69	A	-0.1	86.0	0.528	0.804	-29.2	7.0	0.889	0.925
OX	35	12	26.08.71	C	-1.5	-1.5	0.807	0.811	5.1	-21.7	0.919	0.955
KAAI		1	25.03.81	C	-5.2	18.4	0.787	0.809	-28.3	6.7	0.795	0.851
KAAI		2	26.04.81	C	-3.4	1.8	0.892	0.901	-6.1	6.4	0.791	0.824
KAAI		3	5.05.81	C	-12.2	1.1	0.716	0.807	11.6	55.2	-0.500	0.371
KAAI		4	28.05.81	C	-1.7	-13.6	0.876	0.879	-13.1	-18.7	0.857	0.872
KAAI		6	24.08.81	C	-3.7	2.2	0.746	0.789	-8.8	16.9	0.451	0.657
KAAI		7	27.08.81	C	-5.1	7.6	0.515	0.692	-6.6	25.3	-0.019	0.502
KAAI		8	30.08.81	C	-2.6	-5.6	0.385	0.645	-13.6	3.2	-0.209	0.412
KAAI		9	18.02.82	C	-7.9	-17.1	0.769	0.785	11.6	44.0	-0.556	0.499
KAAI		10	3.03.82	C	-10.2	-1.4	0.810	0.840	-2.9	73.3	-0.143	0.502
KAAI		11	12.09.82	C	-2.8	56.3	0.024	0.276	52.8	232.6	-4.112	0.121
KAAI		12	12.06.83	C	-14.9	-20.6	0.845	0.892	23.6	-17.4	0.727	0.862
KAAI		13	2.10.83	C	-4.8	-26.0	0.735	0.763	NOT MODELLED			
KAAI		14	28.10.85	C	-5.2	-5.3	0.856	0.858	-10.0	-5.7	0.375	0.574
KAAI		15	2.11.85	B	-3.9	2.8	-0.104	0.275	34.2	44.6	0.323	0.707
KAAI		16	8.11.85	B	-5.1	19.4	0.711	0.871	-2.0	18.7	-2.227	0.022
KAAI		17	2.12.85	B	-7.6	-3.0	0.748	0.881	-19.7	58.5	-0.146	0.601
MALGAS		1	25.03.81	C	-6.5	8.6	0.707	0.735	-17.7	12.2	0.820	0.852
MALGAS		2	26.04.81	C	-3.1	20.1	0.868	0.893	20.3	75.3	0.276	0.730
MALGAS		3	5.05.81	C	-12.9	10.4	0.307	0.600	-26.2	28.5	0.184	0.715
MALGAS		4	28.05.81	C	-4.4	-6.6	0.929	0.932	18.6	23.7	0.752	0.883
MALGAS		6	24.08.81	C	-4.4	39.3	-1.315	0.038	24.8	133.3	-4.871	0.003
MALGAS		7	27.08.81	C	-6.7	27.9	0.417	0.745	5.6	84.9	-0.321	0.575
MALGAS		8	30.08.81	C	2.8	13.1	0.756	0.912	-8.6	11.8	0.423	0.730
MALGAS		9	15.10.81	C	-6.8	5.4	0.922	0.955	-8.7	15.6	0.761	0.883
MALGAS		10	15.01.82	C	-12.3	1.6	0.185	0.362	176.9	327.9	-24.244	0.048
MALGAS		11	18.02.82	C	-7.7	-16.3	0.931	0.940	-15.6	-2.2	0.730	0.801
MALGAS		12	3.03.82	C	-8.7	3.6	0.941	0.956	-32.0	41.2	0.723	0.864
MALGAS		13	1.09.82	C	-11.2	23.9	0.097	0.493	NOT MODELLED			
MALGAS		14	11.06.83	C	-5.1	2.2	0.061	0.301	-4.0	57.9	-1.026	0.135
MALGAS		15	22.09.83	C	-8.8	16.9	0.499	0.601	-11.0	71.4	-0.624	0.217
MALGAS		16	15.10.85	B	-11.0	-5.9	0.912	0.921	-32.4	-14.1	0.872	0.953
MALGAS		17	21.01.86	B	-10.6	-39.1	0.143	0.237	136.1	158.3	-1.430	0.031
ND	1	1	24.10.59	A	-3.8	2.5	0.987	0.991	NOT MODELLED			
ND	1	2	30.07.60	A	11.6	-10.8	0.869	0.886	NOT MODELLED			
ND	1	4	31.07.62	B	2.4	-10.5	0.972	0.973	NOT MODELLED			

Catch. name		Storm No.	Storm date	Storm type	Calibration % Error Vol.	Peak	Coefficient Eff.	Det.	Validation % Error Vol.	Peak	Coefficient Eff.	Det.
ND	1	6	22.07.64	B	-1.4	-0.9	0.043	0.378	NOT MODELLED			
ND	1	7	7.06.65	C	7.5	-6.6	0.906	0.915	NOT MODELLED			
ND	1	8	19.10.66	C	-2.1	-0.3	0.967	0.986	NOT MODELLED			
ND	1	9	16.07.67	C	-5.3	-12.3	0.871	0.883	NOT MODELLED			
ND	1	10	11.09.68	C	1.7	-2.7	0.996	0.997	NOT MODELLED			
ND	1	12	23.08.71	C	-1.3	-1.3	0.972	0.984	NOT MODELLED			
ND	1	13	3.07.72	C	-1.3	-12.6	0.797	0.779	NOT MODELLED			
ND	1	14	10.07.72	C	2.7	-0.6	0.957	0.966	NOT MODELLED			
ND	1	15	17.09.73	A	1.9	-7.0	0.972	0.972	NOT MODELLED			
ND	5	1	30.07.60	A	6.8	-6.8	0.838	0.859	3.7	-16.7	0.748	0.750
ND	5	3	31.07.62	B	-0.1	0.9	0.994	0.995	-21.5	-27.0	0.866	0.969
ND	5	6	7.06.65	C	-0.9	-9.6	0.911	0.912	-43.5	-49.1	0.202	0.815
ND	5	7	19.10.66	C	-1.6	3.9	0.965	0.968	-54.5	-56.9	-0.463	0.984
ND	5	8	16.07.67	C	0.3	3.2	0.947	0.958	-41.1	-39.1	0.384	0.934
ND	5	9	11.09.68	C	-6.8	0.0	0.981	0.988	-1.7	6.8	0.922	0.941
ND	5	10	7.09.69	C	DATA SUSPECT				-10.8	-14.0	0.778	0.868
ND	5	11	23.08.71	C	-1.2	1.0	0.976	0.983	6.4	10.6	0.938	0.984
ND	5	12	10.07.72	C	2.6	2.8	0.978	0.985	-33.9	-32.1	0.646	0.955
ND	5	13	20.07.72	C	1.4	3.6	0.937	0.949	-30.9	-33.3	0.726	0.917
ND	5	14	14.07.73	C	2.8	1.7	0.871	0.881	-28.8	-36.2	0.555	0.900
ND	5	15	17.09.73	A	1.7	-2.9	0.978	0.980	-19.2	-25.0	0.847	0.933

APPENDIX D

Computer listing of catchment and soil characteristic indices.

AREA	Catchment area (km^2)
SLOPE	Average catchment slope (%)
DDENS	Drainage density (mm/km^2)
TC	Time of concentration
ORD1	Shreve channel order
CDIST	Channel distance between sub-area nodes (km)
ROUGH	Channel roughness characteristic index
DEPTH	Soil depth index
INFIL	Soil infiltration characteristics index
PERMC	Soil permeability characteristics index
VEGC	Catchment vegetation cover index
ENERG	Incoming radiation index
WHCAP	Soil water holding capacity index
SL/V	Valley slope to valley bottom soil depth ratio

CATCHMENT CHARACTERISTICS

Area	ID	1 AREA	2 SLOPE	3 DDENS	4 TC	5 ORD1	6 CDIST	7 ROUGH
TM11	1	3.000	7.900	4.000	1.000	1.000	4.400	2.000
TM11	2	3.200	7.900	4.000	0.900	3.000	4.300	2.000
TM11	3	2.000	7.900	4.000	1.000	5.000	3.100	2.000
TM8	4	2.100	7.900	4.000	1.300	2.000	2.100	2.000
TM8	5	1.800	7.900	4.000	1.200	5.000	2.000	2.000
TM8	6	1.600	7.900	4.000	0.900	7.000	1.500	2.000
TM8	7	1.800	7.900	4.000	0.500	7.000	2.600	2.000
TM3	1	2.200	7.900	4.000	1.700	5.000	2.600	2.000
TM3	2	2.400	7.900	4.000	1.300	6.000	3.500	2.000
TM3	3	2.300	7.900	4.000	0.800	2.000	1.500	2.000
TM3	4	2.100	7.900	4.000	0.500	8.000	1.500	2.000
TM6	1	9.500	9.000	4.000	3.300	5.000	9.100	2.000
TM6	2	7.600	7.900	4.000	1.900	6.000	5.500	2.000
TM6	3	13.300	7.900	4.000	2.700	1.000	9.200	2.000
TM6	4	10.400	7.900	4.000	2.700	3.000	9.600	2.000
TM6	5	13.300	8.000	4.000	2.000	4.000	2.500	2.000
TM6	6	8.600	8.000	4.000	1.400	7.000	2.800	2.000
TM6	7	10.500	12.500	4.000	1.200	5.000	3.200	2.000
TM6	8	7.100	8.000	4.000	0.800	21.000	3.500	2.000
TM2	10	10.200	8.000	4.000	1.100	40.000	4.900	2.000
TM1	11	10.200	10.000	4.000	1.900	11.000	3.400	2.000
TM1	12	11.200	8.000	4.000	1.800	3.000	5.300	2.000
TM1	13	10.500	11.500	4.000	1.100	66.000	2.800	2.000
ECCA	1	9.900	13.000	1.200	4.600	6.000	3.300	8.000
ECCA	2	4.400	13.000	1.800	4.100	14.000	3.800	8.000
ECCA	3	4.100	13.000	1.800	4.100	9.000	3.200	8.000
ECCA	4	5.100	20.000	1.800	3.700	32.000	2.400	8.000
ECCA	5	4.600	15.000	1.800	3.700	6.000	3.000	8.000
ECCA	6	5.200	15.000	1.800	3.800	5.000	2.400	8.000
ECCA	7	8.300	18.000	2.400	3.000	19.000	2.500	8.000
ECCA	8	5.800	17.000	2.400	2.600	18.000	2.000	8.000
ECCA	9	4.400	20.000	2.200	2.100	12.000	1.600	8.000
ECCA	10	7.100	20.000	2.000	1.600	110.000	3.400	8.000
ECCA	11	9.500	21.400	2.200	1.100	22.000	3.800	8.000
ECCA	12	5.500	13.000	2.200	0.600	146.000	1.400	8.000
BETH	1	10.300	3.500	1.000	3.900	5.000	3.900	6.000
BETH	2	11.200	3.500	0.750	3.100	8.000	3.900	6.000
BETH	3	10.100	3.000	0.850	3.300	2.000	5.300	6.000
BETH	4	14.700	3.000	1.000	3.300	6.000	4.800	6.000
BETH	5	6.900	4.000	0.750	2.000	17.000	3.800	6.000
BETH	6	11.200	3.500	1.000	2.200	11.000	5.000	6.000
BETH	7	3.600	3.500	0.750	1.300	1.000	3.600	6.000
BETH	8	8.000	4.000	0.900	1.200	5.000	3.400	6.000
BETH	9	7.000	3.000	1.000	0.400	38.000	1.400	6.000
HOEK	1	2.100	15.000	1.500	0.600	1.000	1.300	6.000
HOEK	2	0.800	32.000	2.000	0.600	8.000	1.500	6.000
HOEK	3	3.000	25.000	3.500	0.800	23.000	1.900	6.000
HOEK	4	2.100	25.000	3.500	0.800	14.000	1.400	6.000
HOEK	5	1.000	22.000	3.000	0.700	2.000	1.200	6.000
HOEK	6	1.300	10.000	2.000	0.600	41.000	0.800	6.000
HOEK	7	1.000	35.000	2.000	0.400	58.000	1.300	6.000
HOEK	8	1.300	10.000	2.500	0.400	6.000	2.000	6.000
HOEK	9	2.000	25.000	3.500	0.200	13.000	1.400	6.000
CED	1	1.900	20.000	2.900	0.450	8.000	1.950	6.000
CED	2	1.600	16.000	2.900	0.420	8.000	1.800	6.000
CED	3	1.700	12.000	2.900	0.180	24.000	1.800	6.000
ZULU	1	1.700	19.000	2.500	1.100	7.000	1.400	4.000
ZULU	2	1.400	17.500	2.500	0.900	12.000	2.100	4.000
ZULU	3	1.800	21.500	2.500	0.600	17.000	0.600	4.000
ZULU	4	1.800	24.000	1.500	0.600	1.000	0.800	4.000
ZULU	5	1.200	30.000	2.500	1.000	3.000	2.100	4.000

Area ID		1 AREA	2 SLOPE	3 DDENS	4 TC	5 ORD1	6 CDIST	7 ROUGH
ZULU	6	1.500	30.000	2.500	0.800	3.000	1.600	4.000
ZULU	7	1.200	34.000	2.500	0.600	9.000	1.100	4.000
ZULU	8	1.000	16.000	2.500	0.400	31.000	1.300	4.000
ZULU	9	0.600	16.000	2.500	0.200	32.000	1.000	4.000
ZULU	10	1.400	16.000	2.500	0.300	34.000	1.400	4.000
OX4W	1	4.100	12.000	2.000	0.800	2.000	1.400	3.000
OX4W	2	4.000	12.000	2.000	0.400	5.000	1.400	3.000
OX4S	1	4.100	12.000	2.000	0.800	2.000	1.400	3.000
OX4S	2	4.000	12.000	2.000	0.400	5.000	1.400	3.000
OX12W	1	8.400	13.000	2.000	3.300	5.000	4.500	3.000
OX12W	2	8.200	13.000	2.000	3.000	7.000	4.700	3.000
OX12W	3	4.000	12.000	2.000	3.400	5.000	2.100	3.000
OX12W	4	7.200	12.000	2.000	2.900	7.000	4.500	3.000
OX12W	5	9.300	8.000	1.500	1.600	23.000	3.500	3.000
OX12W	7	11.800	8.000	1.500	1.600	7.000	4.200	3.000
OX12W	8	10.000	12.000	2.000	2.700	6.000	2.200	3.000
OX12W	9	7.100	13.000	2.000	2.000	9.000	2.300	3.000
OX12W	10	7.800	8.000	1.500	1.200	9.000	2.700	3.000
OX12W	11	4.500	8.500	1.800	2.400	1.000	2.300	3.000
OX12W	12	6.100	8.000	1.800	1.700	2.000	4.500	3.000
OX12P	1	8.400	13.000	2.000	3.300	5.000	4.500	3.000
OX12P	2	8.200	13.000	2.000	3.000	7.000	4.700	3.000
OX12P	3	4.000	12.000	2.000	3.400	5.000	2.100	3.000
OX12P	4	7.200	12.000	2.000	2.900	7.000	4.500	3.000
OX12P	5	9.300	8.000	1.500	1.600	23.000	3.500	3.000
OX12P	7	11.800	8.000	1.500	1.600	7.000	4.200	3.000
OX12P	8	10.000	12.000	2.000	2.700	6.000	2.200	3.000
OX12P	9	7.100	13.000	2.000	2.000	9.000	2.300	3.000
OX12P	10	7.800	8.000	1.500	1.200	9.000	2.300	3.000
OX12P	11	4.500	8.500	1.800	2.400	1.000	2.300	3.000
OX12P	12	6.100	8.000	1.800	1.700	2.000	4.500	3.000
OX12S	1	8.400	13.000	2.000	3.300	5.000	4.500	3.000
OX12S	2	8.200	13.000	2.000	3.000	7.000	4.700	3.000
OX12S	3	4.000	12.000	2.000	3.400	5.000	2.100	3.000
OX12S	4	7.200	12.000	2.000	2.900	7.000	4.500	3.000
OX12S	5	9.300	8.000	1.500	1.600	23.000	3.500	3.000
OX12S	7	11.800	8.000	1.500	1.600	7.000	4.200	3.000
OX12S	8	10.000	12.000	2.000	2.700	6.000	2.200	3.000
OX12S	9	7.100	13.000	2.000	2.000	9.000	2.300	3.000
OX12S	10	7.800	8.000	1.500	1.200	9.000	2.700	3.000
OX12S	11	4.500	8.500	1.800	2.400	1.000	2.300	3.000
OX12S	12	6.100	8.000	1.800	1.700	2.000	4.500	3.000
OX10W	1	6.100	11.000	2.000	1.600	4.000	1.700	3.000
OX10W	2	4.800	11.000	2.000	1.000	5.000	2.500	3.000
OX10W	3	3.900	11.000	2.000	1.300	2.000	3.300	3.000
OX10W	4	4.500	11.000	2.000	0.700	2.000	1.800	3.000
OX10W	5	3.100	11.000	2.000	0.500	9.000	1.500	3.000
OX10P	1	6.100	11.000	2.000	1.600	4.000	1.700	3.000
OX10P	2	4.800	11.000	2.000	1.000	5.000	2.500	3.000
OX10P	3	3.900	11.000	2.000	1.300	2.000	3.300	3.000
OX10P	4	4.500	11.000	2.000	0.700	2.000	1.800	3.000
OX10P	5	3.100	11.000	2.000	0.500	9.000	1.500	3.000
OX10S	1	6.100	11.000	2.000	1.600	4.000	1.700	3.000
OX10S	2	4.800	11.000	2.000	1.000	5.000	2.500	3.000
OX10S	3	3.900	11.000	2.000	1.300	2.000	3.300	3.000
OX10S	4	4.500	11.000	2.000	0.700	2.000	1.800	3.000
OX10S	5	3.100	11.000	2.000	0.500	9.000	1.500	3.000
OX35W	1	4.200	9.000	1.500	3.200	2.000	2.600	3.000
OX35W	2	5.000	9.000	1.500	2.400	6.000	2.700	3.000
OX35W	3	2.100	9.000	1.500	2.600	2.000	1.700	3.000
OX35W	4	3.100	9.000	1.500	2.100	3.000	2.400	3.000
OX35W	5	2.700	9.000	1.500	2.100	12.000	2.300	3.000
OX35W	6	4.600	9.000	1.500	1.500	12.000	4.100	3.000

