Daly River Catchment Water Model: Progress Report

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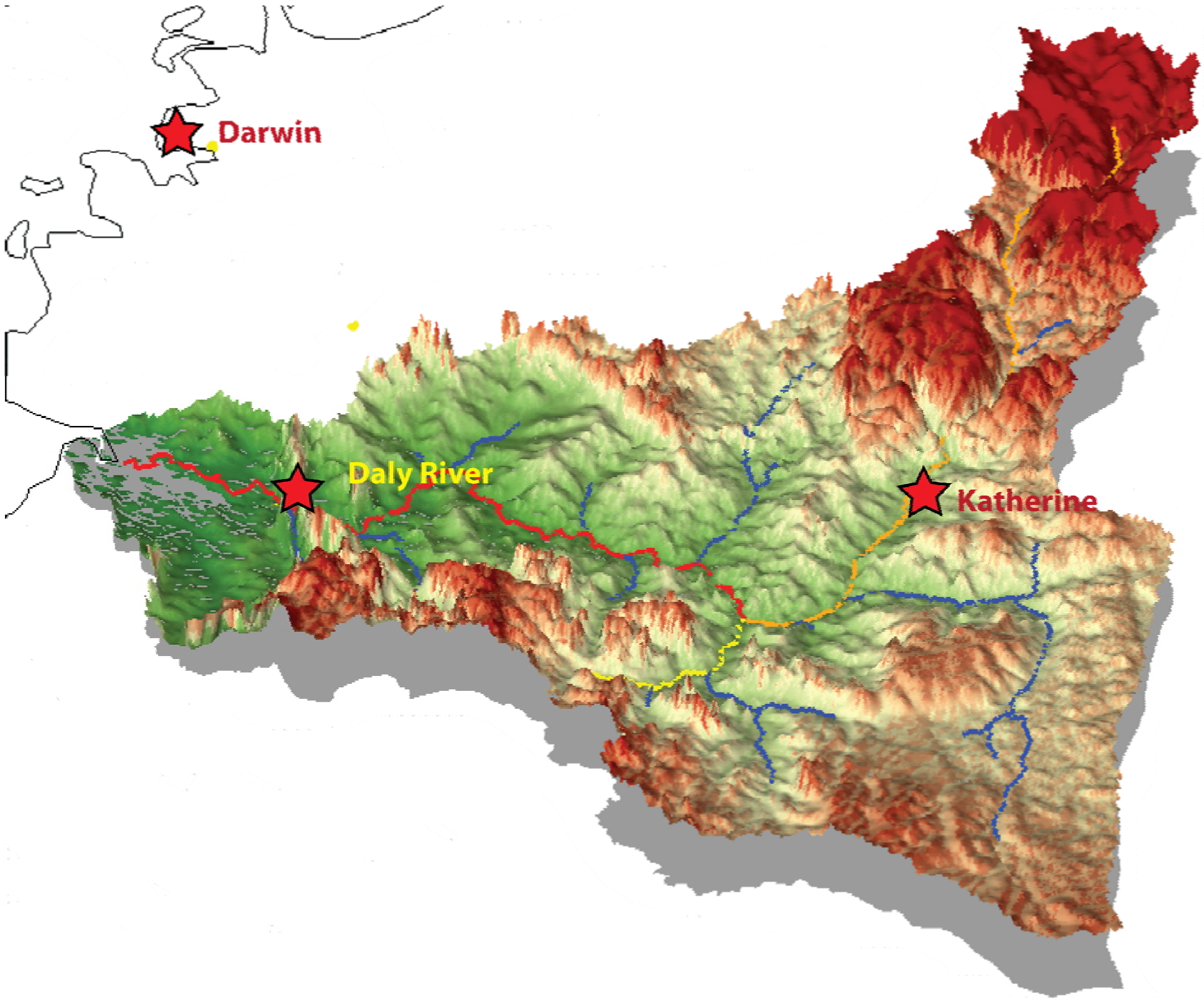
TRaCK
Tropical Rivers and Coastal Knowledge



Australian Government
Department of the Environment, Water, Heritage and the Arts
Land & Water Australia
National Water Commission

TRaCK brings together leading tropical river researchers and managers from Charles Darwin University, Griffith University, the University of Western Australia, CSIRO, James Cook University, the Australian National University, Geoscience Australia, the Environmental Research Institute of the Supervising Scientist, the Australian Institute of Marine Science, the North Australia Indigenous Land and Sea Management Alliance, and the Governments of Queensland, the Northern Territory and Western Australia.

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EXECUTIVE SUMMARY

Introduction

The Knowledge Integration and Delivery project within TRaCK's Theme 1 (Project 1.4) has two main objectives: to improve our knowledge of the catchments under investigation with regards to their response to management actions (including conservation), and to deliver that knowledge effectively to TRaCK stakeholders in general, and resource managers and their advisors in particular.

A set of models and software products, based on a broad conceptual framework (Management Strategy Evaluation or MSE) form the basis of the delivery of flexible management scenario evaluation capability to the TRaCK program and its stakeholders. Project 1.4 (P1.4) proposes to do this by (further) developing and implementing the broad framework for Catchment-to-Coast management strategy evaluation (C2C MSE) for the Northern Rivers. These tools then will be used to support evidence-based decision-making in water-related resource management.

P1.4 is initially focusing on the Daly River catchment and will develop a C2C MSE tool for this catchment. The C2C MSE tool contains a catchment water model. It is this water model that is the focus of this report. This report documents the steps taken to produce the spatially explicit catchment water model needed for management strategy evaluation.

Daly River Catchment

The Daly River catchment is located in the Northern Territory of Australia and is one of the major tropical river systems being researched by TRaCK. Lying to the south of Darwin, the Daly River catchment is about 53,000km^2 in area (about 80% of the size of Tasmania). It includes the major tributaries of Katherine, King, Fergusson, Douglas, Edith and Flora Rivers. The Daly River flows in a general westerly direction into the Timor Sea. The volume of water discharged into the sea is the second highest of any river in Australia (CSIRO, 2009a).

Dry season flow is dominated by groundwater discharge. This groundwater flows from the two major limestone aquifer systems of the Daly Basin. These aquifers store and transmit significant volumes of groundwater and are separated by impervious siltstone formations. Groundwater extraction from the aquifers occurs via bores with the extracted water used primarily for agricultural irrigation. These extractions may reduce dry season flows within the Daly River catchment and subsequently may impact upon the ecological and socio-economic systems dependent upon the dry season flows.

Due to the areas of permanent water within the Daly River system, distinctive ecosystems are supported both within the river and along its banks. Notably, the endangered pig-nosed turtle breeds and lives within the middle reaches of the Daly River.

Catchment Water Model

A catchment water model that models the conversion of rain into river discharges is a core model used in the MSE approach and forms a backbone for the integration of many of the other knowledge areas within TRaCK, including socio-economics and ecology.

Over the last year, Project 1.4 has developed a catchment water model for the Daly Catchment to function as a straw-man for the MSE software development. This model will enable scenario evaluations to be undertaken within the Daly River catchment. The catchment water model is required to represent a large range of complex processes. Subsequently, a large amount of data

is required in order to ensure that the model sufficiently represents the natural environment. Data needed includes rainfall, flow, groundwater capacity, bore locations and extractions, and potential evapotranspiration (PET). These datasets, amongst others, have been sourced and investigations of data quality and suitability have been undertaken.

There are many types of catchment water models ranging from the very simple to the highly complex. It is perhaps obvious but nevertheless important to state, that simple models tend to be less data and time intensive and complex models the converse. With this in mind, consider the following points:

1. The Daly River catchment is a data poor catchment (CSIRO, 2009a). That is, the available data is sparse and when available, not always accurate.

2. The MSE framework requires a model capable of undertaking many simulations in a relatively short period of time to enable a multitude of strategies to be assessed.

Based on these factors, the most suitable model for the task is undoubtedly a simple model. That is not to say that complex models do not have a place in the Daly River catchment but such models are likely to be highly specialised models.

The major components of the catchment water model are described as follows:

- Conceptual Rainfall-Runoff Model

  One of the major physical processes requiring simulation by the catchment water model is the conversion of rainfall to runoff. To represent this process SIMHYD, a conceptual rainfall-runoff model from the eWater rainfall runoff library toolkit, has been selected. Input data is daily rainfall and PET. The catchment has been divided into 44 subcatchments and each of these further divided into 6 functional units based on land-use categorisation.

- Flow Routing

  Routing of flows between subcatchments is undertaken by the Muskingum method. P1.4 has developed the code to implement this method within the MSE framework.

- Groundwater Model

  As described previously, some areas of the Daly River catchment overlie regional groundwater systems. Excess rainfall can recharge into these systems during the wet season and groundwater can discharge into watercourses during the dry season. It is essential to include a groundwater model within the MSE to enable these groundwater interactions to be modelled. P1.4 is researching the most suitable format for the groundwater model.

- Hydraulic Model

  One of the requirements of the Daly catchment water model will be to predict changes to hydraulic characteristics that are known to impact upon ecological habitat. Examples of such hydraulic characteristics are water velocities and size of the dry season pools. In the dry season these pools form the only habitat for many aquatic species. Changes to these hydraulic characteristics can be directly linked to changes in aquatic species populations. P1.4 is currently investigating potential means for estimating hydraulic characteristics.

Calibration

Model calibration is the process of comparing model predictions to measured variables, making adjustments to the model and/or inputs until the model is able to replicate real world behaviour, within the bounds of data uncertainty and model capability. Calibration requires that the model is able to *sufficiently* replicate the shape and timing of the measured flow hydrographs. The term sufficiently is an important term to define in this context: the calibration results are sufficient to allow the model to perform simulations with an accuracy fit for purpose.

Following the development of the catchment water model, the P1.4 is currently calibrating the Daly catchment water model using the datasets described in the previous sections. Functionality has been added to the MSE GUI to allow calibration to be undertaken within the MSE system. Full calibration of this catchment water model will only be possible once groundwater behaviour and floodplain inundation losses have been successfully modelled. The result will be a simple and but time efficient whole-of-catchment water model. The model will allow water strategy and scenario evaluation to be undertaken within the MSE framework.

