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Trees on Farms to Reduce Salinity in the Clearing Control Catchments

Volume 3: Kent Catchment

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Cover Photograph:
Lake Nunijup in the Kent Catchment, May 1995

TREES ON FARMS TO REDUCE SALINITY IN THE CLEARING CONTROL CATCHMENTS

Volume 3: Kent Catchment

by

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Summary

The hydrological effects of vegetation in the Upper Kent River Catchment was modelled using the Water and Rivers Commission's computer modelling process, M.A.G.I.C (for MicroStation And Geographic Information Computation). It was used to predict areas of saline groundwater discharge in the steady-state. The model also identified sites for tree-planting that would most efficiently reduce groundwater discharge, to give a target mean salinity for the water resource while still maximising the area available for agriculture. Details of analysis and results of the model are included in this report.

The M.A.G.I.C. modelling of the Upper Kent River catchment is based on the predominant soil profile of salinity-affected areas in the South West of Western Australia. The model represents two layers of soil, a thick clay layer with low permeability above bedrock, and a thin more permeable layer at the surface. Both layers are parallel to the ground surface. Soil depths and permeabilities are constants in the model. The constant values for the top soil layer are typical for the region, while the permeability of the bottom soil layer is set by calibrating modelled deep groundwater discharge to the value estimated by dividing gauged salt flux by typical deep groundwater salinity. In the groundwater calculations, the ground slope is used as an approximation of the direction of groundwater flow. Water balance in the surface layer is simulated for one year in monthly time steps. Deep groundwater flows are assumed constant. The main results of the model are an estimate of deep groundwater discharge and surface run-off from the catchment when in its steady state with a year of average rainfall.

Maps produced at a scale of 1:20 000 show the predicted groundwater discharge areas resulting from cleared land in 1991, and potential tree-planting positions for the Upper Kent River catchment. These maps can be used as a management guide when planning tree layouts in farm plans that will also incorporate farm objectives and operational constraints. Samples of these maps are included in this report. Copies of the full set of maps, referred to as Map Appendix 3, are limited but are available on request from the Catchment and Salinity Investigations Branch of the Water and Rivers Commission.

1. Introduction

The Upper Kent River Catchment is situated in the Southwest of Western Australia. The southern boundary of the catchment is located 14 km south of Muirs Highway while the northern boundary extends nearly to Cranbrook. The western edge of the catchment is near Rocky Gully and the eastern boundary close to Tenterden (Figure 1).

The replacing of deep-rooted perennial native vegetation with annual shallow-rooted agricultural species has resulted in increased salinity degradation of land and water in the southwest of Western Australia. An increase in the streamflow salinity of the Lower Kent River Catchment has resulted from the extensive clearing of land for agricultural use that occurred in the 1960s and 1970s in the Upper Kent Catchment. By 1995, 57% of the Upper Kent Catchment (644 km^2) had been cleared for agricultural use.

A licensing system to control the clearing of native vegetation in the Kent River Catchment was introduced in 1978 as an amendment to the Country Areas Water Supply Act 1947. A landowner who is refused permission to clear under the legislation has a right to claim compensation. Allowances were made for limited use of remnants for stock shelter and grazing. However, the impacts of grazing of stock have been greater than expected. Degradation of the majority of the remnants has continued from the effects of stock grazing, waterlogging and land salinisation.

The Kent River is a potential valuable water resource for the South Coast towns and the Great Southern agricultural district. A likely location of a future dam would be near the Styx Junction Gauging Station (S604053 in Figure 1). However, deterioration in water quality has put at risk the development of the catchment as a source of potable (suitable for drinking) water.

The Kent River is a 'recovery' catchment under the WA Salinity Action Plan (Government of Western Australia 1996b). The aim is to control salinisation and return the water quality of the Kent River catchment to potable levels by the year 2030. Future management options will promote farm forestry on private land, integrated with improved annual cropping and pasture management. As well, a reduced level of commercial planting will be encouraged in the lower landscape positions adjacent to saline discharge areas. The existing remnant vegetation will be improved by using options such as fencing them off from sheep and cattle.

The Kent River is also a 'focus' catchment selected by the National Dryland Salinity Research, Development and Extension Program. The Kent Steering Committee was formed in 1994 by this program to "oversee the development and implementation of catchment management plans integrating salinity management and other resource issues, and ensuring that program activities carried out in the catchment meet the needs of communities and the objectives of the outlined plans". As a last stage of the current program, the Kent Steering Committee has let a contract to Burdass, Grieve and Robinson Agricultural and Management Consultants to develop an Integrated Catchment Management Development Plan for the Upper Kent River Catchment. Their report should be finished in July 1998.

The Water and Rivers Commission has developed a computing modelling process called M.A.G.I.C (for MicroStation And Geographic Information Computation) which models the hydrological effects of vegetation in catchments where dryland salinity occurs. The process was developed within the Wellington and Denmark Catchment Areas in the southwest of Western Australia and is reported by Mauger (1996).

The M.A.G.I.C. modelling process was used on the Upper Kent River catchment to predict areas of groundwater discharge in the steady-state. The model also identified sites for tree-planting that would most efficiently reduce groundwater discharge, while still maximising the area available for agriculture. Maps produced at a scale of 1:20,000 showed the predicted groundwater discharge areas and potential tree-planting positions for the Upper Kent River catchment. These maps can be used by people involved in Land Conservation District Committees and subcatchment groups, by individual farmers and by anyone with an interest in integrated catchment management. They are especially useful for planning tree layouts on farms. The maps are in Map Appendix 3 of this report, but are not printed with this report. They are available on request from the Catchment and Salinity Investigations Section of the Water and Rivers Commission.

2. Description of Catchment

2.1 Geography and Climate

The Kent River Catchment is situated in the southwest of Western Australia between latitudes 34°20' and 35° south and longitudes 116°50' and 117°30' east. In the north, the catchment consists of a gently undulating upland plateau with low gravelly ridges separating broad, shallow poorly drained valleys containing many swamps and lakes. The mainstream valleys become more deeply incised as they progress south, but the tributary valleys remain broad, shallow and swampy (Collins & Fowlie 1981).

The Kent Catchment has a Mediterranean-type climate, experiencing warm summers and cool winters. The summer maximum average temperature ranges from 27°C inland to 24°C near the coast while the winter maximum averages range from 15°C to 16°C . The total annual rainfall ranges from 530 mm in the north to 1200 mm in the south (Figure 1) and the mean annual pan evaporation figures are 1500 mm and 1200 mm respectively.

2.2 Subcatchments and Landuse

A national body called the Australian Water Resources Council defined Basin 604 to consist of the Kent, Bow and Kordabup Rivers, with a total area of approximately 2490 km². The Kent River Catchment covers more than 1900 km² of this area.

For the purpose of this study, there were three sub-catchments of special interest in the Kent Catchment — the Wamballup, the Upper Kent (which includes Wamballup) and the Lower Kent, as shown in Figure 1. The catchment areas are 102 km², 1102 km² and 1843 km² respectively (Spreadsheet 2).

Two Water and Rivers Commission gauging stations were used to delimit the catchment boundary divides for the Upper and Lower Kent Subcatchments; Rocky Glen (S604001) and Styx Junction (S604053) respectively (Figure 1).

Most of the lower part of the Kent River Catchment is forested. Most of this forest is part of Reserve 29660, which extends from just south of Muirs Highway to the proximity of the south coast. The portion of the forest within the catchment totals 680 km² in the area (Kelly 1995). The Lower Kent Catchment was used to set the salinity reduction target for the Kent Catchment but was not modelled.

The Wamballup and Upper Kent Catchments were modelled. The position of the outlet point on the most downstream subcatchment was made to coincide with the gauging station at Rocky Glen (S604001).

The Upper Kent Catchment was divided into 55 subcatchments to facilitate modelling and presentation of results. It lies in a low-to-intermediate rainfall zone of 530 to 840 mm (Spreadsheet 2). In 1996, 35% of the catchment was forest without upstream clearing (Spreadsheet 2). There are 112 individual holdings in the Upper Kent. The farms range from 400 ha to more than 4000 ha. Most of the land is used for sheep and wool production. Other activities are breeding of beef cattle and cropping such as oats, barley, wheat, canola, lupins and fieldpeas. Some land is being planted with blue gums and pines for commercial use and to help control salinity. A small number of the farmers are trying viticultural and horticultural production (Kelly 1995).

The Wamballup Subcatchment is situated in the southeast corner of the Upper Kent Catchment (Figure 1). It is made up of subcatchments 21, 22, 20, 18 and 11 (Figure 2). The associated landscape has low relief. Average rainfall in the catchment varies from 594 to 641 mm (Spreadsheet 5). By 1996, 86% of the catchment was cleared (Spreadsheet 5).

2.3 Vegetation of the Upper Kent Catchment

Bands 3, 4 and 5 of the Landsat Thematic Mapper (TM) satellite data taken in December 1991 were used to classify the land surface in the catchment. In December ephemeral grasses have died, but tree canopies are not greatly stressed by summer drought. Thus provided a discrimination in favour of trees in conditions not greatly influenced by climatic variations (Mauger, 1996).

Landsat data are supplied as one set of values per 25 m x 25 m 'cell' of land surface (or 'pixel'). In rural land, most of the cells contain four types of reflecting surfaces: sunlit green leaves, dry grass, bare sandy soil and shaded areas. An index referred to as the 'greenness' — a percentage of pure green component — was computed by the method outlined by Mauger (Section 5.6, 1996). Cells were classified as 'native forest', 'pasture only', 'pasture and trees' or 'clay' according to their values of 'greenness' and Band 5. Water was classified by using Band 4 (Mauger 1996, Section 5.7).

The natural 'greenness' of the vegetation was assumed to be 0.0087 × rainfall - 0.0051 × pan evaporation + 35.85. The coefficients for the natural 'greenness' formula were obtained from Mauger (1994), since the same December 1991 Landsat scene was used in that study.

The transpiration rate from trees in any cell was computed as:

$$\frac{\text{(actual greenness)}}{\text{('natural' greenness)}} \times \text{('natural' transpiration rate)}$$

where 'natural' transpiration rate is proportional to annual rainfall (Mauger 1996, Section 5.9).

Transpiration from pasture was assumed to be proportional to a leaf area index (LAI) of 2.7 and pan evaporation. In cells that were mixtures of pasture and trees, the fraction of the cell assigned to trees was found as the fraction of actual greenness to natural greenness. The rest was assigned to pasture (Mauger 1996, Section 5.10).

In the higher rainfall country, impressive jarrah (*Eucalyptus marginata*) and jarrah-marri (*E. calophylla*) forests can be found. At least one valley carries a stand of karri (*E. diversicolor*), immediately south of Muirs Highway (Kelly 1995). The vegetation system is a mosaic with jarrah-marri forest as the dominant member, enclosing numerous areas of jarrah forest, paperbark (*Melaleuca* spp.) forest. In the flat swampy terrain in the middle of the catchment, the jarrah-marri forest is mixed with yate (*E.occidentalis*), swamp yate and wandoo (*E. Wandoo*). In the low rainfall area in the north of the catchment, the native vegetation is mostly characterised by jarrah-marri-wandoo open woodlands on upper slopes and flat topped yate-wandoo open woodlands on the lower slopes.

Most of the Upper Kent Catchment is poorly drained and covered with swamps and lakes. Flooded gum (*E. rudis*) can occur around lakes. The narrow swamps along drainage lines contain reeds and heath with scattered paperbark trees. Teatree (e.g. *Melaleuca* spp.) can be found along the creeks. Redheart (*E. decipiens*) may occur in the wet sandy depressions.

In 1995 the Water Authority of Western Australia commissioned a consultant to prepare a map showing the extent and condition of the remnant vegetation in the Upper Kent Catchment. This map will be published in 1998 by the Water and Rivers Commission as part of a project entitled 'The extent and condition of remnant vegetation in potable water supply recovery catchments in south Western Australia'. The proportion of the Upper Kent Catchment with remnant vegetation in good condition was found to be 21%, while 11% of the catchment contained modified vegetation. Scattered vegetation made up 4% of the catchment, 3% plantations, 57% cleared and 4% made up of lakes and degraded areas.

Much of the remnant bushland has been degraded due to salinity, introduced grazing, feral grazing, historical uses and the effects of adjoining agricultural land use. Grazing of domestic stock has decreased the understorey diversity in the remnants (True *et al.* 1992).

In 1995, 3000 ha of plantation timber had been established. Local knowledge indicates that a further 2–3000 ha has been planted in 1996 and 1997 (Burdass, Grieve and Robinson Agricultural Consultants 1997). Most of the plantings are Tasmanian blue gums for chipping, owned by specialist timber or investment companies. They occur mainly in the southwest of the catchment, in the higher rainfall country near Rocky Gully. Some farmers also are involved with blue gums. Small amounts of pines have been planted for sawlog production. Some non-commercial species have been planted by individual landowners to counter salinity or for use as shelter belts. The areas containing mature plantations can be clearly distinguished in the model from native vegetation, since they have a high value of 'greenness'.

2.4 Geology and Soils

In the extreme northern edge of the Upper Kent River Catchment the dominant feature is the Yilgarn Craton (the Great Plateau), which was formed in the Archaean era. The Yilgarn Craton consists mainly of granite, with some metamorphic rocks including gneisses. Many fractures and shear zones have formed due to stresses. Dolerite and quartz dykes have seeped through these cracks when they were in the magma stage (Kelly 1995).

The Yilgarn Craton is so weathered that most of the mountain ranges have been worn down to a low plateau with little relief, with lateritic soil profiles up to 60 m deep (Kelly 1995). A typical lateritic profile exists of the bedrock and weathered rock overlain by 10 to 40 m layer of pallid clay, overlain by 1 to 5 m of mottled clay, overlain by up to 1 m of laterite and gravel, with up to 0.5 m of sand at the surface (Kelly 1995).

Most of the Kent River Catchment is underlain by the Albany–Fraser Orogen formed 1200 million years ago and composed mainly of gneisses and other metamorphic rocks. Granite is less common than in the Yilgarn Craton and is present in the younger intrusions. Doleritic dykes are not so prevalent as in the Yilgarn Craton. The process of lateritisation of the landscape has occurred in the Albany–Fraser Orogen as in the Yilgarn Craton (Kelly 1995).

A deformed and metamorphosed zone separates the Yilgarn Craton and Albany–Fraser Orogen. It is a jagged eastwest line running approximately parallel with the Stirling Ranges. It passes through the northern part of the catchment near Geekabee Hill and Lake Nunijup (Kelly 1995).

In the Upper Kent Catchment, bedrock outcropping is rare north of Muirs Highway. This is due to the lateritisation of the land surface and the subsequent deposition of alluvium in the broad valleys and colluvium on the gentle slopes. Ancient rivers and watercourses have been filled with clay, sand, silt and gravel from erosion of the landscape. This has resulted in broad, flat valleys dispersed with a chain of lakes. The ancient drainage course became defunct due to changes in the tilt of the land surface associated with the separation of Australia and Antarctica approximately 55 million years ago. The ancient rivers used to run in a westerly direction, but now the land surface tilts to the South from a hinge line called the Jarrahwood Axis, situated more than 100 km from the coast (Kelly 1995).

Some minor areas of lateritic deposits exist on the hill crests, these are present as massive ironstone or gravelly deposits. There are also sandy colluvial deposits, often with ironstone gravel, over the lateritic material on some slopes. However, the alluvial and colluvial deposits predominate in the Upper Kent north of Muirs Highway (Kelly 1995). In the broad valleys and on the eastern sandplains, laterites are mantled by leached sands with peaty horizons in the swampy depressions (Collins & Fowlie 1981). The current drainage system is very sluggish through the northern end of the catchment but becomes more efficient near Perillup. In this facility, outcropping of the ancient Albany–Fraser Orogen becomes more frequent (Kelly 1995).

South of Muirs Highway, the landscape has greater relief. Bedrock outcropping is more prevalent, especially near the coast. The outcrops are usually surrounded by lateritic materials except for the sands and podzols on the coastal plain and the loamy red earths developed from the granite outcrops. The valleys become narrower, but still contain alluvial material. South of Table Hill are more recent deposits in the form of Quaternary colluvial materials (Kelly 1995).

The soil profile in the catchment is generally the result of deep weathering in-situ (up to 60 m deep, but usually around 20 m). In the model, the soil profile was represented as two layers of equal slope to the surface slope. This assumed the depth of the soil was small compared to the topographic relief. So, as an approximation, bedrock levels were assumed to be parallel to the ground surface.

The top soil layer throughout the catchment was taken to be 1.5 metres deep with a permeability of 30 m/month/unit hydraulic gradient and a porosity of 0.2, and bottom layer 20 metres deep with a permeability of 3 m/year/unit hydraulic gradient.

Geological features such as faults and dykes have not been represented in the model and future reviews of the model, in the Upper Kent Catchment, could take this into account. These features restrict the lateral movement of ground-water. Soil mapping of the catchment could also be incorporated into the model by assigning different permeabilities to different soil types.

2.5 Clearing History

From 1826 onwards, pioneers used the Denmark, Kendenup and Mt Barker areas to graze their sheep. The forest resources were used between the 1880s and 1920s to cater for local and export timber demand. Wheat and sheep farming began around 1900.

Initial alienations of the land in the early 1900s was centred around Cranbrook, Mt Barker and Denmark. The land between Kojonup and Mt Barker was settled between 1900 and 1930 (Kelly 1995). In March 1948 the Government introduced an act in the Legislative Assembly that authorised clearing of land for agriculture (Evans *et al.* 1995). After World War II, soldier settlement schemes existed, the terms of conditional purchase requiring that farmland be cleared with no official provision for the retention of shelter belts or riparian vegetation around drainage lines (Kelly 1995).

During the 1950s most of the areas with low forest and scrubland were cleared. In the 1960s the farmers had more resources to clear land, and mass clearing occurred. Since 1978 trees have been planted in the catchment. The clearing history of the Upper Kent Catchment is shown in Table 1.

Table 1: Clearing History of the Upper Kent Catchment

Year	Percentage of Catchment Cleared
1930	15%
1950	35%
1978	68%
1995	57%

The Western Australian Government introduced clearing control legislation for the Kent in 1978 to limit further increases in secondary salinity in the catchment. At this time, the proportion of cleared land was 40% of the total catchment area at Styx Junction. This legislation limited further clearing under licence to 4800 ha. This was mainly in the lower risk areas.

2.6 Salinisation

In streams in the southwest, the main component of stream salt is sodium chloride that originated from the ocean and was deposited on the landscape in rainfall and dry fallout from the prevailing winds. The chloride concentrations in rainfall and chloride precipitation decrease with increasing distance from the coast. Rainfall salinities are typically in the order of 10–20 milligrams per litre (mg/L) Total Dissolved Solids (TDS) in the southwest water catchments of Western Australia (Schofield *et al.* 1988). Most of the salt fall is washed into streams quite quickly, but under native vegetation some accumulates in the clays where deep-rooted plants have drawn their water during summer and left the salt behind. A strong correlation of increasing soil salt storage with decreasing rainfall has been found for land east of the Darling Scarp, where the average annual rainfall is below 1000 mm/yr. In the Upper Kent Catchment, the average annual rainfall varies between 566 and 834 mm for the individual catchments (Spreadsheet 2).

The clearing of native deep-rooted perennial plant species and their replacement with shallow-rooted annual agricultural species alters the water balance in favour of increased groundwater recharge. Groundwater levels rise until they intersect the valley surface. Salt previously accumulated over millennia in the soil is leached from it and bought to the surface or discharged directly into streams.

The salt balance of a catchment subject to agricultural clearing is changed from a state of equilibrium or accumulation to a state of net salt export. Approximately 1000 years is required in low rainfall areas to leach the salt from the soil and to return the stream salinity to low levels generated by atmospheric solute input. It is more appropriate to halt or reverse the increasing salinity trends within a period of 10–30 years (Schofield *et al.* 1988).

The gauging station at Styx Junction (S604053) measures the streamflow and salinity from the lower catchment. Figure 8 shows the annual flow-weighted (FW) stream salinity at Styx Junction and Kenton (S604010) for the years 1940–97. Kenton is a closed gauging station in the vicinity of Styx Junction, which was used in the earlier years to measure streamflow and salinity. The effects of clearing the native vegetation can be seen in the increasing Annual Stream Salinity Smooth Curve. Between 1940 and 1959 the annual flow-weighted salinity was within the fresh classification for a river (< 500 mg/L TDS). From 1959 it steadily increased and was 1650 mg/L (TDS) in 1997. The curve seems to be reaching a plateau, which indicates it is nearing its steady-state value of salinity. Variations in the water quality are dynamic from year to year and are influenced by climatic variations as well as secondary salinity. This is indicated by the large scatter of the annual stream salinity values in Figure 8.

Another gauging station named Rocky Glen (S604001) is situated 13 km from the town Rocky Gully (Figure 1). This station measures the streamflow and salinity for the Upper Kent River catchment and has records since 1979. The annual flow weighted stream salinity for Rocky Junction is shown in Figure 9. The Salinity Smooth Curve varies from 3100 to 3600 mg/L TDS in the years 1979 to 1997. The annual flow-weighted salinities for this period range from brackish (i.e. in the range 1000 to 5000 mg/L TDS) to saline (>5000 mg/L TDS). The average annual stream salinity is higher at Rocky Glen than at Styx Junction because a higher percentage of the catchment has been cleared.

The extent of salinity in the Upper Kent Catchment has been mapped by CSIRO (Leeuwin Centre) using satellite data obtained over several years and other landform attributes. The area surveyed was 1063 km^2. In 1988, the saline land was estimated to be 6.1%. In 1994 it increased to 14.1% of the catchment. By extrapolating the results, it can be concluded that without significant changes in land use and management, the salt-affected area could increase to 30% of the cleared area (Government of Western Australia 1996a).

3. Model of Catchment

The Kent Catchment was modelled using the personal-computer based M.A.G.I.C. (MicroStation and Geographic Information Computation) modelling system. The principles and assumptions used to develop the model are in a report titled 'Modelling Dryland Salinity with the M.A.G.I.C. System' (Mauger 1996). The model was developed to assess the effect of vegetation on the hydrology in catchments affected by dryland salinity in the southwest of Western Australia.

A Geographic Information System approach was used in the development of the model. The resulting process can provide information at a scale of tens of metres, useful for planning tree-planting on farms, while effects can be integrated for the whole catchment with areas up to hundreds of square kilometres. The whole catchment was subdivided into 55 subcatchments of areas from 4 to 45 km^2 which were modelled separately and the results subsequently integrated.

The catchment boundaries, identifying numbers of each subcatchment and flow directions are illustrated in Figure 2. Gauging stations run by the Water and Rivers Commission, which were used to obtain gauged yearly average rainfall, streamflow and salt load, are shown in Figure 1. These were Rocky Glen (S604001) for the Upper Kent River Catchment and Styx Junction for the Lower Kent River Catchment. Spreadsheet 1 details the AMG coordinates of outlet locations in the subcatchments and the flow directions (i.e. points at which totals are reported).

The raster processing program RASCAL computed quantities needed as input into the model of the catchment. Gridded elevation cells were generated from contour linework in MicroStation PC (geographical information drawing software package) format. Slope and drainage distribution information was generated from the elevation map in each RASCAL project. Average annual pan evaporation isopleths and average annual rainfall isohyets (1926–81) polygons in MicroStation PC format were converted into RASCAL maps in each project.

The model, a two-layer groundwater simulation with inputs of rainfall and evapotranspiration, was then executed using RASCAL. The soil profile was represented as two layers of equal slope to the surface slope. Soil depths and permeabilities were constants (Mauger 1996).

The model was run in monthly time steps for three years running. The first year ran the shallow groundwater simulation as a preliminary analysis to get an estimate of the initial water storage in each cell. The simulation of deep groundwater was a "steady-state" analysis, i.e. the average over a long period of time assuming vegetation cover remained the same throughout. The shallow groundwater simulation was run for the next two years using the final storage from the previous year as the initial storage. Ideally, after the third year the final water storage in each cell should have equalled the initial water storage.

The complete details of the computing processes used in the Kent Catchment are documented in Appendix A. Since the Upper Denmark and Wellington Catchments were modelled (Arumugasamy & Mauger 1994), the processes were modified to incorporate more hydrologic functions and to improve the computing procedure. Due to the extent of the changes, a complete revision of the appendix was necessary. Reprocessing those catchments with the revised procedure has negligible impact on the results, however.

The Upper Kent Catchment contains many lakes and swamps. To model the hydrology of the catchment more efficiently, at the end of each year in the modelling process, the annual evaporation from lakes and major streams was removed. The amount of pan evaporation removed from the lakes was the pan correction factor (0.7) times the actual pan evaporation. The amount of evaporation removed from the major streams was proportional to the width of the stream and the pan correction factor times the pan evaporation. The width of the streams was assumed to be 5 m for cells with an upstream catchment area greater than 250 km^2. For cells on streams with an upstream catchment area less than 250 km^2, this process was not applied. The subcatchments with major streams were 55, 50, 48, 39, 36, 33, 23, 16 and 15.

The results of the model for each subcatchment are relayed in Spreadsheets 2 to 4. Each spreadsheet has the sums for isolated individual catchments and aggregates for subcatchments including all the upstream catchments.

Spreadsheet 2 contains all of the area statistics for the Upper Kent Catchment, such as catchment area (km^2), average rainfall (mm), total rainfall ($10^6 \times m^3$), cleared areas (km^2 and % of catchment), forest without upstream clearing (km^2 and % of catchment). The flows for 1991 clearing are in Spreadsheet 3. This includes streamflow (m^3 and mm), deep groundwater discharge ('seepage') (m^3 and mm), seepage inside and outside forest.