Area ID	1 AREA	2 SLOPE	3 DDENS	4 TC	5 ORD1	6 CDIST	7 ROUGH
OX35W 7	4.000	9.000	2.000	1.000	6.000	3.600	3.000
OX35W 8	4.700	9.000	2.000	0.800	22.000	3.100	3.000
OX35P 1	4.200	9.000	1.500	3.200	2.000	2.600	3.000
OX35P 2	5.000	9.000	1.500	2.400	6.000	2.700	3.000
OX35P 3	2.100	9.000	1.500	2.600	2.000	1.700	3.000
OX35P 4	3.100	9.000	1.500	2.100	3.000	2.400	3.000
OX35P 5	2.700	9.000	1.500	2.100	12.000	2.300	3.000
OX35P 6	4.600	9.000	1.500	1.500	12.000	4.100	3.000
OX35P 7	4.000	9.000	2.000	1.000	6.000	3.600	3.000
OX35P 8	4.700	9.000	2.000	0.800	22.000	3.100	3.000
OX35S 1	4.200	9.000	1.500	3.200	2.000	2.600	3.000
OX35S 2	5.000	9.000	1.500	2.400	6.000	2.700	3.000
OX35S 3	2.100	9.000	1.500	2.600	2.000	1.700	3.000
OX35S 4	3.100	9.000	1.500	2.100	3.000	2.400	3.000
OX35S 5	2.700	9.000	1.500	2.100	12.000	2.300	3.000
OX35S 6	4.600	9.000	1.500	1.500	12.000	4.100	3.000
OX35S 7	4.000	9.000	2.000	1.000	6.000	3.600	3.000
OX35S 8	4.700	9.000	2.000	0.800	22.000	3.100	3.000
OX17W 11	6.400	12.000	1.800	3.000	4.000	1.800	3.000
OX17W 12	5.200	10.000	1.500	2.500	5.000	2.600	3.000
OX17W 13	6.400	10.000	1.500	1.600	46.000	3.300	3.000
OX17W 14	9.200	13.000	2.000	1.900	3.000	2.500	3.000
OX17W 15	6.500	8.000	1.500	1.100	3.000	2.600	3.000
OX17W 16	4.700	10.000	1.500	0.700	2.000	2.300	3.000
OX17P 11	6.400	12.000	1.800	3.000	4.000	1.800	3.000
OX17P 12	5.200	10.000	1.500	2.500	5.000	2.600	3.000
OX17P 13	6.400	10.000	1.500	1.600	46.000	3.300	3.000
OX17P 14	9.200	13.000	2.000	1.900	3.000	2.500	3.000
OX17P 15	6.500	8.000	1.500	1.100	3.000	2.600	3.000
OX17P 16	4.700	10.000	1.500	0.700	2.000	2.300	3.000
OX17S 11	6.400	12.000	1.800	3.000	4.000	1.800	3.000
OX17S 12	5.200	10.000	1.500	2.500	5.000	2.600	3.000
OX17S 13	6.400	10.000	1.500	1.600	46.000	3.300	3.000
OX17S 14	9.200	13.000	2.000	1.900	3.000	2.500	3.000
OX17S 15	6.500	8.000	1.500	1.100	3.000	2.600	3.000
OX17S 16	4.700	10.000	1.500	0.700	2.000	2.300	3.000
OX32W 9	4.400	7.000	1.500	3.900	2.000	3.700	3.000
OX32W 10	5.200	7.000	1.200	2.700	24.000	2.100	3.000
OX32W 11	5.900	7.000	1.200	1.900	25.000	0.500	3.000
OX32W 12	6.000	7.000	1.200	1.200	28.000	2.200	3.000
OX32W 18	6.900	7.000	1.800	0.800	40.000	2.400	3.000
OX32P 9	4.400	7.000	1.500	3.900	2.000	3.700	3.000
OX32P 10	5.200	7.000	1.200	2.700	24.000	2.100	3.000
OX32P 11	5.900	7.000	1.200	1.900	25.000	0.500	3.000
OX32P 12	6.000	7.000	1.200	1.200	28.000	2.200	3.000
OX32P 18	6.900	7.000	1.800	0.800	40.000	2.400	3.000
OX32S 9	4.400	7.000	1.500	3.900	2.000	3.700	3.000
OX32S 10	5.200	7.000	1.500	2.700	24.000	2.100	3.000
OX32S 11	5.900	7.000	1.200	1.900	25.000	0.500	3.000
OX32S 12	6.000	7.000	1.200	1.200	28.000	2.200	3.000
OX32S 18	6.900	7.000	1.800	0.800	40.000	2.400	3.000
KAAI 1	7.500	44.000	2.800	3.200	17.000	3.000	6.000
KAAI 2	4.100	44.000	2.000	3.000	52.000	3.400	6.000
KAAI 3	4.200	46.000	2.800	2.900	33.000	4.500	6.000
KAAI 4	8.300	44.000	2.800	3.000	19.000	4.500	6.000
KAAI 5	5.300	48.000	2.600	2.500	87.000	2.400	6.000
KAAI 6	6.200	40.000	2.600	2.200	102.000	2.700	6.000
KAAI 7	5.300	36.000	2.600	1.800	113.000	4.200	6.000
KAAI 8	4.400	36.000	2.400	1.000	129.000	3.000	6.000
KAAI 9	2.700	36.000	2.400	0.600	4.000	3.500	6.000
MALG 1	5.200	46.000	2.200	1.400	12.000	3.000	7.000
MALG 2	4.400	46.000	2.200	1.300	11.000	2.500	7.000
MALG 3	2.700	42.000	1.900	1.100	2.000	3.800	7.000

Area ID		1 AREA	2 SLOPE	3 DDENS	4 TC	5 ORD1	6 CDIST	7 ROUGH
MALG	4	4.100	42.000	1.900	1.200	38.000	3.500	7.000
MALG	5	5.400	38.000	1.900	0.900	5.000	3.800	7.000
MALG	6	4.900	38.000	1.900	0.800	7.000	3.700	7.000
MALG	7	2.900	30.000	1.900	0.500	50.000	1.900	7.000
MALG	8	4.400	30.000	1.900	0.500	3.000	2.800	7.000
NDAN5	1	8.400	12.500	1.200	2.200	4.000	2.900	5.000
NDAN5	2	5.800	11.000	1.200	1.900	7.000	6.400	5.000
NDAN5	3	7.700	12.000	1.200	2.100	3.000	5.100	5.000
NDAN5	4	8.400	13.900	1.200	2.200	3.000	3.200	5.000
NDAN5	5	7.200	12.000	0.800	1.900	6.000	2.700	5.000
NDAN5	6	5.400	12.500	0.800	1.400	14.000	2.900	5.000
NDAN5	7	5.800	11.500	1.000	1.800	2.000	3.700	5.000
NDAN5	8	6.200	11.000	0.800	1.500	1.000	1.800	5.000
NDAN5	9	4.800	12.000	0.600	1.200	3.000	2.700	5.000
NDAN5	10	8.600	14.000	1.200	2.900	4.000	2.500	5.000
NDAN5	11	5.500	12.000	1.000	2.700	5.000	2.700	5.000
NDAN5	12	5.500	12.000	0.900	2.300	9.000	4.200	5.000
NDAN5	13	4.900	13.000	0.900	2.900	1.000	3.900	5.000
NDAN5	14	8.400	15.000	1.200	2.400	4.000	4.400	5.000
NDAN5	15	5.100	16.000	1.200	2.100	2.000	3.100	5.000
NDAN5	16	6.000	15.000	1.000	1.500	12.000	3.200	5.000
NDAN5	17	2.200	14.500	1.000	0.600	1.000	0.500	5.000
NDAN5	18	5.700	14.500	0.900	0.800	2.000	2.100	5.000

SOIL CHARACTERISTICS

Area	ID	1 DEPTH	2 INFIL	3 PERMC	4 VEGC	5 ENERG	6 WHCAP	7 S1/V
TM11	1	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM11	2	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM11	3	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM8	4	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM8	5	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM8	6	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM8	7	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM3	1	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM3	2	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM3	3	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM3	4	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM6	1	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM6	2	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM6	3	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM6	4	7.000	8.000	6.000	2.000	9.000	5.000	0.850
TM6	5	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM6	6	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM6	7	6.000	8.000	6.000	2.000	9.000	5.000	0.900
TM6	8	8.000	8.000	6.000	2.000	9.000	5.000	0.750
TM2	10	8.000	8.000	6.000	2.000	9.000	5.000	0.900
TM1	11	6.000	8.000	6.000	2.000	9.000	5.000	0.800
TM1	12	8.000	8.000	6.000	2.000	9.000	5.000	0.850
TM1	13	8.000	8.000	6.000	2.000	9.000	5.000	0.800
ECCA	1	6.000	4.000	3.000	4.000	4.000	8.000	0.400
ECCA	2	4.500	4.000	3.000	4.000	4.000	8.000	0.400
ECCA	3	4.500	4.000	3.000	4.000	4.000	8.000	0.400
ECCA	4	4.000	4.000	3.000	4.000	4.000	8.000	0.400
ECCA	5	4.000	4.000	3.000	4.000	4.000	8.000	0.400
ECCA	6	4.000	4.000	3.000	4.000	4.000	8.000	0.400
ECCA	7	4.000	4.000	3.000	4.000	4.000	8.000	0.200
ECCA	8	4.000	4.000	3.000	4.000	4.000	8.000	0.200
ECCA	9	4.000	4.000	3.000	4.000	4.000	8.000	0.200
ECCA	10	5.000	4.000	3.000	4.000	4.000	8.000	0.200
ECCA	11	4.000	4.000	3.000	4.000	4.000	8.000	0.200
ECCA	12	5.000	4.000	3.000	4.000	4.000	8.000	0.400
BETH	1	6.000	3.000	6.000	5.000	7.000	4.000	1.000
BETH	2	6.000	3.000	6.000	5.000	7.000	4.000	1.000
BETH	3	6.000	3.000	6.000	5.000	7.000	4.000	1.000
BETH	4	6.000	3.000	6.000	5.000	7.000	4.000	1.000
BETH	5	6.000	3.000	6.000	5.000	7.000	4.000	1.000
BETH	6	6.000	3.000	6.000	5.000	7.000	4.000	1.000
BETH	7	6.000	3.000	6.000	5.000	7.000	4.000	1.000
BETH	8	6.000	3.000	6.000	5.000	7.000	4.000	1.000
BETH	9	6.000	3.000	6.000	5.000	7.000	4.000	1.000
HOEK	1	6.500	6.000	6.000	6.000	7.000	6.500	0.800
HOEK	2	3.000	5.000	5.000	5.000	7.000	6.500	0.300
HOEK	3	5.500	4.500	4.000	5.000	7.000	6.500	0.700
HOEK	4	6.000	5.000	4.500	5.000	7.000	6.500	0.700
HOEK	5	5.500	4.500	4.500	5.000	7.000	6.500	0.600
HOEK	6	7.000	4.500	3.500	5.000	7.000	6.500	1.000
HOEK	7	3.000	4.500	4.500	5.000	7.000	6.500	0.300
HOEK	8	6.000	5.000	3.500	5.000	7.000	6.500	0.900
HOEK	9	5.500	5.000	4.000	5.000	7.000	6.500	0.700
CED	1	8.000	8.000	6.000	8.000	7.000	6.000	0.850
CED	2	8.000	8.000	6.000	8.000	7.000	6.000	0.850
CED	3	8.000	8.000	6.000	8.000	7.000	6.000	0.850
ZULU	1	9.000	7.000	6.000	7.000	6.000	6.000	0.850
ZULU	2	9.000	7.000	6.000	7.000	6.000	6.000	0.850
ZULU	3	7.000	7.000	5.000	7.000	6.000	6.000	0.850
ZULU	4	5.000	7.000	5.000	7.000	6.000	6.000	0.600
ZULU	5	2.000	4.000	5.000	5.000	6.000	6.000	0.600

Area ID	1 DEPTH	2 INFIL	3 PERMC	4 VEGC	5 ENERG	6 WHCAP	7 S1/V
ZULU 6	3.000	7.000	5.000	6.000	6.000	6.000	0.600
ZULU 7	3.000	7.000	5.000	6.000	6.000	6.000	0.600
ZULU 8	5.000	7.000	5.000	7.000	6.000	6.000	0.600
ZULU 9	5.000	7.000	5.000	7.000	6.000	6.000	0.600
ZULU 10	5.000	7.000	5.000	7.000	6.000	6.000	0.600
OX4W 1	5.000	6.000	6.000	3.000	4.000	7.000	0.800
OX4W 2	5.000	6.000	6.000	3.000	4.000	7.000	0.800
OX4S 1	5.000	6.000	6.000	5.000	7.000	7.000	0.800
OX4S 2	5.000	6.000	6.000	5.000	7.000	7.000	0.800
OX12W 1	5.000	6.000	6.000	3.000	4.000	7.000	0.800
OX12W 2	5.000	6.000	6.000	3.000	4.000	7.000	0.800
OX12W 3	5.000	6.000	6.000	3.000	4.000	7.000	0.900
OX12W 4	5.500	6.000	6.000	3.000	4.000	7.000	0.900
OX12W 5	5.500	6.000	6.000	3.000	4.000	7.000	1.000
OX12W 7	5.500	6.000	6.000	3.000	4.000	7.000	1.000
OX12W 8	5.000	6.000	6.000	3.000	4.000	7.000	0.800
OX12W 9	5.500	6.000	6.000	3.000	4.000	7.000	0.800
OX12W 10	5.500	6.000	6.000	3.000	4.000	7.000	1.000
OX12W 11	5.000	6.000	6.000	3.000	4.000	7.000	0.800
OX12W 12	5.500	6.000	6.000	3.000	4.000	7.000	0.900
OX12P 1	5.000	6.000	6.000	4.000	5.500	7.000	0.800
OX12P 2	5.000	6.000	6.000	4.000	5.500	7.000	0.800
OX12P 3	5.000	6.000	6.000	4.000	5.500	7.000	0.900
OX12P 4	5.500	6.000	6.000	4.000	5.500	7.000	0.900
OX12P 5	5.500	6.000	6.000	4.000	5.500	7.000	1.000
OX12P 7	5.500	6.000	6.000	4.000	5.500	7.000	1.000
OX12P 8	5.000	6.000	6.000	4.000	5.500	7.000	0.800
OX12P 9	5.500	6.000	6.000	4.000	5.500	7.000	0.800
OX12P 10	5.500	6.000	6.000	4.000	5.500	7.000	1.000
OX12P 11	5.000	6.000	6.000	4.000	5.500	7.000	0.800
OX12P 12	5.500	6.000	6.000	4.000	5.500	7.000	0.900
OX12S 1	5.000	6.000	6.000	5.000	7.000	7.000	0.800
OX12S 2	5.000	6.000	6.000	5.000	7.000	7.000	0.800
OX12S 3	5.000	6.000	6.000	5.000	7.000	7.000	0.900
OX12S 4	5.500	6.000	6.000	5.000	7.000	7.000	0.900
OX12S 5	5.500	6.000	6.000	5.000	7.000	7.000	1.000
OX12S 7	5.500	6.000	6.000	5.000	7.000	7.000	1.000
OX12S 8	5.000	6.000	6.000	5.000	7.000	7.000	0.800
OX12S 9	5.500	6.000	6.000	5.000	7.000	7.000	0.800
OX12S 10	5.500	6.000	6.000	5.000	7.000	7.000	1.000
OX12S 11	5.000	6.000	6.000	5.000	7.000	7.000	0.800
OX12S 12	5.500	6.000	6.000	5.000	7.000	7.000	0.900
OX10W 1	5.000	6.000	6.000	3.000	4.000	7.000	0.900
OX10W 2	5.500	6.000	6.000	3.000	4.000	7.000	0.900
OX10W 3	5.500	6.000	6.000	3.000	4.000	7.000	0.900
OX10W 4	5.000	6.000	6.000	3.000	4.000	7.000	0.900
OX10W 5	5.500	6.000	6.000	3.000	4.000	7.000	0.900
OX10P 1	5.000	6.000	6.000	4.000	5.500	7.000	0.900
OX10P 2	5.500	6.000	6.000	4.000	5.500	7.000	0.900
OX10P 3	5.500	6.000	6.000	4.000	5.500	7.000	0.900
OX10P 4	5.000	6.000	6.000	4.000	5.500	7.000	0.900
OX10P 5	5.500	6.000	6.000	4.000	5.500	7.000	0.900
OX10S 1	5.000	6.000	6.000	5.000	7.000	7.000	0.900
OX10S 2	5.500	6.000	6.000	5.000	7.000	7.000	0.900
OX10S 3	5.500	6.000	6.000	5.000	7.000	7.000	0.900
OX10S 4	5.000	6.000	6.000	5.000	7.000	7.000	0.900
OX10S 5	5.500	6.000	6.000	5.000	7.000	7.000	0.900
OX35W 1	5.000	6.000	6.000	3.000	4.000	7.000	1.000
OX35W 2	5.000	6.000	6.000	3.000	4.000	7.000	1.000
OX35W 3	5.000	6.000	6.000	3.000	4.000	7.000	1.000
OX35W 4	5.000	6.000	6.000	3.000	4.000	7.000	1.000
OX35W 5	5.000	6.000	6.000	3.000	4.000	7.000	1.000
OX35W 6	5.000	6.000	6.000	3.000	4.000	7.000	1.000

Area ID	1 DEPTH	2 INFIL	3 PERMC	4 VEGC	5 ENERG	6 WHCAP	7 S1/V
OX35W 7	5.000	6.000	6.000	3.000	4.000	7.000	1.000
OX35W 8	5.000	6.000	6.000	3.000	4.000	7.000	1.000
OX35P 1	5.000	6.000	6.000	4.000	5.500	7.000	1.000
OX35P 2	5.000	6.000	6.000	4.000	5.500	7.000	1.000
OX35P 3	5.000	6.000	6.000	4.000	5.500	7.000	1.000
OX35P 4	5.000	6.000	6.000	4.000	5.500	7.000	1.000
OX35P 5	5.000	6.000	6.000	4.000	5.500	7.000	1.000
OX35P 6	5.000	6.000	6.000	4.000	5.500	7.000	1.000
OX35P 7	5.000	6.000	6.000	4.000	5.500	7.000	1.000
OX35P 8	5.000	6.000	6.000	4.000	5.500	7.000	1.000
OX35S 1	5.000	6.000	6.000	5.000	7.000	7.000	1.000
OX35S 2	5.000	6.000	6.000	5.000	7.000	7.000	1.000
OX35S 3	5.000	6.000	6.000	5.000	7.000	7.000	1.000
OX35S 4	5.000	6.000	6.000	5.000	7.000	7.000	1.000
OX35S 5	5.000	6.000	6.000	5.000	7.000	7.000	1.000
OX35S 6	5.000	6.000	6.000	5.000	7.000	7.000	1.000
OX35S 7	5.000	6.000	6.000	5.000	7.000	7.000	1.000
OX35S 8	5.000	6.000	6.000	5.000	7.000	7.000	1.000
OX17W 11	5.000	6.000	6.000	3.000	4.000	7.000	0.800
OX17W 12	5.500	6.000	6.000	3.000	4.000	7.000	0.900
OX17W 13	6.000	6.000	6.000	3.000	4.000	7.000	1.000
OX17W 14	5.000	6.000	6.000	3.000	4.000	7.000	0.800
OX17W 15	6.500	6.000	6.000	3.000	4.000	7.000	1.000
OX17W 16	6.000	6.000	6.000	3.000	4.000	7.000	0.900
OX17P 11	5.000	6.000	6.000	4.000	5.500	7.000	0.800
OX17P 12	5.500	6.000	6.000	4.000	5.500	7.000	0.900
OX17P 13	6.000	6.000	6.000	4.000	5.500	7.000	1.000
OX17P 14	5.000	6.000	6.000	4.000	5.500	7.000	0.800
OX17P 15	6.500	6.000	6.000	4.000	5.500	7.000	1.000
OX17P 16	6.000	6.000	6.000	4.000	5.500	7.000	0.900
OX17S 11	5.000	6.000	6.000	5.000	7.000	7.000	0.800
OX17S 12	5.500	6.000	6.000	5.000	7.000	7.000	0.900
OX17S 13	6.000	6.000	6.000	5.000	7.000	7.000	1.000
OX17S 14	5.000	6.000	6.000	5.000	7.000	7.000	0.800
OX17S 15	6.500	6.000	6.000	5.000	7.000	7.000	1.000
OX17S 16	6.000	6.000	6.000	5.000	7.000	7.000	0.900
OX32W 9	5.500	6.000	6.000	3.000	4.000	7.000	0.900
OX32W 10	6.000	6.000	6.000	3.000	4.000	7.000	1.000
OX32W 11	6.000	6.000	6.000	3.000	4.000	7.000	1.000
OX32W 12	6.000	6.000	6.000	3.000	4.000	7.000	1.000
OX32W 18	6.000	6.000	6.000	3.000	4.000	7.000	0.900
OX32P 9	5.500	6.000	6.000	4.000	5.500	7.000	0.900
OX32P 10	6.000	6.000	6.000	4.000	5.500	7.000	1.000
OX32P 11	6.000	6.000	6.000	4.000	5.500	7.000	1.000
OX32P 12	6.000	6.000	6.000	4.000	5.500	7.000	1.000
OX32P 18	6.000	6.000	6.000	4.000	5.500	7.000	0.900
OX32S 9	5.500	6.000	6.000	5.000	7.000	7.000	0.900
OX32S 10	6.000	6.000	6.000	5.000	7.000	7.000	1.000
OX32S 11	6.000	6.000	6.000	5.000	7.000	7.000	1.000
OX32S 12	6.000	6.000	6.000	5.000	7.000	7.000	1.000
OX32S 18	6.000	6.000	6.000	5.000	7.000	7.000	0.900
KAAI 1	5.000	7.000	7.000	8.000	4.000	7.000	0.900
KAAI 2	5.000	7.000	7.000	8.000	4.000	7.000	0.900
KAAI 3	5.000	7.000	7.000	8.000	4.000	7.000	0.900
KAAI 4	5.000	7.000	7.000	8.000	4.000	7.000	1.000
KAAI 5	6.000	7.000	7.000	8.000	4.000	7.000	1.000
KAAI 6	6.000	7.000	7.000	8.000	4.000	7.000	1.000
KAAI 7	6.000	7.000	7.000	9.000	4.000	7.000	1.000
KAAI 8	7.000	7.000	7.000	10.000	4.000	7.000	1.000
KAAI 9	7.000	7.000	7.000	10.000	4.000	7.000	1.000
MALG 1	5.000	7.000	7.000	8.000	4.000	7.000	1.000
MALG 2	5.000	7.000	7.000	8.000	4.000	7.000	1.000
MALG 3	5.000	7.000	7.000	8.000	4.000	7.000	1.000