Conclusion

TRaCK Project 1.4 has successfully developed a spatially explicit catchment water model linked with constituent models. Calibration of this model is currently underway for the Daly River catchment. Datasets required for this purpose have been investigated and collated. Calibration of the catchment water model may lead to some refinements to the model as the relative importance of the groundwater behaviour and floodplain losses are better understood. The model will allow water strategy and scenario evaluation to be undertaken within the MSE framework.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 TRACK KNOWLEDGE INTEGRATION AND DELIVERY: PROJECT 1.4

TRaCK (Tropical Rivers and Coastal Knowledge) is a research hub under the Commonwealth Environmental Research Facilities scheme, managed by the Department of Environment, Water, Heritage and the Arts. TRaCK draws together more than 70 of Australia's leading social, cultural, environmental and economic researchers. TRaCK's research focuses on the tropical north of Australia from Cape York to Broome and is organised into a number of themes and projects. For more information on TRaCK, its themes and its projects, see http://www.track.gov.au/

The Knowledge Integration and Delivery project within TRaCK's Theme 1 (project 1.4) has two main objectives: to improve our knowledge of the catchments under investigation with regards to their response to management actions (including conservation) and to deliver that knowledge effectively to TRaCK stakeholders in general, and resource managers and their advisors in particular.

Project 1.4 (P1.4) aims to meet these objectives by integrating (collating and connecting) knowledge on two levels: on the first level, Project 1.4 integrates knowledge from various TRaCK science disciplines (e.g. projects on hydrodynamics, ecology and socio-economics), and on the second level, by coupling that knowledge with the resource management domain knowledge and needs (e.g. setting objectives for resource management, device feasible management actions, develop and implement monitoring and assessment programs).

A set of models and software products, based on a broad conceptual framework (Management Strategy Evaluation or MSE) that encompass these two levels of integration form the basis of the delivery of flexible management scenario evaluation capability to the TRaCK program and its stakeholders. Project 1.4 proposes to do this by (further) developing and implementing the broad framework for Catchment-to-Coast management strategy evaluation (C2C MSE) for the Northern Rivers. These tools then will be used to support evidence-based decision-making in water-related resource management.

P1.4 is initially focusing on the Daly River catchment and will develop a C2C MSE tool for this catchment. This report documents the steps taken to produce the spatially explicit catchment water model that exists as a component within the C2C MSE.

1.2 DESCRIPTION OF THE DALY RIVER CATCHMENT

The Daly River catchment is located in the Northern Territory of Australia and is one of the major tropical river systems being researched by TRaCK. The location of the Daly catchment is shown in Figure 1-1. Lying to the south of Darwin, the Daly River catchment is about 53,000km^2 in area (about 80% of the size of Tasmania). It includes the major tributaries of Katherine, King, Fergusson, Douglas, Edith and Flora Rivers. The Daly River flows in a general westerly direction into the Timor Sea. The volume of water discharged into the sea is the second highest of any river in Australia (CSIRO, 2009a).

FIGURE 1-1 LOCATION OF THE DALY RIVER CATCHMENT

The Daly River is one of the largest perennial river systems in Northern Australia. Being located in the tropical region of Australia, it experiences a wet season (November to April) and a dry season (May to October). Dry season flow is dominated by groundwater discharge. This groundwater flows from the two major limestone aquifer systems located within the geological basin known as the Daly Basin (Tickell, 2009). These aquifers store and transmit significant volumes of groundwater and are named the Oolloo Dolostone and the Tindall Limestone. They are separated by impervious siltstone formations named the Jinduckin formation, and thus water does not flow between them. In addition to the major Daly Basin aquifers, the Wiso Basin also discharges some groundwater to the Flora River. This basin is separate from the Daly Basin and is located to the south. However, it does provide an important 50% of the Flora River dry season flows (CSIRO, 2009a).

Groundwater extraction from the aquifers occurs via bores with the extracted water used primarily for agricultural irrigation. These extractions may reduce dry season flows within the Daly River catchment and subsequently may impact upon the ecological and socio-economic systems dependent upon the dry season flows. The Northern Territory government (NRETAS) has developed a Water Allocation Plan designed to maintain the dry season flows.

The topography of the Daly River catchment is relatively flat with a maximum elevation of around 500m AHD (Australian Height Datum). As shown in Figure 1-2, these maximum elevations are found in the upper reaches of the Katherine River and some areas along the south-west catchment boundary. Consequently, river profiles are also relatively flat as shown in Figure 1-3 and Table 1-1. The Daly River has a mean slope of 0.0002 and the Katherine River a mean slope of 0.0011.

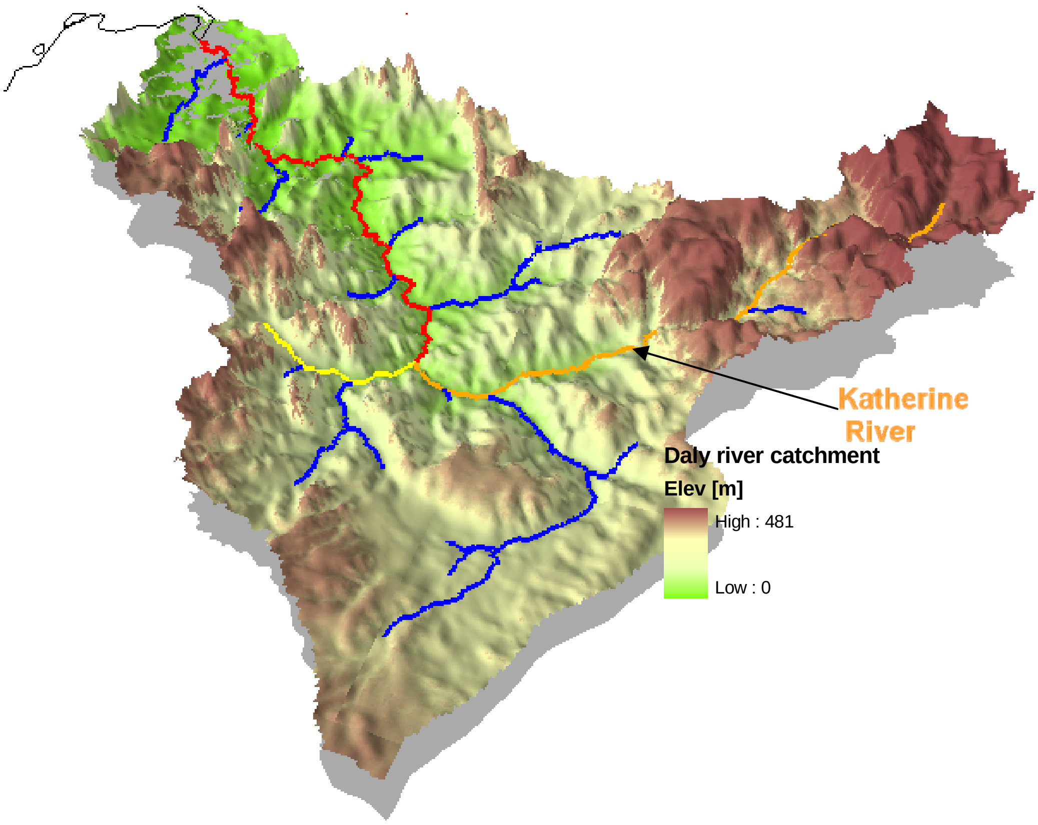

FIGURE 1-2 DALY RIVER CATCHMENT ELEVATIONS

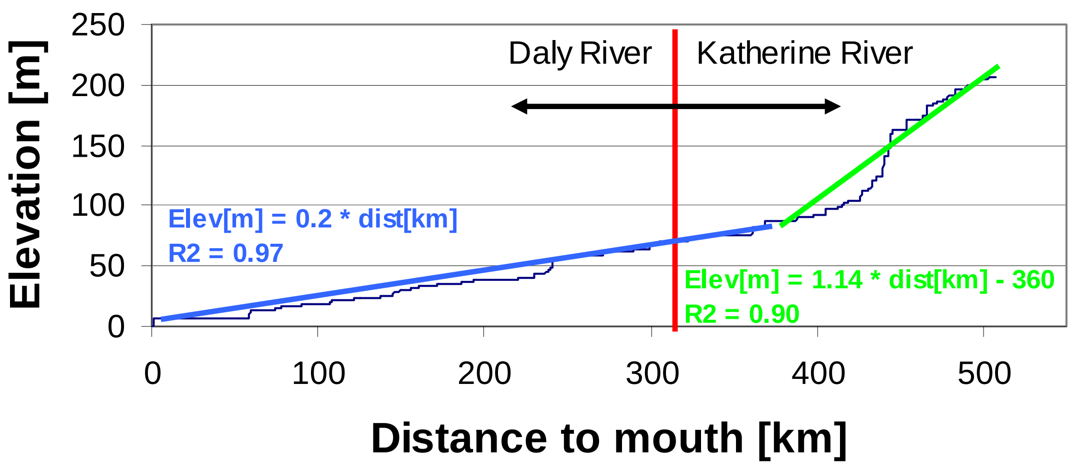

FIGURE 1-3 DALY RIVER AND KATHERINE RIVER PROFILES

Watercourse	Main Channel Longitudinal Length* (km)	Main Channel Longitudinal Slope (m/km)
Daly River	325	0.2
Katherine River	180	1.1
Flora River	85	0.9
King River	65	0.6
Dry River	125	0.6

*as per available GIS Data

TABLE 1-1 MAJOR WATERCOURSE LENGTHS AND SLOPES

Approximately 10,000 people live within the Daly River catchment, with 27% of these being Aboriginal people. The population density is less than 0.2 people per square kilometre.

Grazing is the most extensive land-use within the Daly River catchment, with the majority of this occurring within natural vegetation. The second largest land-use is for traditional indigenous purpose. Less than 0.4% of the catchment is currently under intensive agriculture, such as peanut and tobacco farming. The catchment contains Nitmiluk (Katherine Gorge) National Park and Flora River Nature Reserve, as well as a part of Kakadu National Park.