In Spreadsheet 4, the model minimum tree-planting for a 67% reduction in seepage for the gauging station at Styx Junction is reported for each subcatchment. This includes the predicted and review seepages and streamflows that would occur if the trees were planted on areas where the seepage > 12 mm/yr.

The Wamballup Subcatchment was modelled twice. It was first modelled using 5 m surface contours and then with more accurate elevation data derived from soft photogrammetry. This was done to compare the model results of the different elevation data.

4. Modelling Parameters

The main parameters that determined the estimates of streamflow and seepage rates were:

- Cleared areas were used for annual pasture with a peak Leaf Area Index (LAI) of 2.7.
- The top soil layer throughout the catchment was taken to be 1.5 metres deep with a permeability of 30 m/month/unit hydraulic gradient and a porosity of 0.2.
- The bottom soil layer was taken to be 20 metres deep with a permeability of 3 m/year/unit hydraulic gradient.

The streamflow results obtained from the shallow groundwater simulations were compared to historical streamflow records at Rocky Glen for the years 1979–93. The results of the comparisons are illustrated in Table 2. The modelling process overestimated the annual streamflow by 12×10^6 m^3. This could have been due to several factors.

The average annual rainfall isohyets for the period 1926–81 were used for the input of rainfall in the model. This corresponded to a mean annual rainfall of 724 mm for the Upper Kent Catchment (Spreadsheet 2, catchment 55). However, the mean annual rainfall for the period of streamflow record (1979–93) was 565 mm. This meant the model was run with a 22% increase in rainfall compared to the period of record and would result in a higher value for streamflow.

Overestimating the streamflow should not have a large effect on the tree-planting results. The percentage reduction in seepage is the main criterion used when predicting the density and location of tree-planting, and an overestimation of streamflow does not affect this to a significant degree.

The monthly rainfall and average pan evaporation coefficients used in the model were the same as those used in the Upper Denmark and Wellington Catchments (Arumugasamy & Mauger 1994).

The bottom soil layer permeability is usually set by calibrating modelled deep groundwater discharge out of the forest to the value estimated by dividing gauged salt flux by typical deep groundwater salinity (Mauger 1996). Seepage from forested areas is not counted in contributing to salt output. In order to separate seepage originating from pasture areas from seepage generated within forested areas, a map was generated in which cells were marked as 'outside forest' if more than 2% of the catchment area upstream from them was pasture. Only seepage from 'outside forest' cells was assumed to carry salt. A value of 3 m/year/unit hydraulic gradient was used for the bottom soil layer in the model. It appeared to be consistent with gauged results obtained at Rocky Glen, which are shown in Table 2.

Maps showing the location of predicted deep groundwater discharge (seepage), classed by the rate of discharge are in Map Appendix 3A. Also shown on the maps is native forest interpreted from the Landsat TM data for December 1991, streamlines, property information and contours taken from planimetric maps. A sample of a map is shown in Figure 3.

5. Seepage Reduction Objectives

The Upper Kent River Catchment is gauged at Rocky Glen (S604001), and the Lower Kent River Catchment is gauged at Styx Junction (S604053). The locations of the gauging stations are shown in Figure 1. At each of these stations, the streamflow and conductivity of the water is continually recorded. The annual flow-weighted salinity was calculated for the years 1979–93 for Rocky Glen and 1976–93 for Styx Junction.

If a dam were to be built in the vicinity of Styx Junction, then it is desirable that the taste limit of the water is not exceeded 90% of the time. This corresponds to a flow-weighted average value of 550 mg/L TDS at Styx Junction.

The flow-weighted salinity at the Styx Junction gauge was 1138 mg/L for 1979–93 and at Rocky Glen the flow-weighted salinity was 3151 mg/L for 1979–93. The salt load resulting from seepage in the catchment was estimated by subtracting from the stream's salt load the salt contributed directly by rainfall. The concentration of the salt in the rainfall was assumed to be 20 mg/L TDS, and 75% of this was assumed to end up in the stream in one year, while 25% was assumed to infiltrate into the bottom soil layer. This division of rain salt has been established by salt balance on large areas of totally forested catchments.

The calculation of how much reduction in deep groundwater discharge from cleared areas is required to meet a streamflow salinity target is set out in Table 2. In this table, a typical deep groundwater salinity of 9000 mg/L TDS was used. This figure was determined on the basis of available catchment boredata.

The salt concentration after treatment at Styx Junction was set to 550 mg/L and the corresponding figure for Rocky Glen was estimated to be 1442 mg/L. In making this calculation, planting to meet salinity targets is assumed to reduce streamflow at Styx Junction by 10%.

6. Tree-Planting to Reduce Seepage

The result of the calculation in Table 2 was that total seepage should be reduced to 33% of current seepage rates.

In order to identify sites and areas for tree-planting, the following criteria were used:

- minimise the areas to be planted in order to reduce seepage to the required degree;
- plant in areas currently not native forest

The computer analysis process selected the areas of highest seepage rate first, then progressively lower seepage rates until the total reduction in seepage target was met. Cells with deep groundwater discharge rates in the bottom soil layer exceeding 12.5mm/year were selected for planting. The results of the analysis are presented as 'denoted sites for trees' as shown in the map sheets titled 'Recommended sites for tree-planting' in Map Appendix 4B. A sample of one of these maps is shown in Figure 3.

The numerical results of the analysis are tabled in Spreadsheet 4. Firstly, an estimate was made of the effect the tree-planting would have on the seepage. The results are under the heading 'PREDICTED SEEPAGE'. The area of planting to achieve the predicted seepage is also estimated. The review process then puts the planted trees in the model, and the steady-state modelling of the streamflow and seepage is re-analysed. The results are labelled 'REVIEW STREAMFLOW' and 'REVIEW SEEPAGE'. The review streamflow was used as an estimate of the effect of planting on the mean streamflow in Table 2.

The reviewed seepage was used to confirm the predicted seepage estimate. The average Review/Predicted Out-of-Forest Seepage was 99.5% for the Upper Kent Catchment (Subcatchment 55 at Rocky Glen). The total area of cells identified as 'Recommended Sites for Tree-planting' amounted to 37% of cleared area in the catchment.

7. Modelling of the Wamballup Subcatchment

The aim of remodelling the Wamballup Subcatchment was to compare the effects of more accurate elevation data on the model. The subcatchment was first modelled using 5m surface contours for elevation (old model). This is tabulated in Spreadsheets 7 and 8. More accurate elevation data were supplied at 25 m cell centres derived from soft photogrammetry by Department of Agriculture WA for the Wamballup subcatchment. This elevation data was used to re-model the Wamballup Subcatchment (new model) and a comparison made of the results from both models.

The Subcatchment numbers and outlets for the new model are shown in the right hand corner of Figures 5, 6 and 7. The outlet at subcatchment number 11 is the outlet for the Wamballup Catchment. The outlet at subcatchment number 111 is the outlet of subcatchment 11 used in the old model. The drainage paths generated in both models varied slightly, the major difference being for sub-catchment 21. In the new model, this subcatchment had two outlets hence subcatchments 211 and 212 were made to coincide with the old model's subcatchment 21, which had one outlet.

Spreadsheets 5 and 6 have the results of the model using soft photogrammetry for elevation. Figure 5 displays the groundwater seepage, catchment boundaries and streamflows for the new model. The results for the models using soft photogrammetry and 5m contours for elevation are compared in Spreadsheet 9: "Seepage and areas for isolated catchment parts common to both models in the Wamballup Subcatchment". A common catchment boundary was created that consisted of areas common to both models, and the sums within this common catchment were reported in this table.

The seepage (deep groundwater discharge) outside forest is compared between the new and old models. This figure varied between 107% to 157%, indicating an increase in seepage for the more accurate elevation data. This was due to more variability of slope in the landscape. The less slope variation in the landscape the less discharge results. The new/old streamflow varied between 62% and 108% for the individual subcatchments.

The different seepages generated are portrayed in Figure 7. The distribution of the groundwater seepage varied between the two models due to the variation in slope. Also displayed in this figure are the streamlines generated from the new model, and the watercourses supplied by DOLA. Catchment boundaries generated from the old and new models and a hand-drawn catchment boundary interpreted from 5 m contours are also shown. Native vegetation and scattered trees was outputed from the model by interpreting a Landsat scene captured in December 1991 and is also shown in Figures 5, 6 and 7.

Figure 6 contains areas of saline land and land predicted to be at risk of salinity. This information was obtained from a study funded by the Land and Water Resources Research and Development Corporation titled "Integrating remotely sensed data with other spatial data sets to predict areas at risk from salinity" (Evans *et al.* 1995). The aim of the study was to evaluate methods for predicting areas at risk from salinity. Primary data sets were assembled that consisted of Landsat TM data, Landsat MSS data, digital height data in the form of 5m contours and historical air photos. Derived data sets were obtained that contained factors identified as indicators of salinity risk. The primary and derived data sets were assembled in a Geographical Information System and rule-based classifiers and probabilistic networks were used to produce salinity and salinity risk maps.

When the salinity and salinity risk map is compared to the predicted deep groundwater discharge produced from the new model, the seepage from the later has more areas on upper slopes. This could be explained by seepage on the steeper gradients being able to travel in the shallow top layer of soil with little impact on the surface. Saline land and land being identified as being at risk of salinity by CSIRO occurred where the deep groundwater drainage accumulated in the flat areas lower in the landscape.

8. Conclusion

To meet the salt reduction target of 550 mg/L TDS at Styx Junction, it was estimated that the seepage outside the forest should be reduced by 67%. This can be achieved by planting trees on 37% of the cleared areas in the Upper Kent Catchment.

The model was re-run with the suggested trees planted, and the resulting seepage volume was compared to the target reduction in seepage volume. This comparison suggested that the initial criteria chosen for tree-planting were appropriate. To meet the target, trees need to be planted where the seepage exceeds 12.5 mm/year (based on a bottom soil layer permeability of 3 m/year/unit hydraulic gradient).

Hydrological analysis of the Upper Kent River Catchment predicted the distribution of saline groundwater discharge resulting from clearing native vegetation for pasture. It also suggested sites and densities of tree-planting to meet a target reduction in the total rate of seepage. The results are illustrated in Map Appendix 3 and are available on request from the Catchment and Salinity Investigations Section of the Water and Rivers Commission. These maps can be used as a management guide when planning tree layouts in farm plans. Actual plans should also incorporate farm objectives and operational constraints. If farm plans are prepared, then their effectiveness in reducing salinity should be reviewed by modelling them.

In the future, the model of the Upper Kent Catchment could be improved by incorporating the soil types and geology. A more recent Landsat scene should also be used.

9. References

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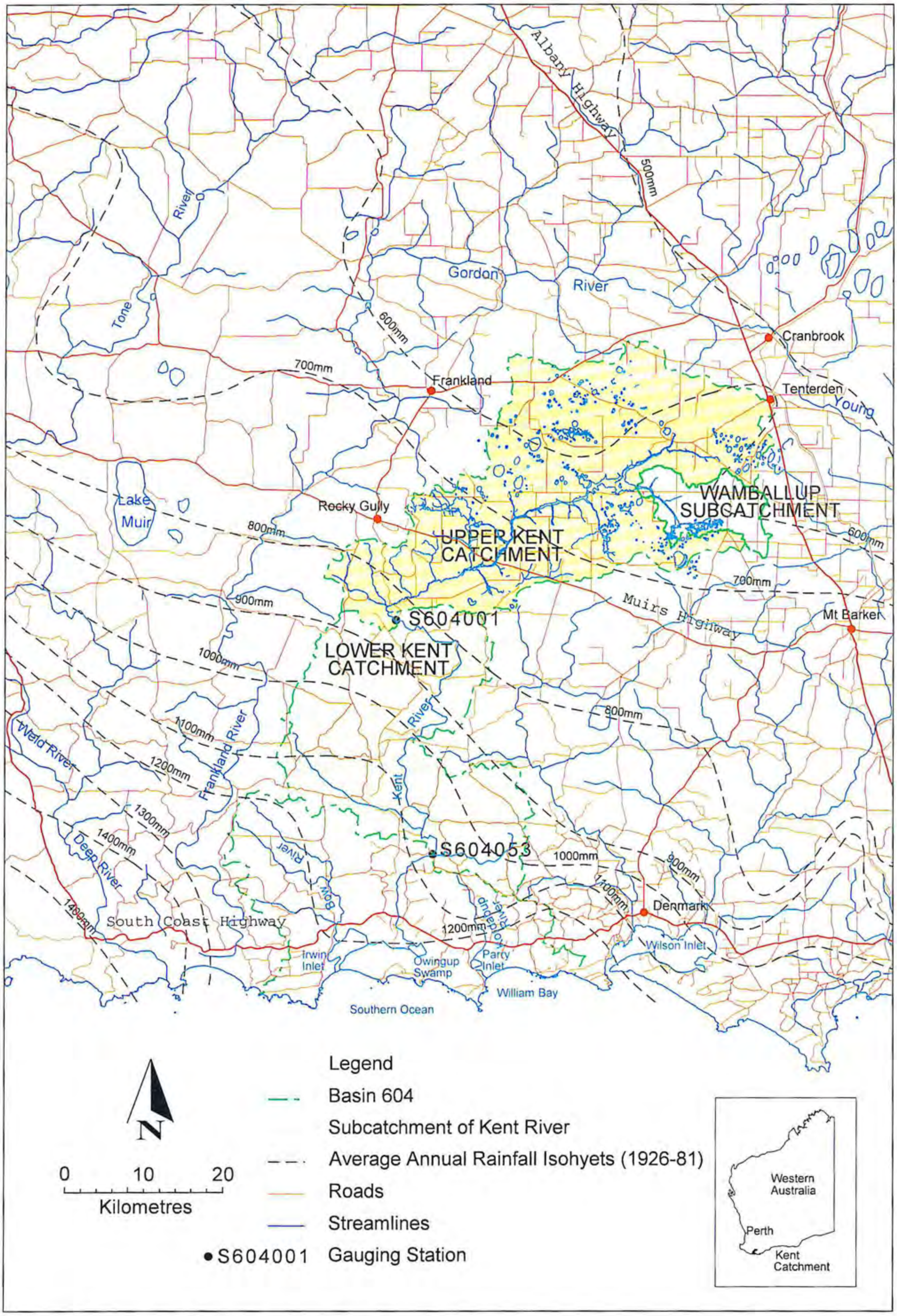

Figure 1. Location Map of the Kent Catchment

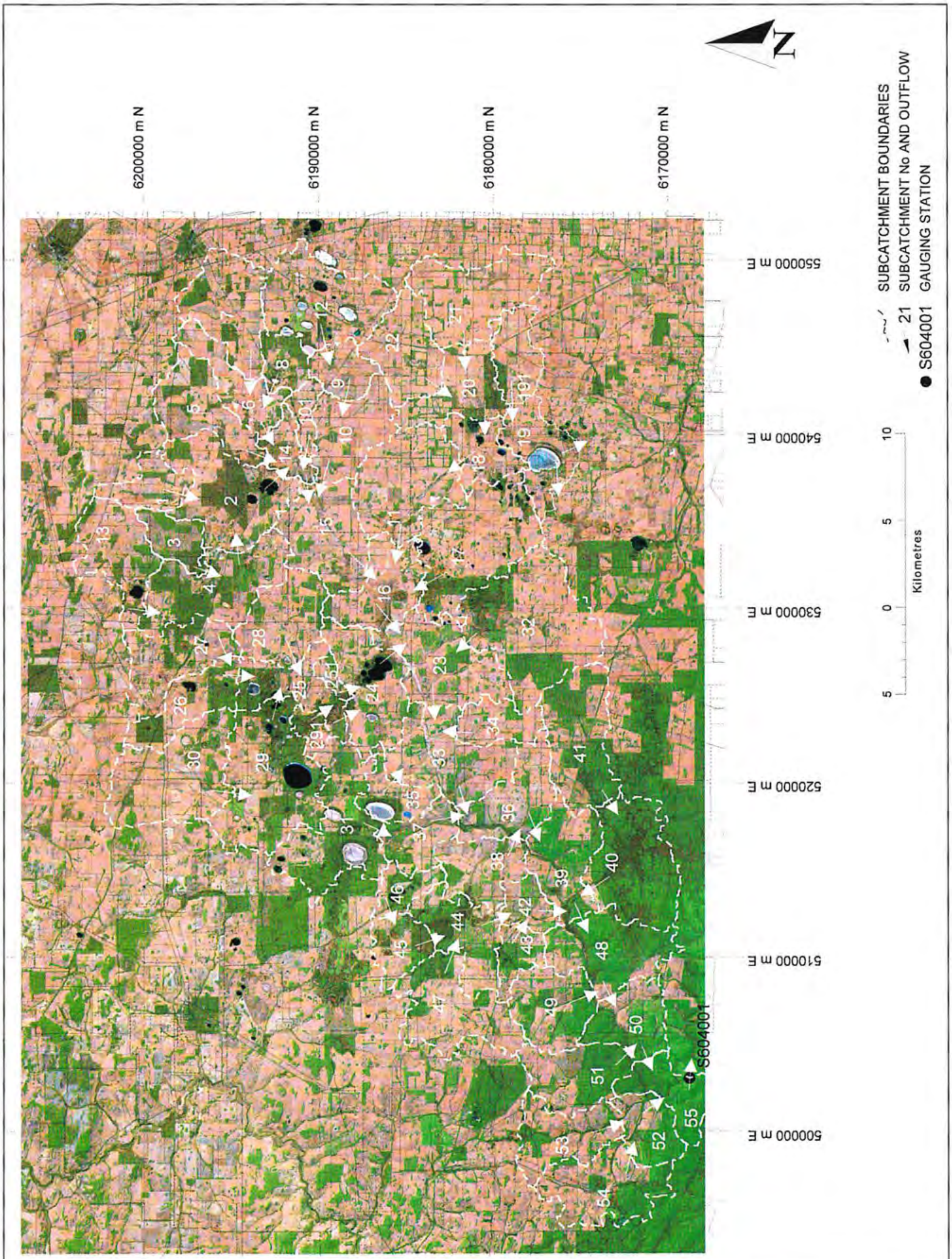

Figure 2. Subcatchments of the Upper Kent Catchment

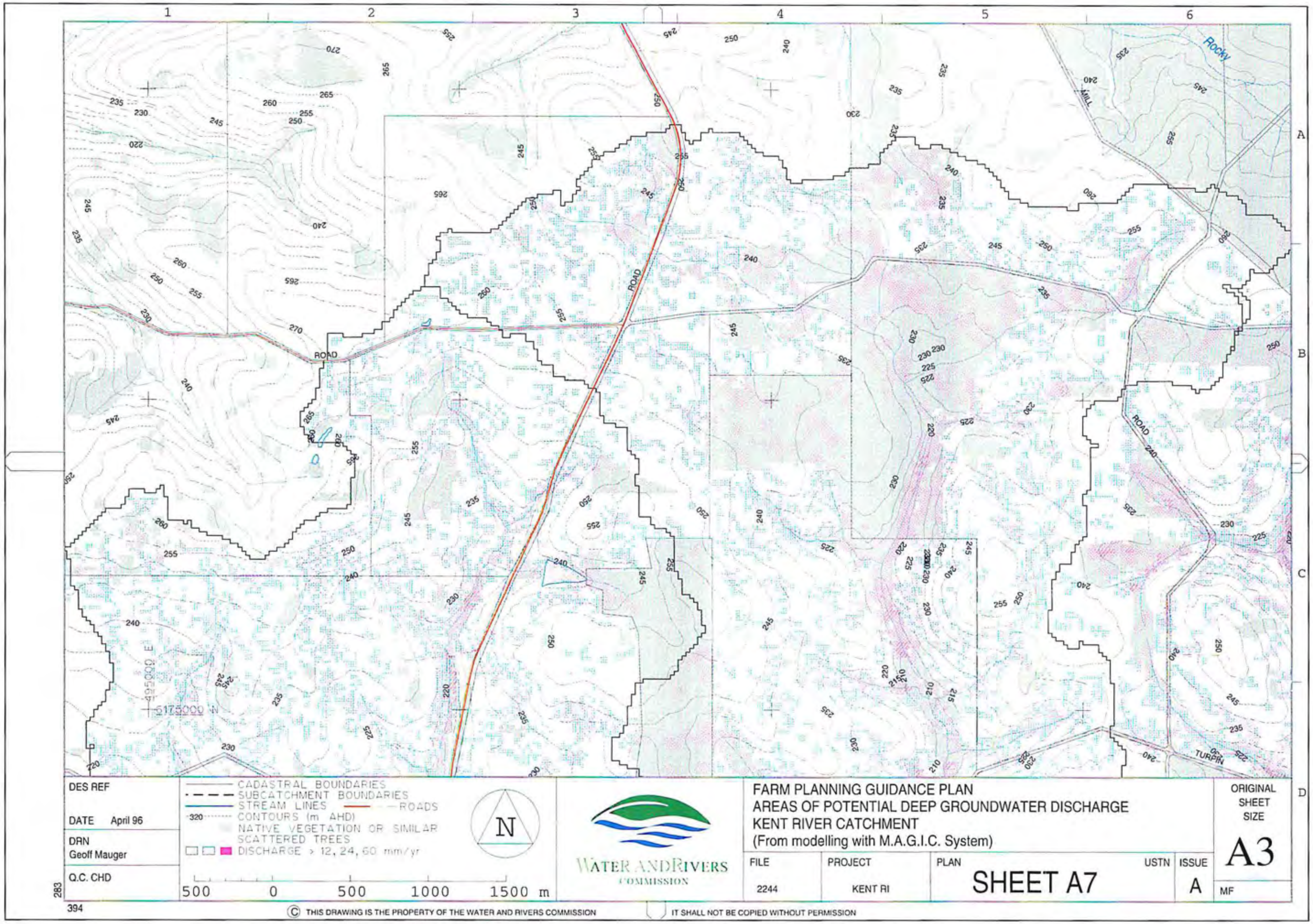

Figure 3. Sample of Map from Map Appendix 3A

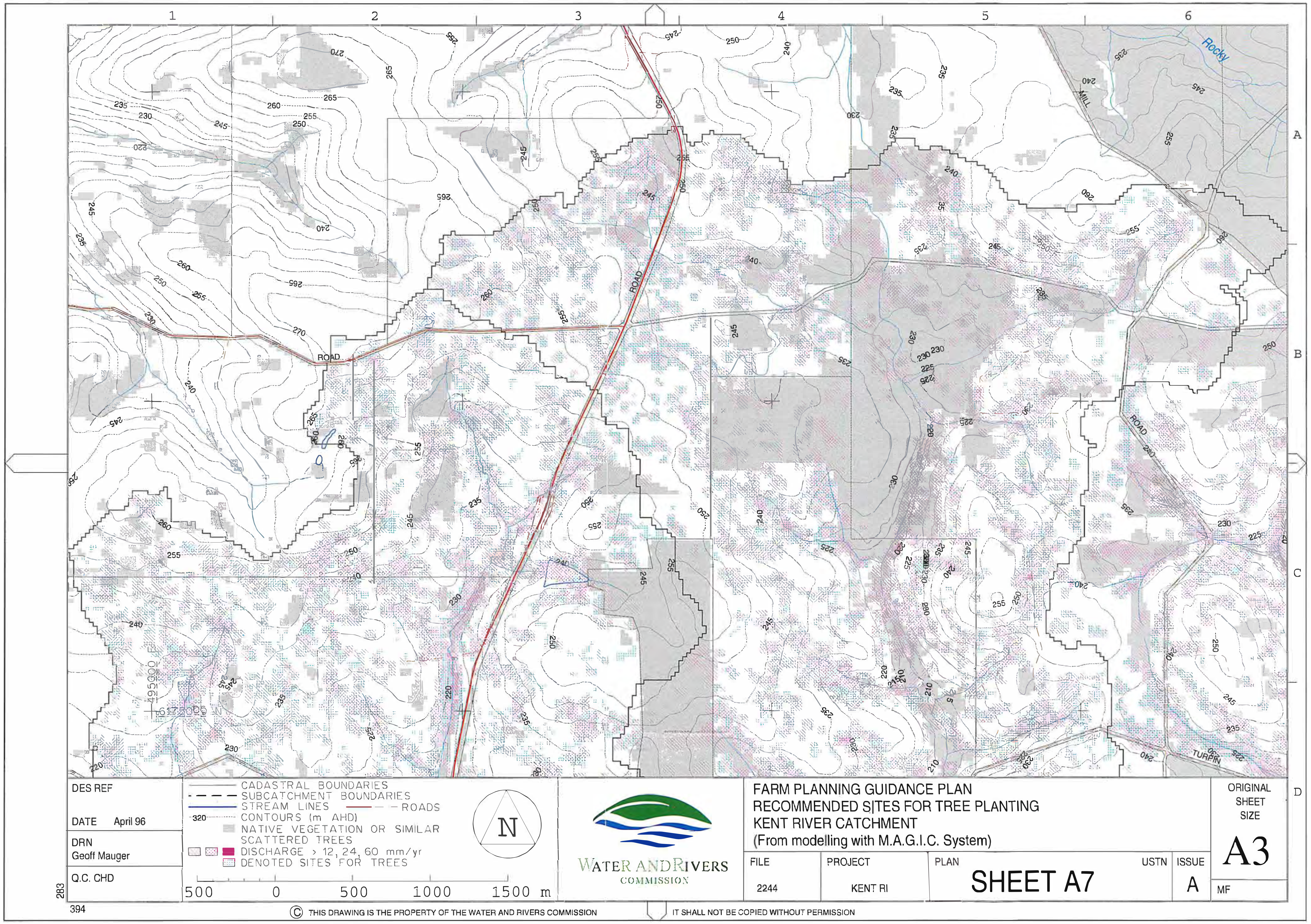

Figure 4. Sample of Map from Map Appendix 3B

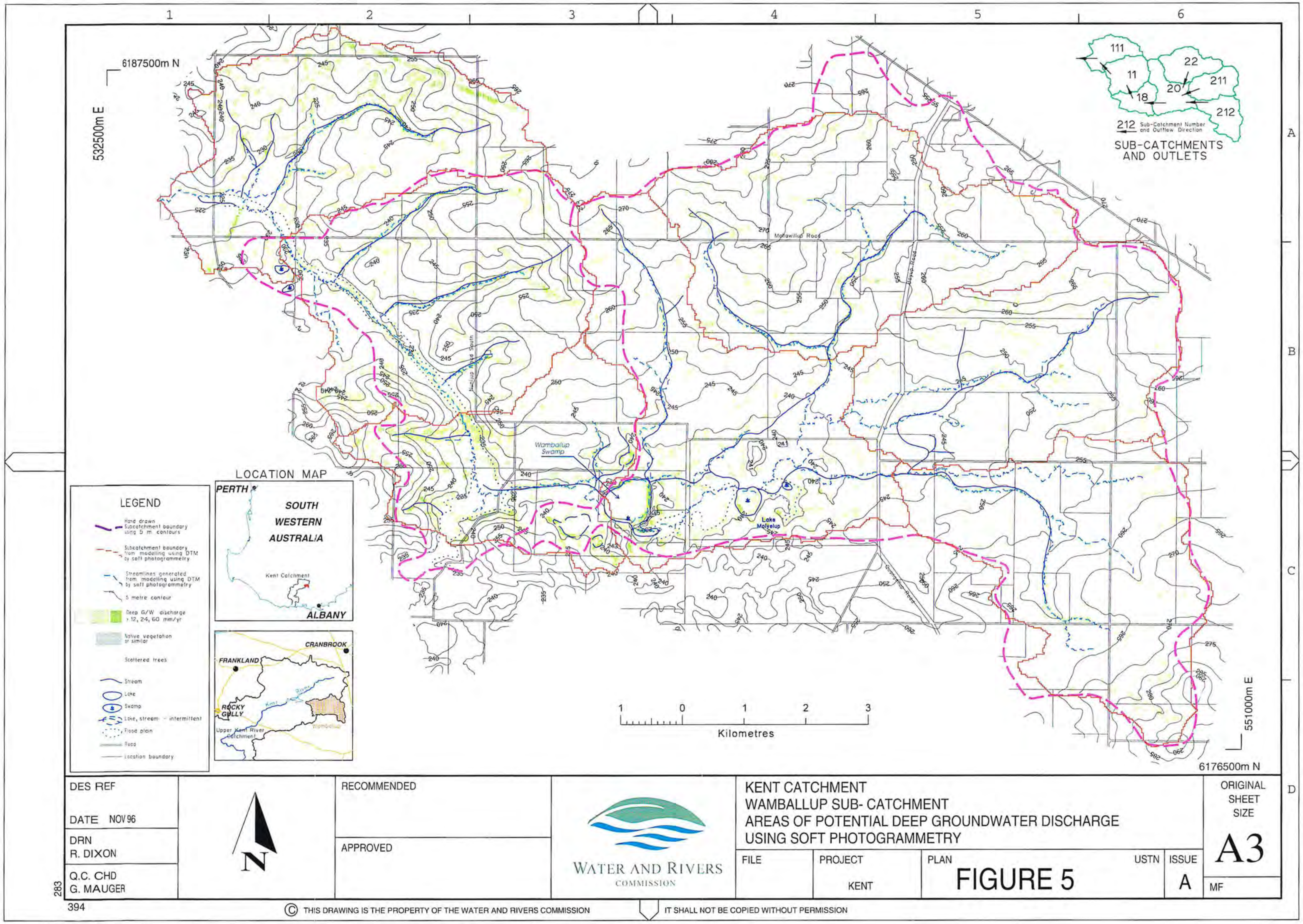

Figure 5. Wamballup Subcatchment: Areas of Potential Deep Groundwater Discharge Using Soft Photogrammetry