Area ID	1 DEPTH	2 INFIL	3 PERMC	4 VEGC	5 ENERG	6 WHCAP	7 S1/V
MALG 4	5.000	7.000	7.000	8.000	4.000	7.000	1.000
MALG 5	5.000	7.000	7.000	8.000	4.000	7.000	1.000
MALG 6	5.000	7.000	7.000	8.000	4.000	7.000	1.000
MALG 7	7.000	7.000	7.000	9.000	4.000	7.000	1.000
MALG 8	7.000	7.000	7.000	9.000	4.000	7.000	1.000
NDAN5 1	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 2	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 3	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 4	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 5	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 6	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 7	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 8	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 9	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 10	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 11	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 12	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 13	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 14	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 15	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 16	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 17	5.500	6.000	7.500	7.500	5.500	7.000	0.900
NDAN5 18	5.500	6.000	7.500	7.500	5.500	7.000	0.900

APPENDIX E

Summaries of storm data for all catchments.

SUMMARY OF STORM DATA FOR ECCA AT Q9M20 CATCHMENT AREA (km^2) 73.94 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	28. 2.77	15.00	8	24.61	13.75	14.05	1.79	55.50	91.95	99.77	100.00	46.45
2	6. 3.77	10.00	10	8.05	4.50	16.65	1.79	15.35	29.19	90.50	100.00	48.52
3	7. 5.77	4.00	10	45.53	20.25	28.13	2.25	29.13	55.20	70.81	100.00	16.46
4	19. 4.78	13.00	10	44.87	24.50	8.02	1.83	15.26	29.83	79.29	100.00	10.53
5	21. 4.78	6.00	10	35.50	18.25	15.29	1.95	80.25	98.81	98.81	100.00	43.59
6	20. 7.79	2.00	10	164.86	49.50	20.70	3.33	13.27	37.18	78.35	100.00	1.30
7	23. 7.79	22.00	8	29.07	26.75	5.48	1.09	57.71	94.04	99.24	100.00	100.43
8	19. 8.79	20.00	10	113.91	66.50	8.22	1.71	40.10	83.19	88.57	100.00	16.59
9	26. 3.81	8.00	8	23.45	12.50	6.64	1.88	27.24	87.12	99.59	100.00	51.97
10	22.10.81	13.00	10	48.13	12.50	52.06	3.85	64.06	82.72	99.53	100.00	8.21
11	23.12.81	14.00	10	35.22	13.00	60.11	2.71	35.89	37.42	99.89	100.00	5.86
12	2.08.85	7.00	5	50.80	28.00	11.16	1.81	64.83	86.71	97.73	100.00	60.23
13	25.08.85	19.00	6	65.54	38.25	32.93	1.71	76.82	99.63	99.92	100.00	12.66
14	1.12.85	16.00	10	24.16	24.75	30.48	.98	87.05	99.30	99.33	100.00	44.37
15	3.12.85	8.00	5	30.66	26.50	11.61	1.16	63.06	85.26	94.62	100.00	49.72

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	28. 2.77	15.00	.11	.35	.45	33.31	.021	.516	1.066	6.00
2	6. 3.77	10.00	.10	.56	.66	48.63	.004	.477	3.227	4.00
3	7. 5.77	4.00	.10	.37	.47	34.47	.001	.614	1.158	20.00
4	19. 4.78	13.00	.05	.05	.09	6.76	.000	.248	.411	21.50
5	21. 4.78	6.00	.21	1.19	1.39	103.07	.053	.859	2.586	5.25
6	20. 7.79	2.00	16.79	11.54	28.33	2094.63	.000	2.269	31.582	49.25
7	23. 7.79	22.00	3.68	6.72	10.40	769.11	1.650	2.987	12.238	14.50
8	19. 8.79	20.00	12.69	33.13	45.82	3387.75	.039	3.507	35.678	34.75
9	26. 3.81	8.00	.04	.09	.13	9.32	.020	.300	.550	8.00
10	22.10.81	13.00	.22	.78	1.00	74.06	.000	.636	1.923	5.50
11	23.12.81	14.00	.05	.05	.10	7.56	.000	.278	.667	10.75
12	2.08.85	7.00	3.65	11.24	14.89	1100.92	1.380	2.930	15.342	12.25
13	25.08.85	19.00	.91	11.38	12.29	908.67	.004	1.761	15.172	5.75
14	1.12.85	16.00	.37	1.88	2.25	166.00	.295	1.236	5.979	5.25
15	3.12.85	8.00	7.56	5.98	13.55	1001.59	1.610	3.342	7.007	26.50

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	28. 2.77	15.00	.09	.19	.28	20.81	.927	3.00	3.00	12.25
2	6. 3.77	10.00	.10	.41	.51	37.55	3.176	1.00	3.00	11.75
3	7. 5.77	4.00	.07	.15	.22	16.61	.983	2.75	17.25	13.50
4	19. 4.78	13.00	.02	.03	.05	3.44	.287	2.25	18.50	5.50
5	21. 4.78	6.00	.18	.74	.92	67.69	2.396	3.25	2.00	20.25
6	20. 7.79	2.00	16.12	9.02	25.14	1858.81	30.537	26.00	23.25	56.75
7	23. 7.79	22.00	2.40	3.92	6.32	467.42	10.141	12.50	2.00	34.75
8	19. 8.79	20.00	11.86	26.37	38.23	2826.48	34.524	26.25	8.50	85.25
9	26. 3.81	8.00	.02	.04	.06	4.39	.415	2.50	5.50	6.75
10	22.10.81	13.00	.21	.52	.73	54.13	1.772	3.50	2.00	16.00
11	23.12.81	14.00	.04	.02	.06	4.40	.487	1.75	9.00	4.00
12	2.08.85	7.00	2.73	7.91	10.63	786.17	13.564	10.50	1.75	39.25
13	25.08.85	19.00	.89	9.46	10.36	765.73	15.005	3.50	2.25	43.50
14	1.12.85	16.00	.28	1.07	1.34	99.26	5.521	4.00	1.25	23.25
15	3.12.85	8.00	2.86	4.89	7.75	573.23	4.911	16.50	.25	49.50

SUMMARY OF STORM DATA FOR ECCA B AT Q9M21 CATCHMENT AREA (km^2) 9.10 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	28. 2.77	15.00	1	29.82	5.50	40.56	5.42	4.36	62.88	91.85	100.00	46.45
2	6. 3.77	10.00	1	15.91	4.25	40.20	3.74	23.26	30.17	98.55	100.00	48.52
3	7. 5.77	4.00	1	49.48	18.75	32.00	2.64	28.15	51.84	78.17	100.00	16.46
4	19. 4.78	13.00	1	45.71	24.25	10.04	1.88	25.01	39.66	81.05	100.00	10.53
5	21. 4.78	6.00	1	38.17	17.25	25.48	2.21	71.71	98.56	98.56	100.00	43.59
6	20. 7.79	2.00	1	157.47	48.00	20.56	3.28	12.62	33.68	77.30	100.00	1.30
7	23. 7.79	22.00	1	28.83	26.75	7.00	1.08	59.35	92.47	98.92	100.00	100.43
8	19. 8.79	20.00	1	108.83	66.25	8.04	1.64	37.28	78.94	86.68	100.00	16.59
9	26. 3.81	8.00	1	24.61	12.50	8.52	1.97	20.20	88.95	99.39	100.00	51.97
10	22.10.81	13.00	1	59.30	10.00	49.32	5.93	42.06	77.93	82.68	100.00	8.21
11	23.12.81	14.00	1	33.24	11.00	54.80	3.02	40.94	42.54	97.92	100.00	5.86
12	2.08.85	7.00	1	58.35	26.00	15.84	2.24	53.71	79.54	97.24	100.00	60.23
13	25.11.85	19.00	1	75.91	38.25	42.24	1.98	86.04	99.83	99.91	100.00	12.66
14	1.12.85	16.00	1	9.36	4.25	24.24	2.20	92.09	95.73	98.40	100.00	44.37
15	3.12.85	8.00	1	30.75	26.50	14.32	1.16	73.76	92.20	96.68	100.00	49.72

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	28. 2.77	15.00	.08	.32	.40	3.64	.000	.236	.811	3.00
2	6. 3.77	10.00	.21	.20	.41	3.74	.000	.107	1.156	3.25
3	7. 5.77	4.00	.35	1.58	1.94	17.62	.000	.117	1.213	18.50
4	19. 4.78	13.00	.00	.01	.01	.12	.000	.000	.003	7.75
5	21. 4.78	6.00	.29	.92	1.21	10.97	.000	.082	.433	5.00
6	20. 7.79	2.00	14.18	15.22	29.40	267.56	.000	.300	4.621	45.50
7	23. 7.79	22.00	3.43	8.22	11.65	105.97	.217	.384	1.809	10.75
8	19. 8.79	20.00	13.65	21.76	35.41	322.26	.007	.439	2.501	38.00
9	26. 3.81	8.00	.09	.20	.29	2.67	.001	.054	.187	6.50
10	22.10.81	13.00	.00	.01	.01	.07	.002	.001	.002	.25
11	23.12.81	14.00	.16	.17	.33	3.02	.000	.047	.458	9.25
12	2.08.85	7.00	4.54	11.82	16.36	148.86	.039	.285	1.733	13.00
13	25.11.85	19.00	.01	1.27	1.28	11.67	.089	.059	.089	.25
14	1.12.85	16.00	.10	.17	.27	2.48	.058	.087	.129	3.00
15	3.12.85	8.00	.99	9.63	10.63	96.70	.209	.399	1.115	6.25

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	28. 2.77	15.00	.01	.02	.02	.21	.069	.00	4.25	1.00
2	6. 3.77	10.00	.19	.11	.30	2.71	1.045	.25	3.00	2.00
3	7. 5.77	4.00	.32	1.10	1.42	12.92	1.173	7.75	10.75	23.00
4	19. 4.78	13.00	.12	.60	.72	6.58	.370	14.00	7.75	26.00
5	21. 4.78	6.00	.28	.65	.93	8.44	.419	2.50	2.50	16.25
6	20. 7.79	2.00	13.59	12.22	25.81	234.85	4.500	24.25	21.25	60.00
7	23. 7.79	22.00	2.48	4.70	7.17	65.28	1.562	8.25	2.50	36.00
8	19. 8.79	20.00	6.56	21.12	27.68	251.91	2.329	25.25	5.75	85.25
9	26. 3.81	8.00	.07	.11	.18	1.60	.162	4.50	2.00	10.75
10	22.10.81	13.00	.00	.00	.00	.00	.000	6.50	.00	12.75
11	23.12.81	14.00	.19	.12	.31	2.83	.418	8.00	1.25	10.50
12	2.08.85	7.00	4.21	8.90	13.10	119.25	1.637	11.75	1.25	50.00
13	25.11.85	19.00	.00	.00	.00	.00	.000	13.00	.00	51.25
14	1.12.85	16.00	.02	.05	.07	.62	.062	1.00	1.75	5.25
15	3.12.85	8.00	.50	5.03	5.53	50.34	.902	5.00	1.25	42.50

SUMMARY OF STORM DATA FOR DE HOEK AT V1M19 CATCHMENT AREA (km^2) 14.64 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	2. 3.79	23.00	9	38.23	23.25	32.02	1.64	96.00	96.20	99.40	100.00	33.13
2	4. 5.79	18.50	9	28.36	10.00	29.02	2.84	77.82	87.16	95.06	100.00	6.34
3	16. 2.80	17.50	9	32.51	9.75	54.59	3.33	99.91	99.91	99.91	100.00	23.98
4	17. 2.80	17.00	9	40.01	31.00	33.27	1.29	74.36	74.57	75.36	100.00	46.34
5	17.12.80	13.50	9	16.20	5.50	18.00	2.95	10.09	10.79	64.90	100.00	63.59
6	8. 1.81	13.00	9	15.22	9.25	15.91	1.65	62.74	64.89	86.12	100.00	53.28
7	1. 2.81	17.50	9	39.50	10.50	17.03	3.76	58.98	94.05	99.56	100.00	70.41
8	19. 2.81	16.50	9	10.24	8.00	19.46	1.28	94.62	94.62	94.62	100.00	77.86
9	21. 2.81	14.00	9	53.80	22.50	51.01	2.39	92.49	97.41	99.31	100.00	74.18
10	24. 2.81	19.00	9	11.01	10.50	7.98	1.05	44.57	99.19	99.63	100.00	81.61
11	21. 3.82	20.00	9	23.65	24.50	3.55	.97	53.12	80.12	94.61	100.00	53.90
12	8. 4.82	21.17	9	12.94	9.25	31.90	1.40	93.42	98.89	99.57	100.00	22.08
13	26.11.83	18.00	9	23.71	17.25	14.72	1.37	25.00	92.07	99.87	100.00	26.96
14	28.11.83	16.50	9	46.53	25.75	17.45	1.81	79.79	82.57	93.69	100.00	43.63
15	17.12.83	13.50	9	21.20	12.75	24.30	1.66	26.64	87.18	99.75	100.00	25.36
16	24.12.83	17.50	9	24.12	14.75	36.17	1.64	99.85	99.85	99.85	100.00	31.27
17	26.10.84	17.08	9	17.87	11.25	19.26	1.59	5.21	99.47	99.77	100.00	33.15

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	2. 3.79	23.00	2.02	4.42	6.44	94.29	.000	.285	3.965	3.75
2	4. 5.79	18.50	.12	.42	.54	7.93	.000	.080	.813	1.50
3	16. 2.80	17.50	.97	2.29	3.26	47.76	.000	.163	5.219	2.00
4	17. 2.80	17.00	3.16	6.79	9.95	145.67	.084	.371	15.189	3.00
5	17.12.80	13.50	.36	1.68	2.04	29.84	.041	.166	2.399	5.50
6	8. 1.81	13.00	.28	1.19	1.48	21.63	.041	.143	1.455	3.50
7	1. 2.81	17.50	3.41	17.81	21.22	310.64	.163	.416	23.633	3.00
8	19. 2.81	16.50	1.11	3.26	4.37	63.98	.163	.294	4.880	2.25
9	21. 2.81	14.00	7.31	25.83	33.14	485.20	.244	.849	63.165	2.25
10	24. 2.81	19.00	1.27	3.23	4.50	65.83	.330	.535	6.575	3.50
11	21. 3.82	20.00	.89	.66	1.56	22.77	.041	.209	.407	15.75
12	8. 4.82	21.17	.05	.33	.38	5.49	.000	.158	.732	1.00
13	26.11.83	18.00	.25	.25	.50	7.29	.000	.078	.452	11.75
14	28.11.83	16.50	2.20	3.81	6.01	87.98	.000	.251	6.599	5.25
15	17.12.83	13.50	.08	.32	.41	5.95	.000	.093	.732	5.00
16	24.12.83	17.50	1.14	2.39	3.53	51.67	.000	.119	5.661	2.25
17	26.10.84	17.08	.16	.44	.61	8.90	.000	.086	2.440	5.25

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	2. 3.79	23.00	1.95	3.27	5.22	76.42	3.861	2.75	1.00	26.00
2	4. 5.79	18.50	.12	.32	.44	6.42	.804	1.00	.50	9.75
3	16. 2.80	17.50	.94	1.98	2.93	42.84	5.127	1.25	.75	10.50
4	17. 2.80	17.00	3.08	5.13	8.21	120.16	15.054	1.50	1.50	31.75
5	17.12.80	13.50	.29	1.33	1.62	23.76	2.312	.75	4.75	11.00
6	8. 1.81	13.00	.25	.85	1.10	16.10	1.407	.75	2.75	14.00
7	1. 2.81	17.50	3.29	15.59	18.88	276.41	23.458	1.50	1.50	31.50
8	19. 2.81	16.50	1.02	2.38	3.41	49.85	4.705	1.50	.75	16.25
9	21. 2.81	14.00	7.09	21.96	29.05	425.32	62.470	.50	1.75	20.50
10	24. 2.81	19.00	.91	2.12	3.03	44.33	6.111	2.00	1.50	10.75
11	21. 3.82	20.00	.58	.28	.86	12.63	.267	12.25	3.50	20.75
12	8. 4.82	21.17	.02	.06	.08	1.14	.160	.25	4.75	4.25
13	26.11.83	18.00	.23	.16	.40	5.78	.420	4.00	7.75	9.50
14	28.11.83	16.50	2.15	2.88	5.02	73.54	6.529	3.50	1.75	26.50
15	17.12.83	13.50	.08	.18	.25	3.70	.687	.50	4.50	8.00
16	24.12.83	17.50	1.14	2.17	3.31	48.40	5.649	1.25	1.00	14.50
17	26.10.84	17.08	.15	.34	.50	7.28	2.396	.25	5.00	6.00