Due to the areas of permanent water within the Daly River system, distinctive ecosystems are supported both within the river and along its banks. Notably, the endangered pig-nosed turtle breeds and lives within the middle reaches of the Daly River. Rare species of shark and sawfish are also found within these reaches. The lower reaches and estuary of the Daly River support a significant number of bird breeding sites and an estimated 30,000 birds utilise this area in one wet season. The river and tributaries also form the habitat for many species of freshwater and estuarine fish, including the well-known Barramundi. It is considered the best Barramundi fishing river in Australia.

1.3 CATCHMENT WATER MODEL

A catchment water model that models the conversion of rain into river discharges is a core model used in the MSE approach and forms a backbone for the integration of many of the other knowledge areas within TRaCK, including socio-economics and ecology.

Over the last year, Project 1.4 has developed a catchment water model for the Daly Catchment to function as a straw-man for the MSE software development. This model will enable scenario evaluations to be undertaken within the Daly River catchment. Due to the natural system described in the preceding Section 1.2, the model must be capable of modelling the following natural processes:

1. Conversion of rainfall to surface water;
2. Loss of water to the atmosphere via evapotranspiration;
3. Recharge of the regional groundwater systems;
4. Spatial and temporal movement of water through the groundwater systems (including extraction of water through bores);
5. Discharge of water from the groundwater systems to watercourses;
6. Spatial and temporal movement of surface water flow into watercourses.
7. Spatial and temporal flow of channelised water.

In addition, the broader MSE model must also be able to simulate the ecological and socio-economic systems that are dependent upon the water processes listed above. These physical systems are described further in the preceding section.

The catchment water model is thus required to represent a large range of complex processes. Subsequently, a large amount of data is required in order to ensure that the model sufficiently represents the natural environment. A detailed description of the development of this water model is provided in Section 3.

1.4 MODEL DATA

Substantial amounts of time have been invested in collating and acquiring data for the catchment water model. This data is sought in order to allow the model to adequately represent the natural environment and also to allow a model calibration to be undertaken. This has involved liaison with a large number of organisations and individuals and manipulation and assessment of a broad set of data types. Further details on these datasets are provided in Section 2.

1.5 LITERATURE REVIEWS

Project 1.4 team members undertook a review of all available literature on previous water related work in the Daly River catchment. These included external reports on groundwater modelling, flood studies, and data assessments. A list of references obtained in the literature search is included in Section 5. Where available, reports from other TRaCK projects were also reviewed. However, in most cases, direct liaison with team members from other TRaCK projects was more efficient. These reviews and communications allowed the Project 1.4 team to develop a draft summary of the water work undertaken in the Daly River catchment. This was further refined following the “Flows Workshop”, as described in the following section (and presented in Table 1-2).

1.6 COMMUNICATION & LIAISON

The Project 1.4 team found it was beneficial to draw together a core group of researchers from around Australia to participate in a one day “Flows Workshop” in Darwin. These researchers were those that were involved in the water modelling components of the Daly River TRaCK projects. The workshop had several goals:

1. To provide a forum in which researchers that were not usually in touch, could discuss their own projects, learn of others and discover synergies between.

2. To develop an inventory of the science that has been developed in the area of water modelling, and

3. Examine how our understanding of the physical processes and underlying data could be used to further develop, extend and improve a the Daly River catchment water model.

The “Flows Workshop” was held in December 2009 and was facilitated by Project 1.4 team members. It was successful in all three goals listed above. An outcome of the workshop was a valuable summary of Daly water work, as provided in Table 1-2.

SUMMARY of FLOW INVESTIGATIONS IN THE DALY RIVER CATCHMENT

TRaCK Project No.	Project Component	Water Investigation or Model Used or Being Considered	Contact Person	Purpose / Aim	Year of Develop.	Generic Model Description	Link	Timestep	Width	Extent/ Location	Distance	CALIBRATION Type	Dates	GROUNDWATER Network	Discharge	Recharge	HYDROGRAPHIC DATA Rainfall	PET	Flow	TOPOGRAPHIC DATA DEM	Cross-sections	Land-Use & RoughnessData	BOUNDARY CONDITION Upstream	Downstream	ADDITIONAL COMMENTS
4.1	Water Budgets	Covariance Flux Towers	Lindsay Hutley (CDU)	To measure ET at 3 locations	2007 ongoing	To measure ET at 3 locations	N/A	N/A	Point	Stray Creek: 1. uncleared, 2. recently cleared with native veg & 3. improved pastures	N/A		N/A					N/A			N/A				
		APSIM	Richard Weinmann (CDU)	Point-scale modelling at flux tower sites. Try to distribute ET across the catchment	Future	Point-scale modelling at flux tower sites. Soil water (ET & soil moisture capacity). Try to distribute ET across the catchment.	http://www.apsim.info/apsim/releases/Apsim.asp					Deliver water to river - surface routing but no river routing		Groundwater Recharge Compenent to be given??											
		Upscaling point-scale data from Flux Towers	Guy Boggs (CDU)	To map water balance across catchment	2010					Catchment-wide										3sec DEM					
		WetSpa? MIKE-SHE?	Richard Weinmann (CDU)	To characterise surface runoff behaviour over the catchment	Potentially in the Future?	Integrated groundwater / surface water model	http://www.dhigroup.com/Software/WaterResources/MIKESHE.aspx							Using the FEFlow Finite Element Network (modflow)			BoM Gridded Data	MODIS CSIRO Monthly ET Data		3sec DEM		Vegetation Type and Coverage from Satellite Mapping			
		Floodplain Mapping	Renee Bartolo (eriss), Doug Ward (CDU)	To map movement of water across floodplain & estmate volume	2009 Wettest Wet 2004 Dryest Wet	Monthly time-series of water surface areas through wettest wet and dryest wet year.	N/A	N/A		Floodplain: Landsat-30m pixel image, Radar 10m pixel	?	-	-							Landsat & Radar images of ground. Ground levels needed to determine volumes.					
4.2	Regional Scale In-bank Sediment/Nutrient Movement	RMA 10 (hydrodynamic) & RMA 10S (morphological)	Eric Valentine (CDU)	To model in-bank sediment transport	2009 ongoing	3D finite element model for stratified surface flow		5-10min	in-bank	Claravale to Beeboom	129km	Not done yet. Will be based on gauging station records.			None at this stage but can be input as point source when data is available		None	None	None Yet. Gauging Station Flow /Stage/Rating Curve required	Approx. 50 xsections from NRETAS - these are combined using google earth as a guide to sand/rock bar locations. Breaklines join xsections to provide an in-bank DEM. This DEM has been improved in 2009 with use of thalweg (2002)		in-bank roughness values	- Q from Gauge Data - Sediment concentration proportional to Q (based on other TRaCK findings and David Williams work)	Qh Relationship	
		Flood Frequency Analysis	Paul Rustomji (CSIRO)	To determine return period (ARI / AEP) of bankfull flow & develop regional flood quantile estimate.	2009	"A Statistical Analysis of Flood hydrology & Bankfull discharge for the Daly River catchment, NT Aust"	N/A	N/A	N/A	10 gauging stations		N/A	N/A	N/A	N/A	N/A	Gridded mean annual rainfall developed by Jeffrey et al (2001)	N/A	Gauging Stations to 2007. Rating curves used	N/A	At gauging station sites.	N/A	N/A	N/A	L-Moment Fit with GEV Distribution on Peaks over threshold. Statistical relationship developed to quantify Q quantiles at ungauged catchments using catchment area, rainfall (mean annual) & "b"
		SedNet	Paul Rustomji (CSIRO)	To determine sediment & nutrient budgets across the catchment	2009 ongoing	Sediment & nutrient (K&N) budget model	http://www.toolkit.net.au/SedNet					Needs calibration using tracer samples collected													
4.3	Links flows with ecology	HEC-RAS	Ian Webster (CSIRO)	To provide low flows to feed a geochemical model to determine nutrient movement	2009	1D steady-state hydraulic model			in-bank	Claravale to Beeboom	150km	Google Map Widths	?	-	One point discharge based on Tickel's report	None					19 xsections + 46 xsections from Eric Valentine + thalweg (from Georges et al) to create 1000 xsections		Flow from Dorisvale Gauge	Stage from Beeboom Gauge	
4.4	Reach Scale In- & Out- Bank Sediment/Nutrient Movement	RMA 10 (hydrodynamic) & RMA 10S (morphological)	Eric Valentine (CDU)	To model inbank & floodplain sediment movement	2009 ongoing	3D finite element model for stratified surface flow			in-bank	Daly R Crossing to Nancar	10km	Not done yet - may require time series of sediment movement on floodplains across a wet season (ie time series of "sand" bank movement)			Not considered		Not considered		Gauging Stations	LIDAR data collected in 2008 dry season from Mt Nancar gauging station to Daly River crossing across a width of 2-3km.	In-bank details from xsections. In-bank DEM created as per above method	LIDAR & site inspection	Mt Nancar flows from Gauging Station	Daly River Gauge and use road as weir/culvert crossing relationship	- Determining the erosive capacity of floodplain flow - Would like to know what output is required for other TRaCK projects
Not Track	NRETAS RMA Model for Spyrogyra Study	RMA2	Simon Townsend (CDU)	To model shear velocities to determine success of Spyrogyra algae	2002	2D surface flow	N/A	?	in-bank	Upstream of Douglas R confluence	17.5km	Yes. No details.	2001 Dry Season		No details		Not considered		Gauging Stations	N/A	Yes. Simon chasing up with Julia Fortune	n=0.025	No details		Model deleted accidentally post-2002. But topographic/bathymetric data set (inbank) may still exist
Not Track	RMA Model for Algal Growth Study	RMA2	Simon Townsend (CDU)	To model shear velocities to determine success of Spyrogyra algae	2008?	2D surface flow	N/A	?	in-bank	15km d/s of Katherine on Katherine R	10km	?	?		?		Not considered		?	N/A	Yes. Simon has these.	?	?		Model developed by Eric Valentine and then modified by WRL to produce shear v. Model still with WRL.
Not Track	NRETAS RMA Model (David Williams)	RMA	David Williams?	?	?	3D finite element model for stratified surface flow				D/S Daly River															
Not Track	NRETAS Integrated Modelling (Not a TRaCK Model)	FEFLOW	Des Yinfoo (NRETAS)	To model groundwater flow & scenario assessments to assist in water allocations	2008 with subsequent updates	Finite Element groundwater model			-	Boundaries of Tindall Aquifer (up into King/Dry River and to Katherine town)		Continuous Simulation	1971 to 2006		Inflows to river 1970, 1982 & 2000										
		MIKE11	Des Yinfoo (NRETAS)	Linked with FEFLOW - estimates in-bank surface water flows	2008	1D hydrodynamic surface water flow model		1h timestep	in-bank	D/S limit is Nancar GS, u/s limit is Katherine Gorge	huge	Focus on low flows. Match flows to gauged data at each gauge. Adjust n. Incorporate low flow d/s controls. Modelled h>measured h			Inflows to river 1970, 1982 & 2000		See NAM	N/A	See NAM	Daly River DEM GA NT 90m (WGS84)	Inbank only. Sparse 1. Gauging Station xsections (not AHD) 2. Top End Water Projects (not AHD) 3. HECRAS model (Uni of Canberra)	Calibration "n". Vary with depth	NAM Flows	NRETAS rating curve (q-h)	Calibration not good as you would expect with in-bank portions of xsections only. Some locations out by 4m.
		NAM (RR)	Des Yinfoo (NRETAS)	Feeds runoff minus baseflow to MIKE11 model	2008	A lumped rainfall runoff model simulating overland flow, interflow & baseflow	http://www.dhigroup.com/Software/WaterResources/MIKE11/Details/Hydrology/RRNAM.aspx	14 subcatchments		Full catchment		Continuous. Compare modelled to recorded flow hydrographs of individual catchments (u/s recorded flow subtracted)	1983 to 2003		Lower baseflow (diffuse recharge) is removed prior to being fed into M11 model as this component will come from FEFlow		DataDrill (Qld DERM Interpolated Surfaces) - 10 interrogation sites. Areal distribution using Thiessen Polygon	DataDrill (Qld DERM Interpolated Surfaces) - 10 interrogation sites. Areal distribution using Thiessen Polygon	13 flow gauges						
Not Track	Katherine Flood Study	URBS	Des Yinfoo (NRETAS)	Estimates runoff to feed CELLFLOW model	2000	Runoff-routing model	Water Studies Software - not commercially available	20 subcatchments		Katherine River catchment to Stuart Hwy		Event-based	1984, 1987, 1995, 1998		Not considered separately		Daily (26) & Pluvio (14) Gauges	N/A	River Gauges (Flow from Rating Curve)	N/A	N/A		N/A	N/A	
		CELLFLOW	Des Yinfoo (NRETAS)	To determine peak flood levels for a range event magnitudes around Katherine	2000	1D unsteady flow model	Water Studies Software - not commercially available	?	>10km	Katherine Gorge GS to Vampire Creek	About 50km	Event-based	1984, 1987, 1991, 1995, 1998		Not considered separately		Daily & Pluvio Gauges	N/A	River Flow Gauges and Floodplain Level Gauges	1998 Photogrammetry: A 30m gridded DEM about 60km in length and a minimum of 10km wide surrounding Katherine. 1m contours produced from this.	- 33 xs d/s of Katherine (1994) - 42 river xs u/s Katherine (1998) - 35 floodplain xs u/s Katherine (1998)		Flow from URBS	Qh Rating Curve	
Not Track	NASY Hydrologic Modelling	Sacramento IHACRES Classic Simhyd SMARG AWBM	Cuan Petharem & Paul Rustomji (CSIRO)	To determine water availability	2009	Variety of models used with Ihacres and Sacramento being the preferred models based on Nash-Sutcliffe Efficiency		15 subcatchments		Full catchment		Continuous. 8 calibration catchments using automated optimised parameters. Compare modelled to recorded flow hydrographs (monthly steramflow data) of individual catchments (u/s recorded flow subtracted in middle reaches).	1930 to 2007				0.05deg (5km) gridded daily rainfall SILO data	0.05deg (5km) gridded daily rainfall SILO data	8 Gauges	Yes - used for definition of sub-catchments (unsure which one)	N/A		N/A	N/A	
Not Track	TRIAP Hydrology																								