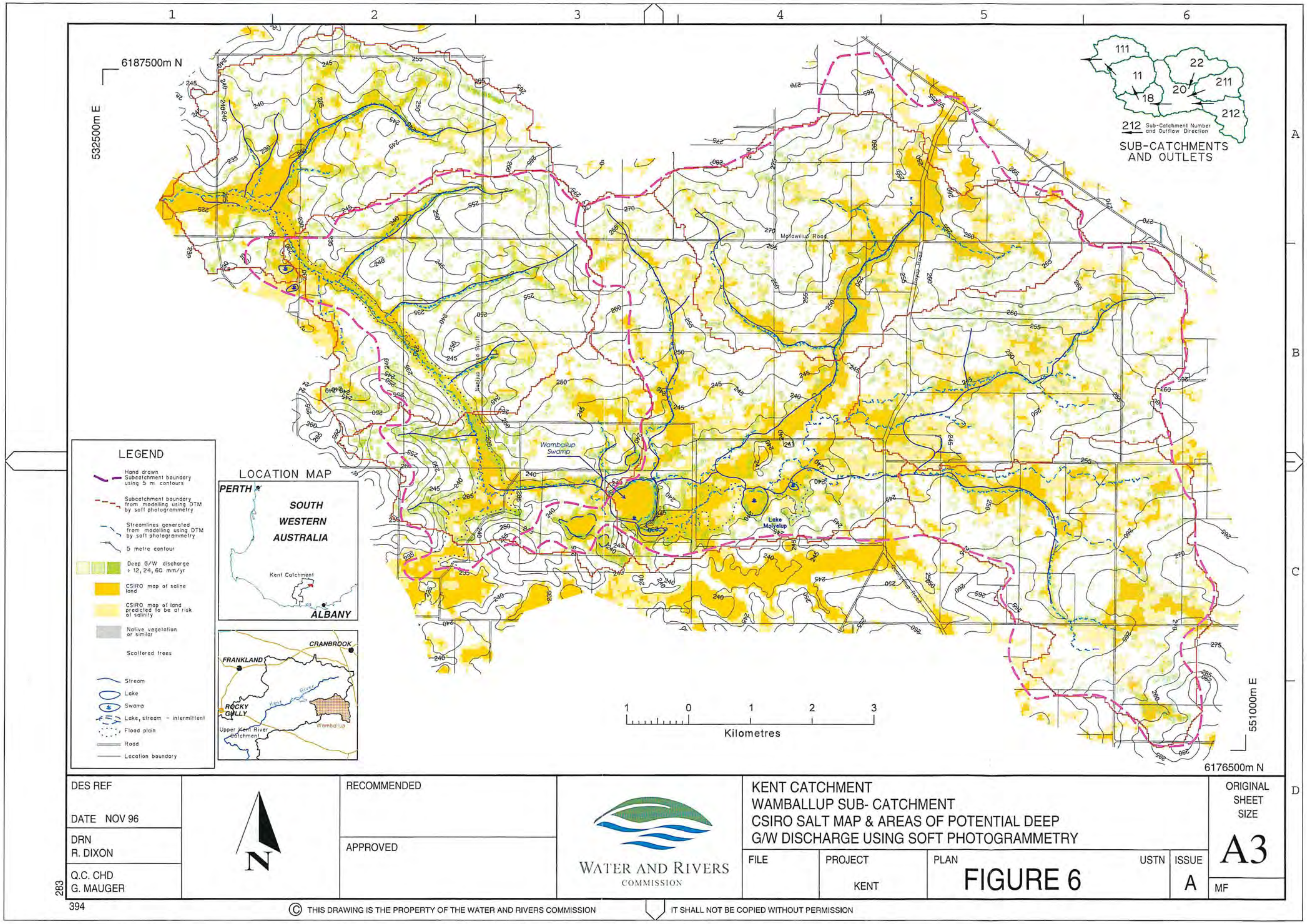

Figure 6. Wamballup Subcatchment: CSIRO Salt Map and Areas of Potential Deep Groundwater Discharge Using Soft Photogrammetry

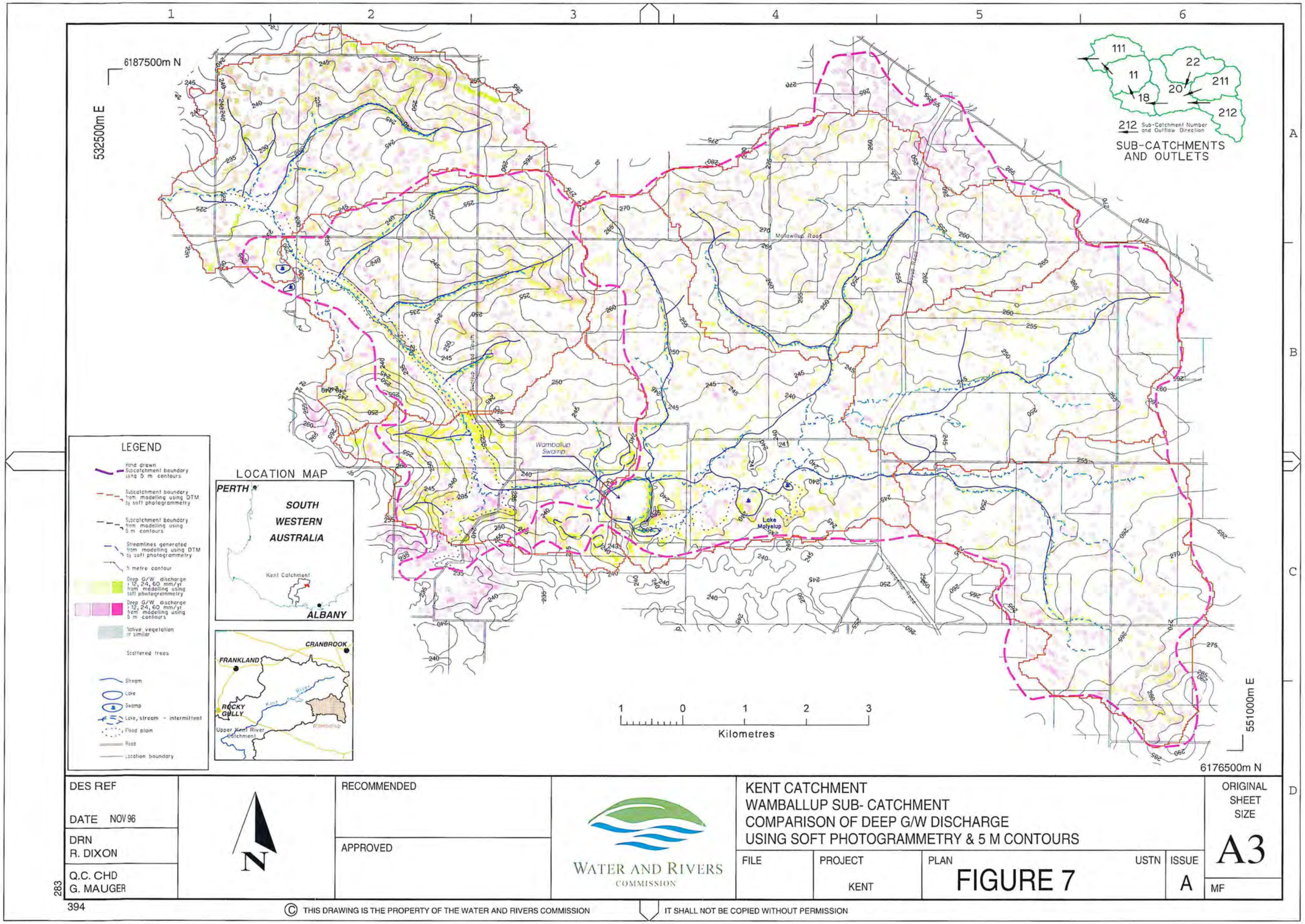

Figure 7. Wamballup Subcatchment: Comparison of Deep Groundwater Discharge Using Soft Photogrammetry and 5 m Contours

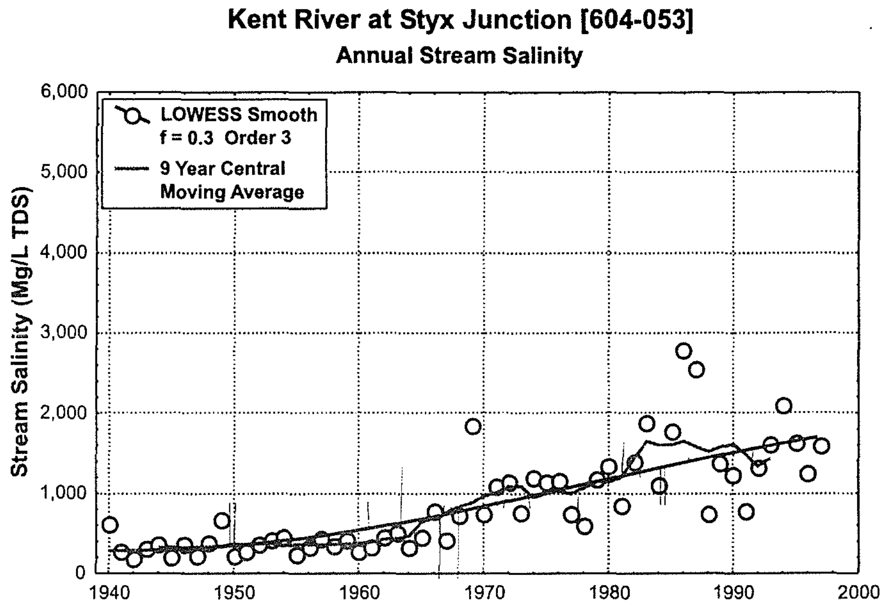

Figure 8: Annual Stream Salinity:
Kent River at Styx Junction [604-053] and Kenton [604-010]
(J. Scholz, unpublished data)

LOWESS: LOcally WEighted Scatterplot Smoothing (Helsel and Hirsch 1992)

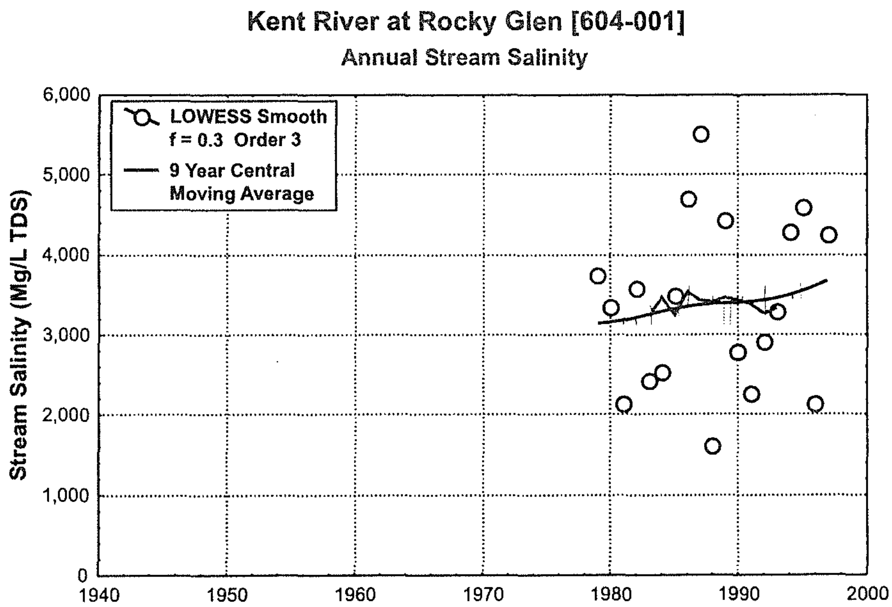

Figure 9: Annual Stream Salinity:
Kent River at Rocky Glen [604-001]

(J. Scholz, unpublished data)

LOWESS: LOcally WEighted Scatterplot Smoothing (Helsel and Hirsch 1992)

Table 2. Calculation of Salinity Reduction Target for Kent Catchment

Catchment	RAIN				
	Area km²	Volume m³ x 10⁶	Volume mm	Salt mg/L	Salt tonnes
Rocky Glen 1979-93	1102	623	565	20	12453
Styx Junction 1976-93	1843	1267	688	20	25341
S.J. - R.G.	741	644	870	20	12889

Catchment	STREAM									
	Before Treatment					After Treatment				
	Volume			Salt		Volume			Salt	
	Model $m^3 \times 10^6$	Record $m^3 \times 10^6$	mm	mg/L	tonnes	Model $m^3 \times 10^6$	Estimate $m^3 \times 10^6$	mm	mg/L	tonnes
Rocky Glen 1979-93	36.49	24.57	22.3	3131	76933	17.91	22.12	20.1	1429	31614
Styx Junction 1976-93		81.28	44.1	1143	92879		78.82	42.8	**550**	43350
S.J. - R.G.		56.70	76.5	281	15946		56.70	76.5	207	11736
Styx Junction 1956-65	=			390						

Catchment	SEEPAGE (SALT LOAD = SALT IN STREAM - 75% SALT IN RAIN)										
	Before Treatment						After Treatment				
	Volume			Salt		Reduce seepage to	Volume			Salt	
	Model $m^3 \times 10^6$	Record $m^3 \times 10^6$	mm	mg/L	tonnes		Model $m^3 \times 10^6$	Estimate $m^3 \times 10^6$	mm	mg/L	tonnes
Rocky Glen 1979-93	10.28	7.51	6.8	9000	67594		3.17	2.48	2.2	9000	22275
Styx Junction 1976-93		8.21	4.5	9000	73873	**33%**		2.70	1.5	9000	24344
S.J. - R.G.		0.70	0.9	9000	6280			0.23	0.3	9000	2069

N.b. Estimate 50% streamflow reduction at Rocky Glen after treatment

Median data used for record

1. Lake Nunijup in the Kent Catchment, May 1995

2. Swamp area in the Kent Catchment, May 1995

3. Jarrah/marri remnant vegetation in the Kent Catchment, May 1995

4. Salt-affected remnant vegetation in the Kent Catchment, January 1995

5. Salt-affected land in the Kent Catchment, January 1995

6. Young Tasmanian blue gum (E. globulus) *plantation in the Kent Catchment*

Spreadsheets

1. Locations and Sizes of RASCAL Projects for Subcatchments of the Upper Kent Catchmment

Subcatchment	PROJECT SW CORNER E	PROJECT SW CORNER N	SIZE C	SIZE R	OUTLET LOCATION E	OUTLET LOCATION N	OUTLET LOCATION C	OUTLET LOCATION R
47	503500	6177500	300	340	510362	6183112	274	224
45	507500	6182500	220	220	510537	6183412	121	36
46	511500	6182000	180	220	512462	6185362	38	134
31	513000	6185500	280	320	517287	6194937	171	377
44	507500	6178500	300	280	512312	6179437	192	37
38	512000	6177000	220	280	516812	6178712	192	68
37	513500	6181500	260	260	518062	6182012	182	20
54	493500	6169000	280	380	498937	6172252	217	130
53	496500	6172000	240	300	500487	6172637	159	25
49	503500	6173000	260	280	507937	6174187	177	47
43	506500	6176000	240	180	511912	6178387	216	95
42	510500	6175500	200	200	512562	6176237	82	29
36	516000	6176000	300	280	517087	6177812	43	72
52	497000	6167500	240	260	501812	6170487	192	119
51	500000	6171000	240	340	504662	6172312	186	52
48	507000	6169000	280	360	507587	6173362	23	174
39	511000	6172500	380	260	512262	6174987	50	99
55	498500	6166500	280	300	503087	6168662	183	86
50	503500	6169500	240	260	504162	6171287	26	71
40	511000	6168500	380	280	513737	6174637	109	245
41	517500	6172000	400	240	519062	6173287	62	51

Inflow from Catchment 33

continued ...

1. Locations and Sizes of RASCAL Projects for Subcatchments of the Upper Kent Catchmment

... continued

Subcatchment	PROJECT SW CORNER E	PROJECT SW CORNER N	SIZE C	SIZE R	OUTLET LOCATION E	OUTLET LOCATION N	OUTLET LOCATION C	OUTLET LOCATION R
13	528000	6198000	360	260	530062	6199912	82	76
30	516500	6194500	340	340	519512	6194937	120	17
27	523000	6194000	320	320	526937	6195887	157	75
4	527000	6191000	320	440	533337	6195462	253	178
3	531000	6196000	200	200	531987	6196462	39	18
1	535000	6196000	200	280	537537	6196987	101	39
29	515000	6185500	420	460	524687	6192412	387	276
26	520000	6194000	320	320	525412	6194562	216	22
28	526000	6189000	280	280	526612	6192037	24	121
2	533000	6190000	320	360	538287	6192912	211	116
5	537800	6192500	308	300	538737	6192962	37	18
7	542500	6192500	360	260	543112	6194062	24	62
291	521200	6189300	132	108	523787	6189687	103	15
25	521500	6187000	300	340	524487	6188462	119	58
251	524500	6187900	120	104	525512	6188512	40	24
14	536000	6187000	280	280	537262	6190262	50	130
6	539500	6191000	300	320	539762	6192987	10	79
8	541600	6190300	216	132	542362	6192837	30	101
35	516500	6182000	220	240	519837	6184887	133	115
24	521000	6184000	360	260	527662	6186437	266	97
15	530000	6186500	320	260	531762	6187187	70	27
10	536000	6184000	400	360	537137	6189987	45	239
101	538000	6189500	220	120	538487	6190537	19	41
12	544000	6185000	360	360	544812	6189812	32	192
33	518000	6178000	300	360	518812	6181662	32	146
23	523500	6178000	300	380	524362	6183512	34	220
16	528000	6183000	280	300	528837	6185887	33	115
11	532500	6175000	380	600	533437	6185387	37	415
9	541400	6186000	184	194	542087	6189162	27	126
22	540500	6182000	360	240	544387	6182787	155	31
34	521000	6176000	200	280	522987	6182187	79	247
32	523500	6173500	420	380	528562	6181812	202	332
17	528500	6176000	400	360	531137	6184112	105	324
18	535000	6177000	280	240	538462	6181937	138	197
20	539000	6176500	348	400	540712	6180437	68	157
21	544000	551500	300	380	544537	6181712	21	225208
19	534000	6174500	352	240	537112	6176412	124	76
191	541000	6176500	260	160	541737	6178912	29	96

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2. Areas for Subcatchments of the Upper Kent Catchment

Subcatchment identifier	13	4	3	1	2	5	7	8	6	12	9	101	14	10	15
Drains to	4	2	2	2	14	14	6	6	14	9	10	14	15	15	16
SUMS FOR ISOLATED SUBCATCHMENTS															
Areas (km²)	20.48	28.90	9.06	10.58	31.45	20.14	23.23	7.94	14.57	30.31	9.37	5.41	7.10	19.30	24.53
Total rainfall ($m^3 \times 10^6$)	11.60	16.95	5.26	6.11	18.84	12.10	14.23	4.80	8.88	18.14	5.65	3.28	4.36	11.79	15.03
Average rainfall (mm)	566.2	586.5	580.9	577.5	599.0	600.8	612.7	604.9	609.6	598.6	602.8	606.8	614.4	610.7	612.6
As at 1991															
Cleared area (km²)	15.14	14.45	5.44	8.22	18.39	14.28	18.65	5.21	11.76	22.30	8.50	4.69	5.72	17.50	20.09
Clearing (%)	74%	50%	60%	78%	58%	71%	80%	66%	81%	74%	91%	87%	80%	91%	82%
Forest w/o u/s clearing	3.23	10.54	2.75	1.44	9.18	3.49	2.91	1.48	1.4	4.47	0.39	0.31	0.71	0.77	2.58
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS															
Areas (km²)	20.48	49.38	9.06	10.58	100.46	20.14	23.23	7.94	45.74	30.31	39.68	5.41	178.85	58.97	262.36
Total rainfall ($m^3 \times 10^6$)	11.60	28.55	5.26	6.11	58.76	12.10	14.23	4.80	27.92	18.14	23.79	3.28	106.42	35.58	157.02
Average rainfall (mm)	566.2	578.1	580.9	577.5	584.8	600.8	612.7	604.9	610.3	598.6	599.6	606.8	595.0	603.2	598.5
As at 1991															
Cleared area (km²)	15.14	29.6	5.44	8.22	61.65	14.28	18.65	5.21	35.62	22.3	30.8	4.69	121.95	48.3	190.35
Clearing (%)	74%	60%	60%	78%	61%	71%	80%	66%	78%	74%	78%	87%	68%	82%	73%
Forest w/o u/s clearing	3.23	13.78	2.75	1.44	27.15	3.49	2.91	1.48	5.79	4.47	4.85	0.31	37.46	5.63	45.66

Subcatchment identifier	17	21	22	20	18	11	16	191	19	32	30	29	291	28	27
Drains to	16	20	20	18	11	16	23	19		23	29	25	25	25	26
SUMS FOR ISOLATED SUBCATCHMENTS															
Areas (km²)	37.80	27.33	19.31	18.67	12.06	29.95	19.15	11.92	16.62	44.79	33.94	39.29	3.92	20.26	20.73
Total rainfall ($m^3 \times 10^6$)	24.91	16.55	11.53	11.49	7.79	18.70	11.94	7.55	11.15	30.78	18.01	23.29	2.34	12.03	11.94
Average rainfall (mm)	659.0	605.5	597.1	615.3	645.8	624.4	623.5	633.5	671.1	687.2	530.6	592.8	596.1	593.8	575.9
As at 1991															
Cleared area (km²)	27.54	24.24	17.41	14.74	9.99	26.21	15.47	8.15	11.24	27.80	26.15	21.53	1.55	15.60	15.58
Clearing (%)	73%	89%	90%	79%	83%	88%	81%	68%	68%	62%	77%	55%	40%	77%	75%
Forest w/o u/s clearing	6.45	1.13	0.71	2.17	1.05	1.7	2.28	2.59	2.71	12.95	5.74	11.98	1.82	2.82	3.11
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS															
Areas (km²)	37.80	27.33	19.31	65.31	77.37	107.32	426.63	11.92	28.54	44.79	33.94	73.23	3.92	20.26	20.73
Total rainfall ($m^3 \times 10^6$)	24.91	16.55	11.53	39.56	47.35	66.05	259.93	7.55	18.7	30.78	18.01	41.30	2.34	12.03	11.94
Average rainfall (mm)	659.0	605.5	597.1	605.8	612.0	615.5	609.3	633.5	655.4	687.2	530.6	564.0	596.1	593.8	575.9
As at 1991															
Cleared area (km²)	27.54	24.24	17.41	56.38	66.37	92.59	325.94	8.15	19.39	27.8	26.15	47.68	1.55	15.6	15.58
Clearing (%)	73%	89%	90%	86%	86%	86%	76%	68%	68%	62%	77%	65%	40%	77%	75%
Forest w/o u/s clearing	6.45	1.13	0.71	4.01	5.06	6.77	61.15	2.59	5.30	12.95	5.74	17.73	1.82	2.82	3.11

Abbreviations:
km² = square kilometres
w/o = without
u/s = upstream

continued ...