SUMMARY OF STORM DATA FOR CEDARA AT U2M16 CATCHMENT AREA (km^2) 5.25 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	11.11.78	16.50	6	46.81	15.50	45.24	3.02	10.66	93.19	99.25	100.00	20.67
2	9.12.78	20.00	6	27.28	18.75	9.02	1.46	62.52	98.19	99.12	100.00	48.80
3	28.12.78	17.00	6	41.35	15.00	44.13	2.76	86.84	89.23	96.69	100.00	41.45
4	2. 1.79	13.00	6	41.21	13.50	36.71	3.05	81.98	99.19	99.19	100.00	51.53
5	25. 2.79	17.00	6	35.02	4.50	33.53	7.78	60.49	99.47	99.87	100.00	47.71
6	2.12.84	17.50	6	25.15	12.00	45.48	2.10	95.86	96.18	99.52	100.00	30.66
7	9. 2.85	12.00	6	78.02	33.75	24.76	2.31	66.21	88.42	95.94	100.00	79.52
8	24. 2.85	14.00	6	32.69	5.00	61.80	6.54	58.86	98.78	98.78	100.00	55.84
9	11. 3.85	14.50	6	28.07	7.75	46.00	3.62	97.97	98.22	99.75	100.00	31.19
10	14. 3.86	17.00	6	53.08	4.50	44.50	11.79	36.14	88.18	99.50	100.00	45.69

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	11.11.78	16.50	.21	.46	.67	3.52	.000	.045	.365	9.75
2	9.12.78	20.00	.14	.63	.77	4.06	.015	.058	.088	6.75
3	28.12.78	17.00	.29	.85	1.14	5.99	.002	.058	.496	3.75
4	2. 1.79	13.00	.34	1.45	1.79	9.40	.015	.058	.423	5.00
5	25. 2.79	17.00	.18	.85	1.03	5.43	.015	.045	.602	2.75
6	2.12.84	17.50	.05	.40	.45	2.36	.000	.028	.131	2.75
7	9. 2.85	12.00	1.42	5.99	7.41	38.93	.015	.150	1.094	10.25
8	24. 2.85	14.00	.74	1.96	2.70	14.16	.015	.084	2.363	2.75
9	11. 3.85	14.50	.12	.82	.94	4.92	.000	.046	.335	3.75
10	14. 3.86	17.00	.54	1.77	2.32	12.16	.000	.088	.871	3.50

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	11.11.78	16.50	.17	.30	.47	2.49	.332	1.25	8.50	6.75
2	9.12.78	20.00	.07	.30	.37	1.93	.066	2.50	4.25	14.50
3	28.12.78	17.00	.28	.64	.92	4.81	.485	3.50	.25	14.75
4	2. 1.79	13.00	.29	1.10	1.39	7.28	.401	2.25	2.75	14.50
5	25. 2.79	17.00	.16	.62	.78	4.07	.586	.50	2.25	10.75
6	2.12.84	17.50	.05	.29	.35	1.81	.128	.75	2.00	9.50
7	9. 2.85	12.00	1.27	4.87	6.14	32.23	1.059	7.00	3.25	30.50
8	24. 2.85	14.00	.71	1.78	2.49	13.07	2.345	1.00	1.75	9.50
9	11. 3.85	14.50	.10	.58	.68	3.56	.317	.75	3.00	11.00
10	14. 3.86	17.00	.54	1.60	2.14	11.24	.866	1.75	1.75	13.25

SUMMARY OF STORM DATA FOR ZULULAND AT W1M15 CATCHMENT AREA (km^2) 13.65 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	29. 1.77	17.50	8	64.61	10.25	36.44	6.30	63.18	91.28	99.90	100.00	61.73
2	6. 2.77	1.00	8	271.89	74.25	59.50	3.66	46.45	73.88	92.27	100.00	84.05
3	14. 2.77	20.00	8	193.38	64.00	18.00	3.02	34.56	57.32	90.49	100.00	101.54
4	14. 3.77	20.00	8	96.00	60.00	35.30	1.60	50.25	65.73	99.28	100.00	35.09
5	9.10.77	20.00	8	33.02	11.50	22.72	2.87	30.86	75.34	99.16	100.00	44.28
6	9.11.77	16.00	8	44.27	14.75	77.66	3.00	97.09	99.53	99.58	100.00	17.18
7	19.12.77	20.00	8	51.41	7.75	58.09	6.63	92.34	95.95	99.87	100.00	19.56
8	19. 1.78	20.00	3	92.78	30.00	65.91	3.09	93.87	93.87	93.94	100.00	22.70
9	21. 1.78	.50	3	156.67	54.50	29.64	2.87	68.36	74.05	77.72	100.00	71.14
10	21. 2.78	18.00	8	57.71	33.75	17.37	1.71	57.01	98.43	99.41	100.00	34.37
11	1. 3.78	10.00	8	29.91	17.50	13.23	1.71	54.70	95.51	96.17	100.00	53.60
12	9. 3.78	2.00	8	60.43	32.75	20.63	1.85	65.01	98.23	99.79	100.00	43.22
13	27. 3.78	20.00	8	53.16	16.25	40.61	3.27	41.18	94.22	98.87	100.00	13.73
14	8. 9.78	21.00	8	54.42	26.25	13.39	2.07	35.46	93.05	99.89	100.00	8.19
15	18.10.78	19.00	8	46.72	39.50	27.12	1.18	60.00	60.00	93.82	100.00	40.99

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	29. 1.77	17.50	9.55	14.77	24.32	331.93	.190	.585	10.350	6.25
2	6. 2.77	1.00	25.71	163.62	189.34	2584.44	.236	1.449	61.652	15.25
3	14. 2.77	20.00	21.49	103.48	124.98	1705.97	.303	1.459	33.939	16.75
4	14. 3.77	20.00	23.68	13.86	37.54	512.42	.152	.818	9.413	36.50
5	9.10.77	20.00	1.17	6.91	8.08	110.34	.114	.341	4.258	5.00
6	9.11.77	16.00	2.71	8.79	11.49	156.90	.038	.412	17.931	1.75
7	19.12.77	20.00	1.81	6.91	8.72	119.01	.101	.392	11.425	1.50
8	19. 1.78	20.00	2.77	22.38	25.15	343.26	.076	.522	24.191	2.00
9	21. 1.78	.50	30.94	68.67	99.61	1359.62	.493	1.358	51.377	12.25
10	21. 2.78	18.00	7.79	13.41	21.20	289.40	.152	.629	13.468	10.50
11	1. 3.78	10.00	5.54	4.53	10.07	137.52	.299	1.137	3.974	8.50
12	9. 3.78	2.00	2.65	20.12	22.77	310.87	.169	.731	7.123	4.50
13	27. 3.78	20.00	4.12	10.08	14.20	193.82	.076	.304	10.238	8.50
14	8. 9.78	21.00	4.32	5.33	9.64	131.60	.038	.348	3.564	13.75
15	18.10.78	19.00	1.59	15.76	17.34	236.72	.152	.910	11.861	6.00

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	29. 1.77	17.50	9.20	12.33	21.53	293.84	10.117	5.75	.50	33.25
2	6. 2.77	1.00	24.57	154.73	179.30	2447.43	61.312	15.00	.25	74.75
3	14. 2.77	20.00	19.92	93.79	113.72	1552.26	33.522	15.00	1.75	73.00
4	14. 3.77	20.00	20.92	10.69	31.62	431.59	8.991	36.00	.50	59.50
5	9.10.77	20.00	1.02	5.70	6.71	91.60	4.122	2.75	2.25	24.00
6	9.11.77	16.00	2.69	8.44	11.13	151.88	17.882	1.25	.50	14.50
7	19.12.77	20.00	1.79	6.55	8.34	113.87	11.376	1.25	.25	14.75
8	19. 1.78	20.00	2.73	20.99	23.72	323.72	24.108	.75	1.25	28.75
9	21. 1.78	.50	29.22	58.53	87.75	1197.83	50.801	11.00	1.25	61.25
10	21. 2.78	18.00	7.28	11.52	18.80	256.66	13.247	9.00	1.50	32.25
11	1. 3.78	10.00	4.87	3.67	8.54	116.59	3.644	8.25	.25	17.25
12	9. 3.78	2.00	2.45	17.43	19.88	271.33	6.937	4.25	.25	37.25
13	27. 3.78	20.00	3.88	8.75	12.63	172.42	10.104	7.50	1.00	30.25
14	8. 9.78	21.00	4.05	4.54	8.60	117.34	3.443	11.00	2.75	27.25
15	18.10.78	19.00	1.34	13.03	14.37	196.13	11.700	1.00	5.00	36.25

SUMMARY OF STORM DATA FOR ZULULAND AT W1M16 CATCHMENT AREA (km^2) 3.22 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	29. 1.77	17.50	1	71.35	8.25	67.44	8.65	60.31	75.28	96.92	100.00	65.05
2	6. 2.77	1.00	1	298.67	73.75	65.68	4.05	44.00	78.11	93.58	100.00	95.66
3	14. 2.77	20.00	1	188.56	64.00	30.28	2.95	31.24	55.57	89.80	100.00	98.01
4	14. 3.77	20.00	1	104.03	45.75	51.48	2.27	56.10	57.28	83.18	100.00	40.14
5	9.10.77	20.00	1	33.17	11.50	33.36	2.88	28.58	73.38	98.82	100.00	49.91
6	9.11.77	16.00	1	52.05	22.00	101.88	2.37	96.06	98.94	99.52	100.00	17.71
7	19.12.77	20.00	1	56.48	17.25	67.12	3.27	96.74	99.72	99.73	100.00	25.67
8	19. 1.78	20.00	1	74.82	6.50	55.04	11.51	51.87	83.52	98.16	100.00	15.82
9	21. 1.78	.50	1	160.97	68.50	33.32	2.35	73.13	74.40	98.99	100.00	61.67
10	21. 2.78	18.00	1	54.70	33.50	16.04	1.63	62.07	97.73	99.05	100.00	38.01
11	1. 3.78	10.00	1	36.88	20.50	15.24	1.80	47.80	89.45	90.75	100.00	55.29
12	9. 3.78	2.00	1	68.84	20.75	31.20	3.32	66.53	73.34	97.89	100.00	45.70
13	27. 3.78	20.00	1	107.05	14.75	89.72	7.26	53.52	90.70	97.31	100.00	17.79
14	8. 9.78	21.00	1	53.54	26.25	22.60	2.04	32.11	91.58	99.65	100.00	7.97
15	18.10.78	19.00	1	43.62	45.00	32.00	.97	51.01	51.88	92.37	100.00	48.09

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	29. 1.77	17.50	6.84	13.47	20.32	65.41	.088	.193	1.475	5.75
2	6. 2.77	1.00	155.43	88.15	243.58	784.33	.073	.362	20.559	27.25
3	14. 2.77	20.00	45.57	34.52	80.08	257.87	.082	.593	3.096	38.75
4	14. 3.77	20.00	24.16	9.49	33.65	108.35	.184	.310	1.259	37.25
5	9.10.77	20.00	2.99	4.82	7.82	25.17	.027	.095	.590	9.25
6	9.11.77	16.00	1.10	10.27	11.37	36.60	.012	.086	1.901	1.00
7	19.12.77	20.00	3.04	5.67	8.71	28.03	.007	.085	1.106	4.00
8	19. 1.78	20.00	4.38	10.87	15.25	49.12	.018	.132	1.682	5.00
9	21. 1.78	.50	20.28	53.69	73.97	238.18	.125	.464	5.648	13.00
10	21. 2.78	18.00	4.85	11.91	16.76	53.97	.037	.153	1.229	10.50
11	1. 3.78	10.00	4.22	6.94	11.16	35.94	.074	.122	.671	10.50
12	9. 3.78	2.00	3.63	18.92	22.55	72.62	.047	.182	1.115	5.75
13	27. 3.78	20.00	8.08	10.40	18.48	59.51	.019	.108	3.292	9.25
14	8. 9.78	21.00	2.94	4.82	7.77	25.01	.009	.092	.569	14.50
15	18.10.78	19.00	.96	15.79	16.75	53.93	.046	.182	1.431	5.50

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	29. 1.77	17.50	6.46	11.59	18.05	58.12	1.411	5.50	.25	26.00
2	6. 2.77	1.00	152.50	77.73	230.23	741.34	20.439	27.00	.25	82.25
3	14. 2.77	20.00	40.57	28.90	69.48	223.72	2.946	38.50	.25	67.25
4	14. 3.77	20.00	20.90	7.74	28.64	92.21	1.148	37.00	.25	49.75
5	9.10.77	20.00	2.67	3.79	6.45	20.77	.551	6.75	2.50	23.75
6	9.11.77	16.00	1.09	9.56	10.65	34.28	1.891	.75	.25	22.25
7	19.12.77	20.00	3.02	5.33	8.35	26.90	1.099	3.75	.25	18.50
8	19. 1.78	20.00	4.26	9.82	14.08	45.34	1.657	4.00	1.00	25.25
9	21. 1.78	.50	18.32	41.05	59.37	191.17	5.502	11.75	1.25	69.25
10	21. 2.78	18.00	4.31	9.54	13.86	44.62	1.174	10.25	.25	37.25
11	1. 3.78	10.00	3.35	4.24	7.59	24.43	.587	10.25	.25	33.25
12	9. 3.78	2.00	3.31	15.49	18.81	60.55	1.060	5.50	.25	41.00
13	27. 3.78	20.00	7.81	9.18	16.98	54.69	3.258	9.00	.25	29.75
14	8. 9.78	21.00	2.64	4.05	6.68	21.52	.538	12.50	2.00	28.00
15	18.10.78	19.00	.65	11.83	12.48	40.18	1.376	4.25	1.25	43.75

SUMMARY OF STORM DATA FOR BETHLEHEM AT C8M25 CATCHMENT AREA (km^2) 83.00 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	1.11.80	15.00	4	19.83	9.00	17.46	2.20	21.10	82.84	99.22	100.00	1.55
2	15.12.80	12.50	8	7.07	5.50	8.71	1.29	.00	50.23	97.33	100.00	43.97
3	24. 1.81	23.50	6	45.85	27.75	18.73	1.65	64.58	73.82	97.67	100.00	56.77
4	26. 1.81	21.00	6	8.75	15.00	14.60	.58	91.78	91.78	92.84	100.00	83.53
5	5. 2.81	17.00	6	9.14	5.25	10.03	1.74	30.58	90.38	99.66	100.00	50.13
6	10. 2.81	23.00	8	30.84	11.25	16.39	2.74	69.45	95.60	99.74	100.00	54.55
7	14. 2.81	15.00	8	21.01	23.25	33.18	.90	96.27	96.67	96.95	100.00	60.60
8	17. 2.81	.50	6	40.73	34.00	23.72	1.20	86.59	91.31	99.94	100.00	64.66
9	27. 2.81	19.50	7	16.37	25.25	15.08	.65	69.77	69.77	69.77	100.00	44.47
10	22. 3.81	15.00	7	17.14	18.75	14.80	.91	57.81	93.20	99.71	100.00	23.28
11	30.12.81	15.00	6	44.83	14.00	44.93	3.20	91.93	98.80	99.73	100.00	13.99

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	1.11.80	15.00	.15	1.10	1.25	103.66	.000	.540	4.670	2.75
2	15.12.80	12.50	.20	.23	.42	35.21	.020	.600	1.240	9.50
3	24. 1.81	23.50	.45	1.80	2.25	186.55	.180	1.400	2.890	11.00
4	26. 1.81	21.00	.47	.48	.95	79.23	.360	1.020	2.040	9.25
5	5. 2.81	17.00	.62	.88	1.50	124.91	.020	.480	11.680	3.25
6	10. 2.81	23.00	1.75	4.79	6.55	543.28	.310	1.360	21.640	7.00
7	14. 2.81	15.00	.99	3.67	4.66	386.50	.060	1.090	23.480	5.50
8	17. 2.81	.50	3.39	11.77	15.17	1258.71	.210	1.750	51.830	7.50
9	27. 2.81	19.50	.70	4.22	4.93	408.83	.320	1.300	19.400	6.25
10	22. 3.81	15.00	.30	.72	1.02	84.88	.050	.730	2.500	7.75
11	30.12.81	15.00	.69	.86	1.55	128.99	.000	.630	5.460	5.75

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	1.11.80	15.00	.15	.95	1.10	91.17	4.640	.50	2.25	11.75
2	15.12.80	12.50	.11	.14	.24	20.12	.900	5.75	3.00	12.00
3	24. 1.81	23.50	.24	1.04	1.28	106.23	2.330	7.50	3.00	26.50
4	26. 1.81	21.00	.26	.20	.46	38.56	1.320	7.75	1.50	14.75
5	5. 2.81	17.00	.61	.77	1.38	114.44	11.550	2.25	1.00	10.25
6	10. 2.81	23.00	1.64	4.03	5.67	470.24	21.110	4.50	2.50	22.75
7	14. 2.81	15.00	.95	3.13	4.07	337.90	23.180	4.75	.75	22.25
8	17. 2.81	.50	3.29	10.40	13.69	1135.97	51.340	5.00	2.50	32.75
9	27. 2.81	19.50	.61	3.47	4.08	338.28	19.000	1.00	5.25	21.00
10	22. 3.81	15.00	.27	.48	.76	62.73	2.280	3.75	4.00	14.75
11	30.12.81	15.00	.67	.68	1.35	112.12	5.230	4.75	1.00	13.75

SUMMARY OF STORM DATA FOR KAAIMANS AT K3M01 CATCHMENT AREA (km^2) 48.00 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	25.03.81	11.30	2	107.32	21.00	22.04	5.11	5.46	47.21	90.78	100.00	33.81
2	26.04.81	16.00	2	141.10	26.00	20.45	5.43	6.67	37.30	81.16	100.00	24.89
3	05.05.81	3.45	2	27.75	18.00	7.73	1.54	52.40	73.67	87.94	100.00	94.66
4	28.05.81	20.30	1	205.31	27.25	17.61	7.53	15.22	51.09	83.08	100.00	31.44
5	06.06.81	16.30	1	10.75	11.00	6.44	.98	21.14	74.76	85.51	100.00	99.54
6	24.08.81	15.00	2	54.88	13.00	10.88	4.22	20.07	42.26	88.11	100.00	19.13
7	27.08.81	8.00	2	76.28	49.25	21.71	1.55	31.35	91.62	96.69	100.00	38.74
8	30.08.81	1.00	3	94.11	45.50	26.17	2.07	72.65	81.65	95.91	100.00	60.68
9	18.02.82	6.00	2	34.96	11.00	19.98	3.18	35.59	83.21	98.29	100.00	31.53
10	03.03.82	12.30	1	40.16	12.50	14.82	3.21	14.38	64.64	90.27	100.00	47.68
11	12.09.82	19.45	1	110.87	75.75	8.62	1.46	24.69	56.90	81.71	100.00	33.22
12	12.06.83	7.00	1	47.80	29.75	7.39	1.61	31.76	86.17	96.70	100.00	28.39
13	22.09.83	22.00	3	62.60	40.25	19.66	1.56	70.18	90.32	97.42	100.00	12.64
14	02.10.83	17.00	1	94.88	31.25	13.15	3.04	47.63	76.79	98.55	100.00	27.62
15	28.10.85	14.00	3	145.71	72.25	12.86	2.02	18.70	70.60	92.95	100.00	28.45
16	2.11.85	6.00	3	22.49	18.75	5.89	1.20	49.90	79.80	97.21	100.00	69.58
17	8.11.85	16.00	3	40.86	21.75	19.83	1.88	75.34	96.93	99.62	100.00	68.85
18	2.12.85	18.30	3	57.65	29.25	6.55	1.97	33.50	62.24	99.30	100.00	31.06