TABLE 1-2 SUMMARY OF DALY RIVER WATER ASSESSMENTS

2 CATCHMENT DATA

Data required to support the catchment water model was sourced and collated by the P1.4 team. The following sections summarise the assessments undertaken to date in each genre of data.

2.1 RAINFALL

Investigation of the various rainfall datasets available across the Daly River catchment was undertaken. A summary of these datasets is provided in Appendix A. Following this investigation, the P1.4 team made the decision to acquire the NT daily patched point rainfall dataset from DERM (Qld Department of Environment & Resource Management). The location of the patched point data (PPD) stations across the Daly River catchment is provided in Figure 2-1. Following receipt of this data, data quality, fragmentation and statistical assessments were undertaken to determine the usability and reliability of the rainfall data. For example, correlations between PPD daily rain data for the period for 1980 to 2009 was undertaken to determine the region over which the data from each gauge may be applicable. Results of this correlation, with respect to distance between gauges, are provided in Figure 2-2. This indicates that the distance of applicability is no more than about 25km. Statistics of this type were used to determine which PPD stations were to be used. These are shown in Figure 2-2.

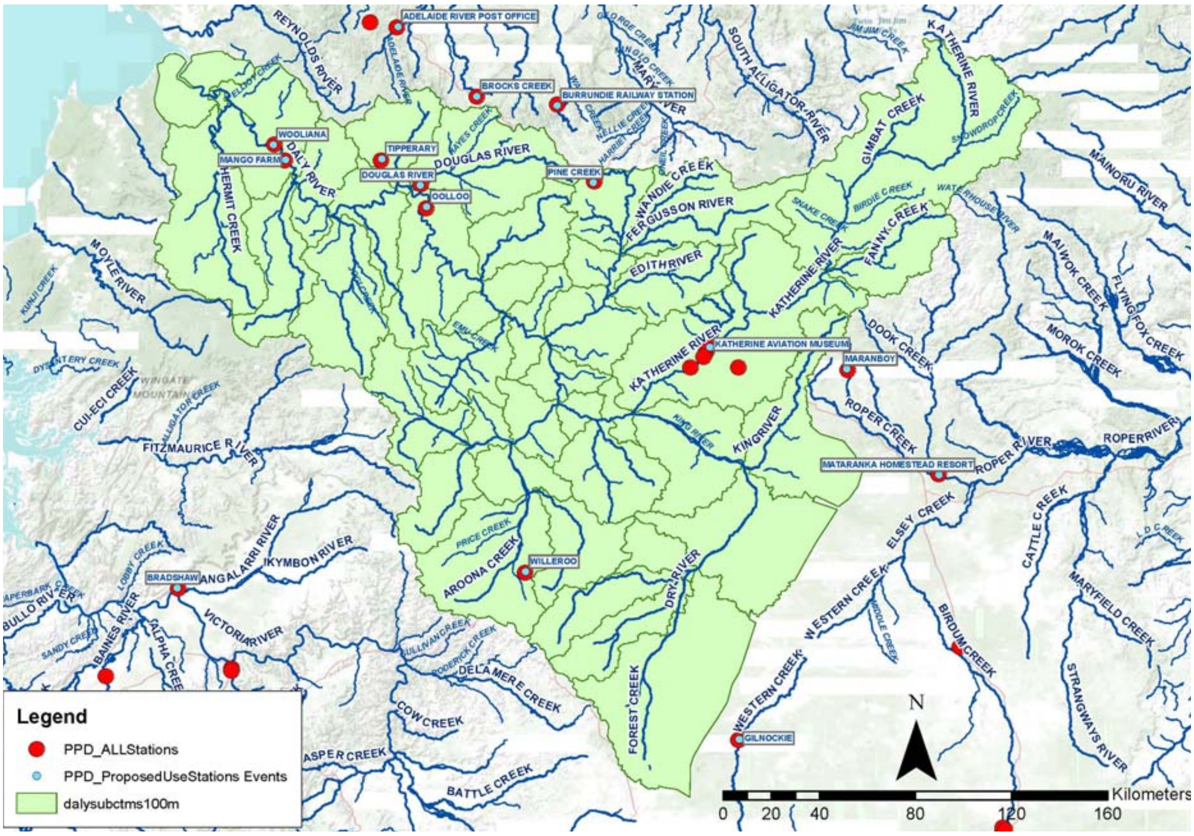

FIGURE 2-1 LOCATION OF PATCHED POINT DATA (PPD) STATIONS

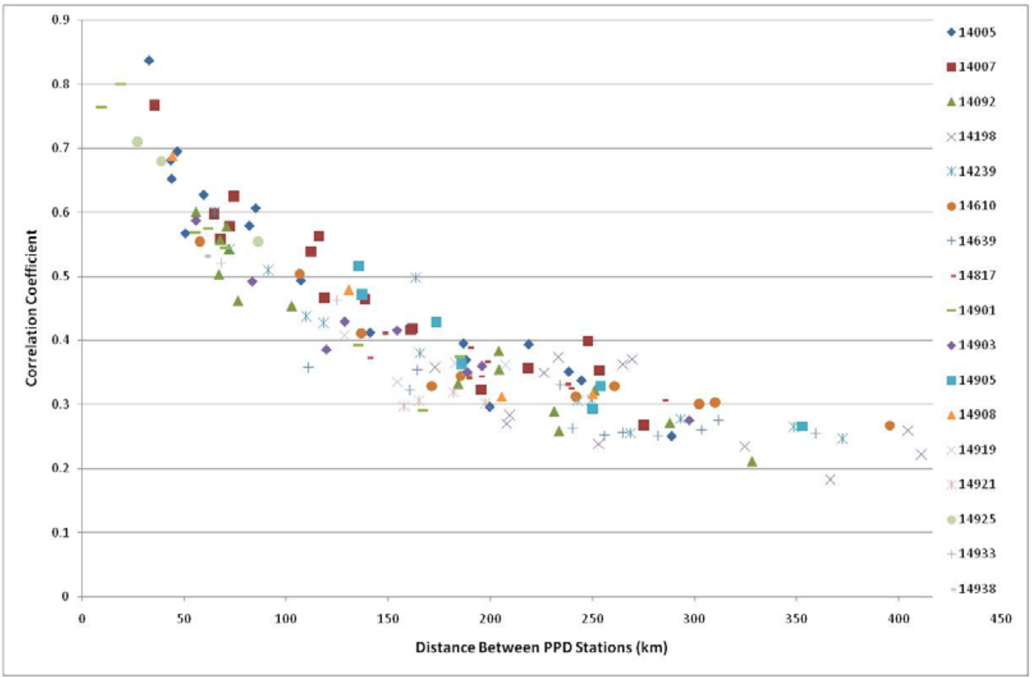

FIGURE 2-2 CORRELATION BETWEEN PPD STATIONS USING ALL PPD DATA POST-1979

Another source of rainfall data investigated was the SILO daily gridded rainfall data set. This data exists as a set of daily rain depths on a 0.05 degree spatial grid. The grids are developed by SILO based on a process of spatial interpolation procedures using recorded rainfall data. The grids are costly and it was not an option to pursue this dataset. However, P1.4 was able to obtain a processed form of these grids specifically for the Daly River catchment from CSIRO. This data was provided in the form of an average, maximum and minimum daily rainfall across each of the MSE Daly subcatchments (discussed in following sections). The average daily rainfall for each MSE subcatchment from the SILO gridded dataset for 1885 to 2010 is shown in Figure 2-3. It shows a small variation in the average daily rainfall across the catchment as a whole with areas in the north-west (close to the mouth) receiving an average daily rainfall of around 3.5mm, to areas in the south receiving around 2mm per day. As expected, this compares well with that presented in the NASY report (CSIRO, 2009) due to the same rainfall dataset being used in both cases. It is important to note that there were very few rain records in the region prior to 1950 on which to base the SILO grids, and accuracy of these grids is not expected to be high.