2. Areas for Subcatchments of the Upper Kent Catchment
... continued

Subcatchment identifier	26	25	251	24	23	35	34	33	38	31	37	36	41	40	43
Drains to	25	24	24	23	33	33	33	36	36	37	36	39	40	39	42
SUMS FOR ISOLATED SUBCATCHMENTS															
Areas (km²)	15.65	16.08	2.60	23.98	26.41	9.49	10.46	26.59	16.09	31.07	12.12	19.67	27.24	30.20	7.94
Total rainfall ($m^3 \times 10^6$)	9.05	9.51	1.56	14.74	17.25	6.18	7.20	17.81	11.49	19.50	8.24	13.96	19.54	22.52	5.87
Average rainfall (mm)	578.4	591.3	599.1	614.9	653.2	651.9	688.2	669.7	714.0	627.7	679.9	709.5	717.1	745.8	740.3
As at 1991															
Cleared area (km²)	9.21	7.31	1.95	15.53	20.43	4.53	8.82	20.45	10.83	12.65	7.39	15.24	14.36	3.36	3.25
Clearing (%)	59%	45%	75%	65%	77%	48%	84%	77%	67%	41%	61%	77%	53%	11%	41%
Forest w/o u/s clearing	5.05	6.89	0.4	5.27	3.91	3.74	0.81	3.36	3.26	15.15	3.52	1.92	9.52	25.64	3.63
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS															
Areas (km²)	36.38	149.87	2.60	176.44	674.26	9.49	10.46	720.80	16.09	31.07	43.19	799.75	27.24	57.44	7.94
Total rainfall ($m^3 \times 10^6$)	20.99	86.17	1.56	102.47	410.42	6.18	7.20	441.61	11.49	19.50	27.74	494.80	19.54	42.06	5.87
Average rainfall (mm)	577.0	574.9	599.1	580.7	608.7	651.9	688.2	612.7	714.0	627.7	642.3	618.7	717.1	732.2	740.3
As at 1991															
Cleared area (km²)	24.79	96.93	1.95	114.41	488.58	4.53	8.82	522.37	10.83	12.65	20.03	568.48	14.36	17.72	3.25
Clearing (%)	68%	65%	75%	65%	72%	48%	84%	72%	67%	41%	46%	71%	53%	31%	41%
Forest w/o u/s clearing	8.16	37.42	0.40	43.09	121.10	3.74	0.81	129.02	3.26	15.15	18.67	152.87	9.52	35.17	3.63

Subcatchment identifier	46	45	47	44	42	39	49	48	51	50	53	54	52	55
Drains to	45	44	44	42	39	48	48	50	50	55	52	52	55	
SUMS FOR ISOLATED SUBCATCHMENTS														
Areas (km²)	7.13	10.48	26.03	18.52	7.54	20.36	19.00	24.42	19.05	15.62	18.46	23.96	12.08	13.91
Total rainfall ($m^3 \times 10^6$)	4.90	7.36	19.14	13.37	5.54	14.93	14.36	18.44	14.89	12.18	14.70	19.90	10.10	11.61
Average rainfall (mm)	687.9	702.2	735.4	722.2	734.6	733.6	755.9	755.0	781.4	779.8	796.0	830.8	836.3	834.2
As at 1991														
Cleared area (km²)	3.95	6.53	18.33	7.69	6.55	15.05	11.50	6.50	9.65	5.76	13.00	15.60	7.05	0.48
Clearing (%)	55%	62%	70%	42%	87%	74%	61%	27%	51%	37%	70%	65%	58%	3%
Forest w/o u/s clearing	2.20	2.82	5.58	8.60	0.28	2.74	4.36	15.79	3.16	8.62	3.12	5.41	3.16	12.83
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS														
Areas (km²)	7.13	17.61	26.03	62.16	77.63	955.18	19.00	998.60	19.05	1033.27	18.46	23.96	54.50	1101.68
Total rainfall ($m^3 \times 10^6$)	4.90	12.26	19.14	44.78	56.19	607.98	14.36	640.78	14.89	667.85	14.70	19.90	44.70	724.16
Average rainfall (mm)	687.9	696.4	735.4	720.4	723.8	636.5	755.9	641.7	781.4	646.3	796.0	830.8	820.2	657.3
As at 1991														
Cleared area (km²)	3.95	10.48	18.33	36.50	46.31	647.57	11.5	665.56	9.65	680.97	13	15.6	35.65	717.1
Clearing (%)	55%	60%	70%	59%	60%	68%	61%	67%	51%	66%	70%	65%	65%	65%
Forest w/o u/s clearing	2.20	5.02	5.58	19.20	23.11	213.88	4.36	234.03	3.16	245.81	3.12	5.41	11.68	270.33

Abbreviations:
km² = square kilometres
w/o = without
u/s = upstream

3. Flows for 1991 Clearing for Subcatchments of the Upper Kent Catchment

Subcatchment identifier	13	4	3	1	2	5	7	8	6	12	9	101	14	10	15
Drains to	4	2	2	2	14	14	6	6	14	9	10	14	15	15	16
SUMS FOR ISOLATED SUBCATCHMENTS															
Stream flow (m^3)	86281	1324749	278841	248707	930345	663514	686195	226127	419840	-533075	116363	65038	172990	266810	449021
Stream flow (mm)	4	46	31	24	30	33	30	28	29	-18	12	12	24	14	18
Seepage (m^3)	240590	433279	108886	147730	335580	217045	245769	113412	170780	347032	75043	40695	49191	151871	251380
Seepage (mm)	12	15	12	14	11	11	11	14	12	11	8	8	7	8	10
Seepage/stream flow (%)	279%	33%	39%	59%	36%	33%	36%	50%	41%	-65%	64%	63%	28%	57%	56%
Seepage inside forest (m^3)	30364	119659	24486	11374	79242	33743	23239	14645	12251	45553	1709	1934	4241	4277	16668
Seepage inside forest (mm)	9	11	9	8	9	10	8	10	9	10	4	6	6	6	6
Seepage outside forest (m^3)	210225	313620	84400	136356	256339	183302	222530	98767	158530	301479	73335	38761	44949	147595	234712
Seepage outside forest (mm)	12	17	13	15	12	11	11	15	12	12	8	8	7	8	11
Storage loss (m^3)	-109068	-216062	-72771	-62242	-143752	-86600	-56430	-42256	-50389	-82916	-19564	-18526	-19174	-38237	-101995
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS															
Stream flow (m^3)	86281	1411029	278841	248707	2868922	663514	686195	226127	1332162	-533075	-416712	65038	5102627	-149902	5401746
Stream flow (mm)	4	29	31	24	29	33	30	28	29	-18	-11	12	29	-3	21
Seepage (m^3)	240590	673869	108886	147730	1266065	217045	245769	113412	529961	347032	422075	40695	2102957	573946	2928283
Seepage (mm)	12	14	12	14	13	11	11	14	12	11	11	8	12	10	11
Seepage/stream flow (%)	279%	48%	39%	59%	44%	33%	36%	50%	40%	-65%	-101%	63%	41%	-383%	54%
Seepage inside forest (m^3)	30364	150023	24486	11374	265125	33743	23239	14645	50134	45553	47261	1934	355178	51538	423385
Seepage inside forest (mm)	9	11	9	8	10	10	8	10	9	10	10	6	9	9	9
Seepage outside forest (m^3)	210225	523845	84400	136356	1000939	183302	222530	98767	479827	301479	374814	38761	1747778	522408	2504899
Seepage outside forest (mm)	12	15	13	15	14	11	11	15	12	12	11	8	12	10	12
Storage loss (m^3)	-109068	-325129	-72771	-62242	-603894	-86600	-56430	-42256	-149075	-82916	-102479	-18526	-877270	-140716	-1119981

Subcatchment identifier	17	21	22	20	18	11	16	191	19	32	30	29	291	28	27
Drains to	16	20	20	18	11	16	23	19		23	29	25	25	25	26
SUMS FOR ISOLATED SUBCATCHMENTS															
Stream flow (m^3)	1322352	234519	191579	457287	388717	537125	458539	542771	-143343	1892430	442055	-810961	194159	259843	317326
Stream flow (mm)	35	9	10	24	32	18	24	46	-9	42	13	-21	50	13	15
Seepage (m^3)	500642	171111	142348	111701	129005	289597	199640	106282	201924	504654	364268	315996	36559	237415	288946
Seepage (mm)	13	6	7	6	11	10	10	9	12	11	11	8	9	12	14
Seepage/stream flow (%)	38%	73%	74%	24%	33%	54%	44%	20%	-141%	27%	82%	-39%	19%	91%	91%
Seepage inside forest (m^3)	67328	5657	3234	12223	6981	9428	20059	23475	26081	109097	34580	75459	11494	20141	26766
Seepage inside forest (mm)	10	5	5	6	7	6	9	9	10	8	6	6	6	7	9
Seepage outside forest (m^3)	433314	165455	139114	99477	122024	280169	179580	82807	175842	395557	329688	240537	25064	217274	262180
Seepage outside forest (mm)	14	6	7	6	11	10	11	9	13	12	12	9	12	12	15
Storage loss (m^3)	-136019	-72993	-44822	-42970	-30611	-76002	-64955	-45620	-30843	-188271	-86375	-215384	-18405	-102522	-93107
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS															
Stream flow (m^3)	1322352	234519	191579	883385	1272103	1809228	8991864	542771	-143343	1892430	442055	-368906	194159	259843	317326
Stream flow (mm)	35	9	10	14	16	17	21	46	-5	42	13	-5	50	13	15
Seepage (m^3)	500642	171111	142348	425160	554165	843762	4472327	106282	201924	504654	364268	680264	36559	237415	288946
Seepage (mm)	13	6	7	7	7	8	10	9	7	11	11	9	9	12	14
Seepage/stream flow (%)	38%	73%	74%	48%	44%	47%	50%	20%	-141%	27%	82%	-184%	19%	91%	91%
Seepage inside forest (m^3)	67328	5657	3234	21114	28095	37523	548295	23475	26081	109097	34580	110039	11494	20141	26766
Seepage inside forest (mm)	10	5	5	5	6	6	9	9	5	8	6	6	6	7	9
Seepage outside forest (m^3)	433314	165455	139114	404046	526069	806239	3924032	82807	175842	395557	329688	570225	25064	217274	262180
Seepage outside forest (mm)	14	6	7	7	7	8	11	9	8	12	12	10	12	12	15
Storage loss (m^3)	-136019	-72993	-44822	-160785	-191396	-267398	-1588354	-45620	-30843	-188271	-86375	-301758	-18405	-102522	-93107

Abbreviations:
Storage loss (m^3) = cubic metres
mm = millimetres

Assumptions:
Lower soil layer 20 m deep with permeability 3m/yr/unit hydraulic gradient
Peak leaf area index for pasture = 2.7

continued ...

3. Flows for 1991 Clearing for Subcatchments of the Upper Kent Catchment

... continued

Subcatchment identifier	26	25	251	24	23	35	34	33	38	31	37	36	41	40	43
Drains to	25	24	24	23	33	33	33	36	36	37	36	39	40	39	42
SUMS FOR ISOLATED SUBCATCHMENTS															
Stream flow (m³)	565410	276842	71639	-369074	795143	-343127	398098	1054193	897208	-485127	710333	1305802	1178184	2094687	480083
Stream flow (mm)	36	17	28	-15	30	-36	38	40	56	-16	59	66	43	69	60
Seepage (m³)	213459	218834	28953	287302	316754	108960	121946	357467	214108	345736	190948	304062	255809	230392	107818
Seepage (mm)	14	14	11	12	12	11	12	13	13	11	16	15	9	8	14
Seepage/stream flow (%)	38%	79%	40%	-78%	40%	-32%	31%	34%	24%	-71%	27%	23%	22%	11%	22%
Seepage inside forest (m³)	58231	83899	3216	39126	27801	32602	5771	22767	32380	131708	42424	24247	83034	181825	39338
Seepage inside forest (mm)	12	12	8	7	7	9	7	7	10	9	12	13	9	7	11
Seepage outside forest (m³)	155228	134935	25736	248176	288952	76357	116175	334700	181728	214029	148524	279815	172775	48568	68480
Seepage outside forest (mm)	15	15	12	13	13	13	12	14	14	13	17	16	10	11	16
Storage loss (m³)	-102043	-116201	-10372	-81433	-77009	-37875	-25919	-68109	-48724	-196122	-56545	-58809	-145665	-102502	-33424
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS															
Stream flow (m³)	882736	1244674	71639	947239	12626677	-343127	398098	13735841	897208	-485127	225206	16164057	1178184	3272871	480083
Stream flow (mm)	24	8	28	5	19	-36	38	19	56	-16	5	20	43	57	60
Seepage (m³)	502405	1675476	28953	1991731	7285465	108960	121946	7873837	214108	345736	536684	8928692	255809	486201	107818
Seepage (mm)	14	11	11	11	11	11	12	11	13	11	12	11	9	8	14
Seepage/stream flow (%)	57%	135%	40%	210%	58%	-32%	31%	57%	24%	-71%	238%	55%	22%	15%	22%
Seepage inside forest (m³)	84997	310569	3216	352912	1038105	32602	5771	1099245	32380	131708	174132	1330004	83034	264859	39338
Seepage inside forest (mm)	10	8	8	8	9	9	7	9	10	9	9	9	9	8	11
Seepage outside forest (m³)	417408	1364907	25736	1638819	6247360	76357	116175	6774592	181728	214029	362552	7598688	172775	221342	68480
Seepage outside forest (mm)	15	12	12	12	11	13	12	11	14	13	15	12	10	10	16
Storage loss (m³)	-195149	-734035	-10372	-825840	-2679474	-37875	-25919	-2811377	-48724	-196122	-252666	-3171576	-145665	-248167	-33424

Subcatchment identifier	46	45	47	44	42	39	49	48	51	50	53	54	52	55
Drains to	45	44	44	42	39	48	48	50	50	55	52	52	55	
SUMS FOR ISOLATED SUBCATCHMENTS														
Stream flow (m³)	156248	501997	1482446	1275966	462365	1210301	1430368	1214060	1369750	1037186	1705117	2424581	1427657	879918
Stream flow (mm)	22	48	57	69	61	59	75	50	72	66	92	101	118	63
Seepage (m³)	114521	139038	301497	195460	95908	247074	266897	271485	224699	161001	291849	371759	228384	24971
Seepage (mm)	16	13	12	11	13	12	14	11	12	10	16	16	19	2
Seepage/stream flow (%)	73%	28%	20%	15%	21%	20%	19%	22%	16%	16%	17%	15%	16%	3%
Seepage inside forest (m³)	30348	22949	35998	85384	2347	25776	30814	135892	24382	34139	28517	50361	18791	16940
Seepage inside forest (mm)	14	8	6	10	8	9	7	9	8	4	9	9	6	1
Seepage outside forest (m³)	84173	116088	265499	110076	93561	221298	236083	135593	200317	126862	263332	321398	209594	8030
Seepage outside forest (mm)	17	15	13	11	13	13	16	16	13	18	17	17	24	7
Storage loss (m³)	-30621	-24145	-51604	-75000	-12944	-54306	-32149	-86610	-26474	-16328	-27631	-32185	-13450	-125
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS														
Stream flow (m³)	156248	658245	1482446	3416656	4359104	25006333	1430368	27650762	1369750	30057698	1705117	2424581	5557355	36494970
Stream flow (mm)	22	37	57	55	56	26	75	28	72	29	92	101	102	33
Seepage (m³)	114521	253558	301497	750515	954240	10616207	266897	11154589	224699	11540288	291849	371759	891993	12457252
Seepage (mm)	16	14	12	12	12	11	14	11	12	11	16	16	16	11
Seepage/stream flow (%)	73%	39%	20%	22%	22%	42%	19%	40%	16%	38%	17%	15%	16%	34%
Seepage inside forest (m³)	30348	53297	35998	174679	216364	1837003	30814	2003708	24382	2062229	28517	50361	97669	2176839
Seepage inside forest (mm)	14	11	6	9	9	9	7	9	8	8	9	9	8	8
Seepage outside forest (m³)	84173	200261	265499	575836	737876	8779204	236083	9150880	200317	9478059	263332	321398	794324	10280413
Seepage outside forest (mm)	17	16	13	13	14	12	16	12	13	12	17	17	19	12
Storage loss (m³)	-30621	-54765	-51604	-181369	-227737	-3701787	-32149	-3820545	-26474	-3863346	-27631	-32185	-73266	-3936737

Abbreviations:

Storage loss (m³) = cubic metres

mm = millimetres

Assumptions:

Lower soil layer 20 m deep with permeability 3m/yr/unit hydraulic gradient

Peak leaf area index for pasture = 2.7

4. Model Minimum Tree-Planting for Subcatchments of the Upper Kent Catchment

Target: 67% reduction in seepage
Criteria: Plant on pasture land where
seepage > 12 mm/yr
Allow draw to 30% depth of bottom soil layer

Subcatchment identifier	**13**	**4**	**3**	**1**	**2**	**5**	**7**	**8**	**6**	**12**	**9**	**101**	**14**	**10**	**15**
Drains to	4	2	2	2	14	14	6	6	14	9	10	14	15	15	16
SUMS FOR ISOLATED SUBCATCHMENTS															
Area planted (km²)	5.76	6.81	2.28	3.6	5.62	4.63	6.36	2.31	3.93	7.46	1.91	1.07	1.06	4.08	6.92
Planted/cleared area (%)	38%	47%	42%	44%	31%	32%	34%	44%	33%	33%	22%	23%	19%	23%	34%
Predicted seepage (m³)	83696	204381	44195	33296	171098	92080	77214	39648	49666	143572	29988	14279	23510	58626	77256
Predicted out.for. seepage (m³)	60666	109369	23763	24607	109345	67824	59685	29361	42058	113045	28909	12860	20689	56560	64460
% of 1991 seepage	35%	47%	41%	23%	51%	42%	31%	35%	29%	41%	40%	35%	48%	39%	31%
% of 1991 out. for. seepage	29%	35%	28%	18%	43%	37%	27%	30%	27%	37%	39%	33%	46%	38%	27%
Review seepage (m³)	93380	220421	50993	39563	186128	98483	83017	47691	55474	167662	31428	15688	24908	60073	82910
Review out. for. seepage (m³)	65327	108340	27475	29069	110043	66798	61135	34625	44528	125563	29831	13932	21253	56257	67586
Review streamflow (m³)	-80378	930935	187904	87634	668745	467228	401671	98463	195226	-745185	56414	26212	131156	128898	180923
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS															
area planted (km²)	5.76	12.57	2.28	3.6	24.07	4.63	6.36	2.31	12.61	7.46	9.37	1.07	43.43	13.45	63.8
Planted/cleared area (%)	38%	42%	42%	44%	39%	32%	34%	44%	35%	33%	30%	23%	36%	28%	34%
Predicted seepage (m³)	83696	288077	44195	33296	536666	92080	77214	39648	166529	143572	173561	14279	833064	232187	1142507
Predicted out. for. seepage (m³)	60666	170035	23763	24607	327750	67824	59685	29361	131104	113045	141955	12860	560227	198515	823203
% of 1991 seepage	35%	43%	41%	23%	42%	42%	31%	35%	31%	41%	41%	35%	40%	40%	39%
% of 1991 out. for. seepage	29%	32%	28%	18%	33%	37%	27%	30%	27%	37%	38%	33%	32%	38%	33%
Review seepage (m³)	93380	313801	50993	39563	590486	98483	83017	47691	186181	167662	199089	15688	915746	259163	1257819
Review out. for. seepage (m³)	65327	173667	27475	29069	340253	66798	61135	34625	140288	125563	155394	13932	582523	211651	861760
Review streamflow (m³)	-80378	850556	187904	87634	1794840	467228	401671	98463	695360	-745185	-688771	26212	3114796	-559873	2735846

Subcatchment identifier	**17**	**21**	**22**	**20**	**18**	**11**	**16**	**191**	**19**	**32**	**30**	**29**	**291**	**28**	**27**
Drains to	16	20	20	18	11	16	23	19		23	29	25	25	25	26
SUMS FOR ISOLATED SUBCATCHMENTS															
Area planted (km²)	10.31	3.74	3.71	2.12	3.33	8.14	4.93	1.95	3.79	10.33	9.58	5.64	0.58	6.19	6.91
Planted/cleared area (%)	37%	15%	21%	14%	33%	31%	32%	24%	34%	37%	37%	26%	38%	40%	44%
Predicted seepage (m³)	165210	89130	61036	65258	37417	84032	70217	57733	87799	208821	116906	171525	20278	65751	74286
Predicted out. for. seepage (m³)	119879	86838	59777	58106	33798	78473	55016	39763	72675	118622	89543	116003	11122	52219	55457
% of 1991 seepage	33%	52%	43%	58%	29%	29%	35%	54%	43%	41%	32%	54%	55%	28%	26%
% of 1991 out. for. seepage	28%	52%	43%	58%	28%	28%	31%	48%	41%	30%	27%	48%	44%	24%	21%
Review seepage (m³)	177797	90615	61604	66405	40164	92662	75442	58371	91100	218824	126494	183399	21199	78317	86629
Review out. for. seepage (m³)	115412	85371	58890	54882	34054	84327	56625	36183	67484	112908	93789	109940	10109	60059	62194
Review streamflow (m³)	474235	123709	97730	388099	169634	169277	243669	430950	-427931	988368	147868	-964016	166831	27744	38035
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS															
Area planted (km²)	10.31	3.74	3.71	9.57	12.89	21.03	100.06	1.95	5.75	10.33	9.58	15.22	0.58	6.19	6.91
Planted/cleared area (%)	37%	15%	21%	17%	19%	23%	31%	24%	30%	37%	37%	32%	38%	40%	44%
Predicted seepage (m³)	165210	89130	61036	215424	252841	336873	1714806	57733	145532	208821	116906	288431	20278	65751	74286
Predicted out. for. seepage (m³)	119879	86838	59777	204721	238519	316992	1315090	39763	112439	118622	89543	205546	11122	52219	55457
% of 1991 seepage	33%	52%	43%	51%	46%	40%	38%	54%	72%	41%	32%	42%	55%	28%	26%
% of 1991 out. for. seepage	28%	52%	43%	51%	45%	39%	34%	48%	64%	30%	27%	36%	44%	24%	21%
Review seepage (m³)	177797	90615	61604	218625	258789	351451	1862509	58371	149471	218824	126494	309893	21199	78317	86629
Review out. for. seepage (m³)	115412	85371	58890	199144	233197	317524	1351321	36183	103667	112908	93789	203729	10109	60059	62194
Review streamflow (m³)	474235	123709	97730	609538	779172	948449	4402199	430950	3019	988368	147868	-816148	166831	27744	38035

Abbreviations:
km² = square kilometres
m³ = cubic metres
mm = millimetres
out. for. = outside forest

continued ...