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	25.03.81	11.30	10.19	83.26	93.46	4485.96	1.920	7.450	119.130	11.75
2	26.04.81	16.00	24.22	56.15	80.38	3858.13	.990	7.240	87.180	19.75
3	05.05.81	3.45	3.37	18.54	21.91	1051.58	2.050	5.810	13.710	9.25
4	28.05.81	20.30	31.02	150.28	181.30	8702.40	1.040	7.400	170.330	13.75
5	06.06.81	16.30	5.49	11.82	17.31	830.86	2.340	5.630	14.840	12.50
6	24.08.81	15.00	1.71	28.68	30.39	1458.68	1.220	5.530	40.380	9.50
7	27.08.81	8.00	10.16	45.40	55.56	2666.68	2.790	7.330	53.330	19.25
8	30.08.81	1.00	22.79	61.18	83.98	4030.89	6.270	10.650	75.960	14.00
9	18.02.82	6.00	2.59	15.02	17.61	845.40	2.030	3.610	27.480	8.50
10	03.03.82	12.30	7.44	16.76	24.20	1161.77	.630	3.540	22.190	12.75
11	12.09.82	19.45	6.25	41.16	47.41	2275.70	.720	4.850	12.210	31.25
12	12.06.83	7.00	8.37	25.09	33.46	1605.89	.880	5.320	34.810	14.00
13	22.09.83	22.00	4.10	21.01	25.11	1205.33	.440	5.300	26.050	15.00
14	02.10.83	17.00	31.26	38.75	70.02	3360.78	1.160	6.400	78.470	18.75
15	28.10.85	14.00	20.85	58.94	79.79	3830.01	.560	6.838	60.460	37.75
16	2.11.85	6.00	5.23	10.44	15.68	752.47	2.992	4.803	12.640	15.50
17	8.11.85	16.00	5.57	30.39	35.96	1725.86	3.491	5.904	36.671	8.75
18	2.12.85	18.30	13.72	19.90	33.62	1613.68	.604	4.986	26.718	21.75

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	25.03.81	11.30	8.36	77.38	85.74	4115.35	116.860	5.25	6.50	34.75
2	26.04.81	16.00	22.71	53.18	75.89	3642.68	85.940	10.00	9.75	35.25
3	05.05.81	3.45	1.89	13.83	15.72	754.45	11.470	6.75	2.50	31.25
4	28.05.81	20.30	29.79	144.14	173.93	8348.80	168.970	10.00	3.75	52.50
5	06.06.81	16.30	3.16	8.03	11.19	537.28	12.190	10.75	1.75	28.25
6	24.08.81	15.00	.82	25.68	26.50	1272.20	39.050	2.00	7.50	26.25
7	27.08.81	8.00	5.96	36.50	42.46	2038.32	50.210	11.00	8.25	44.25
8	30.08.81	1.00	16.37	41.64	58.01	2784.65	69.700	9.50	4.50	48.00
9	18.02.82	6.00	1.28	11.03	12.30	590.53	25.290	2.00	6.50	23.50
10	03.03.82	12.30	6.70	14.41	21.11	1013.05	21.250	10.00	2.75	34.75
11	12.09.82	19.45	3.71	30.31	34.03	1633.26	10.730	27.75	3.50	90.25
12	12.06.83	7.00	7.24	21.78	29.01	1392.69	33.550	13.50	.50	40.75
13	22.09.83	22.00	3.35	18.48	21.83	1047.91	25.120	3.25	11.75	29.50
14	02.10.83	17.00	29.13	34.56	63.68	3056.88	76.690	14.25	4.50	40.50
15	28.10.85	14.00	18.38	53.82	72.20	3465.54	59.119	29.00	8.75	66.25
16	2.11.85	6.00	1.87	6.03	7.90	379.37	9.659	5.25	10.25	23.50
17	8.11.85	16.00	3.35	22.16	25.51	1224.38	33.235	4.50	4.25	33.25
18	2.12.85	18.30	12.28	17.34	29.62	1421.55	25.555	19.25	2.50	42.50

SUMMARY OF STORM DATA FOR MALGAS AT K3M04 CATCHMENT AREA (km^2) 34.00 DATA TIME INTERVAL (hrs) 1.00

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	25.03.81	11.30	2	109.99	84.00	5.65	1.31	5.46	47.21	90.78	100.00	35.21
2	26.04.81	16.00	1	142.03	104.00	8.09	1.37	6.54	41.17	88.59	100.00	26.63
3	05.05.81	3.45	1	27.77	73.00	1.68	.38	29.69	79.93	95.40	100.00	94.49
4	28.05.81	20.30	1	194.74	174.00	4.08	1.12	30.24	83.82	97.77	100.00	31.62
5	06.06.81	12.45	1	13.96	75.00	1.90	.19	2.11	69.38	95.78	100.00	100.69
6	24.08.81	15.00	2	51.50	52.00	2.55	.99	20.07	42.26	88.11	100.00	20.47
7	27.08.81	8.00	2	74.04	180.00	4.57	.41	27.40	87.70	94.87	100.00	46.47
8	30.08.81	1.00	3	83.35	182.00	3.52	.46	76.96	81.84	97.46	100.00	66.50
9	15.10.81	21.30	1	58.95	71.00	2.43	.83	25.61	57.46	83.97	100.00	17.91
10	15.01.82	14.00	3	29.62	46.00	2.82	.64	40.40	81.27	97.77	100.00	26.43
11	18.02.82	6.00	1	40.19	44.00	5.74	.91	35.59	83.21	98.29	100.00	33.74
12	03.03.82	12.30	1	40.87	50.00	3.77	.82	14.38	64.64	90.27	100.00	48.54
13	01.09.82	.45	2	38.48	123.00	1.20	.31	27.68	78.92	90.91	100.00	9.70
14	11.06.83	16.00	1	87.96	147.00	5.08	.60	46.75	52.66	88.95	100.00	9.73
15	22.09.83	22.00	3	59.23	161.00	3.40	.37	64.36	92.76	98.54	100.00	13.53
16	15.10.85	8.45	3	35.96	70.00	5.78	.51	2.88	66.54	98.91	100.00	45.49
17	21. 1.86	10.00	3	45.81	59.00	2.62	.78	32.76	69.37	87.95	100.00	8.75

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	25.03.81	11.30	132.65	191.61	324.26	11024.93	1.650	7.150	94.460	50.00
2	26.04.81	16.00	111.05	175.63	286.68	9747.25	.450	4.340	58.020	79.00
3	05.05.81	3.45	15.73	88.47	104.21	3543.01	.760	3.110	15.390	27.00
4	28.05.81	20.30	227.23	391.13	618.37	21024.47	.430	6.180	97.210	65.00
5	06.06.81	12.45	32.95	45.14	78.09	2654.89	.960	2.310	10.290	61.00
6	24.08.81	15.00	16.45	60.73	77.18	2624.08	.290	1.910	14.360	60.00
7	27.08.81	8.00	45.70	143.83	189.52	6443.82	1.060	5.910	32.080	72.00
8	30.08.81	1.00	106.84	174.19	281.03	9555.12	3.550	5.760	48.540	52.00
9	15.10.81	21.30	45.04	82.83	127.87	4347.50	.300	2.170	20.680	49.00
10	15.01.82	14.00	4.87	15.36	20.23	687.85	.180	1.030	4.290	40.00
11	18.02.82	6.00	28.67	76.17	104.84	3564.58	.900	1.880	35.830	29.00
12	03.03.82	12.30	25.11	111.24	136.35	4636.01	.250	1.750	25.500	29.00
13	01.09.82	.45	22.65	60.98	83.63	2843.39	.170	2.760	10.520	65.00
14	11.06.83	16.00	78.42	108.24	186.66	6346.40	.090	4.280	29.450	112.00
15	22.09.83	22.00	51.43	91.62	143.05	4863.56	.080	3.260	18.580	54.00
16	15.10.85	8.45	40.04	76.18	116.22	3951.50	.474	1.880	35.790	45.00
17	21. 1.86	10.00	10.75	25.11	35.86	1219.32	.007	1.280	10.000	55.00

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	25.03.81	11.30	123.40	177.75	301.15	10239.01	92.600	46.00	4.00	111.00
2	26.04.81	16.00	106.10	166.79	272.89	9278.32	57.250	59.00	20.00	145.00
3	05.05.81	3.45	13.40	75.55	88.95	3024.40	14.510	25.00	2.00	133.00
4	28.05.81	20.30	223.88	380.10	603.98	20535.37	96.570	64.00	1.00	179.00
5	06.06.81	12.45	25.20	32.91	58.11	1975.79	9.100	59.00	1.00	149.00
6	24.08.81	15.00	14.22	52.76	66.97	2277.11	13.890	35.00	25.00	140.00
7	27.08.81	8.00	36.62	125.43	162.05	5509.66	30.730	66.00	6.00	174.00
8	30.08.81	1.00	87.52	114.42	201.95	6866.14	44.930	44.00	8.00	187.00
9	15.10.81	21.30	42.68	74.20	116.87	3973.72	20.110	41.00	8.00	142.00
10	15.01.82	14.00	3.88	12.11	15.98	543.42	3.970	30.00	10.00	95.00
11	18.02.82	6.00	25.94	65.05	90.99	3093.59	34.890	18.00	11.00	109.00
12	03.03.82	12.30	24.15	102.77	126.92	4315.14	25.120	22.00	7.00	143.00
13	01.09.82	.45	20.72	52.46	73.19	2488.32	10.090	64.00	1.00	179.00
14	11.06.83	16.00	74.81	100.05	174.86	5945.22	28.890	100.00	12.00	198.00
15	22.09.83	22.00	50.29	84.77	135.06	4592.12	18.260	50.00	4.00	161.00
16	15.10.85	8.45	37.39	67.90	105.30	3580.09	35.130	44.00	1.00	134.00
17	21. 1.86	10.00	10.43	22.99	33.42	1136.23	9.850	22.00	33.00	87.00

SUMMARY OF STORM DATA FOR KARATARA AT K4M02 CATCHMENT AREA (km^2) 22.00 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	02.02.81	20.00	1	16.14	8.75	4.93	1.84	44.03	73.58	85.00	100.00	114.41
2	15.02.81	6.00	1	11.54	8.25	6.96	1.40	69.05	96.10	96.10	100.00	44.35
3	16.02.82	21.00	1	19.67	10.75	7.73	1.83	20.43	52.38	77.15	100.00	24.50
4	18.02.82	9.30	1	21.23	6.00	16.04	3.54	13.86	48.56	89.63	100.00	39.99
5	03.03.82	12.00	1	61.36	13.50	25.43	4.55	16.44	66.84	91.97	100.00	19.66
6	12.06.83	7.00	1	83.10	28.00	15.04	2.97	63.43	73.79	86.33	100.00	18.15
7	22.09.83	23.00	1	50.40	26.25	15.84	1.92	51.07	89.18	94.64	100.00	12.59
8	02.10.83	17.00	1	69.90	30.50	19.08	2.29	41.57	84.26	96.42	100.00	37.54

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	02.02.81	20.00	1.49	13.42	14.91	327.93	.290	.920	6.920	5.25
2	15.02.81	6.00	1.81	7.87	9.68	212.90	.160	.880	6.660	5.50
3	16.02.82	21.00	1.63	4.31	5.94	130.69	.090	.640	2.520	10.00
4	18.02.82	9.30	2.35	14.67	17.03	374.56	.000	.790	14.280	3.25
5	03.03.82	12.00	16.91	21.43	38.33	843.32	.110	1.000	20.220	12.25
6	12.06.83	7.00	6.64	37.18	43.82	964.08	.430	.790	12.040	8.25
7	22.09.83	23.00	8.68	12.79	21.47	472.33	.010	.900	8.490	16.00
8	02.10.83	17.00	7.54	36.66	44.20	972.46	.110	1.120	21.700	11.50

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	02.02.81	20.00	1.21	10.98	12.19	268.18	6.570	2.25	3.00	30.75
2	15.02.81	6.00	1.66	6.81	8.47	186.26	6.470	2.00	3.50	22.75
3	16.02.82	21.00	1.39	3.21	4.60	101.27	2.310	5.00	5.00	25.00
4	18.02.82	9.30	2.10	12.08	14.18	311.93	13.780	2.00	1.25	26.25
5	03.03.82	12.00	16.60	19.86	36.46	802.12	20.000	8.00	4.25	33.25
6	12.06.83	7.00	6.35	33.42	39.77	874.94	11.780	8.00	.25	51.25
7	22.09.83	23.00	8.47	10.81	19.28	424.12	8.320	13.00	3.00	45.75
8	02.10.83	17.00	7.29	34.30	41.59	914.88	21.510	3.75	7.75	39.75

SUMMARY OF STORM DATA FOR DIEP AT K4M03 CATCHMENT AREA (km^2) 71.00 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	31.01.70	21.00	1	30.63	21.50	6.78	1.42	43.24	81.49	97.69	100.00	5.48
2	15.02.70	19.00	1	34.39	21.75	3.58	1.58	42.44	78.36	91.52	100.00	33.67
3	25.08.70	4.45	1	59.53	33.25	7.17	1.79	51.62	69.42	89.57	100.00	7.91
4	04.04.71	16.00	1	70.09	18.25	24.52	3.84	12.56	33.21	68.73	100.00	40.31
5	29.07.71	14.75	1	61.50	27.50	7.43	2.24	26.32	55.95	68.05	100.00	22.14
6	05.02.72	19.30	1	36.81	13.50	16.93	2.73	51.43	57.89	85.00	100.00	42.81
7	01.04.74	2.00	1	49.47	20.75	8.47	2.38	31.17	74.21	95.60	100.00	16.50
8	25.03.81	15.15	1	136.10	23.00	26.81	5.92	49.47	87.73	99.57	100.00	40.70
9	26.04.81	23.30	1	100.91	18.50	15.74	5.45	28.13	55.49	93.96	100.00	15.53
10	28.05.81	21.00	1	248.13	27.25	21.28	9.11	15.22	51.09	83.08	100.00	27.69
11	25.07.83	3.00	1	121.49	66.50	35.38	1.83	46.45	82.72	88.63	100.00	40.33
12	02.10.83	17.00	1	76.95	23.00	10.82	3.35	25.49	55.85	85.19	100.00	12.78
13	29.10.85	15.30	6	70.40	44.00	8.16	1.60	53.81	85.80	98.86	100.00	35.28
14	8.11.85	16.00	3	34.75	34.00	12.47	1.02	77.24	85.55	99.72	100.00	66.14

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	31.01.70	21.00	.39	.43	.82	58.09	.050	.880	1.140	14.25
2	15.02.70	19.00	1.07	1.89	2.96	210.08	.100	1.860	3.350	15.25
3	25.08.70	4.45	.85	4.75	5.60	397.48	.070	2.100	5.180	13.25
4	04.04.71	16.00	10.47	11.51	21.98	1560.38	.940	3.330	30.590	19.75
5	29.07.71	14.75	5.38	7.54	12.92	917.55	.390	3.230	16.940	23.50
6	05.02.72	19.30	2.62	1.29	3.91	277.61	.290	2.060	4.950	22.25
7	01.04.74	2.00	1.14	2.03	3.17	224.85	.130	1.050	8.330	13.50
8	25.03.81	15.15	17.48	88.05	105.53	7492.45	.250	13.730	205.500	10.50
9	26.04.81	23.30	10.34	25.02	35.36	2510.85	.680	7.310	40.630	14.50
10	28.05.81	21.00	38.78	120.71	159.49	11323.77	1.610	15.680	240.180	16.25
11	25.07.83	3.00	29.28	34.44	63.72	4524.12	.180	9.580	44.420	44.25
12	02.10.83	17.00	1.80	20.55	22.35	1587.19	.330	3.920	22.830	10.00
13	29.10.85	15.30	2.80	8.79	11.59	822.82	.180	2.464	18.512	16.00
14	8.11.85	16.00	1.51	7.16	8.67	615.82	1.092	2.455	9.627	8.25

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	31.01.70	21.00	.05	.24	.29	20.52	.650	3.00	7.00	15.00
2	15.02.70	19.00	.66	1.02	1.68	119.40	2.470	10.00	5.25	24.75
3	25.08.70	4.45	.62	3.07	3.69	261.86	4.540	6.25	7.00	34.25
4	04.04.71	16.00	9.19	8.75	17.94	1273.60	28.930	19.50	.25	44.75
5	29.07.71	14.75	4.36	5.65	10.01	711.00	15.640	22.75	.75	44.25
6	05.02.72	19.30	.94	1.43	2.37	168.10	3.700	10.25	7.75	22.25
7	01.04.74	2.00	.93	1.50	2.43	172.64	7.780	8.00	5.50	20.50
8	25.03.81	15.15	17.29	85.54	102.83	7300.84	204.950	6.50	4.00	44.75
9	26.04.81	23.30	9.65	22.23	31.89	2264.05	39.420	13.00	1.50	43.50
10	28.05.81	21.00	37.53	116.63	154.16	10945.22	238.340	16.00	.25	48.50
11	25.07.83	3.00	26.80	30.44	57.24	4064.16	42.460	41.25	3.00	72.00
12	02.10.83	17.00	1.61	18.41	20.01	1421.04	22.310	4.75	5.25	39.75
13	29.10.85	15.30	2.47	6.91	9.37	665.46	17.800	13.50	2.50	42.50
14	8.11.85	16.00	1.02	4.33	5.36	380.28	8.315	5.75	2.50	35.00

SUMMARY OF STORM DATA FOR N.DANVILLE AT ND1 CATCHMENT AREA (km^2) 42.94 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	24.10.59	5.00	1	74.30	17.00	20.83	4.37	44.32	49.48	92.77	100.00	40.89
2	30. 7.60	12.00	3	45.35	12.00	14.77	3.78	24.00	61.52	85.08	100.00	11.37
3	2. 6.61	2.00	3	22.76	6.75	11.98	3.37	30.19	41.95	93.62	100.00	15.53
4	31. 7.62	4.00	3	51.66	9.25	35.60	5.59	32.83	62.97	71.92	100.00	24.01
5	30. 7.63	2.00	8	23.30	4.00	18.25	5.82	42.59	51.15	85.87	100.00	15.63
6	22. 7.64	17.00	8	19.52	1.50	35.98	13.02	8.26	36.50	100.00	100.00	28.42
7	7. 6.65	15.25	3	39.49	8.75	32.51	4.51	53.82	75.52	94.38	100.00	9.79
8	19.10.66	20.15	3	30.05	32.50	8.51	.92	57.52	91.41	98.36	100.00	16.73
9	16. 7.67	4.00	3	33.78	10.25	20.63	3.30	65.02	81.28	96.23	100.00	26.67
10	11. 9.68	4.00	3	43.24	31.25	14.45	1.38	50.33	92.24	94.11	100.00	14.41
11	7. 9.69	17.00	3	20.65	12.00	36.28	1.72	96.74	99.28	99.55	100.00	27.48
12	23. 8.71	3.00	3	30.61	21.00	18.88	1.46	84.33	94.87	98.00	100.00	36.39
13	3. 7.72	11.00	1	26.23	5.50	23.22	4.77	4.45	45.08	92.91	100.00	43.69
14	10. 7.72	10.45	3	34.93	13.75	23.99	2.54	6.99	83.39	86.74	100.00	34.87
15	17. 9.73	24.00	3	37.76	16.25	7.75	2.32	11.49	52.72	92.14	100.00	36.26