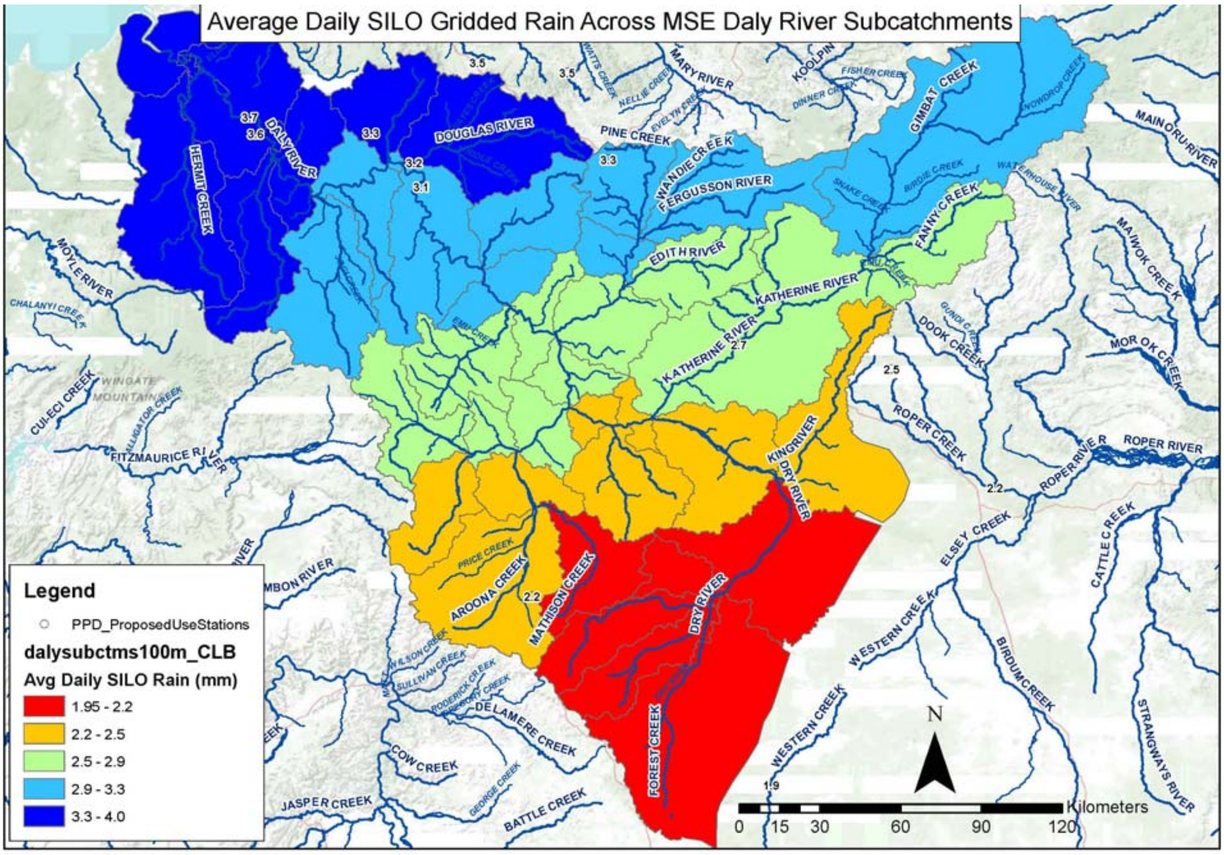

FIGURE 2-3 AVERAGE DAILY GRIDDED RAINFALL ACROSS DALY SUBCATCHMENTS (SILO, 1885 TO 2010)

2.2 FLOW

In general, flow data is the primary historical record set used to calibrate a water model. The calibration process is described in Section 3.5. In using flow data, it is essential to recognise that flow is **not** measured but rather derived. It is the stage (water level) that is physically measured at a gauging station, not the flow. The stage is converted to flow using a rating curve; a plot of stage versus flow. The rating curve is derived from actual gauging of the watercourse at the location of the gauge. That is, when the river is flowing, gauging officers will visit the gauge site and measure the stage AND gauge the flow (usually from a boat). This gauging forms one point on the rating curve. Gauging needs to be undertaken across the full range of flow magnitudes to develop a rating curve that is reliable. This sometimes does not occur as it is often difficult to access gauge sites when the river is in flood. Very often, gaugings are not undertaken for large magnitude events and the rating curve must be extrapolated beyond the highest stage gauged to allow conversion of measured stage to derived flow. This is one reason that large flows may not be accurate. Hence, it is always recommended that the rating curve for a gauge site be investigated before using the flow data.

P1.4 has sourced the most up-to-date daily stage and flow data from NRETAS for each flow gauge station within the Daly River catchment. Rating information for each gauge has also been obtained to provide an indication of reliability. P1.4 has undertaken statistical and critical review of the flow records in order to determine which records and stations are usable and reliable. Such analysis is demonstrated in Figure 2-4.

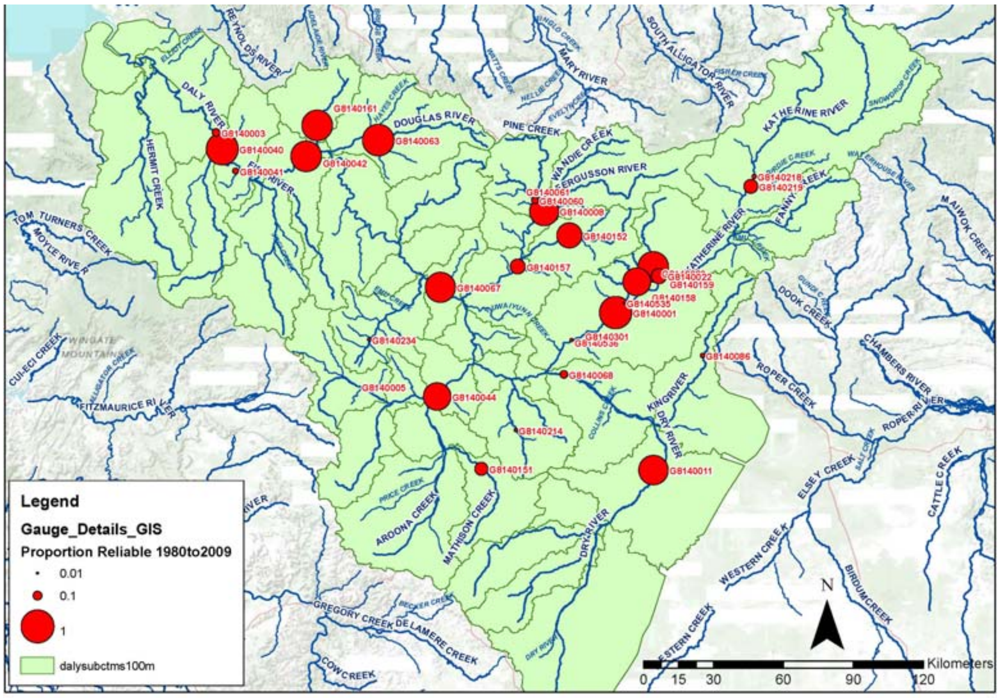

FIGURE 2-4 PROPORTION OF FLOW DATA RELIABLE FOR THE PERIOD 1980 TO 2009

Rating curves were also assessed as a means for determining reliable data. As shown in Figure 2-5, rating curve 1 (used prior to 1966) would not have produced accurate flows above about 700m^3/s. This is because up until 1966, the gaugings that had taken place at that site were for small flows only. This meant that the rating curve above 700m^3/s was manually extrapolated. Following 1966, when further gaugings at higher flows had been undertaken, the rating curves were updated to better reflect the stage-flow relationship at the site. It is interesting to note that if a stage of 7m had been recorded prior to the update in the rating curves in 1966, it would have been recorded as a flow of about 3,000m^3/s (see Figure 2-5). However, the same recorded stage of 7m today, would result in a flow of around 1,700m^3/s being recorded. Thus, flow values are only as good as the rating curve.