4. Model Minimum Tree-Planting for Subcatchments of the Upper Kent Catchment
... continued

Target: 67% reduction in seepage
Criteria: Plant on pasture land where
seepage > 12 mm/yr
Allow draw to 30% depth of bottom soil layer

Subcatchment identifier	**26**	**25**	**251**	**24**	**23**	**35**	**34**	**33**	**38**	**31**	**37**	**36**	**41**	**40**	**43**
Drains to	25	24	24	23	33	33	33	36	36	37	36	39	40	39	42
SUMS FOR ISOLATED SUBCATCHMENTS															
Area planted (km²)	3.7	2.94	0.76	6.86	8.43	1.84	3.06	9.21	4.65	4.94	3.73	6.72	4.3	1.1	1.68
Planted/cleared area (%)	40%	40%	39%	44%	41%	41%	35%	45%	43%	39%	50%	44%	30%	33%	52%
Predicted seepage (m³)	100041	128963	10159	97821	83124	53040	33578	85359	75096	193709	67678	91277	153852	200957	58546
Predicted out. for. seepage (m³)	52028	59895	8017	70529	61128	26200	30556	69888	49508	80277	30508	76359	83104	25691	25095
% of 1991 seepage	47%	59%	35%	34%	26%	49%	28%	24%	35%	56%	35%	30%	60%	87%	54%
% of 1991 out. for. seepage	34%	44%	31%	28%	21%	34%	26%	21%	27%	38%	21%	27%	48%	53%	37%
Review seepage (m³)	106061	140822	10866	117317	90242	56583	35125	92029	84711	208633	73117	91673	161197	202439	60833
Review out. for. seepage (m³)	49995	59916	7729	80774	65766	24847	29793	72835	53888	80292	32738	70470	79587	21201	22349
Review streamflow (m³)	409602	175616	43642	-654516	242365	-478006	122247	316771	426245	-699312	321255	595946	822988	1975422	295063
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS															
Area planted (km²)	10.61	35.55	0.76	43.17	161.98	1.84	3.06	176.09	4.65	4.94	8.67	196.13	4.3	5.4	1.68
Planted/cleared area (%)	43%	37%	39%	38%	33%	41%	35%	34%	43%	39%	43%	35%	30%	30%	52%
Predicted seepage (m³)	174326	677749	10159	785729	2792480	53040	33578	2964457	75096	193709	261387	3392217	153852	354809	58546
Predicted out. for. seepage (m³)	107485	436268	8017	514814	2009654	26200	30556	2136299	49508	80277	110784	2372951	83104	108795	25095
% of 1991 seepage	35%	40%	35%	39%	38%	49%	28%	38%	35%	56%	49%	38%	60%	73%	54%
% of 1991 out. for. seepage	26%	32%	31%	31%	32%	34%	26%	32%	27%	38%	31%	31%	48%	49%	37%
Review seepage (m³)	192690	742920	10866	871104	3042680	56583	35125	3226417	84711	208633	281749	3684550	161197	363636	60833
Review out. for. seepage (m³)	112189	446003	7729	534505	2064501	24847	29793	2191975	53888	80292	113030	2429363	79587	100788	22349
Review streamflow (m³)	447637	1680	43642	-609194	5023737	-478006	122247	4984749	426245	-699312	-378057	5628883	822988	2798410	295063

Subcatchment identifier	**46**	**45**	**47**	**44**	**42**	**39**	**49**	**48**	**51**	**50**	**53**	**54**	**52**	**55**
Drains to	45	44	44	42	39	48	48	50	50	55	52	52	55	
SUMS FOR ISOLATED SUBCATCHMENTS														
Area planted (km²)	1.94	2.89	7.35	2.75	2.68	5.8	5.52	3.15	4.42	2.92	7.06	8.97	4.44	0.19
Planted/cleared area (%)	49%	44%	40%	36%	41%	39%	48%	48%	46%	51%	54%	58%	63%	38%
Predicted seepage (m³)	51990	46588	92664	125221	21580	83365	91333	178051	72443	60824	87300	116095	63815	19125
Predicted out. for. seepage (m³)	28193	29629	65341	49564	20889	65772	74145	57903	55921	32469	68328	78080	53249	3217
% of 1991 seepage	45%	34%	31%	64%	23%	34%	34%	66%	32%	38%	30%	31%	28%	77%
% of 1991 out. for. seepage	33%	26%	25%	45%	22%	30%	31%	43%	28%	26%	26%	24%	25%	40%
Review seepage (m³)	55838	50061	96531	132114	23991	87012	91626	180671	69052	60945	89219	120349	58996	20249
Review out. for. seepage (m³)	26580	28427	62655	47938	22344	63712	63722	46714	47260	27880	63265	73752	43646	3745
Review streamflow (m³)	-25150	206834	659735	1018998	174585	623319	741370	866309	756268	647640	778773	1145069	709051	893869
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS														
area planted (km²)	1.94	4.84	7.35	14.94	19.3	226.63	5.52	235.29	4.42	242.64	7.06	8.97	20.47	263.29
Planted/cleared area (%)	49%	46%	40%	41%	42%	35%	48%	35%	46%	36%	54%	58%	57%	37%
Predicted seepage (m³)	51990	98578	92664	316463	396589	4226981	91333	4496366	72443	4629634	87300	116095	267211	4915970
Predicted out. for. seepage (m³)	28193	57822	65341	172728	218712	2766230	74145	2898277	55921	2986668	68328	78080	199657	3189542
% of 1991 seepage	45%	39%	31%	42%	42%	40%	34%	40%	32%	40%	30%	31%	30%	39%
% of 1991 out. for. seepage	33%	29%	25%	30%	30%	32%	31%	32%	28%	32%	26%	24%	25%	31%
Review seepage (m³)	55838	105899	96531	334544	419369	4554567	91626	4826864	69052	4956861	89219	120349	268564	5245674
Review out. for. seepage (m³)	26580	55007	62655	165601	210293	2804156	63722	2914592	47260	2989732	63265	73752	180662	3174139
Review streamflow (m³)	-25150	181684	659735	1860417	2330065	11380677	741370	12988356	756268	14392264	778773	1145069	2632893	17919026

Abbreviations:
km² = square kilometres
m³ = cubic metres
mm = millimetres
out. for. = outside forest

5. Areas for the Wamballup Subcatchment Model Using Soft Photogrammetry for Elevation

Sub-catchments	211	212	22	20	18	11	111
Drains to	20	20	20	18	11	111	
SUMS FOR ISOLATED SUBCATCHMENTS							
Areas (km²)	14.05	14.54	17.05	16.77	10.11	15.68	13.81
Total rainfall ($m^3 \times 10^6$)	8.34	8.97	10.18	10.31	6.47	9.83	8.58
Average rainfall (mm)	593.7	616.8	597.0	614.4	640.4	626.7	621.3
As at 1991							
Cleared area (km²)	11.91	13.42	15.30	13.12	8.62	13.62	12.07
Clearing (%)	85%	92%	90%	78%	85%	87%	87%
Forest without u/s clearing (km²)	1.51	0.84	1.20	2.47	0.76	1.54	1.42
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS							
Areas (km²)	14.05	14.54	17.05	62.41	72.52	88.20	102.00
Total rainfall ($m^3 \times 10^6$)	8.34	8.97	10.18	37.79	44.26	54.09	62.67
Average rainfall (mm)	593.7	616.8	597.0	605.5	610.4	613.3	614.4
As at 1991							
Cleared area (km²)	11.91	13.42	15.30	53.76	62.38	76.00	88.07
Clearing (%)	85%	92%	90%	86%	86%	86%	86%
Forest without u/s clearing (km²)	1.51	0.84	1.20	6.02	6.78	8.32	9.74

Abbreviations:
km² = square kilometres   mm = millimetres   m³ = cubic metres   u/s = upstream

6. Flows for 1991 Clearing on the Wamballup Subcatchment Model Using Soft Photogrammetry for Elevation

Sub-catchments	211	212	22	20	18	11	111
drains to	20	20	20	18	11	111	
SUMS FOR ISOLATED SUBCATCHMENTS							
Stream flow (m³)	117023	84259	155719	415776	219670	273927	221453
Stream flow (mm)	8.33	5.80	9.13	24.79	21.73	17.47	16.04
Seepage (m³)	116489	108241	145029	156571	112430	173263	143310
Seepage (mm)	8.29	7.45	8.51	9.33	11.12	11.05	10.38
Seepage/stream flow (%)	100%	128%	93%	38%	51%	63%	65%
Seepage inside forest (m³)	10251	4758	8000	23943	5182	12570	11463
Seepage inside forest (mm)	6.79	5.65	6.67	9.69	6.85	8.15	8.06
Seepage outside forest (m³)	106237	103483	137029	132628	107248	160693	131846
Seepage outside forest (mm)	8.47	7.56	8.65	9.27	11.47	11.37	10.65
Storage loss (m³)	-49784	-27324	-39532	-49598	-23517	-46723	-39341
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS							
Stream flow (m³)	117023	84259	155719	772777	992447	1266374	1487827
Stream flow (mm)	8.33	5.80	9.13	12.38	13.69	14.36	14.59
Seepage (m³)	116489	108241	145029	526330	638760	812023	955333
Seepage (mm)	8.29	7.45	8.51	8.43	8.81	9.21	9.37
Seepage/stream flow (%)	100%	128%	93%	68%	64%	64%	64%
Seepage inside forest (m³)	10251	4758	8000	46952	52134	64704	76167
Seepage inside forest (mm)	6.79	5.65	6.67	7.80	7.69	7.78	7.82
Seepage outside forest (m³)	106237	103483	137029	479378	586626	747319	879166
Seepage outside forest (mm)	8.47	7.56	8.65	8.50	8.92	9.36	9.53
Storage loss (m³)	-49784	-27324	-39532	-166238	-189755	-236479	-275819

Abbreviations:
m³ = cubic metres
mm = millimetres

Assumptions:
Rainfall from isohyets. Catchment mean = 662 mm
Lower soil layer 20 m deep with permeability 3 m/yr/unit hydraulic gradient
Peak leaf area index for pasture = 2.7

7. Areas for the Wamballup Subcatchment Model Using 5 m Contours for Elevation

Sub-catchments	**21**	**22**	**20**	**18**	**11**	**111**
drains to	20	20	18	11	111	
SUMS FOR ISOLATED SUBCATCHMENTS						
Areas (km^2)	27.33	19.31	18.67	12.06	16.18	13.77
total rainfall ($m^3 \times 10^6$)	16.55	11.53	11.49	7.79	10.14	8.56
average rainfall (mm)	605.5	597.1	615.3	645.8	626.9	621.5
As at 1991						
Cleared area (km^2)	31.17	22.38	18.95	12.84	18.15	15.55
clearing (%)	114%	116%	102%	106%	112%	113%
forest without upstream clearing (km^2)	1.13	0.71	2.17	1.05	0.89	0.81
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS						
areas (km^2)	27.33	19.31	65.31	77.37	93.55	107.32
total rainfall ($m^3 \times 10^6$)	16.55	11.53	39.56	47.35	57.50	66.05
average rainfall (mm)	605.5	597.1	605.8	612.0	614.6	615.5
As at 1991						
Cleared area (km^2)	31.17	22.38	72.49	85.34	103.49	119.04
clearing (%)	114%	116%	111%	110%	111%	111%
forest without upstream clearing (km^2)	1.13	0.71	4.01	5.06	5.96	6.77

Abbreviations:
km^2 = square kilometres mm = millimetres m^3 = cubic metres

8. Flows for 1991 Clearing for the Wamballup Subcatchment Model Using 5 m Contours for Elevation

Sub-catchments	**21**	**22**	**20**	**18**	**11**	**111**
drains to	20	20	18	11	111	
SUMS FOR ISOLATED SUBCATCHMENTS						
Stream flow (m^3)	235350	192085	454549	388747	305942	234183
Stream flow (mm)	8.61	9.95	24.35	32.23	18.91	17.01
Seepage (m^3)	171110	142348	111699	128993	161730	127865
Seepage (mm)	6.26	7.37	5.98	10.69	10.00	9.29
Seepage/stream flow (%)	73%	74%	25%	33%	53%	55%
Seepage inside forest (m^3)	5657	3234	12223	6981	4543	4885
Seepage inside forest (mm)	5.02	4.53	5.63	6.65	5.08	6.03
Seepage outside forest (m^3)	165453	139114	99476	122012	157187	122980
Seepage outside forest (mm)	6.31	7.48	6.03	11.08	10.28	9.49
Storage loss (m^3)	-72471	-44626	-42708	-30433	-42065	-33771
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS						
Stream flow (m^3)	235350	192085	881984	1270731	1576673	1810856
Stream flow (mm)	8.61	9.95	13.50	16.42	16.85	16.87
Seepage (m^3)	171110	142348	425157	554150	715880	843745
Seepage (mm)	6.26	7.37	6.51	7.16	7.65	7.86
Seepage/stream flow (%)	73%	74%	48%	44%	45%	47%
Seepage inside forest (m^3)	5657	3234	21114	28095	32638	37522
Seepage inside forest (mm)	5.02	4.53	5.26	5.55	5.48	5.55
Seepage outside forest (m^3)	165453	139114	404043	526056	683243	806223
Seepage outside forest (mm)	6.31	7.48	6.59	7.28	7.80	8.02
Storage loss (m^3)	-72471	-44626	-159806	-190239	-232304	-266075

Abbreviations:
m^3 = cubic metres
mm = millimetres

Assumptions:
Lower soil layer 20 m deep with permeability 3 m/yr/unit hydraulic gradient
Peak leaf area index for pasture = 2.7

9. Seepage and Areas for Isolated Parts Common to Both Models of the Wamballup Subcatchment

Sub-catchments	211	212	22	20	18	11	total to	111
Drains to	20	20	20	18	11	111	11	
SUMS FOR SUBCATCHMENTS								
Areas (km²)	13.05	13.03	16.61	16.23	9.29	15.46	83.67	13.66
Total rainfall ($m^3 \times 10^6$)	7.75	8.04	9.92	9.97	5.96	9.69	51.32	8.48
Average rainfall (mm)	593.6	617.3	597.0	614.6	640.9	626.6	613.4	621.3
As at 1991								
Cleared area (km²)	11.05	12.03	14.88	12.63	7.96	13.48	72.04	11.99
Clearing (%)	85%	92%	90%	78%	86%	87%	86%	88%
Forest w/o u/s clearing (km²)	1.40	0.79	1.19	2.43	0.67	1.48	7.96	1.37
Old seepage (m³)	76469	86761	120636	99231	96154	154179	633430	127165
Old seepage (mm)	5.86	6.66	7.26	6.11	10.35	9.98	7.57	9.31
Old seepage outside forest (m³)	64098	75788	117646	87487	92135	149769	586923	122279
Old seepage outside forest (mm)	46	96	99	36	138	101	74	89
Old seepage inside forest (m³)	12370	10973	2989	11744	4020	4411	46507	4886
Old seepage inside forest (mm)	1.06	0.90	0.19	0.85	0.47	0.32	0.61	0.40
New seepage (m³)	110371	97949	143414	154082	103491	172597	781904	141849
New seepage (mm)	8.46	7.52	8.64	9.49	11.14	11.17	9.35	10.39
New seepage outside forest (m³)	100511	93483	135420	130224	99114	160124	718877	131158
New seepage outside forest (mm)	72	119	114	54	149	108	90	96
New seepage inside forest (m³)	9860	4466	7994	23858	4377	12472	63027	10691
New seepage inside forest (mm)	0.85	0.36	0.52	1.73	0.51	0.89	0.83	0.87
New/old seepage %	144%	113%	119%	155%	108%	112%	123%	112%
New/old seepage outside forest (%)	**157%**	**123%**	**115%**	**149%**	**108%**	**107%**	**122%**	**107%**
New/old seepage inside forest (%)	80%	41%	267%	203%	109%	283%	136%	219%
Old streamflow (m³)	108864	119467	168978	416927	218685	290384	1323305	233288
New streamflow (m³)	117665	73984	155157	412814	192895	272777	1225291	213451
New/old streamflow %	**108%**	**62%**	**92%**	**99%**	**88%**	**94%**	**93%**	**91%**

Abbreviations:

km² = square kilometres

m³ = cubic metres

mm = millimetres

Assumptions:

Rainfall from isohyets. Catchment mean = 662 mm

Lower soil layer 20 m deep with permeability 3 m/yr/unit hydraulic gradient

Peak leaf area index for pasture = 2.7

New = model using soft photogrammetry for elevation

Old = model using 5 m contours for elevation

Appendix A
Details of Computing Processes

A1. INTRODUCTION

The basic process to analyse a catchment is reported by Mauger (1996). That paper showed the major stages of the process and listed the RASCAL maps that were the principal products of each stage. Since then there have been changes to the process to incorporate more hydrologic functions and to improve the computing procedure. Due to the extent of the changes, a complete revision of this appendix has been necessary, compared to that published with Volumes 1 and 2 for the Upper Denmark and Wellington Catchments respectively. Reprocessing those catchments with the revised procedure has negligible impact on their results.

This appendix gives details of each stage in the processes in a top-down hierarchical style, based on the computing commands and input data files needed to execute the processes using the M.A.G.I.C. system.

A2. Conventions

Within this appendix the following fonts are used for computer inputs and outputs:

- `User input from the console or in batch files`
- `User input in data files`
- `Output from computer`

Data which may vary from case to case is shown in italics. File names are identified by having an extension (e.g. EXAMPLE.DAT). Files with extensions ".IN" are used as a substitute for console input when programs are run from batch files or when otherwise convenient.

Section numbers in [ ] show where more instructions or contents of data files are to be found within this appendix. In sections giving contents of files, '[ ]' references and comments in normal type on the same lines as computer inputs are not included in the actual file contents.

HOW TOPIC refers to background information and details of how to use TOPIC that can be found through the help screens of the MAGIC system on the computer.

A map numbering convention has been established to give some structure to the storage of maps in the RASCAL projects, and to enable command files to work on any project without the need to modify map numbers. Table A1 shows the categories of maps and Table A2 a normal assignment of maps to map numbers.

Table A1: Map Categories

Map number range	Map category	Notes
1-100	Raw data	Stored in project from external source
101-200	Derived data	Basic data computed from raw data or derived data
201-300	Catchment model	Result maps of shallow and deep groundwater modelling
301-400	Planting prediction	Result maps of predicting tree-planting
401-510	Scratch maps	Maps only needed temporarily while modelling

Table A2: Map Number Assignments

Raw Data	Derived Data	Catchment Model	Planting Prediction	Scratch Maps
1	101	201 Cumulative run-off	301	401
2	102 Aspect	202 Total pasture ET	302	:
3 TM band 3	103 Plan curvature	203 Streamflow	303 Tree greenness	409
4 TM band 4	104 Slope curvature	204 Minimum shallow + deep store	for current model	410 Possible pasture
5 TM band 5	105 Drain reduced slope	205 Storage loss	304 Annual pasture	overdraw
6	106	206 Final shallow storage	for current model	411
7	107 Slope	207 Final deep store	305	412 Current shallow
8	108	208	:	store
9	:	:	330	413 Run-off
10	115 Lake = 0, other = 1	210	331 Deep g/w drawn	414 Infiltration
11 Rainfall	116 Drainage directions	211 Net recharge	by planted trees	415
12 Pan evaporation	117 Dispersed drainage	212 Final deep drainage	332 Planted	:
13	118 Non-dispersed	213 Throughflow	discharge	419
:	Drainage residual	214 Surplus recharge	333 Planted tree	420 Current deep store
20	119 Nos of cells	215 Smoothed seepage volume	greenness	421 Current pasture ET,
21 Elevation	120 Greenness	216 Smoothed deep discharge	334	or a search cell count
22 Lake = 25, stream	121	217 Smoothed throughflow	335 Percentage planting	422 Surplus deep store
= width, other = 0	122	218 Smoothed surplus recharge	over native density	423 Net recharge to deep
23 Soil type	123 Greenness > 0	219 Seepage area	336	store
24	124 Full pasture LAI = 2.7	[*Maps 201-219 are saved results from*	:	424 required deep
25	125 Negligible pasture	*initial analysis*]	400	drainage
26 Farm properties	upstream = 1	220		425
27	126	:		426 Original tree cover
28	:	240		:
29	129	241 Cumulative run-off		435
30 Digitised	130 Smoothed infil rate	242 Total pasture ET		436 Annual
clearing	131	243 Streamflow		tree transpiration (mm)
31	:	244 Minimum shallow + deep store		437
32, 33 Planned	149	245 Storage loss		438 Perennial pasture
perennial pasture	150 Catchments	246 Final shallow storage		transpiration (mm)
34	151	247 Final deep store		439 Pasture max.
:	:	248		transpiration (mm)
49	200	:		440 Initial storage loss
50 Gauging		250		441 Current deep store,
locations		251 Net recharge		net recharge to deep g/w
51		252 Final deep drainage		442 Potential recharge
:		253 Throughflow		and discharge
54		254 Surplus recharge		443
55 Planned		255 Smoothed seepage volume		:
planting		256 Smoothed deep discharge		446
56		257 Smoothed throughflow		447 Final +ve deep
:		258 Smoothed surplus recharge		drainage
100		259 Seepage area		448
		[*Maps 241-259 are results from last*		449 Integrated storage
		analysis]		loss
		260		450
		:		:
		300		510

A3. MAJOR STAGES OF ANALYSIS

A3.1 Convert Raw Data to Equivalent Maps in a RASCAL Project

A. PREPARE RASCAL PROJECTS TO RECEIVE DATA

RASCAL < RASCAL.IN	[A5.1]	Create a series of 6 RASCAL projects that cover one-sixth of the Upper Kent catchment to hold basic maps of TM data, ground elevation and lakes (KNTFOR 1-6.RAS). Also create a low resolution project (cell side length = 200 m) that covers the whole catchment to hold maps of annual rainfall and pan evaporation (KENTISO.RAS).

B. GENERATE DATA BY INTERPOLATION BETWEEN LINES OF EQUAL VALUE

Used to create elevation from contours, annual rainfall from isohyets, and pan evaporation from annual isopleths. Using elevation as the example:

MICROSTATION	[A5.2]	Identify contours in design file and export contours to text file
GRIDSF < GRIDSF.IN	[A5.3]	Generate elevations in grid cells
RASCAL < STORE.IN	[A5.4]	Import elevations to RASCAL project

C. GENERATE GRIDDED THEMATIC MAPS FROM DIGITISED POLYGONS

Used to define areas planned for treatment in farm plans, lakes and mapping of soil types (soil type data have not been used in the project to date).

MICROSTATION	[A5.2]	Prepare data in polygon form and export polygons to text file
LISTIN < LISTIN.IN	[A5.5]	Import polygons to POLYANA file format Join lines into polygons if a polygon is represented by more than 1 line
POL2RAS < POL2RAS.IN	[A5.6]	Generate gridded thematic maps in RASCAL project

D. LOAD LANDSAT THEMATIC MAPPER DATA FROM BULK SOURCE

LSDEX < LSDEX.IN	[A5.7]	Extract TM bands from bulk TM data
RASCAL < STORETM.IN	[A5.8]	Import TM data into RASCAL project

A3.2 Compute Maps Required as Input to the Hydrologic Model

A. PREPARE BASE MAPS

PREMODEL *KENTFOR1*	[A6.1]	Determine vegetation from TM data in base projects Repeat for each of 6 base projects.

B. PREPARE SUBCATCHMENT PROJECTS

Generation of drainage data is best done on relatively small areas due to the search for drainage outlets when sinks are identified. The small areas are complete subcatchments that will be used to report results of modelling, generally having areas of about 30 km^2. Before the drainage is analysed, boundaries of subcatchments will only be known approximately by inspecting contour data. The recommended process described here is to create an over-sized RASCAL project for each subcatchment so that the boundary will not fall outside the project limits. After the boundary has been defined by analysis, a smaller project that fully contains the subcatchment can be specified. The smaller project is created and all the maps from the larger project copied to it so that surplus computing in the modelling process will be minimised. If the subcatchment mapped in the larger project lies within 2 cells of the project boundary at any point, the subcatchment could actually extend beyond the project. In such cases, the process should be repeated using a new project with more clearance on that side.

`RASCAL < RASCAL.IN`	[A5.1]	Create a RASCAL project for each subcatchment that has generous margins around the actual subcatchment boundary
`LOADSC`	[A6.2]	Load base maps from projects with basic maps into subcatchment projects
`INIT` *KENT01*	[A6.3]	Batch run to prepare initial maps for each subcatchment project
`SEERAS` *KENT01*	[A6.4]	Manually edit blank map to define outlets of subcatchments
`RASCAL < CATCH.IN`	[A6.5]	Generate subcatchment map from drainage data and outlet position
`RASCAL < TRIM.IN`	[A6.6]	Mark cells outside catchment to limit drainage integration
`SEERAS` *KENT01*	[A6.4]	View the generated catchment (map 150) and note the limits of a project that has a narrow margin (1 or 2 cells) around the subcatchment
`RASCAL < RASCAL.IN`	[A5.1]	Create a RASCAL project for each subcatchment using the limits noted in the previous step
`CALL COPYIN` *KENTB01 KENT01*		
`COPYRAS < COPYRAS.IN`	[A6.6]	Copy all the maps from the larger project to the smaller project. The larger project may be discarded after this.

At this stage, each subcatchment project contains the following maps:

3 TM BAND 3
4 TM BAND 4
5 TM BAND 5
11 RAINFALL
12 PAN EVAPORATION
21 ELEVATION
22 LAKE=10
50 GAUGING LOCATIONS
102 ASPECT
103 PLAN CURVATURE
104 SLOPE CURVATURE
105 DRAIN REDUCED SLOPE
107 SLOPE
115 LAKE=0, OTHER=1
116 DRAINAGE DIRECTIONS
117 DISPERSED DRAINAGE
118 NON-DISPERSED DRAINAGE RESIDUAL
119 NOS OF CELLS
120 13,103,45,14,12,8,42,47,142,135,150,245
123 GREENNESS > 0
124 FULL PASTURE LAI=2.7

125 NEGLIGIBLE PASTURE UPSTREAM = 1
130 SMOOTHED INFIL RATE
150 CATCHMENTS

(Map 120 is GREENNESS based on values of TM bands 3,4,5 shown in title for pure components of greenness (13,103,45), shade (14,12,8), dead pasture (42,47,142) and bare soil (135,150,245).)

A3.3 Perform Hydrologic Modelling on Each Subcatchment

To automate the processing of all subcatchments, the batch file RUNMODEL.BAT combines the functions of initial modelling, planting and reviewing [A7.2, A7.3, A7.4]. It includes labelling output files with the subcatchment id number, and compressing the RASCAL projects to remove scratch maps and archive the final files. RUNMODEL processes one subcatchment whose id no. is the parameter. A higher level batch file, RUNALL.BAT, runs RUNMODEL for all subcatchments.

`RUNALL`	[A7.1]	Execute RUNMODEL

A3.4 Prepare Data for Presentation of Output

A. CLASSIFY RASTER MAPS

`RASCAL < CLASS.IN`	[A8.1]	Generate maps of: 3 rates of seepage (7, 15 and 37.5 m^3/yr) Native forest and scattered trees Proposed sites for planted trees Major streams

B. CONVERT RASTER MAPS TO POLYGONS FOR PRESENTATION IN MICROSTATION AND CREATE MICROSTATION PLOT FILES FOR MAP APPENDIX 3A AND 3B

`RASCAL < MAP.IN`	[A8.2]	Generate output files of polygon coordinates
`MICROSTATION`	[A8.3.1]	Import polygons to design file as linework, generate polygons, pattern the polygons
	[A8.3.2]	Plot maps of results using MACRO 'ALLDRAW1.BAS' in MicroStation.