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/S)	FINAL FLOW (m^3/S)	PEAK FLOW (m^3/S)	TIME TO PEAK (hrs)
1	24.10.59	5.00	15.38	14.90	30.28	1300.19	1.820	4.480	31.180	14.25
2	30. 7.60	12.00	.82	1.83	2.65	113.86	.040	.540	3.970	11.75
3	2. 6.61	2.00	1.52	4.90	6.42	275.74	.370	1.130	6.270	8.00
4	31. 7.62	4.00	3.27	6.24	9.51	408.29	.080	.830	12.410	10.25
5	30. 7.63	2.00	.10	.07	.16	7.00	.050	.240	.320	8.75
6	22. 7.64	17.00	.38	.78	1.16	49.76	.140	.490	1.700	4.75
7	7. 6.65	15.25	1.58	4.05	5.63	241.93	.110	.500	5.520	9.00
8	19.10.66	20.15	1.45	1.68	3.13	134.20	.100	.830	1.880	17.25
9	16. 7.67	4.00	.41	4.26	4.66	200.30	.140	.780	4.100	4.25
10	11. 9.68	4.00	.68	2.19	2.87	123.28	.070	.650	3.730	12.00
11	7. 9.69	17.00	.35	.61	.96	41.41	.250	.580	1.270	6.50
12	23. 8.71	3.00	.51	1.79	2.30	98.97	.180	.670	2.680	6.75
13	3. 7.72	11.00	.56	3.76	4.32	185.63	.270	.870	5.180	7.25
14	10. 7.72	10.45	.74	3.67	4.42	189.62	.230	.850	5.180	9.25
15	17. 9.73	24.00	1.34	3.60	4.94	211.98	.170	.830	5.000	13.25

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/S)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	24.10.59	5.00	13.05	12.08	25.13	1079.08	29.070	12.00	2.25	26.75
2	30. 7.60	12.00	.71	1.38	2.10	90.00	3.740	8.00	3.75	21.25
3	2. 6.61	2.00	1.21	3.12	4.33	186.10	5.720	7.25	.75	32.00
4	31. 7.62	4.00	3.14	5.10	8.24	353.98	12.150	7.50	2.75	31.75
5	30. 7.63	2.00	.02	.01	.04	1.61	.130	5.75	3.00	8.00
6	22. 7.64	17.00	.30	.46	.76	32.84	1.450	4.00	.75	14.00
7	7. 6.65	15.25	1.44	4.11	5.55	238.25	5.230	8.75	.25	37.25
8	19.10.66	20.15	1.03	.82	1.85	79.56	1.390	16.25	1.00	31.00
9	16. 7.67	4.00	.35	3.22	3.56	152.96	3.880	2.75	1.50	26.75
10	11. 9.68	4.00	.58	1.50	2.08	89.24	3.530	5.25	6.75	24.00
11	7. 9.69	17.00	.18	.27	.45	19.40	.880	5.75	.75	13.75
12	23. 8.71	3.00	.38	1.14	1.52	65.08	2.370	5.25	1.50	20.75
13	3. 7.72	11.00	.38	2.62	3.00	128.84	4.800	4.25	3.00	25.50
14	10. 7.72	10.45	.53	2.57	3.10	133.27	4.810	5.50	3.75	26.50
15	17. 9.73	24.00	1.08	2.58	3.67	157.44	4.640	7.75	5.50	27.75

SUMMARY OF STORM DATA FOR N.DANVILLE AT ND5 CATCHMENT AREA (km^2) 111.60 DATA TIME INTERVAL (hrS) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	30. 7.60	12.00	3	43.98	12.00	14.95	3.66	24.06	61.54	84.59	100.00	11.45
2	2. 6.61	2.00	3	23.09	6.75	12.29	3.42	30.06	41.70	93.54	100.00	15.53
3	31. 7.62	4.00	3	48.55	9.25	34.21	5.25	33.53	63.50	72.16	100.00	24.01
4	30. 7.63	2.00	8	22.61	4.00	14.36	5.65	39.45	49.30	84.44	100.00	9.41
5	22. 7.64	17.00	8	21.78	1.50	43.13	14.52	8.89	30.03	100.00	100.00	27.20
6	7. 6.65	15.15	3	37.48	8.75	29.02	4.28	50.71	76.75	94.88	100.00	9.79
7	19.10.66	20.15	3	29.86	31.75	9.30	.94	58.23	90.98	98.93	100.00	15.15
8	16. 7.67	4.00	3	32.22	10.25	19.08	3.14	63.56	79.77	95.94	100.00	26.67
9	11. 9.68	5.00	3	43.27	30.50	13.75	1.42	70.47	91.53	93.42	100.00	14.02
10	7. 9.69	17.00	3	22.03	12.00	38.48	1.84	96.91	99.28	99.52	100.00	27.33
11	23. 8.71	1.00	3	31.26	23.00	19.44	1.36	77.37	94.66	97.84	100.00	36.39
12	10. 7.72	10.45	3	30.13	13.75	19.74	2.19	7.93	86.53	92.52	100.00	30.50
13	20. 7.72	24.00	1	38.97	25.75	31.79	1.51	14.53	93.79	98.15	100.00	35.49
14	14. 7.73	1.00	1	25.20	6.50	13.85	3.88	22.23	65.11	92.63	100.00	50.07
15	17. 9.73	24.00	3	38.02	16.25	7.62	2.34	11.50	53.33	91.92	100.00	29.97

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrS)
1	30. 7.60	12.00	.86	2.23	3.09	344.52	.160	1.700	10.200	12.75
2	2. 6.61	2.00	1.27	5.19	6.46	721.18	1.180	3.070	15.690	7.75
3	31. 7.62	4.00	3.03	4.96	7.99	891.86	.230	2.170	21.230	11.25
4	30. 7.63	2.00	.10	.02	.12	13.91	.060	.610	.640	10.50
5	22. 7.64	17.00	.46	1.05	1.51	168.59	.330	1.320	5.070	5.75
6	7. 6.65	15.15	1.03	2.42	3.45	384.85	.330	1.990	8.610	10.00
7	19.10.66	20.15	.73	2.10	2.83	315.37	.300	2.030	4.460	13.00
8	16. 7.67	4.00	.54	4.20	4.74	528.56	.420	2.100	11.430	5.50
9	11. 9.68	5.00	.74	2.76	3.50	390.56	.170	2.120	8.920	12.00
10	7. 9.69	17.00	.49	.83	1.32	147.54	.910	1.880	4.100	7.25
11	23. 8.71	1.00	.91	2.27	3.18	354.63	.700	2.180	7.830	10.50
12	10. 7.72	10.45	.72	3.57	4.29	478.55	.650	2.350	11.590	10.25
13	20. 7.72	24.00	1.71	5.74	7.46	832.26	.750	2.820	20.030	14.75
14	14. 7.73	1.00	1.51	3.52	5.03	561.09	2.020	3.370	14.850	7.50
15	17. 9.73	24.00	1.31	4.14	5.45	608.42	.520	2.280	13.800	13.75

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	30. 7.60	12.00	.70	1.58	2.28	254.27	9.450	7.75	5.00	23.50
2	2. 6.61	2.00	.92	3.34	4.26	475.35	14.070	7.00	.75	30.75
3	31. 7.62	4.00	2.86	3.83	6.69	746.36	20.440	8.75	2.50	31.50
4	30. 7.63	2.00	.00	.01	.02	1.68	.130	2.00	3.25	8.00
5	22. 7.64	17.00	.37	.67	1.04	115.61	4.420	5.00	.75	16.50
6	7. 6.65	15.15	.83	1.58	2.41	269.06	7.700	8.75	1.25	26.25
7	19.10.66	20.15	.51	1.21	1.72	191.43	3.570	8.50	4.50	27.00
8	16. 7.67	4.00	.45	3.12	3.57	398.59	10.780	2.75	2.75	26.50
9	11. 9.68	5.00	.62	1.61	2.23	249.06	8.340	5.25	6.75	30.75
10	7. 9.69	17.00	.23	.35	.58	64.91	2.780	6.25	1.00	15.25
11	23. 8.71	1.00	.62	1.33	1.95	217.44	6.700	6.75	3.75	24.00
12	10. 7.72	10.45	.46	2.43	2.89	322.52	10.530	4.75	5.50	25.50
13	20. 7.72	24.00	1.25	4.07	5.32	594.21	18.670	8.00	6.75	32.25
14	14. 7.73	1.00	.97	2.06	3.04	338.81	12.420	6.50	1.00	21.75
15	17. 9.73	24.00	1.02	2.98	4.00	446.11	12.810	6.75	7.00	28.25

SUMMARY OF STORM DATA FOR TOMBSTONE AT TM1 CATCHMENT AREA (km^2) 149.40 DATA TIME INTERVAL (hrs) .08

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	26. 7.59	19.75	6	22.92	2.80	70.85	8.19	94.38	99.36	99.64	100.00	33.57
2	4. 9.65	15.00	16	21.71	2.96	58.60	7.34	1.26	91.49	98.48	100.00	18.78

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/S)	FINAL FLOW (m^3/S)	PEAK FLOW (m^3/S)	TIME TO PEAK (hrs)
1	26. 7.59	19.75	.47	4.02	4.49	670.75	.000	.450	129.960	1.92
2	4. 9.65	15.00	.12	.51	.63	93.73	.000	.430	20.990	2.96

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/S)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	26. 7.59	19.75	.47	3.98	4.45	665.33	129.940	.16	1.76	5.76
2	4. 9.65	15.00	.12	.47	.59	88.16	20.930	.64	2.32	5.84

SUMMARY OF STORM DATA FOR TOMBSTONE AT TM2 CATCHMENT AREA (km^2) 113.70 DATA TIME INTERVAL (hrs) .08

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	26. 7.59	19.75	6	24.59	2.80	68.62	8.78	94.74	99.22	99.56	100.00	33.57
2	17. 8.61	21.00	9	15.42	1.36	41.64	11.34	1.15	74.96	99.64	100.00	6.10
3	4. 9.65	15.00	16	23.16	2.96	64.67	7.83	1.52	92.17	98.35	100.00	18.78
4	25. 8.68	15.75	5	14.15	2.24	42.08	6.32	.38	4.14	49.55	100.00	24.26
5	31. 8.68	11.50	8	16.46	2.96	38.48	5.56	.00	65.84	99.32	100.00	32.68

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/S)	FINAL FLOW (m^3/S)	PEAK FLOW (m^3/S)	TIME TO PEAK (hrs)
1	26. 7.59	19.75	1.31	2.82	4.13	469.50	.000	.440	103.510	1.44
2	17. 8.61	21.00	.54	2.24	2.79	316.75	.000	.400	69.710	1.20
3	4. 9.65	15.00	.46	1.45	1.91	216.94	.000	.400	40.910	2.40
4	25. 8.68	15.75	.10	.22	.32	36.73	.000	.230	17.610	2.88
5	31. 8.68	11.50	.25	.85	1.10	125.19	.010	.470	24.890	3.44

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/S)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	26. 7.59	19.75	1.31	2.77	4.08	463.53	103.440	.96	.48	6.88
2	17. 8.61	21.00	.54	2.20	2.74	312.03	69.670	.48	.72	6.16
3	4. 9.65	15.00	.46	1.41	1.87	212.70	40.830	1.20	1.20	5.92
4	25. 8.68	15.75	.10	.21	.31	35.12	17.530	.40	2.48	2.72
5	31. 8.68	11.50	.24	.80	1.04	118.28	24.690	2.72	.72	7.28

SUMMARY OF STORM DATA FOR TOMBSTONE AT TM3 CATCHMENT AREA (km^2) 9.00 DATA TIME INTERVAL (hrs) .08

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	19. 7.55	21.00	3	48.75	1.68	122.13	29.02	21.50	56.04	99.63	100.00	17.74
2	14. 8.58	13.25	3	19.12	1.12	75.21	17.07	1.42	74.01	98.71	100.00	22.94
3	16. 8.58	18.50	3	31.31	2.80	107.35	11.18	80.30	91.21	95.07	100.00	43.87
4	17. 8.61	21.25	8	35.69	1.12	86.34	31.87	29.94	92.09	99.59	100.00	2.99
5	25. 7.62	21.00	3	27.24	2.88	51.69	9.46	57.73	90.66	97.33	100.00	13.73
6	4. 9.65	15.75	6	23.17	2.16	56.22	10.73	63.42	93.83	98.36	100.00	13.14
7	25. 8.68	16.75	1	17.17	1.28	47.50	13.41	2.81	33.33	92.98	100.00	24.83
8	31. 8.68	12.50	4	16.08	2.00	53.27	8.04	25.71	95.60	99.74	100.00	20.76
9	15. 9.69	8.25	5	15.66	1.20	46.78	13.05	21.64	84.94	98.23	100.00	14.28
10	6. 9.72	13.00	5	17.02	1.36	33.05	12.51	16.77	69.05	98.28	100.00	21.20
11	27. 7.73	13.00	3	17.36	1.68	49.46	10.33	86.07	99.30	99.80	100.00	18.04

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/S)	FINAL FLOW (m^3/S)	PEAK FLOW (m^3/S)	TIME TO PEAK (hrs)
1	19. 7.55	21.00	8.03	7.81	15.84	142.54	.000	.030	78.420	1.28
2	14. 8.58	13.25	1.62	2.28	3.90	35.09	.000	.000	18.730	.80
3	16. 8.58	18.50	1.91	3.60	5.51	49.63	.000	.030	32.780	.80
4	17. 8.61	21.25	1.81	5.64	7.45	67.07	.000	.030	19.000	.80
5	25. 7.62	21.00	.36	.58	.93	8.41	.000	.020	4.190	1.84
6	4. 9.65	15.75	.39	.34	.74	6.62	.000	.060	2.660	2.00
7	25. 8.68	16.75	.37	.18	.55	4.99	.000	.010	3.770	1.36
8	31. 8.68	12.50	.12	.16	.28	2.51	.000	.010	1.520	1.36
9	15. 9.69	8.25	.02	.02	.03	.29	.000	.000	.240	.72
10	6. 9.72	13.00	.19	.22	.42	3.77	.000	.000	1.280	.80
11	27. 7.73	13.00	.34	.26	.60	5.42	.000	.000	2.860	.88

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/S)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	19. 7.55	21.00	8.03	7.77	15.79	142.12	78.420	.48	.80	6.56
2	14. 8.58	13.25	1.62	2.27	3.89	35.00	18.730	.40	.40	3.04
3	16. 8.58	18.50	1.91	3.57	5.48	49.30	32.780	.24	.56	5.76
4	17. 8.61	21.25	1.81	5.60	7.41	66.69	19.000	.32	.48	6.24
5	25. 7.62	21.00	.36	.56	.92	8.26	4.190	.32	1.52	3.60
6	4. 9.65	15.75	.39	.33	.72	6.48	2.650	1.52	.48	3.76
7	25. 8.68	16.75	.37	.18	.55	4.96	3.770	.72	.64	1.84
8	31. 8.68	12.50	.12	.16	.28	2.48	1.520	.56	.80	1.60
9	15. 9.69	8.25	.02	.02	.03	.29	.240	.24	.48	.80
10	6. 9.72	13.00	.19	.22	.42	3.74	1.280	.56	.24	1.76
11	27. 7.73	13.00	.34	.26	.60	5.40	2.860	.56	.32	1.36

SUMMARY OF STORM DATA FOR TOMBSTONE AT TM6 CATCHMENT AREA (km^2) 95.00 DATA TIME INTERVAL (hrs) .08

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	4. 9.65	15.00	10	22.88	2.96	69.57	7.73	1.49	92.07	98.15	100.00	25.00
2	31. 8.68	12.50	5	18.23	2.00	46.73	9.12	55.88	97.02	99.86	100.00	32.68

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/S)	FINAL FLOW (m^3/S)	PEAK FLOW (m^3/S)	TIME TO PEAK (hrs)
1	4. 9.65	15.00	.58	1.22	1.80	171.42	.000	.670	42.630	2.08
2	31. 8.68	12.50	.19	.62	.81	77.12	.000	.320	21.340	1.84

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/S)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	4. 9.65	15.00	.58	1.21	1.79	169.63	42.570	.96	1.12	4.16
2	31. 8.68	12.50	.19	.58	.77	73.58	21.280	1.04	.80	5.84

SUMMARY OF STORM DATA FOR TOMBSTONE AT TM8 CATCHMENT AREA (km^2) 15.50 DATA TIME INTERVAL (hrs) .08

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	19. 8.63	9.00	1	27.19	1.04	64.94	26.15	65.66	94.23	99.47	100.00	8.59
2	22. 7.64	18.25	4	37.76	.80	172.70	47.20	.00	58.81	99.55	100.00	18.15
3	9. 9.64	16.00	3	12.35	.72	37.19	17.16	24.77	92.91	100.00	100.00	28.86
4	9. 9.64	23.40	3	38.08	3.92	68.16	9.71	80.54	96.47	98.63	100.00	40.52
5	11. 9.64	17.00	3	25.93	2.88	49.95	9.00	70.29	95.12	97.13	100.00	54.47
6	17. 7.65	23.50	3	16.89	1.20	54.22	14.07	13.78	95.84	96.48	100.00	26.98
7	4. 9.65	15.15	7	29.35	2.64	60.93	11.12	.00	89.16	96.97	100.00	29.86
8	30. 7.66	15.25	4	18.86	2.24	52.48	8.42	6.89	70.36	98.09	100.00	66.01
9	5. 8.68	18.50	1	21.07	2.16	76.27	9.76	95.02	95.97	99.32	100.00	20.58
10	31. 8.68	12.75	3	13.41	1.76	33.80	7.62	65.17	95.22	99.75	100.00	20.76
11	24. 7.72	16.00	4	22.31	2.64	49.65	8.45	53.52	92.85	98.60	100.00	25.03

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	19. 8.63	9.00	2.08	1.21	3.29	51.02	.000	.000	17.060	1.52
2	22. 7.64	18.25	5.13	2.99	8.12	125.90	.000	.000	121.150	1.20
3	9. 9.64	16.00	.75	2.01	2.76	42.80	.000	.000	20.240	1.04
4	9. 9.64	23.40	.39	1.62	2.01	31.17	.000	.030	20.800	.48
5	11. 9.64	17.00	1.01	2.44	3.44	53.38	.000	.020	54.030	1.28
6	17. 7.65	23.50	.41	1.32	1.73	26.88	.000	.020	12.100	1.20
7	4. 9.65	15.15	1.04	3.06	4.10	63.62	.000	.060	22.540	1.68
8	30. 7.66	15.25	.30	1.83	2.13	33.03	.000	.020	14.450	2.32
9	5. 8.68	18.50	.29	.93	1.22	18.98	.000	.010	15.820	1.28
10	31. 8.68	12.75	.15	.19	.34	5.20	.000	.020	2.100	1.36
11	24. 7.72	16.00	.18	.45	.63	9.82	.000	.010	5.370	1.68