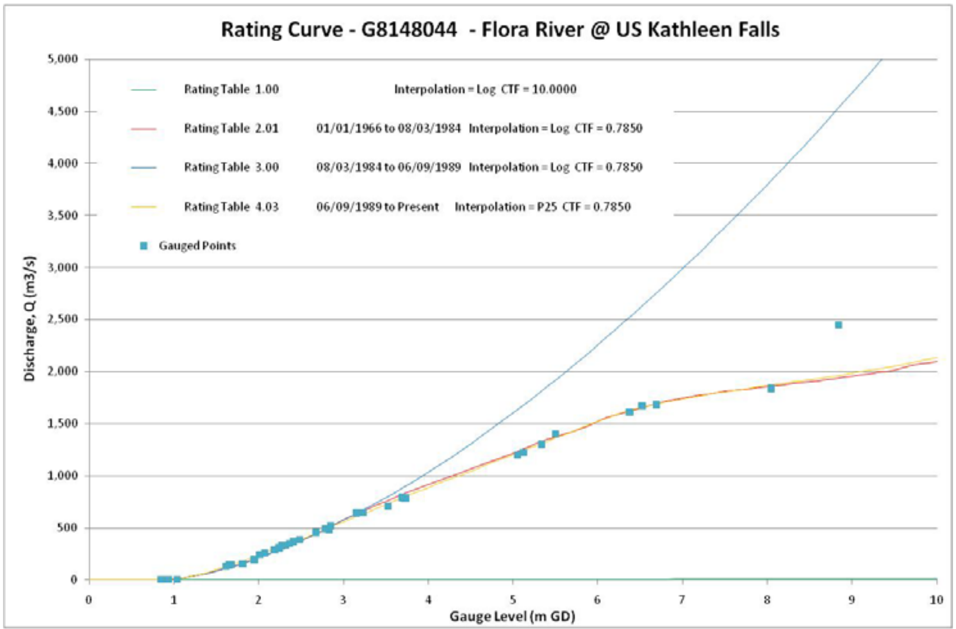

FIGURE 2-5 RATING CURVE EXAMPLE

2.3 GROUNDWATER

P1.4 has obtained groundwater data, is in the process of investigating potential groundwater models for use and establishing connections with data providers and model users. Groundwater data obtained includes extraction rates, licensed bore locations and aquifer extents as shown in Figure 2-6.

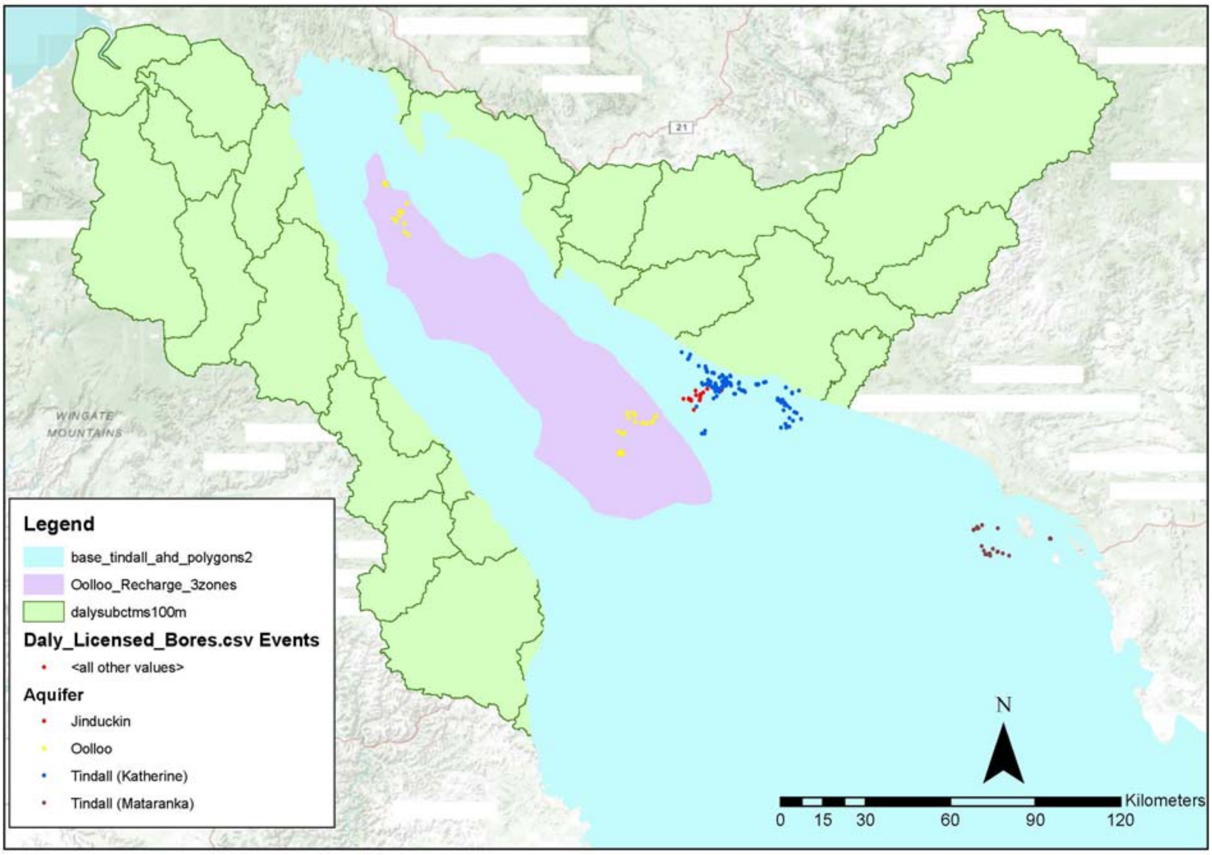

FIGURE 2-6 EXAMPLE GROUNDWATER DATA

2.4 EVAPOTRANSPIRATION

Evapotranspiration is the loss of water to the atmosphere due to evaporation from the soil, waterbodies and interception sites and transpiration from plants. Potential evapotranspiration (PET) is the theoretical maximum evapotranspiration possible if water available was equal to energy available.

Evapotranspiration in the Daly River catchment is significant and represents a relatively large of loss of water to the system in the dry season, when rainfall is usually zero. As shown in Figure 2-7, potential evapotranspiration (PET) ranges from about 200mm/month in the wet season to a low of about 120mm/month in the dry season. The Daly River catchment is water limited as the annual PET of 1942mm exceeds the annual rainfall of 1019mm (CSIRO, 2009a).

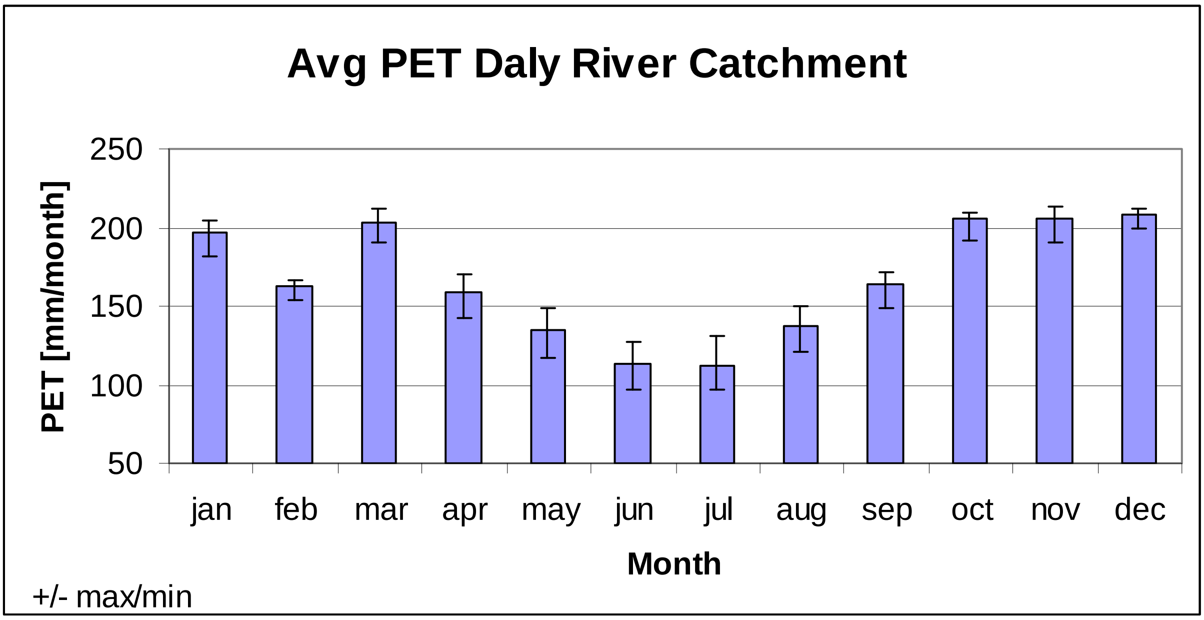

FIGURE 2-7 AVERAGE PET ACROSS THE DALY RIVER CATCHMENT

Evapotranspiration data is available from several sources:

1. PPD. The PPD described previously in Section 2.1, includes a daily PET value at each station. These values have been obtained from the SILO gridded dataset.
2. SILO gridded PET data. As explained previously, this data is not available to P1.4 due to financial constraints. However, CSIRO has provided an averaged form of this data to P1.4 based on subcatchment delineation. This has been provided on daily timesteps.
3. MODIS PET Data. Moderate Resolution Imaging Spectroradiometer (Satellite) Data. Project 4.1 is currently assessing this data and P1.4 are in communication with them about suitability for use.
4. Project 4.1 ET data. Project 4.1 of the TRaCK program has been measuring point-scale evapotranspiration within the Daly River catchment at 3 sites via covariance towers. These towers are situated within different land-use types. Project 4.1 aims to upscale ET data from these 3 sites across the entire Daly River catchment. The end product will be of use to P1.4 as input to the catchment water model. Project 4.1 has advised that the expected completion date will be towards the end of October 2010.