C. OUTPUT DATA FOR TABLES BASED ON CATCHMENT AREAS [A8.4]

`RASCAL < OVROUT.IN`	[A8.5]	Create area output files.
`TABALL`	[A8.4.1]	Reformat the output files from OVROUT into text files that can be read into EXCEL spreadsheet
RUN EXCEL MACRO 'DATAIN'	[A8.4.2]	Load data from text file generated by program TABLIST (in RASCAL\EXE) into EXCEL spreadsheet
RUN EXCEL MACRO 'PRINTALL'	[A8.4.3]	Macro to print all of the required sheets in the spreadsheet

A4. FLOW OF MAP GENERATION IN RASCAL PROJECTS

The following table summarises the maps required as input and the maps produced as output for the processes involving RASCAL projects:

INPUT MAPS	PROCESS	REF	OUTPUT MAPS
	Interpolate from isolines		
	MICROSTATION	[A5.2]	11 Rainfall
	GRIDSF.IN	[A5.3]	12 Pan Evaporation
	STORE.DAT	[A5.4]	21 Elevation
	Grid polygon themes		
	MICROSTATION	[A5.2]	22 Lakes
	LISTIN.IN	[A5.5]	
	POL2RAS	[A5.7]	
	Load Landsat TM data		
	LSDEX.IN	[A5.8]	3 TM Band 3
	STORE.DAT	[A5.9]	4 TM Band 4
			5 TM Band 5
	Prepare base maps		
	PREMODEL.BAT	[A6.1]	
3 TM Band 3 4 TM Band 4 5 TM Band 5	GRNKNT.DAT	[A6.1.1]	120 Greenness labelled by coords of pure components, i.e. 13 103 45, 14 12 8, 42 47 142, 135 150 245
4 TM Band 4 5 TM Band 5 11 Rainfall 12 Pan Evaporation 120 Greenness	GRNPASKNT.DAT	[A6.1.2]	303 Green > 0 304 Full Pasture LAI = 2.7
	Prepare subcatchments		
	INIT.BAT	[A6.3]	
21 Elevation	TERRAIN.DAT	[A6.3.1]	102 Aspect 103 Plan Curvature 105 Slope
21 Elevation 102 Aspect	DRAIN.DAT	[A6.3.2]	116 Drainage Directions
102 Aspect 103 Plan Curvature 116 Drainage Directions	DISPER.DAT	[A6.3.3]	117 Dispersed Drainage
105 Slope 116 Drainage Directions 117 Dispersed Drainage	INFRATE.DAT	[A6.3.4]	130 Smoothed Infiltration Rate 118 Non-dispersed Drainage Residual 107 Actual Slope 105 Drain Reduced Slope

INPUT MAPS	PROCESS	REF	OUTPUT MAPS
116 Drainage Directions	INTDRA.DAT	[A6.3.5]	119 Drain Integral of Nos of Cells
116 Drainage Directions 304 Full Pasture LAI = 2.7	RELG.DAT	[A6.3.6]	125 Negligible Pasture Upstream =1
	BLANK.DAT	[A6.3.7]	50 Blank Map for Gauging Locations
	SEERAS	[A6.4]	50 Gauging Locations
116 Drainage Directions 50 Gauging Locations	CATCH.IN	[A6.5]	150 Catchments
116 Drainage Directions 117 Dispersed Drainage 118 Non-dispersed Drainage Residual 150 Catchments	TRIM.IN	[A6.6]	116 Drainage Directions 117 Dispersed Drainage 118 Non-dispersed Drainage Residual
	Hydrologic modelling GWML.BAT	[A7.2]	
As Above	GRNPASKNT.DAT	[A6.1.2]	As Above
11 Rainfall 12 Pan Evaporation 105 Drain Reduced Slope 116 Drainage Directions 117 Dispersed Drainage 118 Non-disp. Drain Resid 150 Catchments 303 Green > 0 304 Full Pasture LAI = 2.7	GWMLYS.DAT	[A7.2.1]	253 Deep Throughflow 254 Surplus Recharge to deep 411 Rain Minus ET 412 Final Shallow Storage 413 Run-off 414 Infiltration to Deep in Month 421 Pasture ET in Month 436 Annual Tree Transpiration 439 Pasture Max. Transpiration 441 Net Recharge to Deep 442 Potential Recharge, Discharge
As for GWMLYS Plus: 412 Final Shallow Storage 436 Annual Tree Transp. 439 Pasture Max. Transp. 442 Deep Recharge, Discharge	GWMLY2.DAT	[A7.2.2]	As for GWMLYS Plus: 241 Run-off adjusted for Lakes 242 Total Pasture ET 243 Streamflow 244 Minimum Storage 245 Storage Loss 251 Total Net Recharge to Deep 252 Final Deep Drainage 420 Current Deep Store 422 Surplus Deep Store 423 Net Recharge in Month 440 Initial Storage Loss 447 Final +ve Deep Drainage 449 Integrated Storage Loss

INPUT MAPS	PROCESS	REF	OUTPUT MAPS
As for GWMLY2	GWMLY3.DAT	[A7.2.3]	As for GWMLYS Plus: 246 Final Shallow Store 247 Final Deep Store
252 Final Deep Drainage 253 Deep Throughflow 254 Surplus Recharge to deep	SMDISCH.DAT	[A7.2.4]	255 Smoothed Seepage Volume 256 Smoothed Deep Discharge 257 Smoothed Throughflow 258 Smoothed Surplus Recharge 259 Seepage area
241 Run-off Adj. for Lakes 242 Total Pasture ET 243 Streamflow 244 Minimum Storage 245 Storage Loss 251 Total Net Rech. to Deep 252 Final Deep Drainage 253 Deep Throughflow 254 Surplus Recharge to Deep 255 Smoothed Seepage Vol. 256 Smoothed Deep Disch. 257 Smoothed Throughflow 258 Smoothed Surplus Rech. 303 Green > 0 304 Full Pasture LAI = 2.7	SAVORIG.DAT	[A7.2.5]	201 Run-off adj. for Lakes 202 Total Pasture ET 203 Streamflow 204 Minimum Storage 205 Storage Loss 211 Total Net Rech. to Deep 212 Final Deep Drainage 213 Deep Throughflow 214 Surplus Recharge to deep 215 Smoothed Seepage Vol. 216 Smoothed Deep Disch. 217 Smoothed Throughflow 218 Smoothed Surplus Rech.e 123 Green > 0 124 Full Pasture LAI = 2.7
11 Rainfall 12 Pan Evaporation 105 Drain Reduced Slope 117 Dispersed Drainage 118 Non-disp. Drain Resid. 123 Green > 0 124 Full Pasture LAI=2.7 125 Neg. Past. U/s = 1 201 Run-off Adj. for Lakes 202 Total Pasture ET 212 Final Deep Drainage 213 Deep Throughflow 214 Surplus Recharge to Deep 216 Smoothed Deep Disch.	PLANT.DAT	[A7.3]	331 Deep G/W Drawn by Planted Trees 332 Smoothed Planted Discharge 333 Planted Tree Greenness 334 Planted Seepage Volume 335 % Planting Over Native Density 421 Planted Tree Criterion
	REVIEW.BAT	[A7.4]	
123 Green > 0 124 Full Pasture LAI = 2.1 333 Planted Tree Greenness	NEWPAST.DAT	[A7.4.1]	303 Green > 0 304 Full Pasture LAI = 2.7
	Make maps for plotting		
119 Drain Int. of Nos. of Cells 123 Green > 0 227 Smoothed Deep Disch. 333 Planted Tree Greenness	CLASS.IN MAP.IN MICROSTATION	[A8.1] [A8.2] [A8.3.1]	425 Classed Seepage Rates 426 Original Tree Cover 427 Proposed Sites for Planting 428 Streams with Catch. >100ha

A5. CONVERT RAW DATA TO EQUIVALENT MAPS IN A RASCAL PROJECT

A5.1 RASCAL.IN — Input File to Create RASCAL Project

```
KNTFOR1
Y
492000 6162000 840 800 25
N
```

Defines the location and size of the project named 'KENTFOR1'. [ref HOW RASCAL]. Vary name and data for other projects as shown in Table A5.1.

Table A.5.1 Raw Data Rascal Projects Used for the Upper Kent Catchment Model

Project	AMG West	AMG South	No. Rows	No. Columns	Cell Size
KNTFOR1	492000	6162000	840	800	25
KNTFOR2	512000	6162000	840	800	25
KNTFOR3	532000	6162000	840	800	25
KNTFOR4	492000	6183000	840	800	25
KNTFOR5	512000	6183000	840	800	25
KNTFOR6	532000	6183000	840	800	25
KENTISO	485000	6162000	240	350	200

A5.2 MicroStation — Export Digitised Lines Required for Gridding

Open the MicroStation design file containing the data which are to be gridded. Discern at which level the lines are currently residing by using the 'ANALYZE ELEMENT' function. When the gridding is to be interpolated between lines such as contours, then it may be more efficient to export the required region to a new design file first, if the region to be gridded is only a small subset of the contours. It should be noted that an edge strip should be allowed beyond the immediate gridding region such that at least two contours are cut when crossing the strip at any location.

Special functions have been developed by the Computer Services Section of the Water Resources Directorate for use within MicroStation. The functions are referred to as MDLs because they are written in the MicroStation Development Language.

Use the MDL 'DGN2ASC' to export the lines into the text format which can be read by M.A.G.I.C. programs. To load the MDL 'DGN2ASC' type in the 'key-in' window 'MDL L DGN2ASC'. The text format is described in HOW LISTIN. Before executing DGN2ASC, make sure contours are either in a 3D design file or have been 'tagged' with the ground level using the MDL TAGGING. Polygons must be 'tagged' with a value that represents the theme that is mapped by the polygon (e.g. for contour theme, the contour ground level must be 'tagged' in the z value).

A5.3 GRIDSF.IN

GRID.DAT	[A5.3.1]
OUT.PRN	File for messages generated by program
EXAMPLE.TXT	File exported from MicroStation design file
EXAMPLE.GRD	Output file for input to RASCAL project
Y	Yes

For further details of running program refer to manual [ref HOW GRIDSF]

A5.3.1. Contents of GRID.DAT

METHOD,ICONTR,RADIUS,QUAD,EDGE	
2 0 .F. .T. *2000*	Consider data within 2000 m of gridding area
NWX,NWY,WCS,NPTGL,NPTGQ	
0 0 *4000* 6 10	Set basic 'window' over gridding point to 4000 m
FMT, SING,SURF,WIND	
'(2F10.0,F10.4)' .F. .F. 0	Set output format and options for program reports

960 800
512012.5 6173987.5 535987.5 6173987.5
535987.5 6154012.5 512012.5 6154012.5

The last 3 lines define the center of cells for gridding positions in DEN-BASE. See "Quad Option" in HOW GRIDSF. Two numbers on 3rd last line are number of **columns** and **rows** respectively. Sequence of corner coordinates must be NW, NE, SE, SW to generate rows scanning West to East from North to South. Computed values of -99 indicate failure to calculate elevation, possibly due to lack of data in the vicinity. More data may be made available by increasing the EDGE value (2000 in above example). Increasing the window size (WCS) may solve the problem in some situations. Refer [HOW GRIDSF] for further information.

A5.4 Contents of STORE.IN

KENTFOR1	RASCAL project to receive data
STORE.DAT	[A5.4.1]
OUT.PRN	File for messages generated by program
Y	Extra data file to be nominated
EXAMPLE.GRD	[A5.3] Name of extra data file
Y	Update default filenames

Imports the list of gridded values into the RASCAL project 'KENTFOR1'.

A5.4.1 Contents of STORE.DAT

*21*STORE*R4* 1 *ELEVATION*
(20X,F10.0)
END

Specifies that the gridded data are to be stored in map 21 as 4-byte Real values. The input data has '20x,F10.0' format and is located in a separate file. Refer [HOW STORE] for further information.

A5.5 Contents of LISTIN.IN

LAKE.ASC	Text format file created by DGN2ASC
LAKE.PAN	POLYANA file of same data
OUT.PRN	File for messages generated by program
20	Consider joining if distance between ends < 20 m
Y	Update default filenames

Refer HOW LISTIN.

A5.6 Contents of POL2RAS.IN

P	Gridding polygons
LAKE.PAN	Input POLYANA file
KENTFOR1	Receiving RASCAL project
OUT.PRN	File for messages
22	Map no. for output
LAKE = 10	Title of output map
I2	Data type of output map
99	Map no. for recording irregular results
ERROR MAP	Title of map
I2	Data type of map
N	All polygons to be gridded
N	No more selection criteria
Y	Update default filenames

Refer HOW POL2RAS for more information.

A5.7 Contents of LSDEX.IN

EXAMPLE.TM	TM data source file
EXAMPLE	Name for output data files
4000 25 4096 24.91	Size of source data
6200000 450000 7	Location of NW corner, # of bands of source
3 3 4 5	# of bands to output, list of band nos to output
6162000 6183000 492000 512000	Bounds of area to output
25 25	Cell dimensions in output
Y	Update default filenames

The above is an example of LSDEX.IN contents. The actual file contents depends on the source of TM data. Program LSDEX may need to be run on different computers that can use the hardware that stores the TM data, e.g. magnetic tapes or cartridges. Program modifications may be needed to do this. Output files would then be transferred to the PC running RASCAL.

Output data is a separate file for each band at the specified spatial extent and resolution. The names of the files have extensions .LSn, where 'n' is the band number. The above example would generate 3 output files: EXAMPLE.LS3, EXAMPLE.LS4 and EXAMPLE.LS5. Refer to [HOW LSDEX] for further information.

A5.8 STORETM.IN

EXAMPLE	RASCAL project name
STORETM.DAT	[A5.9.1]
OUT.PRN	File for messages
Y	Extra data file to be given
EXAMPLE.LS3	[A5.8] File generated by LSDEX
Y	Update default filenames

A5.8.1 STORETM.DAT

```
3STORE                    2    TM BAND 3
END
```

Imports the Thematic Mapping data from the file 'EXAMPLE.LS3' into the project 'EXAMPLE'. Refer [HOW STORE] for further information.

A6. COMPUTE MAPS REQUIRED AS INPUT TO THE HYDROLOGIC MODEL

A6.1 Contents of PREMODEL.BAT

CALL PMIN GRNKNT.DAT *DUMMY* %1	[6.1.1]	Make greenness from Kent TM data
RASCAL < PMIN.DAT	[6.1.3]	
CALL PMIN GRN&PAS.DAT *DUMMY* %1	[6.1.2]	Interpret tree greenness and pasture LAI
RASCAL < PMIN.DAT		

'CALL PMIN' will execute the batch file PMIN.BAT [6.1.3], which contains the commands used to generate a file called 'PMIN.DAT' [6.1.3.1] containing appropriate keyboard responses to run RASCAL. The file 'PMIN.DAT' is used as input to RASCAL on the subsequent line ('RASCAL < PMIN.DAT'). Parameter DUMMY has no effect in these RASCAL runs.

A6.1.1 Contents of GRNKNT.DAT

```
120EXPR R4 13 103 45,14 12 8,42 47 142,135 150 245
100/(((12-47)*(8-245)-(8-142)*(12-150))*(13-14) :
+((8-142)*(14-135)-(14-42)*(8-245))*(103-12) : GREEN PT TO PLANE
+((14-42)*(12-150)-(12-47)*(14-135))*(45-8)) :
*(((12-47)*(8-245)-(8-142)*(12-150))*(M3-14) :
+((8-142)*(14-135)-(14-42)*(8-245))*(M4-12) : DATA PT TO PLANE
+((14-42)*(12-150)-(12-47)*(14-135))*(M5-8))
END
```

Generates the greenness map. Map title records values of TM data in Bands 3, 4 and 5 corresponding to pure green leaf, shade, dead vegetation and bare soil respectively. Formula computes % of green leaf in cell assumed to contain a mixture of these components. Refer Mauger 1994.

Refer [HOW EXPR] for details about writing an expression.

A6.1.2 Contents of GRNPASKNT .DAT

```
303EXPR R4                    GREEN > 0
IF(M4<(35-8)*.71+12 | M120<6.5 | M5>(144-5)*.79+8,0, : WATER, PASTURE OR CLAY
M120 : NATIVE VEGETATION
)
304EXPR R4 FULL PASTURE LAI= 2.7
IF(M4<(35-8)*.71+12 | M5<(115-5)*.79+8 | M120<-10 ,0, : WATER OR CLAY
: PASTURE LAI=2.7 WITH NO TREES
2.7*(1 - M303 / (.0087*M11-.0051*M12+35.85)): COMBINATION OF PASTURE AND TREES
)
END
```

Generates the greenness >0 of native vegetation, and the peak leaf area index of pasture. Appropriate values of TM data (M4 and M5) were determined for Wellington TM data. Linear transformation to give corresponding values in Kent TM data are shown here.

A6.1.3 Contents of PMIN.BAT

```
ECHO %3 > PMIN.DAT
ECHO %1 >> PMIN.DAT
ECHO OUT.PRN >> PMIN.DAT
ECHO Y >> PMIN.DAT
ECHO %2 >> PMIN.DAT
ECHO Y >> PMIN.DAT
```

Parameter %1 is the name of the RASCAL input command file. %2 is the name of the extra data file for RASCAL. If none of the commands in the command file use an extra data file, the name used is immaterial. %3 is the name of the RASCAL project (i.e. name of file without extension .RAS).

A6.2 Contents of LOADSC.BAT

CALL COPYBASE *KENTB01*	Load maps into subcatchment project KENTB01

Repeat this line in file LOADSC.BAT, changing the number in the subcatchment project name each time, so that the command is performed on every subcatchment.

A6.2.1 Contents of COPYBASE.BAT

CALL COPYIN %1 *KENTFOR1*	Prepare input file for COPYRAS, to copy from the first 'base project'.
COPYRAS < COPYRAS.IN	Then execute COPYRAS.
CALL COPYIN %1 *KENTFOR2*	Repeat for each base project, including low resolution project.
COPYRAS < COPYRAS.IN	
CALL COPYIN %1 *KENTFOR3*	
COPYRAS < COPYRAS.IN	
CALL COPYIN %1 *KENTFOR4*	
COPYRAS < COPYRAS.IN	
CALL COPYIN %1 *KENTFOR5*	
COPYRAS < COPYRAS.IN	
CALL COPYIN %1 *KENTFOR6*	
COPYRAS < COPYRAS.IN	
CALL COPYIN %1 *KENTISO*	
COPYRAS < COPYRAS.IN	

A6.2.1.1 Contents of COPYIN.BAT

ECHO %2 > COPYRAS.IN	Donor project name
ECHO %1 >> COPYRAS.IN	Project receiving maps
ECHO OUT.PRN	>> COPYRAS.IN Output file for messages
ECHO N	>> COPYRAS.IN Take value of 'nearest neighbour' cell
ECHO ALL >> COPYRAS.IN	Copy to whole area of receiving maps
ECHO *1 200* >> COPYRAS.IN	Copy maps numbered 1 through to 200
ECHO *1* >> COPYRAS.IN	Map numbers of copies to start at 1
ECHO 2 1 >> COPYRAS.IN	No more ranges of map numbers to copy
ECHO Y >> COPYRAS.IN	Update default file names from this run

Refer [HOW COPYRAS] for details of running program COPYRAS.

A6.3 Contents of INIT.BAT

CALL PMIN TERRAIN.DAT DUMMY %1	[6.3.1]	Make slope etc. from elevation
RASCAL < PMIN.DAT		
CALL PMIN DRAIN.DAT DUMMY %1	[6.3.2]	Make simple, sink-free drainage directions
RASCAL < PMIN.DAT		
CALL PMIN DISPER.DAT DUMMY %1	[6.3.3]	Make dispersed drainage codes
RASCAL < PMIN.DAT		
CALL PMIN INFRATE.DAT DUMMY %1	[6.3.4]	Infiltration rate to bottom soil layer
RASCAL < PMIN.DAT		
CALL PMIN INTDRA.DAT DUMMY %1	[6.3.5]	# cells in catchment from simple drainage
RASCAL < PMIN.DAT		
CALL PMIN RELG.DAT DUMMY %1	[6.3.6]	Cells with negligible upstream clearing
RASCAL < PMIN.DAT		
CALL PMIN BLANK.DAT DUMMY %1	[6.3.7]	Make blank map for catchment outlets
RASCAL < PMIN.DAT		

'CALL PMIN' will execute the batch file PMIN.BAT [6.1.3]

A6.3.1 Contents of TERRAIN.DAT

```
21TERRAR4105102103
  END
```

Generates slopes, aspect and plan curvature. Refer [HOW TERRA] for further information.

A6.3.2 Contents of DRAIN.DAT

```
117DRAINI2116
  21 102
  END
```

Generates drainage (116) and trace (117) maps. Refer [HOW DRAIN] for further information.

A6.3.3 Contents of DISPER.DAT

```
117DISPEI2102103116
  END
```

Generates dispersed drainage map (117). Overwrites trace map from DRAIN which is not needed. Refer [HOW DISPER] for more explanation.

A6.3.4 Contents of INFRATE.DAT

```
:For the first drainage integration performed after generating the drainage direction maps,
:two extra operations are required that do not need to be repeated for subsequent integrations
:The first is to adjust slope values to compensate for the effects of drainage direction on flow density
:The second is to prepare a map with simple drainage directions in areas where dispersed drainage
:integration does not complete due to circular drainage paths.
:
:Start by putting the original slope map in map 107 so that modified map can be stored in map 105
105SWAP 107
: ADD 'WATER' IN EXCESS OF SATURATION
130EXPR INITIAL CELL STATE
1000

: ALLOW FLOW AS PER SHALLOW GROUNDWATER
: (HENCE ANSWER DEPENDS ON SOIL VALUES OF PERMEABILITY, DEPTH, POROSITY)
: Aspect map 102 in INTDR command invokes slope modification, storing results in map 105
: Nomination of map 118 saves map of cells where integration is not complete at end of command
130INTDRR4130117107118   11102105
1.5 3 .2 0 0 0 0
118EXPR              NON-DISPERSED DRAIN RESIDUAL
: Put simple drain dirn where dispersed integration incomplete
 IF(M118>0,M116,-99)
: Finish integration using simple drainage directions and modified slope
130INTDRR4130118105 0  1
1.5 3 .2 0 0 0 0

: subtract original vol. (+= convergence, -=divergence)
130EXPR R4                 FLOW CONVERGENCE
  M130-1000
```

```
: apply regression found from net recharge under native forest
130EXPR R4                    INFIL RATE EX CONVERGENCE
 18-.63*M130

: average result over adjacent cells
130ASEARR4130 421    SUMMED INFIL RATE EX CONVERGENCE
130EXPR R4                    SMOOTHED INFIL RATE EX CONVERGENCE
 M130/M421

: set any negative values to zero
130EXPR R4                    SMOOTHED INFIL RATE EX CONVERGENCE
  IF(M130<0,0,M130)
  END
```

Generates a map containing cell infiltration rates calculated using balanced infiltration rates and convergence.

A6.3.5 Contents of INTDRA.DAT

```
119INTDRI4 116
   END
```

Generates map (119) of nos. of cells integrated along drainage paths. Each cell thus contains a number equal to the catchment area draining to that cell, in units of nos. of cells. Refer [HOW INTDRA] for more explanation.

A6.3.6 Contents of RELG.DAT

```
125INTDRI4304116              clearing in path
125EXPR              NEGLIGIBLE PASTURE UPSTREAM = 1
: cleared area = M125/LAI. If clearing <-2% of total area, mark as neg. u/s pasture
IF( M125<M119*.05, 1,0)
  END
```

A6.3.7 Contents of BLANK.DAT

```
5QEXPR       GAUGING LOCATIONS
 0
 END
```

Sets all cell values in map 50 to zero.

A6.4 Use of SEERAS for Manual Map Editing and Viewing

SEERAS is the program that displays maps from a RASCAL project on the computer screen. For its operation, refer [HOW SEERAS].

To generate maps of catchment areas, one cell at the outlet of each catchment needs to be given a value that identifies the catchment. If the outlet is a gauging station, its coordinates may be known, and when the map is displayed, the cursor could be placed at those coordinates. However it is essential that the cell chosen is one through which all drainage paths from within the catchment will pass. Such cells are most easily identified by displaying the map of integrated numbers of cells (map 119) [6.3.5] which looks like a drainage network. Consequently, to set the outlet cell values, display map 119 and the blank map 50 [6.3.8] together. Locate the cell closest to the desired coordinates which is also on the main drainage path. Then change the value of that cell in map 50. Saving the changes in map 50 creates the map required as input to catchment area generation [6.5].

To define a smaller rectangular area to be used as the border of a new project, first ensure the display of the map showing features to guide the area is zoomed 'in' (i.e. press

'I'). Then move the cursor to the row or column that will form the new border. Note that the coordinate shown in the detail panel is the cell centre. When creating the new project with RASCAL, the outside edge of the southwest cell must be given, i.e. half a cell width to the south and west. RASCAL also asks for the number of rows and columns in the project. These numbers must be calculated from the coordinates of the northen and eastern extremities.

A6.5 Contents of CATCH.IN

```
CALL PMIN CATCH.DAT DUMMY %1
RASCAL < PMIN.DAT
```

[6.5.1] Catchment map generation

'CALL PMIN' will execute the batch file PMIN.BAT [6.1.3]

A6.5.1 Contents of CATCH.DAT

```
50CATCH  116 50          CATCHMENTS
 END
```

Generates catchment map. Refer [HOW CATCH] for further information.