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	19. 8.63	9.00	2.08	1.20	3.28	50.85	17.050	.96	.56	3.20
2	22. 7.64	18.25	5.13	2.97	8.11	125.66	121.140	.56	.64	3.84
3	9. 9.64	16.00	.75	2.00	2.75	42.65	20.240	.48	.56	2.96
4	9. 9.64	23.40	.39	1.61	2.00	30.93	20.800	.00	.48	3.68
5	11. 9.64	17.00	1.01	2.43	3.43	53.22	54.030	.08	1.20	2.96
6	17. 7.65	23.50	.41	1.31	1.73	26.76	12.100	.08	1.12	2.64
7	4. 9.65	15.15	1.04	3.01	4.05	62.84	22.520	.80	.88	5.36
8	30. 7.66	15.25	.30	1.82	2.12	32.79	14.450	.08	2.24	3.76
9	5. 8.68	18.50	.29	.93	1.22	18.91	15.820	.00	1.28	1.92
10	31. 8.68	12.75	.15	.18	.33	5.11	2.090	.72	.64	2.16
11	24. 7.72	16.00	.18	.44	.63	9.74	5.370	.08	1.60	2.08

SUMMARY OF STORM DATA FOR TOMBSTONE AT TM11 CATCHMENT AREA (km^2) 8.20 DATA TIME INTERVAL (hrs) .08

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	19. 8.63	9.00	1	31.60	1.04	75.47	30.38	65.66	94.23	99.47	100.00	8.59
2	22. 7.64	18.00	3	46.32	1.04	138.92	44.54	11.26	65.04	99.78	100.00	18.22
3	9. 9.64	16.00	1	57.96	11.12	111.66	5.21	24.13	27.59	91.47	100.00	26.13
4	11. 9.64	17.00	3	45.71	2.88	78.27	15.87	76.13	96.99	97.76	100.00	68.92
5	17. 7.65	23.00	3	19.69	1.68	87.58	11.72	.00	81.46	98.20	100.00	26.98
6	4. 9.65	16.00	4	33.90	1.92	93.71	17.66	66.19	91.12	96.55	100.00	32.12
7	30. 7.66	15.00	4	34.26	2.32	99.37	14.77	4.41	35.85	97.98	100.00	66.01
8	5. 8.68	18.50	1	32.91	2.16	119.12	15.24	95.02	95.97	99.32	100.00	20.58
9	31. 8.68	12.75	1	11.89	1.44	47.34	8.26	74.99	94.64	98.82	100.00	20.76
10	13. 8.69	18.30	7	22.38	3.12	83.41	7.17	65.54	90.86	95.50	100.00	25.83
11	15. 9.69	8.25	3	12.83	1.52	39.33	8.44	.00	72.16	90.58	100.00	14.28
12	21. 8.73	18.25	3	40.00	2.80	67.87	14.29	12.63	91.01	97.05	100.00	2.40

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	19. 8.63	9.00	2.55	2.72	5.28	43.28	.000	.010	22.240	.80
2	22. 7.64	18.00	12.37	10.71	23.08	189.26	.000	.000	125.180	.96
3	9. 9.64	16.00	11.24	12.33	23.57	193.29	.000	.040	41.010	8.08
4	11. 9.64	17.00	4.77	12.54	17.31	141.98	.010	.030	47.860	.72
5	17. 7.65	23.00	1.36	1.30	2.66	21.81	.000	.070	19.540	1.20
6	4. 9.65	16.00	4.33	3.15	7.48	61.35	.000	.000	32.800	.80
7	30. 7.66	15.00	2.93	3.63	6.55	53.73	.000	.020	30.010	2.08
8	5. 8.68	18.50	2.10	1.32	3.42	28.07	.000	.010	23.360	.72
9	31. 8.68	12.75	.18	.24	.42	3.40	.000	.010	2.540	.56
10	13. 8.69	18.30	.32	1.66	1.99	16.28	.000	.010	7.400	1.04
11	15. 9.69	8.25	.16	.56	.73	5.95	.000	.010	2.450	.88
12	21. 8.73	18.25	2.56	1.42	3.98	32.62	.000	.020	13.610	1.68

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	19. 8.63	9.00	2.55	2.71	5.27	43.19	22.240	.40	.40	3.20
2	22. 7.64	18.00	12.37	10.70	23.07	189.18	125.180	.32	.64	3.12
3	9. 9.64	16.00	11.23	12.27	23.49	192.65	40.970	7.84	.24	11.04
4	11. 9.64	17.00	4.77	12.48	17.24	141.40	47.850	.56	.16	6.16
5	17. 7.65	23.00	1.36	1.29	2.65	21.76	19.540	.32	.88	2.40
6	4. 9.65	16.00	4.33	3.14	7.46	61.21	32.800	.56	.24	3.92
7	30. 7.66	15.00	2.93	3.62	6.54	53.67	30.010	.32	1.76	2.72
8	5. 8.68	18.50	2.10	1.32	3.42	28.03	23.360	.16	.56	2.16
9	31. 8.68	12.75	.18	.23	.41	3.36	2.540	.08	.48	1.76
10	13. 8.69	18.30	.32	1.66	1.98	16.24	7.400	.08	.96	2.08
11	15. 9.69	8.25	.16	.56	.72	5.91	2.450	.24	.64	2.08
12	21. 8.73	18.25	2.56	1.41	3.97	32.56	13.610	.88	.80	2.72

SUMMARY OF STORM DATA FOR OXFORD4 AT OXW4 CATCHMENT AREA (km^2) 8.10 DATA TIME INTERVAL (hrs) .17

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	3. 4.58	16.50	3	18.02	1.19	30.00	15.14	17.43	73.47	93.01	100.00	42.29
2	17. 1.60	2.50	3	24.98	6.29	10.69	3.97	.00	23.03	80.37	100.00	25.15
3	31. 8.61	16.67	3	30.95	3.23	35.18	9.58	1.68	47.84	95.64	100.00	11.01
4	4. 9.62	15.67	3	54.65	4.08	38.21	13.40	2.98	55.71	97.68	100.00	21.22
5	29. 8.63	4.00	1	79.99	6.12	76.18	13.07	69.26	90.81	92.52	100.00	22.55

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	3. 4.58	16.50	2.10	5.11	7.21	58.39	.210	.240	8.110	1.70
2	17. 1.60	2.50	1.83	3.05	4.88	39.54	.000	.060	3.720	6.29
3	31. 8.61	16.67	.33	1.03	1.35	10.97	.000	.010	2.480	2.89
4	4. 9.62	15.67	1.18	3.61	4.79	38.77	.000	.030	8.210	3.23
5	29. 8.63	4.00	3.42	8.23	11.64	94.31	.000	.030	15.770	2.04

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	3. 4.58	16.50	1.94	4.29	6.24	50.51	7.890	1.19	.51	8.33
2	17. 1.60	2.50	1.82	2.82	4.64	37.61	3.710	3.06	3.23	14.45
3	31. 8.61	16.67	.33	1.01	1.33	10.81	2.470	1.02	1.87	3.91
4	4. 9.62	15.67	1.18	3.54	4.71	38.16	8.200	1.02	2.21	7.99
5	29. 8.63	4.00	3.41	8.15	11.57	93.68	15.760	1.19	.85	8.33

SUMMARY OF STORM DATA FOR OXFORD5 AT OXW5 CATCHMENT AREA (km^2) 4.56 DATA TIME INTERVAL (hrs) .17

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	3. 4.58	16.50	1	17.54	1.02	43.18	17.20	9.92	82.73	100.00	100.00	41.88
2	17. 1.60	2.50	1	23.61	6.12	9.65	3.86	2.12	11.48	65.18	100.00	21.38
3	31. 8.61	16.67	2	47.22	3.23	47.71	14.62	2.39	63.74	94.73	100.00	15.73
4	4. 9.62	15.67	2	49.58	3.91	48.76	12.68	.00	52.66	98.71	100.00	21.22
5	29. 8.63	4.00	1	82.81	6.12	73.18	13.53	62.72	92.02	93.35	100.00	22.55
6	4. 3.64	7.50	1	76.19	5.95	65.29	12.81	1.40	11.58	79.75	100.00	32.75
7	1. 3.65	4.00	1	36.98	12.07	14.29	3.06	10.54	21.70	71.14	100.00	41.74
8	24. 5.66	3.00	1	39.86	6.63	30.41	6.01	10.06	70.20	91.85	100.00	46.24
9	31. 5.67	13.00	1	40.53	3.40	70.41	11.92	.00	5.67	91.99	100.00	26.98

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	3. 4.58	16.50	4.69	9.12	13.82	63.01	.400	.390	9.760	1.53
2	17. 1.60	2.50	3.36	6.93	10.29	46.91	.000	.100	4.090	5.78
3	31. 8.61	16.67	3.16	7.50	10.66	48.62	.000	.010	10.600	2.21
4	4. 9.62	15.67	2.25	4.09	6.34	28.91	.000	.010	5.830	2.72
5	29. 8.63	4.00	8.13	18.35	26.47	120.71	.000	.110	14.840	1.87
6	4. 3.64	7.50	29.84	25.56	55.40	252.63	.030	.310	36.900	5.10
7	1. 3.65	4.00	8.17	11.06	19.24	87.72	.020	.250	6.460	10.03
8	24. 5.66	3.00	1.28	5.42	6.70	30.55	.000	.020	3.020	3.23
9	31. 5.67	13.00	3.81	8.01	11.83	53.94	.000	.020	12.090	2.89

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	3. 4.58	16.50	4.21	7.25	11.47	52.28	9.360	1.02	.51	6.46
2	17. 1.60	2.50	3.35	6.73	10.08	45.94	4.080	2.38	3.40	14.45
3	31. 8.61	16.67	3.16	7.47	10.63	48.48	10.600	.85	1.36	5.44
4	4. 9.62	15.67	2.25	4.06	6.32	28.80	5.830	1.36	1.36	4.59
5	29. 8.63	4.00	8.13	18.20	26.33	120.04	14.840	1.02	.85	11.90
6	4. 3.64	7.50	29.71	25.28	54.99	250.75	36.860	2.72	2.38	10.37
7	1. 3.65	4.00	7.98	10.66	18.64	85.01	6.420	5.95	4.08	16.32
8	24. 5.66	3.00	1.28	5.35	6.62	30.20	3.020	.85	2.38	8.50
9	31. 5.67	13.00	3.81	7.95	11.76	53.63	12.090	.68	2.21	7.48

SUMMARY OF STORM DATA FOR OXFORD-W10 AT OXW10 CATCHMENT AREA (km^2) 22.38 DATA TIME INTERVAL (hrs) .17

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	22. 5.59	16.50	7	23.11	2.55	53.93	9.06	85.09	91.44	96.74	100.00	15.71
2	17. 1.60	5.00	2	24.70	3.57	9.49	6.92	26.94	63.99	90.73	100.00	23.98
3	31. 8.61	16.67	4	66.28	2.89	83.27	22.94	.40	73.74	98.92	100.00	12.33
4	4. 9.62	16.00	5	44.92	4.25	38.76	10.57	28.09	85.71	99.69	100.00	18.92
5	29. 8.63	4.00	1	71.48	5.78	47.17	12.37	72.40	93.34	95.25	100.00	24.27
6	4. 3.64	8.50	1	30.94	5.27	25.31	5.87	4.60	43.00	89.38	100.00	38.76
7	1. 3.65	9.00	1	17.22	6.80	6.78	2.53	18.38	60.15	89.41	100.00	44.29
8	27.12.66	20.50	1	37.35	8.16	13.53	4.58	8.46	44.98	80.51	100.00	42.49
9	31. 5.67	14.00	1	33.76	2.04	42.62	16.55	24.36	62.67	97.16	100.00	35.66
10	1. 2.68	15.50	1	30.33	7.65	17.82	3.96	24.37	82.03	99.77	100.00	25.02
11	17. 4.69	7.00	1	36.05	10.54	46.24	3.42	5.35	7.18	32.68	100.00	60.64
12	26. 8.71	17.00	1	81.80	2.89	67.06	28.30	37.26	93.85	99.76	100.00	16.00

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	22. 5.59	16.50	.69	1.65	2.34	52.32	.090	.150	14.380	1.70
2	17. 1.60	5.00	2.88	4.14	7.02	157.08	.050	.260	13.170	3.91
3	31. 8.61	16.67	7.88	9.00	16.88	377.69	.000	.080	67.800	2.38
4	4. 9.62	16.00	1.95	2.75	4.70	105.17	.000	.090	20.100	3.06
5	29. 8.63	4.00	6.47	10.10	16.57	370.84	.000	.090	53.810	2.04
6	4. 3.64	8.50	3.70	11.71	15.40	344.71	.810	.970	29.860	3.91
7	1. 3.65	9.00	2.65	4.05	6.70	149.95	.020	.500	6.720	5.95
8	27.12.66	20.50	2.91	9.06	11.97	267.78	.110	.270	18.380	5.95
9	31. 5.67	14.00	3.08	2.69	5.78	129.25	.340	.330	25.130	2.04
10	1. 2.68	15.50	3.36	6.62	9.98	223.28	.000	.240	17.900	5.44
11	17. 4.69	7.00	3.04	5.64	8.68	194.17	.000	.210	24.080	9.52
12	26. 8.71	17.00	8.33	6.82	15.15	339.06	.000	.050	69.030	2.55

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	22. 5.59	16.50	.66	1.55	2.21	49.55	14.290	.17	1.53	4.93
2	17. 1.60	5.00	2.83	3.75	6.58	147.25	13.070	3.57	.34	17.00
3	31. 8.61	16.67	7.88	8.96	16.83	376.70	67.780	1.53	.85	6.29
4	4. 9.62	16.00	1.95	2.70	4.64	103.91	20.080	1.19	1.87	7.14
5	29. 8.63	4.00	6.47	10.03	16.50	369.29	53.790	1.70	.34	7.82
6	4. 3.64	8.50	3.22	10.21	13.44	300.69	29.120	1.87	2.04	13.26
7	1. 3.65	9.00	2.61	3.68	6.29	140.72	6.650	4.08	1.87	18.53
8	27.12.66	20.50	2.78	8.74	11.52	257.91	18.210	4.42	1.53	13.09
9	31. 5.67	14.00	2.97	2.51	5.47	122.50	24.770	1.70	.34	4.59
10	1. 2.68	15.50	3.35	6.52	9.87	220.80	17.860	3.06	2.38	10.37
11	17. 4.69	7.00	3.02	5.52	8.54	191.19	24.030	3.91	5.61	11.39
12	26. 8.71	17.00	8.33	6.79	15.12	338.44	69.010	1.36	1.19	4.93

SUMMARY OF STORM DATA FOR OXFORD 12 AT OXW12 CATCHMENT AREA (km^2) 92.20 DATA TIME INTERVAL (hrs) .17

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	2. 3.60	9.00	8	38.33	9.01	16.39	4.25	47.20	84.97	97.57	100.00	24.17
2	31. 8.61	16.67	11	41.53	7.31	33.25	5.68	73.20	96.23	98.20	100.00	10.52
3	4. 9.62	15.67	12	46.88	4.25	33.87	11.03	21.33	72.62	99.72	100.00	21.22
4	29. 8.63	4.00	1	83.52	6.12	65.58	13.65	71.66	93.17	94.37	100.00	22.55
5	4. 3.64	7.82	1	55.17	5.95	40.36	9.27	1.68	13.28	78.79	100.00	34.93
6	1. 3.65	9.00	1	23.82	6.97	8.14	3.42	29.91	62.01	93.47	100.00	43.38
7	24. 5.66	3.00	1	43.44	6.63	31.00	6.55	12.97	73.90	92.64	100.00	46.24
8	31. 5.67	13.00	1	34.73	3.40	46.32	10.21	.00	8.47	92.12	100.00	30.90
9	1. 2.68	16.00	1	27.75	7.14	18.00	3.89	27.42	85.59	99.57	100.00	23.73
10	17. 4.69	14.00	1	27.10	3.74	43.41	7.25	8.52	91.96	99.52	100.00	60.15
11	21. 2.71	6.67	1	71.59	15.81	55.88	4.53	19.11	40.80	67.09	100.00	39.45

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	2. 3.60	9.00	4.39	8.59	12.98	1196.67	3.650	3.760	69.880	4.08
2	31. 8.61	16.67	1.19	1.96	3.15	290.56	.000	.540	34.080	3.23
3	4. 9.62	15.67	1.44	1.69	3.13	288.67	.010	.510	41.470	4.42
4	29. 8.63	4.00	4.30	6.59	10.89	1003.70	.000	.570	102.440	3.23
5	4. 3.64	7.82	8.87	14.06	22.93	2113.85	1.110	1.810	153.210	6.12
6	1. 3.65	9.00	3.87	6.03	9.90	912.86	.240	1.310	44.670	6.12
7	24. 5.66	3.00	3.09	8.44	11.53	1063.30	.110	1.070	69.940	4.42
8	31. 5.67	13.00	1.34	2.77	4.11	378.59	.010	.600	47.960	4.08
9	1. 2.68	16.00	1.44	2.95	4.39	404.48	.050	.810	35.750	5.78
10	17. 4.69	14.00	2.30	7.18	9.48	874.03	.360	2.490	82.690	3.57
11	21. 2.71	6.67	18.70	22.20	40.91	3771.46	.170	5.610	178.840	14.62

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST. OF	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION STORMFLOW (hrs)
1	2. 3.60	9.00	3.79	7.28	11.07	1020.50	66.040	3.57	.51	11.73
2	31. 8.61	16.67	1.18	1.87	3.05	281.27	33.940	2.38	.85	9.69
3	4. 9.62	15.67	1.42	1.59	3.02	278.11	41.250	2.04	2.38	8.33
4	29. 8.63	4.00	4.29	6.44	10.73	989.57	102.290	2.72	.51	11.90
5	4. 3.64	7.82	8.59	13.32	21.92	2020.73	151.930	3.40	2.72	14.96
6	1. 3.65	9.00	3.76	5.49	9.25	852.94	44.060	4.08	2.04	18.02
7	24. 5.66	3.00	3.06	8.01	11.07	1020.85	69.660	2.72	1.70	18.53
8	31. 5.67	13.00	1.33	2.62	3.95	364.34	47.810	2.04	2.04	11.39
9	1. 2.68	16.00	1.40	2.72	4.12	379.87	35.440	2.38	3.40	12.58
10	17. 4.69	14.00	2.24	6.69	8.92	822.80	82.170	2.72	.85	17.00
11	21. 2.71	6.67	18.36	21.52	39.88	3677.21	177.880	12.58	2.04	26.01