P1.4 expects that the Project 4.1 upscaled ET data will potentially be the most applicable to the Daly River catchment. Until the upscaled data is available (October 2010), P1.4 will use another source of ET data as a best estimate.

2.5 OTHER DATA

Other datasets such as soil data, general GIS data etc have also been sourced as part of the data collection phase. As an example, soil data is shown in Figure 2-8.

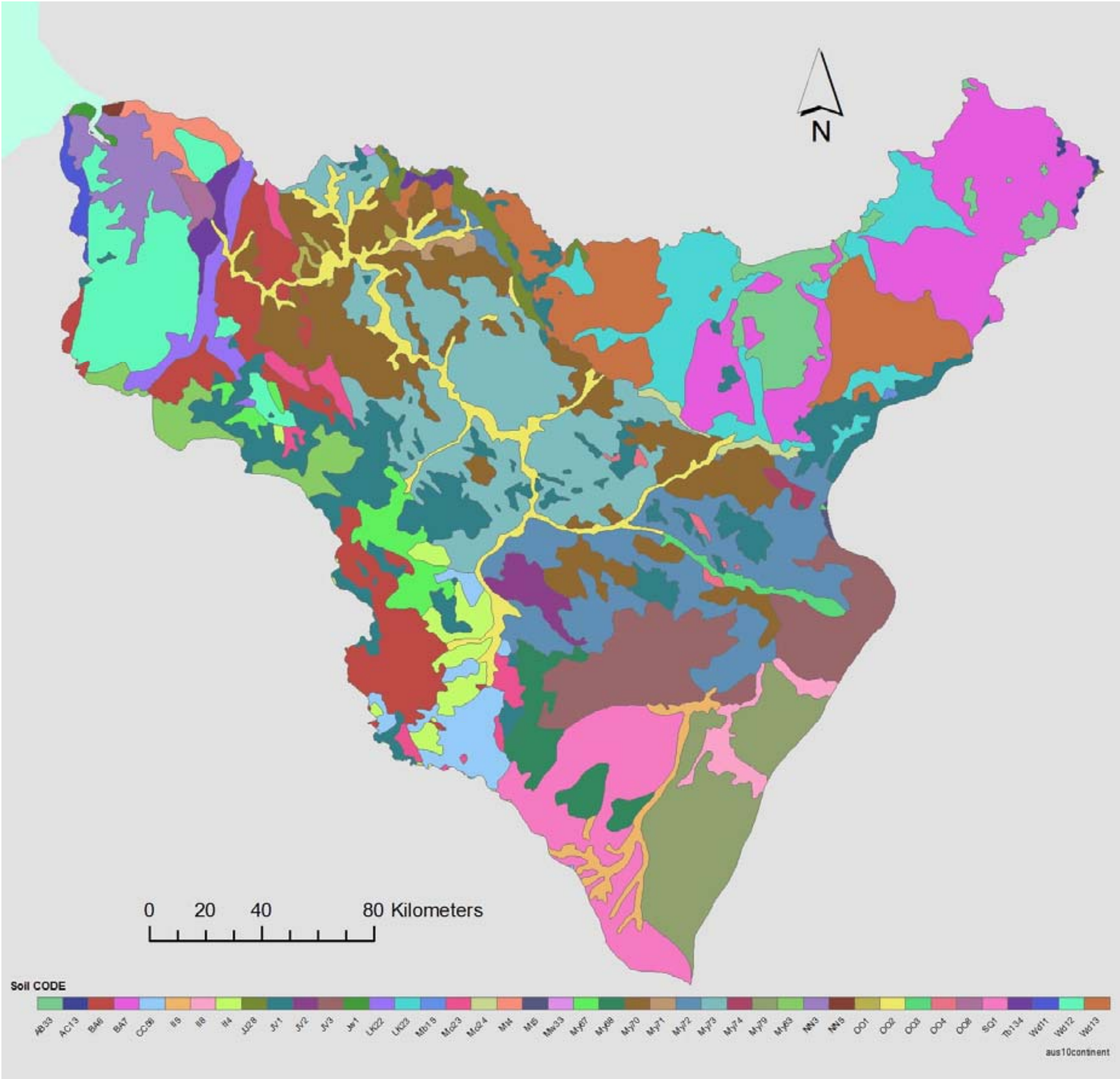

FIGURE 2-8 SOIL DATA ACROSS THE DALY RIVER CATCHMENT

In addition, P1.4 has obtained the hydrodynamic HEC-RAS model and is assessing its suitability for use in predicting hydraulic characteristics within the MSE framework. This is described in Section 3.4.

3 CATCHMENT WATER MODEL DEVELOPMENT

As described previously, the catchment water model is a core model used in the MSE approach and forms a backbone for the integration of many of the other knowledge areas within TRaCK, including socio-economics and ecology.

There are many types of catchment water models ranging from the very simple to the highly complex. It is perhaps obvious but nevertheless important to state, that simple models tend to be less data and time intensive and complex models the converse. With this in mind, consider the following points:

3. The Daly River catchment is a data poor catchment (CSIRO, 2009a). That is, the available data is sparse and when available, not always accurate.

4. The MSE framework requires a model capable of undertaking many simulations in a relatively short period of time to enable a multitude of strategies to be assessed.

Based on these factors, **the most suitable model for the task is undoubtedly a simple model**. That is not to say that complex models do not have a place in the Daly River catchment but such models are likely to be highly specialised models. For example, NRETAS has a complex groundwater model (using the software FEFlow) for assessing the Daly Water Management Plan. One model simulation can take around 18 hours (pers. comm. Des Yinfoo, NRETAS 2009) but as the number of simulations is small, the long simulation time is sustainable. Another example is the complex hydrodynamic and morphological model (using the software RMA) developed by TRaCK Project 4.4 for assessing sediment movement. This model is data intensive and requires an accurate Digital Elevation Model (DEM) and in-bank cross-sections to represent the topography. Again, this is sustainable for the 10km reach of river represented by the model. However, this reach represents less than 0.1% of the total watercourse length within the Daly River catchment is thus not only not sustainable, but just not possible on a catchment scale. Thus, the model selected must be suited to both the data available and to the time required to undertake the necessary simulations.

This section details the catchment water model components currently being used or investigated for use within the MSE framework.

3.1 CONCEPTUAL RAINFALL-RUNOFF MODEL

One of the major physical processes requiring simulation by the catchment water model is the conversion of rainfall to runoff. To represent this process a conceptual rainfall-runoff model called "SIMHYD" has been selected. SIMHYD is one of a suite of conceptual models offered within the eWater rainfall runoff library toolkit (http://www.toolkit.net.au/Tools/RRL). It is relatively simple, with only 7 parameters, and has been used extensively across Australia (eg Chiew (2005), Tan (2005), CSIRO (2009a), Post *et al* (2007,2008) etc). A schematic of the SIMHYD model showing inputs, parameters and outputs is shown in Figure 3-1.

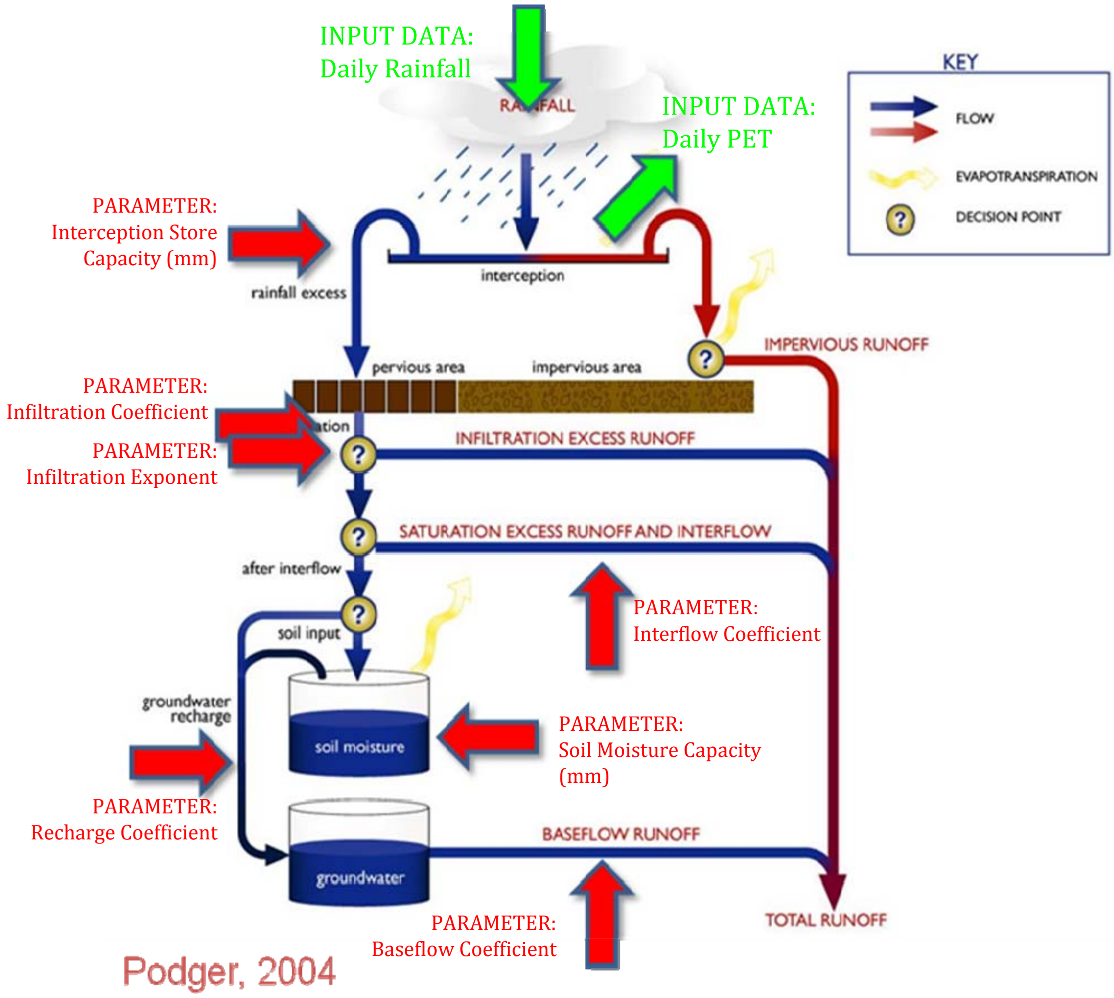

FIGURE 3-1 SIMHYD SCHEMATIC SHOWING INPUTS AND PARAMETERS

The input data required for SIMHYD is daily rainfall and daily PET. Daily flow records are required to allow the model to be calibrated. The catchment area is also required to allow the volume of rainfall to be determined. For this purpose, the Daly River catchment has been divided into a number of sub-catchments. The sub-catchment delineation at this stage of the project is shown in Figure 3-2. Each sub-catchment has been further divided into 6 land-use classes to allow different model parameters to be assigned for each land-use.