A6.6 Contents of TRIM.IN

```
CALL PMIN TRIM.DAT DUMMY %1

RASCAL < PMIN.DAT
```

[6.6.1] Mark cells outside catchment to limit drainage integration

A6.6.1 Contents of TRIM.DAT

```
116EXPR            DRAINAGE DIRECTION TRIMMED
IF(M150>0,M116,-99)
117EXPR            DISPERSED DRAINAGE TRIMMED
IF(M150>0,M117,-99)
118EXPR            RESIDUAL DRAINAGE TRIMMED
IF(M150>0,M118,-99)
  END
```

A7. HYDROLOGIC MODELLING

A7.1 Contents of RUNALL.BAT

CALL RUNMODEL *01*	[7.1.1]	Repeat this line in RUNALL.BAT, changing the catchment id no. for all subcatchments to be run.

A7.1.1 Contents of RUNMODEL.BAT

S:\RID\CSI\KENT\GEOLOGY\INPUT\KENT%1		
CALL GWML KENT %1	[7.2]	Perform modelling, including renaming and COMPRAS
COPY *.Y? RESULT		
COPY *.SM RESULT		
DEL *.Y?		
DEL *.SM		
DEL KENT%1.MAP		Archive output files, delete redundant files
DEL KENT%1.RAS		
PKZIP KENTI%1.ZIP KENTI%1.*		
DEL KENTI%1.MAP		
DEL KENTI%1.RAS		

A7.2 Contents of GWML.BAT

CALL PMIN GRPASKNT.DAT ZZ.OUT %1%2	[6.1.2]	Native forest and pasture density
RASCAL < PMIN.DAT		(change if changing pasture LAI)
CALL PMIN GWMLYS.DAT ZZ.OUT %1%2	[7.2.1]	Start all cells saturated, simulate 1 year to get initial
RASCAL < PMIN.DAT		cell soil moisture and estimate net recharge to deep groundwater flow
CALL PMIN GWMLY2.DAT Y2.OUT %1%2	[7.2.2]	Simulate 1 year with deep g/w flow to improve initial
RASCAL < PMIN.DAT		moisture and net recharge estimates
CALL PMIN GWMLY3.DAT Y2.OUT %1%2	[7.2.3]	Simulate final year to estimate deep g/w discharge
RASCAL < PMIN.DAT		and streamflow
CALL PMIN SMDISCH.DAT Y2.OUT %1%2	[7.2.4]	'Smooth' deep g/w output maps
RASCAL < PMIN.DAT		
CALL PMIN SAVORIG.DAT Y2.OUT %1%2	[7.2.5]	Save output maps from simulations
RASCAL < PMIN.DAT		
CALL PMIN PLANT.DAT Y2.OUT %1%2	[7.3]	Nominate tree-planting to meet deep groundwater use
RASCAL < PMIN.DAT		criteria
COPY ??.Y? ??BS%2.Y?		Copy OVROUT output files to include subcatchment
COPY ??.SM ??BS%2.SM		id no.
COPY ??.OVR ??BS%2.OVR		
CALL REVIEW %1%2	[7.4]	Batch run to review modelling after nominated
COPY ??.Y? ??TR%2.Y?		tree-planting
COPY ??.SM ??TR%2.SM		
CALL COMPRIN %1 %2	[7.5]	Eliminate scratch maps (map no. > 400)
COMPRAS < COMPRIN.DAT		

Refer to section [6.1.3] for explanation of 'CALL PMIN'. Parameter %1 is name of project for a subcatchment.

A7.2.1 Contents of GWMLYS.DAT

```
:RUN SHALLOW GROUNDWATER SIMULATION FOR 12 MONTHS AS A PRELIMINARY
:ANALYSIS TO GET ESTIMATE OF INITIAL WATER STORAGE FOR PROJECTS
:THAT CONTAIN LAKES.
:Parameters can be set and procedures used in the commands, which has the advantage of simplifying and reducing the
:size of the command files.
:Parameters can not be used inside an integration (INTDRA command).
:The parameters are set by including the following line at the beginning of the command file.
:SET NAME VALUE
SET CELLSIZE 25
SET FACTOR CELLSIZE^2/625
SET DRY 20*FACTOR
SET DEPTH 1.5
SET K 30
SET POROSITY .2
SET WATERST POROSITY*DEPTH*CELLSIZE^2
:304COPY 124
:303COPY 123
:Convert pan evap and LAI to transpiration. PAN/LEAF = .352
439EXPR R4                      PASTURE MAX. TRANSPIRATION(MM)
  .352*M12*M304
436EXPR R4                      ANNUAL TREE TRANSPIRATION (MM)
: NET RAIN / NATURAL GREENNESS            * ACTUAL GREENNESS
  1.33 *.85*M11 / (.0087*M11-.0051*M12+35.85) * M303
412EXPR R4                      INITIAL WET STORAGE
 WATERST
441EXPR R4                      INITIAL DEEP STORAGE
 0
:Procedures can now be used for processes that are repeated for each month. A procedure is called by the following
:command.
:PROC NAME PARAMETER1 PARAMETER2
: Procedure commands
:ENDPROC
PROC MONTH RAIN EVAP GROWTH
412EXPR R4                      ADD RAIN
      M412 + M11*RAIN*FACTOR
421EXPR R4                      PASTURE ET
: PASTURE ET CANNOT CAUSE STORE TO BECOME LESS THAN -DRY
      MAX(0, MIN(M412+ DRY, EVAP*FACTOR*GROWTH*M439))
412EXPR R4                      SHALLOW STORE - PASTURE - TREES
      M412 - M421 - EVAP*FACTOR*1.0*M436
412INTDRR4412117105  11
 1.5 30 .2 0 0 0 0
412INTDRR4412118105 0  1
 1.5 30 .2 0 0 0 0
414EXPR R4                      INFILTRATION
      MAX(0,MIN(M412,M130))
441EXPR R4                      DEEP STORE
: OLD STORE + INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE

      M441 +M414 + .6 * MIN(0,M412+DRY)
412EXPR R4                      STORAGE AFTER INFILT and ET
```

```
      MAX(-DRY , M412 - M414)
413EXPR R4                         RUN-OFF
      IF(M412>WATERST,M412-WATERST,0)
412EXPR R4                         FINAL STORAGE
      M412 - M413
ENDPROC
PROC MARCHAPRIL RAIN EVAP NAME
412EXPR R4                         ADD RAIN
      M412 + M11*RAIN*FACTOR
412EXPR R4                         SHALLOW STORE - TREES
      M412 - EVAP*FACTOR*1.0*M436
412INTDRR4412117105   11
 1.5 30 .2 0 0 0 0
412INTDRR4412118105 0 1
 1.5 30 .2 0 0 0 0
414EXPR R4                         INFILTRATION
      MAX(0,MIN(M412,M130))
441EXPR R4 DEEP STORE
: OLD STORE + INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE
      M441 +M414 + .6 * MIN(0,M412+DRY)
412EXPR R4                         STORAGE AFTER INFILT & ET
      MAX(-DRY , M412 - M414)
413EXPR R4                         RUN-OFF
      IF(M412>WATERST,M412-WATERST,0)
412EXPR R4 FINAL STORAGE
      M412 - M413
ENDPROC
 MONTH   .049 ; .036 ; 1 ; SEPTEMBER
 MONTH   .033 ; .054 ; 1 ; OCTOBER
 MONTH   .013 ; .066 ; .93 ; NOVEMBER
 MONTH   .008 ; .086 ; .74 ; DECEMBER
 MONTH   .005 ; .091 ; .37 ; JANUARY
 MONTH   .007 ; .079 ; .07 ; FEBRUARY
 MARCHAPRIL .012 ; .070 ; MARCH
 MARCHAPRIL .028 ; .041 ; APRIL
 MONTH   .075 ; .029 ; .07 ; MAY
 MONTH   .112 ; .022 ; .37 ; JUNE
 MONTH   .106 ; .023 ; .74 ; JULY
 MONTH   .083 ; .027 ; .93 ; AUGUST
442INTDRR4441117105   12           INITIAL DEEP DRAINAGE
20. 3 0 0 0 0
253 254
442INTDRR4254118105   2      INITIAL DEEP DRAINAGE
20. 3 0 0 0 0
-253 254
: COMPUTE CAPACITY OF SITE TO ACCEPT INFILTRATION IF NOT DISCHARGE
442EXPR R4                         POTENTIAL RECHARGE & DISCHARGE
: DISCH<=0, SURP RECH - NET RECH + (-VE) DISCH, ELSE +VE DISCH
IF(M442<=0,M254 - M441 + M442 , M442)
1500VROUT 442                      DD.Y1
1500VROUT 441                      NR.Y1
  END
```

A7.2.2 Contents of GWMLY2.DAT

```
SET CELLSIZE 25
SET FACTOR CELLSIZE^2/625
SET DRY 20*FACTOR
SET DEPTH 1.5
SET K 30
SET POROSITY .2
SET WATERST POROSITY*DEPTH*CELLSIZE^2
440EXPR I2                        INITIAL STORAGE LOSS
 WATERST - M412
420EXPR R4                        INITIAL DEEP STORE
 0
251COPY 420 CUM. NET RECHARGE
241COPY 420                       INITIAL CUMULATIVE RUN-OFF
242COPY 420                       INITIAL PASTURE ET TOTAL
442EXPR R4                        MONTHLY DISCHARGE
      M442/12
PROC MONTH RAIN EVAP GROWTH
420EXPR R4                        ADD DISCHARGE TO DEEP STORE
      MIN(0,M420) + M442
422EXPR R4 SURPLUS DEEP STORE
      MAX(0,M420)
412EXPR R4 ADD RAIN and +VE DISCHARGE
      M412+ M422 + M11*RAIN*FACTOR
421EXPR R4                        PASTURE ET
: PASTURE ET CANNOT CAUSE STORE TO BECOME LESS THAN -DRY
      MAX(0, MIN(M412+DRY, EVAP*FACTOR*GROWTH*M439))
242EXPR R4                        TOTAL PASTURE ET
      M242 + M421
412EXPR R4                        SHALLOW STORE - TREES
      M412 - M421 - EVAP*FACTOR*M436
412INTDRR4412117105     11
 1.5 30 .2 0 0 0 0
412INTDRR4412118105 0   1
 1.5 30 .2 0 0 0 0
414EXPR R4                        INFILTRATION
      MAX(0,MIN(M412,M130))
423EXPR R4                        NET RECHARGE
: INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE
      M414 + .6 * (MIN(0,M412+DRY))
420EXPR R4                        DEEP STORE
      M420 + M423 -M422
251EXPR R4                        CUM. NET RECHARGE
      M251 + M423
412EXPR R4                        STORAGE AFTER INFILT & ET
      MAX(-DRY , M412 - M414 + MAX(0,M420))
413EXPR R4                        RUN-OFF
      IF(M412>WATERST,M412-WATERST,0)
241EXPR R4                        CUMULATIVE RUN-OFF LESS EVAP
      M241 + MAX(M413-M115*MAX(.7*EVAP*FACTOR*M12-M421,0),0)
412EXPR R4                        FINAL STORAGE
      M412 - M413
ENDPROC
```

```
PROC MARCHAPRIL RAIN EVAP NAME
420EXPR R4                        ADD DISCHARGE TO DEEP STORE
       MIN(0,M420) + M442
422EXPR R4                        SURPLUS DEEP STORE
       MAX(0,M420)
412EXPR R4                        ADD RAIN MARCH
       M412+ M422 + M11*RAIN*FACTOR
412EXPR R4                        SHALLOW STORE - TREES MARCH
       M412 - EVAP*FACTOR*M436
412INTDRR4412117105      11
 1.5 30 .2 0 0 0 0
412INTDRR4412118105 0   1
 1.5 30 .2 0 0 0 0
414EXPR R4                        INFILTRATION
       MAX(0,MIN(M412,M130))
423EXPR R4                        NET RECHARGE
: INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE
       M414 + .6 * (MIN(0,M412+DRY))
420EXPR R4                        DEEP STORE
       M420 + M423 -M422
251EXPR R4                        CUM. NET RECHARGE
       M251 + M423
412EXPR R4                        STORAGE AFTER INFILT & ET
       MAX(-DRY , M412 - M414 + MAX(0,M420))
413EXPR R4                        RUN-OFF
       IF(M412>WATERST,M412-WATERST,0)
241EXPR R4                        CUMULATIVE RUN-OFF LESS EVAP
       M241 + MAX(M413-M115*MAX(.7*EVAP*FACTOR*M12-M421,0),0)
412EXPR R4                        FINAL STORAGE
       M412 - M413
ENDPROC
 MONTH   .049 ; .036 ; 1 ; SEPTEMBER
 MONTH   .033 ; .054 ; 1 ; OCTOBER
 MONTH   .013 ; .066 ; .93 ; NOVEMBER
 MONTH   .008 ; .086 ; .74 ; DECEMBER
 MONTH   .005 ; .091 ; .37 ; JANUARY
 MONTH   .007 ; .079 ; .07 ; FEBRUARY
 MARCHAPRIL .012 ; .070 ; MARCH
 MARCHAPRIL .028 ; .041 ; APRIL
245COPY 412                       END OF APRIL SHALLOW STORAGE
 MONTH   .075 ; .029 ; .07 ; MAY
 MONTH   .112 ; .022 ; .37 ; JUNE
 MONTH   .106 ; .023 ; .74 ; JULY
 MONTH   .083 ; .027 ; .93 ; AUGUST
241EXPR R4                        RUN-OFF ADJUSTED FOR LAKES
:For cells in lakes and major streams remove annual evaporation
       M241-CELLSIZE/1000*.7*M12*M23
:sum run-off over catchment and print to file SF.Y2
1500VROUT 241                     SF.Y2
244EXPR R4                        STORAGE LOSS
       WATERST - M440 - M412
1500VROUT 244                     SL.Y2
252INTDRR4251117105   12          FINAL DEEP DRAINAGE
20. 3 0 0 0 0
```

```
253 254
252INTDRR4254118105  2          FINAL DEEP DRAINAGE
20, 3 0 0 0 0
-253 254
447EXPR R4                      FINAL +VE DEEP DRAINAGE
      IF(M252>0,M252,0)
1500VROUT 251 NR.Y2
1500VROUT 447 DD.Y2
  END
```

A7.2.3 Contents of GWMLY3.DAT

Because the storage loss in the year 2 simulation is usually significant, a third year is simulated with soil moisture starting at the final values for year 2. The storage loss in the year 3 simulation is usually acceptably small, as reported in file SL.Y3. The third year simulation of deep groundwater discharge is practically the same as for the second year, but streamflow is markedly different. If further convergence to the steady-state was required, GWMLY3.DAT should be run again.

```
SET CELLSIZE 25
SET FACTOR CELLSIZE^2/625
SET DRY 20*FACTOR
SET DEPTH 1.5
SET K 30
SET POROSITY .2
SET WATERST POROSITY*DEPTH*CELLSIZE^2
: COMPUTE CAPACITY OF SITE TO ACCEPT INFILTRATION IF NOT DISCHARGE
442EXPR R4 POTENTIAL RECHARGE and DISCHARGE
: DISCH<=0, SURP RECH - NET RECH + (-VE) DISCH, ELSE +VE DISCH
IF(M252<=0,M254 - M251 + M252 , M252)
440EXPR I2                      INITIAL STORAGE LOSS
      WATERST-M412
420EXPR R4                      INITIAL DEEP STORAGE
 0
251COPY 420                     CUM. NET RECHARGE
241COPY 420                     INITIAL CUMULATIVE RUN-OFF
242COPY 420                     INITIAL PASTURE ET TOTAL
442EXPR R4                      MONTHLY DISCHARGE
      M442/12
PROC MONTH RAIN EVAP GROWTH
420EXPR R4                      ADD DISCHARGE TO DEEP STORE
      MIN(0,M420) + M442
422EXPR R4                      SURPLUS DEEP STORE
      MAX(0,M420)
412EXPR R4                      ADD RAIN and +VE DISCHARGE
      M412+ M422 + M11*RAIN*FACTOR
421EXPR R4                      PASTURE ET
: PASTURE ET CANNOT CAUSE STORE TO BECOME LESS THAN -DRY
      MAX(0, MIN(M412+DRY, EVAP*FACTOR*GROWTH*M439))
242EXPR R4                      TOTAL PASTURE ET
      M242 + M421
412EXPR R4                      SHALLOW STORE - TREES
      M412 - M421 - EVAP*FACTOR*M436
```

```
412INTDRR4412117105    11
1.5 30 .2 0 0 0 0
412INTDRR4412118105 0   1
1.5 30 .2 0 0 0 0
414EXPR R4                          INFILTRATION
      MAX(0,MIN(M412,M130))
423EXPR R4                          NET RECHARGE
: INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE
      M414 + .6 * (MIN(0,M412+DRY))
420EXPR R4                          DEEP STORE
      M420 + M423 -M422
251EXPR R4                          CUM. NET RECHARGE
      M251 + M423
412EXPR R4                          STORAGE AFTER INFILT and ET
      MAX(-DRY , M412 - M414 + MAX(0,M420))
413EXPR R4                          RUN-OFF
      IF(M412>WATERST,M412-WATERST,0)
241EXPR R4                          CUMULATIVE RUN-OFF LESS EVAP
      M241 + MAX(M413-M115*MAX(.7*EVAP*FACTOR*M12-M421,0),0)
412EXPR R4                          FINAL STORAGE
      M412 - M413
 ENDPROC
PROC MARCHAPRIL RAIN EVAP NAME
420EXPR R4                          ADD DISCHARGE TO DEEP STORE
      MIN(0,M420) + M442
422EXPR R4                          SURPLUS DEEP STORE
      MAX(0,M420)
412EXPR R4                          ADD RAIN MARCH
      M412+ M422 + M11*RAIN*FACTOR
412EXPR R4                          SHALLOW STORE - TREES MARCH
      M412 - EVAP*FACTOR*M436
412INTDRR4412117105    11
1.5 30 .2 0 0 0 0
412INTDRR4412118105 0   1
1.5 30 .2 0 0 0 0
414EXPR R4                          INFILTRATION
      MAX(0,MIN(M412,M130))
423EXPR R4                          NET RECHARGE
: INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE
      M414 + .6 * (MIN(0,M412+DRY))
420EXPR R4                          DEEP STORE
      M420 + M423 -M422
251EXPR R4                          CUM. NET RECHARGE
      M251 + M423
412EXPR R4                          STORAGE AFTER INFILT and ET
      MAX(-DRY , M412 - M414 + MAX(0,M420))
413EXPR R4                          RUN-OFF
      IF(M412>WATERST,M412-WATERST,0)
241EXPR R4                          CUMULATIVE RUN-OFF LESS EVAP
M241 + MAX(M413-M115*MAX(.7*EVAP*FACTOR*M12-M421,0),0)
412EXPR R4                          FINAL STORAGE
      M412 - M413
 ENDPROC
```

```
  MONTH .049 ; .036 ; 1 ; SEPTEMBER
  MONTH .033 ; .054 ; 1 ; OCTOBER
  MONTH .013 ; .066 ; .93 ; NOVEMBER
  MONTH .008 ; .086 ; .74 ; DECEMBER
  MONTH .005 ; .091 ; .37 ; JANUARY
  MONTH .007 ; .079 ; .07 ; FEBRUARY
  MARCHAPRIL .012 ; .070 ; MARCH
  MARCHAPRIL .028 ; .041 ;APRIL
245COPY 412                        END OF APRIL SHALLOW STORAGE
  MONTH .075 ; .029 ; .07 ; MAY
  MONTH .112 ; .022 ; .37 ; JUNE
  MONTH .106 ; .023 ; .74 ; JULY
  MONTH .083 ; .027 ; .93 ; AUGUST
: SAVE FINAL SHALLOW STORE
246SWAP 412
241EXPR R4                         RUN-OFF ADJUSTED FOR LAKES
:For cells in lakes & major streams, remove annual evaporation
      M241-CELLSIZE/1000*.7*M12*M23
1500VROUT 241                      SF.Y3
243INTDRI4241117  0  10            STREAMFLOW
243INTDRI4243118  0  0             STREAMFLOW
244EXPR R4                         STORAGE LOSS
      WATERST - M440 - M246
1500VROUT 244                      SL.Y3
252INTDRR4251117105  12            FINAL DEEP DRAINAGE
20. 3 0 0 0 0
253 254
252INTDRR4254118105  2             FINAL DEEP DRAINAGE
20. 3 0 0 0 0
-253 254
447EXPR R4                         FINAL +VE DEEP DRAINAGE
      IF(M252>0,M252,0)
1500VROUT 251                      NR.Y3
1500VROUT 447                      DD.Y3
  END
```

A7.2.4 Contents of SMDISCH.DAT

This command file 'smooths' maps by assigning to each cell the average of itself plus any adjacent cells that contain valid data. ASEAR (refer HOW ASEARCH) puts sum of valid cells in map 422, and no. of those cells in map 421. Next EXPR calculates positive averages. OVROUT then calculates sum within catchments and writes the sum to a text file.

```
422ASEARR4447  421                 SUMMED ADJACENT
256EXPR R4                         SMOOTHED DEEP DISCHARGE
 IF(M422>0,M422/M421,0)
1500VROUT 256                      DS.SM
422ASEARR4253 421                  SUMMED ADJACENT
257EXPR R4                         SMOOTHED THROUGHFLOW
 IF(M422>0,M422/M421,0)
1500VROUT 257                      TF.SM
422ASEARR4254 421                  SUMMED ADJACENT
258EXPR R4                         SMOOTHED SURPLUS RECHARGE
```

```
 IF(M422>0,M422/M421,0)
255INTDRR4256116 0            SMOOTHED SEEPAGE VOLUME
1500VROUT 125 1256            PS.SM
259EXPR I2                    SEEP AREA
 IF(M256>=7.5 & M125=0,1,0)
1500VROUT 128 1259            SA.SM
259INTDRI4259116              SEEP AREA INTEGRATED
  END
```

A7.2.5 Contents of SAVORIG.DAT

This command file is used to copy maps that will be changed in 'PLANT.DAT' [7.3] and 'REVIEW.BAT' [7.4], enabling comparisons to be made before and after reforestation.

```
303SWAP 123
:TREES GREEN>0
304SWAP 124
:PASTURE LAI=2.7
241SWAP 201
:CUMULATIVE RUN-OFF LESS EVAP
242SWAP 202
:TOTAL PASTURE ET
243SWAP 203
:STREAMFLOW
244SWAP 204
:MINIMUM SHALLOW+DEEP
245SWAP 205
:STORAGE LOSS
246SWAP 206
:FINAL SHALLOW STORE
247SWAP 207
:FINAL DEEP STORE
251SWAP 211
:NET RECHARGE
252SWAP 212
:FINAL DEEP DRAINAGE
253SWAP 213
:THROUGHFLOW
254SWAP 214
:SURPLUS RECHARGE
255SWAP 215
:SMOOTHED SEEPAGE VOLUME
256SWAP 216
:SMOOTHED DEEP DRAINAGE
257SWAP 217
:SMOOTHED THROUGHFLOW
258SWAP 218
:SMOOTHED SURPLUS RECHARGE
259SWAP 219
:SEEPAGE AREA
END
```

A7.3 Contents of PLANT.DAT

Commands used to estimate the amount of reforestation required to minimise discharge and predict their location in the catchment.

```
: To get good correspondence between predicted discharge and reviewed discharge, calculated :greenness must be based on unsmoothed deep groundwater maps.
: To avoid over-fragmenting recommended sites for planting, constrain planting to areas where :smoothed discharge exceeds a specified value, then use unsmoothed maps to plant trees wherever :unsmoothed discharge is greater than zero in the constrained areas.
:USE MAPS FROM 'SAVE ORIGINAL' POSITIONS
: PLANT CELLS THAT ARE PASTURE AND WHERE SMOOTHED DISCHARGE > 7.5
421EXPR I2                          PLANTED TREE CRITERION
 IF(M124=0 OR M216<7.5,0,1)
332INTDRR4212117105    13           PLANTED DISCHARGE
20. 3 0 .3 0 0 0 0
213 214 421 331
332INTDRR4212118105    3            PLANTED DISCHARGE
20. 3 0 .3 0 0 0 0
-213 214 421 331
333EXPR R4                          PLANTED TREE GREENNESS
:Tree must use required g/w + total pasture ET + run-off
IF(M331>0,(M331+M202+M201) :
:compare to use by nat. veg i.e. total rain less interception less summer stress
/(.5*M11) :
: greenness relative to natural veg LESS tree greenness already on cell
 *(.0087*M11-.0051*M12+35.85) - M123,0)
150OVROUT 125  1332                 PD.OVR
150OVROUT 333                       PG.OVR
150OVROUT 421                       PA.OVR
  END
```

A7.4 Contents of REVIEW.BAT

```
CALL PMIN NEWPAST.DAT DUMMY %1%2      [7.4.1]
RASCAL < PMIN.DAT
CALL PMIN GWMLYS.DAT ZZ.OUT %1%2      [7.2.1]
RASCAL < PMIN.DAT
CALL PMIN GWMLY2.DAT Y2.OUT %1%2      [7.2.2]
RASCAL < PMIN.DAT
CALL PMIN GWMLY3.DAT Y2.OUT %1%2      [7.2.3]
RASCAL < PMIN.DAT
CALL PMIN SMDISCH.DAT Y2.OUT %1%2     [7.2.4]
RASCAL < PMIN.DAT
```

Add planted trees to existing trees and adjust pasture accordingly

Refer to section [6.1] for explanation of 'CALL PMIN'.

A7.4.1 Contents of NEWPAST.DAT

```
303EXPR R4                          GREEN WITH PLANTED TREES
  M333 + M123
304EXPR R4                          PASTURE LEFT AFTER PLANTING
  IF(M333>0,0,                      : ZERO WHERE NEW TREES PLANTED
  M124 : AS BEFORE ELSE WHERE
  )
  END
```

A8. CONVERT RASTER MAPS TO POLYGONS FOR PRESENTATION IN MICROSTATION

RASCAL has two functions to produce polygons from raster maps. The first, invoked by command MAP[ref HOW MAP] produces polygons that trace the boundaries of groups of cells that have the same value. If the polygons are to map ranges of values, a new raster map must be made in which all cells in a single range are given the same value. No polygons are produced around cells with the value -99. The command also generates a separate file which can be input to MicroStation to place labels inside each polygon to show the value of the cell group. This is needed if the polygons are to be shaded according to their value using the Polygon Utilities.