SUMMARY OF STORM DATA FOR OXFORD-W17 AT OXW17 CATCHMENT AREA (km^2) 130.00 DATA TIME INTERVAL (hrs) .17

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	2. 3.60	9.00	10	37.57	9.01	17.08	4.17	50.88	87.13	98.11	100.00	25.35
2	31. 8.61	16.67	17	45.90	7.31	39.05	6.28	77.82	98.25	99.17	100.00	14.60
3	4. 9.62	15.67	17	43.33	4.42	31.36	9.80	20.74	70.83	99.71	100.00	21.97
4	29. 8.63	4.00	1	85.82	6.12	69.06	14.02	74.50	93.10	94.98	100.00	21.96
5	4. 3.64	7.67	1	49.30	5.95	34.72	8.29	1.76	14.82	79.32	100.00	38.74
6	1. 3.65	4.00	1	26.69	12.07	8.15	2.21	10.71	23.65	74.25	100.00	39.23
7	24. 5.66	3.00	1	44.84	6.63	32.27	6.76	10.44	75.07	92.79	100.00	46.23
8	31. 5.67	13.00	1	36.11	3.40	43.69	10.62	.00	17.52	93.16	100.00	31.93
9	1. 2.68	15.00	1	30.12	7.65	21.82	3.94	14.51	54.05	99.77	100.00	23.74
10	17. 4.69	11.50	1	29.55	6.29	41.41	4.70	.51	13.98	98.21	100.00	61.56
11	21. 2.71	3.50	1	70.83	19.04	41.65	3.72	7.77	44.29	53.72	100.00	35.10
12	2. 7.72	1.00	1	137.44	18.19	51.18	7.56	20.97	50.90	99.27	100.00	64.97
13	19. 4.73	19.00	1	72.39	5.10	49.76	14.19	48.05	81.81	89.50	100.00	59.40

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	2. 3.60	9.00	5.60	8.94	14.54	1889.67	8.290	9.910	96.840	4.76
2	31. 8.61	16.67	2.81	4.02	6.82	887.10	.280	1.090	92.410	3.40
3	4. 9.62	15.67	1.53	1.97	3.50	454.39	.270	.970	52.430	4.59
4	29. 8.63	4.00	6.36	7.35	13.71	1782.46	.260	1.390	140.760	3.57
5	4. 3.64	7.67	12.85	11.95	24.79	3223.06	5.240	4.440	189.380	7.82
6	1. 3.65	4.00	3.48	6.09	9.57	1244.67	.570	2.490	58.270	11.56
7	24. 5.66	3.00	5.79	10.21	16.00	2080.15	.720	2.400	114.110	4.59
8	31. 5.67	13.00	1.46	3.10	4.56	593.10	.370	1.360	58.950	4.42
9	1. 2.68	15.00	2.92	5.59	8.51	1105.89	.480	1.870	72.030	6.97
10	17. 4.69	11.50	3.80	8.19	11.99	1558.08	.590	2.730	104.100	6.63
11	21. 2.71	3.50	24.68	17.28	41.97	5456.04	.000	5.230	168.660	19.38
12	2. 7.72	1.00	30.71	39.78	70.49	9164.15	.100	3.280	242.500	13.26
13	19. 4.73	19.00	22.16	28.64	50.80	6604.25	1.100	3.440	196.690	5.78

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	2. 3.60	9.00	4.48	6.97	11.45	1488.63	88.220	4.42	.34	12.41
2	31. 8.61	16.67	2.77	3.81	6.58	854.84	91.920	2.72	.68	11.90
3	4. 9.62	15.67	1.49	1.81	3.29	428.19	51.990	2.21	2.38	10.03
4	29. 8.63	4.00	6.32	7.02	13.34	1734.32	140.260	3.23	.34	15.64
5	4. 3.64	7.67	12.03	10.53	22.56	2932.79	185.760	4.59	3.23	17.00
6	1. 3.65	4.00	3.24	5.30	8.53	1108.99	57.120	7.82	3.74	24.31
7	24. 5.66	3.00	5.68	9.53	15.22	1978.19	113.130	3.23	1.36	19.04
8	31. 5.67	13.00	1.40	2.80	4.20	546.33	58.340	3.23	1.19	13.94
9	1. 2.68	15.00	2.79	5.09	7.88	1024.22	71.160	4.93	2.04	18.36
10	17. 4.69	11.50	3.68	7.39	11.07	1438.98	103.260	3.40	3.23	22.27
11	21. 2.71	3.50	24.40	16.47	40.87	5313.21	167.450	16.83	2.55	33.15
12	2. 7.72	1.00	30.53	38.69	69.22	8998.68	241.540	13.09	.17	35.53
13	19. 4.73	19.00	21.95	27.23	49.18	6393.07	195.190	5.44	.34	27.71

SUMMARY OF STORM DATA FOR OXFORD-W32 AT OXW32 CATCHMENT AREA (km^2) 81.10 DATA TIME INTERVAL (hrs) .17

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 dayt API (FACTOR=0.9)
1	22. 5.59	16.50	8	24.95	2.55	58.30	9.79	86.66	93.08	97.57	100.00	19.44
2	2. 3.60	9.00	9	40.05	9.01	18.12	4.44	52.56	87.22	99.24	100.00	20.37
3	31. 8.61	16.67	10	49.20	2.89	68.31	17.03	2.33	83.66	99.57	100.00	11.81
4	4. 9.62	15.67	7	41.94	4.42	43.56	9.49	17.40	77.25	99.45	100.00	19.50
5	29. 8.63	4.00	3	58.75	6.12	42.97	9.60	71.62	92.97	94.31	100.00	15.44
6	4. 3.64	7.50	3	33.49	6.29	29.50	5.32	.00	20.35	90.68	100.00	38.56
7	1. 3.65	4.00	3	18.05	11.56	4.02	1.56	29.48	53.30	85.65	100.00	38.20
8	24. 5.66	3.00	2	57.51	6.63	56.69	8.67	11.81	82.12	94.37	100.00	32.30
9	31. 5.67	13.00	3	32.45	3.06	41.26	10.61	.00	28.24	97.46	100.00	38.35
10	1. 2.68	15.50	1	28.06	5.61	14.29	5.00	17.61	42.69	93.98	100.00	23.65
11	17. 4.69	6.50	1	36.01	11.05	49.00	3.26	4.58	6.55	34.88	100.00	44.02
12	18. 6.71	17.00	1	37.34	2.38	70.00	15.69	22.34	97.51	99.44	100.00	35.64
13	25. 6.72	7.50	1	84.58	4.76	48.82	17.77	44.98	78.04	94.08	100.00	30.69
14	19. 4.73	18.50	1	73.40	5.61	44.53	13.08	36.73	76.21	85.52	100.00	55.52

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	22. 5.59	16.50	1.10	3.34	4.45	360.52	.000	.690	50.800	2.55
2	2. 3.60	9.00	9.94	15.94	25.88	2098.90	19.300	19.080	121.720	3.57
3	31. 8.61	16.67	3.88	6.63	10.51	852.08	.400	1.110	121.740	2.72
4	4. 9.62	15.67	1.33	3.53	4.87	394.67	.010	.510	58.130	3.91
5	29. 8.63	4.00	4.27	6.53	10.80	875.75	.000	.490	106.280	2.55
6	4. 3.64	7.50	9.35	12.45	21.80	1767.85	.000	2.020	129.250	6.46
7	1. 3.65	4.00	2.23	8.04	10.28	833.42	.040	2.150	48.040	9.69
8	24. 5.66	3.00	6.60	17.33	23.93	1940.68	.000	1.710	165.190	3.91
9	31. 5.67	13.00	2.64	5.39	8.03	650.89	.000	.590	80.640	3.57
10	1. 2.68	15.50	3.64	6.94	10.58	858.15	.000	.780	67.250	6.12
11	17. 4.69	6.50	5.34	18.57	23.90	1938.68	.000	2.450	132.250	10.71
12	18. 6.71	17.00	3.87	6.31	10.18	825.67	.000	.530	92.450	2.55
13	25. 6.72	7.50	18.44	15.75	34.19	2773.21	.740	1.590	177.690	4.42
14	19. 4.73	18.50	15.14	41.32	56.46	4579.17	.000	1.980	241.260	3.40

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	22. 5.59	16.50	1.10	3.22	4.33	350.91	50.770	.51	2.04	10.71
2	2. 3.60	9.00	6.87	10.63	17.49	1418.66	102.270	3.23	.34	9.18
3	31. 8.61	16.67	3.83	6.33	10.15	823.20	121.280	1.19	1.53	11.22
4	4. 9.62	15.67	1.33	3.39	4.72	382.71	58.040	1.53	2.38	11.56
5	29. 8.63	4.00	4.27	6.39	10.66	864.30	106.200	1.70	.85	11.56
6	4. 3.64	7.50	9.32	11.98	21.29	1726.72	128.980	5.95	.51	22.44
7	1. 3.65	4.00	2.13	7.47	9.60	778.16	47.580	9.35	.34	25.16
8	24. 5.66	3.00	6.59	16.98	23.58	1911.99	165.080	1.87	2.04	18.36
9	31. 5.67	13.00	2.63	5.26	7.88	639.42	80.520	2.38	1.19	11.56
10	1. 2.68	15.50	3.61	6.66	10.27	833.10	66.990	3.40	2.72	14.96
11	17. 4.69	6.50	5.29	17.86	23.15	1877.78	131.900	3.23	7.48	23.12
12	18. 6.71	17.00	3.86	6.17	10.03	813.54	92.350	2.04	.51	11.90
13	25. 6.72	7.50	18.28	14.84	33.12	2685.94	176.760	4.08	.34	19.72
14	19. 4.73	18.50	15.13	40.49	55.62	4510.50	241.120	3.06	.34	29.07

SUMMARY OF STORM DATA FOR OXFORD-W35 AT OXW35 CATCHMENT AREA (km^2) 30.50 DATA TIME INTERVAL (hrs) .17

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	22. 5.59	16.50	4	30.37	2.55	79.44	11.91	88.06	94.23	98.15	100.00	20.70
2	2. 3.60	9.00	5	47.21	7.14	21.85	6.61	47.07	79.85	94.82	100.00	30.75
3	31. 8.61	16.67	8	33.99	2.89	38.35	11.76	2.55	75.97	99.58	100.00	12.36
4	4. 9.62	15.67	4	40.53	4.42	54.86	9.17	10.87	71.22	99.25	100.00	18.86
5	29. 8.63	4.00	1	39.72	6.12	37.00	6.49	69.80	92.12	92.12	100.00	14.84
6	4. 3.64	7.68	1	38.43	5.95	36.44	6.46	.26	18.27	83.00	100.00	35.03
7	1. 3.65	6.30	1	17.14	9.01	6.01	1.90	12.21	50.72	89.23	100.00	38.88
8	24. 5.66	3.00	1	47.70	6.29	51.97	7.58	9.99	81.23	94.28	100.00	32.85
9	31. 5.67	13.00	1	35.98	3.06	49.00	11.76	.00	26.57	97.63	100.00	39.60
10	1. 2.68	15.00	1	23.11	6.12	9.88	3.78	9.82	30.20	79.92	100.00	23.55
11	17. 4.69	12.17	1	29.83	5.27	51.82	5.66	3.89	21.12	92.86	100.00	58.23
12	26. 8.71	17.00	1	69.59	2.38	56.88	29.24	25.29	64.35	99.38	100.00	23.18

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	22. 5.59	16.50	2.87	4.87	7.74	236.11	.240	.330	36.200	2.04
2	2. 3.60	9.00	9.68	16.53	26.20	799.24	5.210	5.580	49.960	3.23
3	31. 8.61	16.67	.43	1.04	1.47	44.80	.110	.090	7.310	3.40
4	4. 9.62	15.67	1.00	2.95	3.95	120.47	.000	.170	23.040	2.89
5	29. 8.63	4.00	.60	1.13	1.73	52.72	.070	.190	6.490	3.91
6	4. 3.64	7.68	15.07	19.56	34.63	1056.07	.900	1.470	84.740	5.95
7	1. 3.65	6.30	2.31	9.87	12.18	371.35	.380	.800	16.960	6.63
8	24. 5.66	3.00	5.48	7.59	13.07	398.63	.090	.360	42.340	4.42
9	31. 5.67	13.00	5.36	6.83	12.19	371.74	.010	.180	44.970	3.40
10	1. 2.68	15.00	3.46	5.14	8.60	262.17	.060	.350	20.660	6.63
11	17. 4.69	12.17	7.07	12.54	19.61	598.12	.010	.420	40.880	5.61
12	26. 8.71	17.00	8.32	11.01	19.33	589.52	.020	.230	85.150	3.06

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	22. 5.59	16.50	2.84	4.66	7.49	228.48	36.050	1.02	1.02	9.18
2	2. 3.60	9.00	7.68	12.15	19.83	604.86	44.700	2.89	.34	9.86
3	31. 8.61	16.67	.39	.95	1.34	40.79	7.170	1.70	1.70	5.10
4	4. 9.62	15.67	1.00	2.88	3.89	118.51	23.030	.51	2.38	7.82
5	29. 8.63	4.00	.56	1.04	1.59	48.57	6.370	2.55	1.36	7.48
6	4. 3.64	7.68	14.41	18.39	32.80	1000.30	83.760	4.76	1.19	14.11
7	1. 3.65	6.30	1.98	8.44	10.43	317.97	16.490	5.10	4.08	21.42
8	24. 5.66	3.00	5.43	7.32	12.75	388.86	42.220	1.53	2.89	12.41
9	31. 5.67	13.00	5.35	6.74	12.10	368.98	44.930	1.87	1.53	8.67
10	1. 2.68	15.00	3.41	4.96	8.37	255.14	20.560	2.21	4.42	10.88
11	17. 4.69	12.17	7.06	11.88	18.94	577.72	40.820	2.72	2.89	24.82
12	26. 8.71	17.00	8.31	10.81	19.12	583.09	85.110	1.02	2.04	12.75

SUMMARY OF STORM DATA FOR CHICKASHA AT CH111 CATCHMENT AREA (km^2) 67.80 DATA TIME INTERVAL (hrS) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	15. 9.62	5.00	2	56.98	5.50	71.78	10.36	71.21	95.20	98.85	100.00	23.59
2	26. 4.63	13.00	3	43.09	8.25	30.86	5.22	12.75	73.70	98.68	100.00	6.78
3	3.11.64	14.00	2	44.63	7.25	59.05	6.16	77.74	94.75	97.74	100.00	2.36
4	12. 4.67	.00	2	43.23	10.25	63.76	4.22	38.14	85.94	91.02	100.00	42.33
5	31. 5.71	18.00	2	57.38	4.50	103.82	12.75	58.38	94.89	98.65	100.00	32.72
6	1. 6.73	23.00	2	62.81	17.25	40.23	3.64	68.81	78.40	96.82	100.00	55.73

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	15. 9.62	5.00	1.47	1.89	3.37	228.29	.090	.480	21.610	4.75
2	26. 4.63	13.00	.46	.38	.84	57.11	.080	.500	3.930	7.75
3	3.11.64	14.00	.30	.79	1.10	74.53	.030	.370	7.780	3.75
4	12. 4.67	.00	1.08	1.31	2.39	162.11	.060	.510	17.990	5.25
5	31. 5.71	18.00	.46	1.82	2.28	154.75	.000	.360	11.330	2.50
6	1. 6.73	23.00	1.03	4.48	5.51	373.73	.260	1.460	8.980	5.50

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	15. 9.62	5.00	1.44	1.76	3.20	216.64	21.380	3.50	1.25	10.25
2	26. 4.63	13.00	.39	.26	.65	44.40	3.620	5.75	2.00	10.75
3	3.11.64	14.00	.29	.70	.99	66.92	7.650	2.50	1.25	9.00
4	12. 4.67	.00	1.05	1.20	2.26	153.05	17.820	2.50	2.75	9.25
5	31. 5.71	18.00	.46	1.72	2.18	147.63	11.270	1.25	1.25	9.50
6	1. 6.73	23.00	.93	3.03	3.97	268.92	8.560	4.00	1.50	32.25

SUMMARY OF STORM DATA FOR CHICKASHA AT CH512 CATCHMENT AREA (km^2) 92.10 DATA TIME INTERVAL (hrs) .25

SUMMARY TABLE OF RAINFALL DETAILS

ST.	DATE	START TIME	NO.OF RAIN PROFILES	TOTAL RAIN(mm)	DUR. (hrs)	MAX.INT. (mm/hr)	MN.INT. (mm/hr)	QUARTILE RAIN OVER DURATION (CUM%) 1	2	3	4	30 DAY API (FACTOR=0.9)
1	15. 8.64	.00	1	54.34	10.25	49.52	5.30	73.10	85.70	98.27	100.00	23.67
2	20. 9.64	1.00	1	41.41	3.75	56.71	11.04	12.40	97.31	99.42	100.00	24.83
3	7. 8.65	21.00	1	66.29	1.75	106.68	37.88	.00	36.40	99.62	100.00	33.76
4	6. 5.69	14.00	1	44.45	6.50	72.67	6.84	18.84	27.54	87.61	100.00	48.98
5	13. 6.69	22.00	1	85.29	4.75	83.73	17.96	4.37	77.99	98.34	100.00	4.24
6	2.10.71	16.00	2	117.11	10.50	65.60	11.15	46.67	88.88	99.02	100.00	43.68
7	24. 5.73	16.00	3	80.46	3.00	106.95	26.82	2.89	89.22	99.20	100.00	36.20
8	4. 6.73	18.00	2	44.41	2.00	64.19	22.21	5.92	7.01	49.83	100.00	118.19

SUMMARY TABLE OF TOTAL FLOWS

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	INITIAL FLOW (m^3/s)	FINAL FLOW (m^3/s)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)
1	15. 8.64	.00	.35	1.35	1.71	157.28	.000	.740	6.030	4.25
2	20. 9.64	1.00	.93	2.16	3.09	284.83	.000	1.070	25.600	3.00
3	7. 8.65	21.00	7.42	5.24	12.66	1165.99	.480	5.710	85.830	4.75
4	6. 5.69	14.00	4.62	5.26	9.88	910.15	.420	3.840	51.330	8.50
5	13. 6.69	22.00	5.91	7.41	13.32	1226.94	.270	1.430	60.860	5.75
6	2.10.71	16.00	6.61	10.17	16.78	1545.80	.040	1.420	72.580	7.00
7	24. 5.73	16.00	14.94	12.98	27.92	2571.70	.400	1.910	130.810	5.00
8	4. 6.73	18.00	11.12	11.18	22.30	2053.49	1.360	2.790	111.070	6.25

SUMMARY TABLE OF STORM FLOWS (SEP.LINE=1.13mm/day/day)

ST.	DATE	START TIME	FLOW DEPTH (mm) RISING LIMB	FALLING LIMB	TOTAL	FLOW VOLUME (m^3*1000)	PEAK FLOW (m^3/s)	TIME TO PEAK (hrs)	TIME TO STORMFLOW START(hr)	DURATION OF STORMFLOW (hrs)
1	15. 8.64	.00	.34	1.15	1.49	137.32	5.860	3.00	1.25	14.00
2	20. 9.64	1.00	.92	2.06	2.98	274.58	25.470	2.25	.75	10.25
3	7. 8.65	21.00	7.32	5.08	12.40	1141.95	85.190	3.00	1.75	8.25
4	6. 5.69	14.00	4.45	4.94	9.40	865.31	50.630	5.25	3.25	14.00
5	13. 6.69	22.00	5.83	6.67	12.50	1151.51	60.400	3.50	2.25	23.00
6	2.10.71	16.00	4.89	9.56	14.46	1331.35	72.260	1.75	.25	21.50
7	24. 5.73	16.00	14.84	11.71	26.55	2445.39	130.180	4.25	.75	29.50
8	4. 6.73	18.00	10.76	9.12	19.88	1830.94	109.460	4.75	1.50	28.25