The second function, invoked by command INTD [ref HOW INTDRA] produces lines tracing the simple drainage direction from cell to cell. To plot only 'major' drainage lines (streams?), a new raster map must be made that contains drainage directions only in those cells containing the desired lines, and -99 in all other cells.

A8.1 Contents of CLASS.IN

KENTI01		Subcatchment project being processed
CLASS.DAT	[8.1.1]	Prepare maps for polygon generation
OUT.PRN		File for messages
N		No extra file needed
Y		Update default file names from this run

A8.1.1 Contents of CLASS.DAT

```
425EXPR                         CLASSED SEEPAGE
IF(M216>7.5 & M216<=15, 1,                :SEEPAGE 7.5-15 CU.M/YR
IF(M216>15 & M216<=37.5, 2,               :SEEPAGE 15-37.5 CU.M/YR
IF(M216>37.5, 3,                          :SEEPAGE >37.5 CU.M/YR
-99)))
:426EXPR                        ORIGINAL TREE COVER
:IF(M123>0 & M124=0, 1,                   :NATIVE FOREST
:IF(M123>0 & M124>0, 2,                   :SCATTERED PADDOCK TREES
:-99))
427EXPR                         PROPOSED SITES FOR PLANTING
IF(M333>0,1,-99)
428EXPR                         STEAMS WITH CATCHMENT > 100HA
IF(M119>1600, M116, -99)
END
```

A8.2 Contents of MAP.IN

KENTI01		Subcatchment project being processed
MAP.DAT	[A8.2.1]	Generate polygons
OUT.PRN		File for messages
Y		Extra file is needed for polygon output
MAP.ASC		Name of extra file
Y		Update default file names from this run

When using command MAP, the file *MAP*.LAB is generated containing the polygon labels, as well as *MAP.ASC*. Polygons can only be generated from one map in one run of RASCAL due to the need to name the extra file for output.

A8.2.1 Contents of MAP.DAT

To output polygons and labels:

```
425MAP  -1          SEEP.ASC        [HOW MAP]
426MAP  -1          TREE.ASC
427MAP  -1          PLANT.ASC
   END
```

To output drainage lines:

```
428INTD  428  -1    STREAM.ASC      [HOW INTDRA]
   END
```

A8.3.1 Import Polygons to Design File as Linework, Generate Polygons, Pattern Polygons

Use the Polygon Utility ASC2DGN MDL to load polygons into a MicroStation design file. First set the 'active level' to the level where the lines are to be stored. Then use the ASC2DGN option 'import to active level' (not the alternative 'read levels from file'). Even though the data represent complete polygons, they should be read as linestrings, not polygons, so that Polygon Utility's polygon shading process can be used. It is advisable to use a new design file for each subcatchment if patterning is to be generated. After creation, the pattern files may be amalgamated into one file.

If the polygons are to be patterned, load the polygon labels. First make 'active' the level where the labels are to be stored. Next set appropriate text attributes such as size and colour. Then type on the command line:

```
@MAP.LAB
```

To pattern the polygons, the POLYGON UTILITY MDL is used. The first step is to run 'Line Break'. Then omit 'Line Check' and proceed with 'Polygon Create' and 'Load Poly Id'. At this point check that the pattern definition file is correct for the polygons to be patterned. The name of the pattern definition file may have to be altered from the default to achieve this.

A8.3.2 Contents of Microstation Macro (ALLDRAW1.BAS) to Plot Maps of Results

This Macro is run in the design file 'kbase.dgn' to create a series of plots for Maps Appendix 3A and 3B. All the correct reference files levels and displays must be turned on in View 5 before running. It is important to close all tool boxes before running this macro, otherwise it may not run properly.

```
' choose levels to show drawing, create plot file,
' step through all drawing positions

Sub main
  Dim startPoint As MbePoint
  MbeSendCommand "LOCK FENCE VOID OUTSIDE"
' Coordinates are in master units
' a7 displaced 100m west from normal position
  startPoint.x = 494900.000000#
  startPoint.y = 6175000.000000#
  startPoint.z = 0.000000#
  plotpair "a7", "1", startPoint
' a8 displaced 100m west from normal position
  startPoint.x = 494900.000000#
  startPoint.y = 6171000.000000#
  startPoint.z = 0.000000#
  plotpair "a8", "3", startPoint
  startPoint.x = 495000.000000#
  startPoint.y = 6167000.000000#
  startPoint.z = 0.000000#
  plotpair "a9", "1", startPoint
  startPoint.x = 502000.000000#
  startPoint.y = 6183000.000000#
  startPoint.z = 0.000000#
  plotpair "b5", "2", startPoint
  startPoint.x = 502000.000000#
  startPoint.y = 6179000.000000#
  startPoint.z = 0.000000#
  plotpair "b6", "4", startPoint
  startPoint.x = 502000.000000#
  startPoint.y = 6175000.000000#
  startPoint.z = 0.000000#
  plotpair "b7", "2", startPoint
  startPoint.x = 502000.000000#
  startPoint.y = 6171000.000000#
  startPoint.z = 0.000000#
  plotpair "b8", "4", startPoint
  startPoint.x = 502000.000000#
  startPoint.y = 6167000.000000#
  startPoint.z = 0.000000#
  plotpair "b9", "2", startPoint
  startPoint.x = 509000.000000#
```

```
startPoint.y = 6191000.000000#
startPoint.z = 0.000000#
plotpair "c3", "1", startPoint
startPoint.x = 509000.000000#
startPoint.y = 6187000.000000#
startPoint.z = 0.000000#
plotpair "c4", "3", startPoint
startPoint.x = 509000.000000#
startPoint.y = 6183000.000000#
startPoint.z = 0.000000#
plotpair "c5", "1", startPoint
startPoint.x = 509000.000000#
startPoint.y = 6179000.000000#
startPoint.z = 0.000000#
plotpair "c6", "3", startPoint
startPoint.x = 509000.000000#
startPoint.y = 6175000.000000#
startPoint.z = 0.000000#
plotpair "c7", "1", startPoint
startPoint.x = 509000.000000#
startPoint.y = 6171000.000000#
startPoint.z = 0.000000#
plotpair "c8", "3", startPoint
startPoint.x = 509000.000000#
startPoint.y = 6167000.000000#
startPoint.z = 0.000000#
plotpair "c9", "1", startPoint
startPoint.x = 516000.000000#
startPoint.y = 6199000.000000#
startPoint.z = 0.000000#
plotpair "d1", "2", startPoint
startPoint.x = 516000.000000#
startPoint.y = 6187000.000000#
startPoint.z = 0.000000#
plotpair "d2", "4", startPoint
startPoint.x = 516000.000000#
startPoint.y = 6191000.000000#
startPoint.z = 0.000000#
plotpair "d3", "2", startPoint
startPoint.x = 516000.000000#
startPoint.y = 6187000.000000#
startPoint.z = 0.000000#
plotpair "d4", "4", startPoint
startPoint.x = 516000.000000#
startPoint.y = 6183000.000000#
startPoint.z = 0.000000#
plotpair "d5", "2", startPoint
startPoint.x = 516000.000000#
startPoint.y = 6179000.000000#
startPoint.z = 0.000000#
plotpair "d6", "4", startPoint
startPoint.x = 516000.000000#
startPoint.y = 6175000.000000#
startPoint.z = 0.000000#
plotpair "d7", "2", startPoint
startPoint.x = 516000.000000#
startPoint.y = 6171000.000000#
startPoint.z = 0.000000#
plotpair "d8", "4", startPoint
startPoint.x = 516000.000000#
startPoint.y = 6167000.000000#
startPoint.z = 0.000000#
plotpair "d9", "2", startPoint
startPoint.x = 523000.000000#
startPoint.y = 6199000.000000#
startPoint.z = 0.000000#
plotpair "e1", "1", startPoint
startPoint.x = 523000.000000#
startPoint.y = 6195000.000000#
startPoint.z = 0.000000#
plotpair "e2", "3", startPoint
startPoint.x = 523000.000000#
startPoint.y = 6191000.000000#
startPoint.z = 0.000000#
plotpair "e3", "1", startPoint
startPoint.x = 523000.000000#
startPoint.y = 6187000.000000#
startPoint.z = 0.000000#
plotpair "e4", "3", startPoint
startPoint.x = 523000.000000#
startPoint.y = 6183000.000000#
startPoint.z = 0.000000#
plotpair "e5", "1", startPoint
startPoint.x = 523000.000000#
startPoint.y = 6179000.000000#
startPoint.z = 0.000000#
plotpair "e6", "3", startPoint
startPoint.x = 523000.000000#
startPoint.y = 6175000.000000#
startPoint.z = 0.000000#
plotpair "e7", "1", startPoint
startPoint.x = 523000.000000#
startPoint.y = 6171000.000000#
startPoint.z = 0.000000#
plotpair "e8", "3", startPoint
startPoint.x = 523000.000000#
startPoint.y = 6167000.000000#
startPoint.z = 0.000000#
plotpair "e9", "1", startPoint
' f1 displaced 800m north from normal position
startPoint.x = 530000.000000#
startPoint.y = 6199800.000000#
startPoint.z = 0.000000#
plotpair "f1", "2", startPoint
' f2 displaced 400m north from normal position
startPoint.x = 530000.000000#
```

```
startPoint.y = 6187400.000000#
startPoint.z = 0.000000#
plotpair "f2", "4", startPoint
startPoint.x = 530000.000000#
startPoint.y = 6191000.000000#
startPoint.z = 0.000000#
plotpair "f3", "2", startPoint
startPoint.x = 530000.000000#
startPoint.y = 6187000.000000#
startPoint.z = 0.000000#
plotpair "f4", "4", startPoint
startPoint.x = 530000.000000#
startPoint.y = 6183000.000000#
startPoint.z = 0.000000#
plotpair "f5", "2", startPoint
startPoint.x = 530000.000000#
startPoint.y = 6179000.000000#
startPoint.z = 0.000000#
plotpair "f6", "4", startPoint
startPoint.x = 530000.000000#
startPoint.y = 6175000.000000#
startPoint.z = 0.000000#
plotpair "f7", "2", startPoint
startPoint.x = 537000.000000#
startPoint.y = 6199000.000000#
startPoint.z = 0.000000#
plotpair "g1", "1", startPoint
startPoint.x = 537000.000000#
startPoint.y = 6195000.000000#
startPoint.z = 0.000000#
plotpair "g2", "3", startPoint
startPoint.x = 537000.000000#
startPoint.y = 6191000.000000#
startPoint.z = 0.000000#
plotpair "g3", "1", startPoint
startPoint.x = 537000.000000#
startPoint.y = 6187000.000000#
startPoint.z = 0.000000#
plotpair "g4", "3", startPoint
startPoint.x = 537000.000000#
startPoint.y = 6183000.000000#
startPoint.z = 0.000000#
plotpair "g5", "1", startPoint
startPoint.x = 537000.000000#
startPoint.y = 6179000.000000#
startPoint.z = 0.000000#
plotpair "g6", "3", startPoint
startPoint.x = 537000.000000#
startPoint.y = 6175000.000000#
startPoint.z = 0.000000#
plotpair "g7", "1", startPoint
startPoint.x = 544000.000000#
startPoint.y = 6187000.000000#
 startPoint.z = 0.000000#
 plotpair "h2", "4", startPoint
 startPoint.x = 544000.000000#
 startPoint.y = 6191000.000000#
 startPoint.z = 0.000000#
 plotpair "h3", "2", startPoint
 startPoint.x = 544000.000000#
 startPoint.y = 6187000.000000#
 startPoint.z = 0.000000#
 plotpair "h4", "4", startPoint
 startPoint.x = 544000.000000#
 startPoint.y = 6183000.000000#
 startPoint.z = 0.000000#
 plotpair "h5", "2", startPoint
 startPoint.x = 544000.000000#
 startPoint.y = 6179000.000000#
 startPoint.z = 0.000000#
 plotpair "h6", "4", startPoint
 startPoint.x = 544000.000000#
 startPoint.y = 6175000.000000#
 startPoint.z = 0.000000#
 plotpair "h7", "2", startPoint
end sub
sub plotpair(sheet as string, layer as string,startPoint As MbePoint)
 Dim point As MbePoint
' Turn on levels in kframe.dgn for series 1
 MbeSendKeyin "reference levels off"
' kf = kframe.dgn
 MbeSendKeyin "kf"

 MbeSendKeyin "1-63"

' Send a data point to the current command
 point.x = startPoint.x
 point.y = startPoint.y
 point.z = startPoint.z
 MbeSendDataPoint point, 1%
' Turn on levels in kframe.dgn for series 1
 MbeSendKeyin "reference levels on"
 MbeSendKeyin "kf"

 MbeSendKeyin layer + "0," + layer + "3," + layer + "4"

' Send a data point to the current command
 point.x = startPoint.x
 point.y = startPoint.y
 point.z = startPoint.z
 MbeSendDataPoint point, 1%

' Clip boundaries for spreadsheet, then set fence for plot
 setclip startPoint

 MbeSendKeyin "reference display off trees"
```

```
' Turn on levels in kframe.dgn for series 1
  MbeSendKeyin "reference levels on"
  MbeSendKeyin "kf"

  MbeSendKeyin layer + "1"

' Send a data point to the current command
  point.x = startPoint.x
  point.y = startPoint.y
  point.z = startPoint.z
  MbeSendDataPoint point, 1%

  MbeSendKeyin "uc=d:\wr\libr\ucm\autoplot"
  MbeSendKeyin "%ren kbase.000 " + sheet + "d.000"
' Turn on levels in kframe.dgn for series 1
  MbeSendKeyin "reference levels off"
  MbeSendKeyin "kf"

  MbeSendKeyin layer + "1"

' Send a data point to the current command
  point.x = startPoint.x
  point.y = startPoint.y
  point.z = startPoint.z
  MbeSendDataPoint point, 1%
' Turn on levels in kframe.dgn for series 1
  MbeSendKeyin "reference levels on"
  MbeSendKeyin "kf"

  MbeSendKeyin layer + "2"

' Send a data point to the current command
  point.x = startPoint.x
  point.y = startPoint.y
  point.z = startPoint.z
  MbeSendDataPoint point, 1%

  MbeSendKeyin "reference display on trees"
  MbeSendKeyin "uc=d:\wr\libr\ucm\autoplot"
  MbeSendKeyin "%ren kbase.000 " + sheet + "p.000"
end sub
sub setclip(startPoint As MbePoint)
  Dim point As MbePoint, point2 As MbePoint

  MbeSendCommand "PLACE FENCE"

  point.x = startPoint.x - 437.000000#
  point.y = startPoint.y - 427.000000#
  point.z = startPoint.z
  MbeSendDataPoint point, 1%
  point.x = startPoint.x + 7437.000000#
  point.y = startPoint.y + 4427.000000#
  point.z = startPoint.z
  MbeSendDataPoint point, 1%

' f1 = kntfor1f.pat
  MbeSendKeyin "REFERENCE CLIP BOUNDARY f1"
  MbeSendKeyin "REFERENCE CLIP BOUNDARY f2"
  MbeSendKeyin "REFERENCE CLIP BOUNDARY f3"
  MbeSendKeyin "REFERENCE CLIP BOUNDARY f4"
  MbeSendKeyin "REFERENCE CLIP BOUNDARY f5"
  MbeSendKeyin "REFERENCE CLIP BOUNDARY f6"
' p1 = kntfor1p.pat
  MbeSendKeyin "REFERENCE CLIP BOUNDARY p1"
  MbeSendKeyin "REFERENCE CLIP BOUNDARY p2"
  MbeSendKeyin "REFERENCE CLIP BOUNDARY p3"
  MbeSendKeyin "REFERENCE CLIP BOUNDARY p4"
  MbeSendKeyin "REFERENCE CLIP BOUNDARY p5"
  MbeSendKeyin "REFERENCE CLIP BOUNDARY p6"
' cad = kntucad.dgn
  MbeSendKeyin "REFERENCE CLIP BOUNDARY cad"
' scat = kntscbnd.dgn
' Next file should have levels 2 and 4 OFF
  MbeSendKeyin "REFERENCE CLIP BOUNDARY scat"
' disch = disch.pat
  MbeSendKeyin "REFERENCE CLIP BOUNDARY disch"
' trees = ptrees.pat
  MbeSendKeyin "REFERENCE CLIP BOUNDARY trees"
' con = kntcon.dgn
' Next file has only levels 30 and 39 ON
' For level 30, set color =52 using Level Symbology'
  MbeSendKeyin "REFERENCE CLIP BOUNDARY con"
' topo = knttopo.dgn
' Next file has level 57 OFF (catchment boundaries)
' Other levels used are:
' Roads 3
' Major Lakes 20
' Rivers 21
' Swamps 24, 25, 28
  MbeSendKeyin "REFERENCE CLIP BOUNDARY topo"

  MbeSendCommand "PLACE FENCE"
  point.x = startPoint.x - 840.000000#
  point.y = startPoint.y - 1370.000000#
  point.z = startPoint.z
  MbeSendDataPoint point, 1%

  point.x = startPoint.x + 7560.000000#
  point.y = startPoint.y + 4570.000000#
  point.z = startPoint.z
  MbeSendDataPoint point, 1%

End Sub
```

A8.4 Output of Data for Tables Based on Catchment Areas

Basic data to prepare tables of quantities within catchment areas are obtained by overlaying the catchment map (map 150) on a map of data, using command OVROUT [ref HOW OVROUT]. All of the required OVROUT commands are performed in GWM.BAT [7.2] while the modelling is proceeding.

A file produced by OVROUT may be imported into a spreadsheet for reporting and computing other derived quantities. To reduce the manual operations involved in preparing the spreadsheet, program TABLIST [ref HOW TABLIST] is provided to reformat the output files from OVROUT. Batch file TABALL.BAT [8.4.1] automatically runs TABLIST for all the OVROUT files required after modelling. A macro [8.4.2] then automatically loads the data into the spreadsheet ready for printing.

Alternatively, if the basic data have been integrated along drainage lines, the aggregate for the catchment can be read by displaying the integrated map using program SEERAS [ref HOW SEERAS], and positioning the cursor on the cell which is the outlet of the catchment. The value would then be manually copied into the spreadsheet. This method is not recommended where data is required from many subcatchments.

A8.4.1 Contents of TABALL.BAT

CALL TABIN SFBS Y3 1	[8.4.1.1]	Streamflow Base (One-way table)
CALL TABIN DDBS Y3 1	[8.4.1.1]	Deep Discharge Base (One-way table)
CALL TABIN PSBS SM 2	[8.4.1.1]	Streamflow Base (Two-way table)
CALL TABIN SLBS Y3 1	[8.4.1.1]	Storage loss Base (One-way table)
CALL TABIN PDBS OVR 2	[8.4.1.1]	Predicted Discharge (Two-way table)
CALL TABIN NTBS OVR 2	[8.4.1.1]	Planted Area (Two-way table)
CALL TABIN PSTR SM 2	[8.4.1.1]	Streamflow Base (One-way table)
CALL TABIN SFTR Y3 1	[8.4.1.1]	Streamflow Treated (One-way table)
CALL TABIN PD OVR 2	[8.4.1.1]	Planted Discharge (Two-way table)
CALL TABIN PG OVR 1	[8.4.1.1]	Planted Greenness (One-way table)
CALL TABIN PA OVR 1	[8.4.1.1]	Planted Area (One-way table)
CALL TABIN CA OVR 1	[8.4.1.1]	Cleared Area in Catchment (One-way table)
CALL TABIN RAIN OVR 1	[8.4.1.1]	Average Rainfall in Catchment (One-way table)
CALL TABIN FC OVR 1	[8.4.1.1]	Forest Without Upstream Clearing (One-way table)

A8.4.1.1 Contents of TABIN.BAT

Prepares input data file and runs program TABLIST

ECHO %1#.%2 > TABIN.DAT		The template for OVROUT file names
ECHO KNTLST.DAT >> TABIN.DAT	[8.4.1.2]	
ECHO %1.TXT >> TABIN.DAT		Output filename to be read by Excel
ECHO %3 >> TABIN.DAT		Select one-way or two-way table
ECHO Y >> TABIN.DAT		Update default file names
TABLIST < TABIN.DAT		Run program TABLIST+

A8.4.1.2 Contents of KNTLST.DAT

In the actual file, each entry is on a new line. The number sequence is that used in the spreadsheet, which reflects the drainage structure of the catchment. XXX provides a break between data for different sheets within the spreadsheet workbook.

13 04 03 01 02 XXX 05 07 08 06 12 09 101 14 10 XXX 15 17 21 22 20 18 11 16 191 19 XXX 32 30 29 291
28 27 26 25 251 24 23 XXX 35 34 33 38 31 37 36 XXX 41 40 43 46 45 47 44 42 39 XXX 49 48 51 50 53 54 52 55

A8.4.2 Contents of Excel Macro 'DATAIN'

```
' datain Macro
' load data from text file generated by program TABLIST (in RASCAL\EXE)
'
' Keyboard Shortcut: Ctrl+d
'
' datain Macro
' load data from text file generated by program TABLIST (in RASCAL\EXE)
'
' Keyboard Shortcut: Ctrl+d
'
Sub all()
' Edit next line to specify where text files will be found
txtdir = "S:\RID\CSI\KENT\MDL\GEOLOGY\RESULT\RESK3S\"
' Set names of text files to process, the column of data to be taken from the text file
' and the row in the spreadsheet where the data is to be written
' Any not wanted in this run, turn into comments.
'  txtfile = "ca.TXT"
'  load2 txtdir & txtfile
'  storeOne txtfile, "D", 135
' txtfile = "fc.TXT"
'  load2 txtdir & txtfile
'  storeOne txtfile, "D", 136
' txtfile = "rain.TXT"
'  load2 txtdir & txtfile
'  storeOne txtfile, "C", 134
'  storeOne txtfile, "D", 133
' txtfile = "sfbs.TXT"
'  load2 txtdir & txtfile
'  storeOne txtfile, "D", 137
' txtfile = "psbs.TXT"
'  load2 txtdir & txtfile
'  storeOne txtfile, "D", 140
'  storeOne txtfile, "E", 139
' txtfile = "slbs.TXT"
'  load2 txtdir & txtfile
'  storeOne txtfile, "D", 141
' txtfile = "pabs.TXT"
'  load2 txtdir & txtfile
'  storeOne txtfile, "D", 143
  txtfile = "pdbs.TXT"
   load2 txtdir & txtfile
   storeOne txtfile, "D", 145
   storeOne txtfile, "E", 146
  txtfile = "pstr.TXT"
   load2 txtdir & txtfile
   storeOne txtfile, "D", 148
   storeOne txtfile, "E", 149
  txtfile = "sftr.TXT"
   load2 txtdir & txtfile
  storeOne txtfile, "D", 150
' txtfile = "ntrt.TXT"
```

```
'  load2 txtdir & txtfile
'  storeOne txtfile, "D", 143
'
End Sub
Sub storeOne(ByVal txtfile As String, ByVal scol As String, orow)
' In each Excel sheet, specify the rows of data to be selected from the text file,
' and the col in the sheet where the 1st value will be written.
   cutpaste txtfile, "CAT02", scol, 1, 5, "B", orow
   cutpaste txtfile, "CAT14", scol, 7, 15, "C", orow
   cutpaste txtfile, "CAT16", scol, 17, 26, "D", orow
   cutpaste txtfile, "CAT23", scol, 28, 38, "C", orow
   cutpaste txtfile, "CAT36", scol, 40, 46, "C", orow
   cutpaste txtfile, "CAT39", scol, 48, 56, "C", orow
   cutpaste txtfile, "CAT55", scol, 58, 65, "C", orow
End Sub
Sub load2(ByVal strFileName As String)
' Create Excel spreadsheet from txtfile
   Workbooks.OpenText Filename:=strFileName, Origin:= _
    xlWindows, StartRow:=2, DataType:=xlDelimited, TextQualifier _
    :=xlNone, ConsecutiveDelimiter:=True, Tab:=False, Semicolon _
    :=False, Comma:=False, Space:=True, Other:=False, FieldInfo _
    :=Array(Array(1, 1), Array(2, 1), Array(3, 1), Array(4, 1))
 End Sub
Sub cutpaste(ByVal txtfile As String, ByVal xlsheet As String, _
     ByVal scol As String, srowl, srowl, ocol As String, orow)
' Copy specified rows from txtfile to main spreadsheet
' Col A is text id of files not found by TABLIST
' Col B is numeric id of files found by TABLIST
' Col C is summation in catchment for one-way table, or summation for 1st value in two-way table
' Col D is summation in catchment for next value in two-way table.
' More cols for up to 10 values in two-way table.
' Col to be read by this routine is specified in scol
Windows(txtfile).Activate
Range(Cells(srowl, scol), Cells(srowl, scol)).Select
Selection.Copy
' Edit next line to set name of current spreadsheet
Windows("KENTGEO.XLS").Activate
' xlsheet specifies sheet where data are to be written
Sheets(xlsheet).Select
' ocol and orow specify where 1st cell of data is to be placed
Range(ocol & orow).Select
' Paste data with transpose, so that column of data becomes a row
Selection.PasteSpecial Paste:=xlAll, Operation:=xlNone, SkipBlanks _
:=False, Transpose:=True
End Sub
```

A8.4.3 Contents of Macro 'PRINTALL'

Prints all of the required sheets in the spreadsheet.

```
' Macrol Macro
' Macro recorded 27/3/96 by Geoff Mauger
'
'
Sub printall()
```