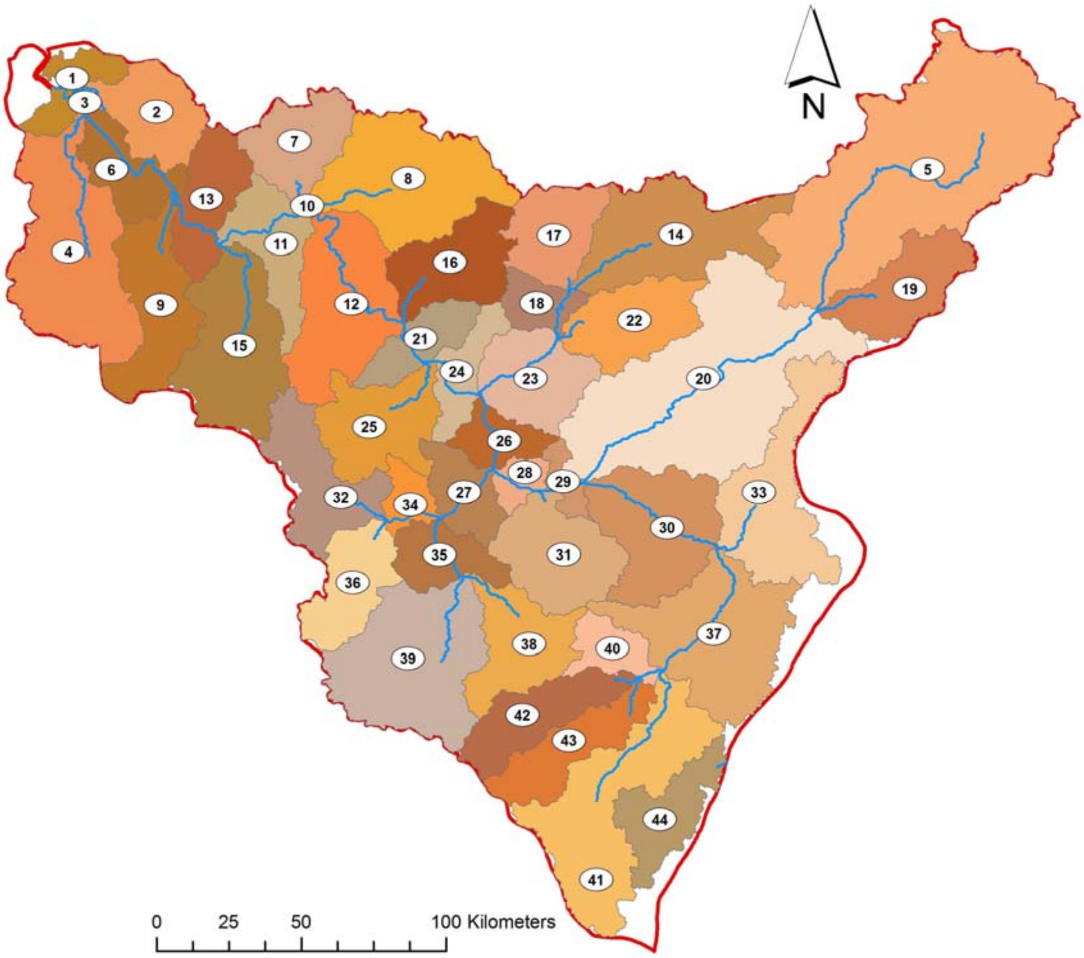

FIGURE 3-2 SUBCATCHMENT DELINEATION FOR THE DALY RIVER CATCHMENT SIMHYD MODEL

3.2 ROUTING OF FLOWS

SIMHYD calculates the amount of rainfall that will become runoff for each of the land-uses within each of the sub-catchments. These output flows are then routed from one sub-catchment to the next. P1.4 has developed Muskingum routing code to allow the flows to be delayed and attenuated (see Figure 3-3) (Lindsay et al., 1975). In such a large catchment, attenuation of flows has a significant impact upon the shape and magnitude of the output hydrograph, particularly further down in the catchment. If routing is not included, calibration of the water model would be impossible on a daily basis. The linking between sub-catchments not only allows the passage of water, but also the passage of sediments and nutrients.

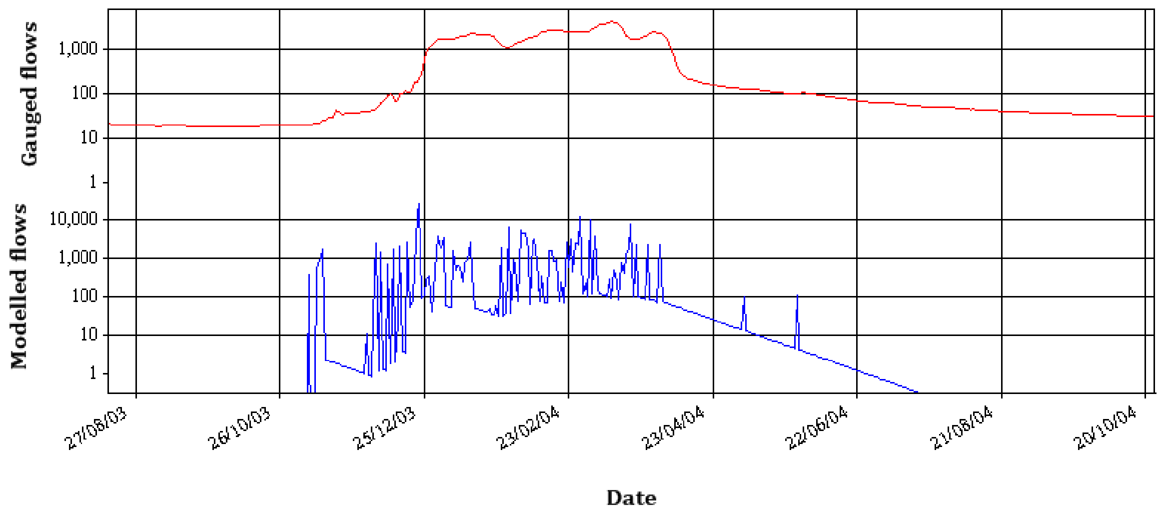

FIGURE 3-3 COMPARISON OF MEASURED (RED TRACE) AND MODELLED (BLUE TRACE) FLOWS.

3.3 GROUNDWATER MODEL

As described previously, some areas of the Daly River catchment overlie regional groundwater systems. Excess rainfall can recharge into these systems during the wet season and groundwater can discharge into watercourses during the dry season. The Daly Basin and a portion of the Wiso Basin have a significant impact upon water behaviour within the Daly River catchment and it is necessary to include these systems within the water catchment model.

SIMHYD will estimate the amount of water entering a groundwater system. However, it does this on an individual sub-catchment land-use basis and does not link these "groundwater storages" in anyway. Thus, a simple groundwater model that can account for the water storage and movement characteristics of each aquifer is required. P1.4 is currently investigating ways of simply modelling these characteristics.

As mentioned previously, NRETAS has a complex model of the Daly groundwater system. While it is not possible to use this model directly within the MSE framework due to simulation time constraints, it will be possible to use some model data and undertake a calibration to model outputs.

3.4 HYDRAULIC CHARACTERISTICS

One of the requirements of the Daly catchment water model will be to predict changes to hydraulic characteristics that are known to impact upon ecological habitat. Examples of such hydraulic characteristics are water velocities and size of the dry season pools. In the dry season these pools form the only habitat for many aquatic species. Changes to these hydraulic characteristics can be directly linked to changes in aquatic species populations.

In order to estimate hydraulic characteristics such as flow velocities and pool sizes, detailed information of the flow shape of the river and flow volumes is required. Flow volumes can be obtained from the conceptual rainfall-runoff model in tandem with the groundwater model. However, the flow shape and roughness of the river is not readily available.

P1.4 is currently investigating potential means for estimating hydraulic characteristics. One means is to utilise a one-dimensional (1D) hydraulic model developed by Ian Webster of CSIRO using the software HEC-RAS for Project 4.3 of TRaCK. Another means is to utilise components of a three-dimensional (3D) hydraulic model developed by Eric Valentine of CDU using the software RMA 10 for Project 4.2 of TRaCK. Both these models cover the same 130km reach of the Daly River from Claravale to Beeboom. However, they have been developed for different purposes and are described in the following sections.

3.4.1 HEC-RAS 1D HYDRAULIC MODEL

HEC-RAS is a one-dimensional, unsteady hydraulic model developed by the Hydraulic Engineering Centre within the U.S. Army Corp of Engineers. HEC-RAS (Hydrologic Engineering Centre's River Analysis System) software operates in both steady and unsteady modes. In steady state (flow at each computation point within the model is unchanging), the solution is based on the standard step method from one cross-section to the next to solve the continuity (conservation of mass) equation and the one-dimensional energy (conservation of energy) equation. Energy losses are evaluated by friction (Manning's Equation) and contraction/expansion losses (a coefficient multiplied by the velocity head). In unsteady mode, the solution is based on the continuity equation in conjunction conservation of momentum equations.

Webster (2009) developed a HEC-RAS model of the middle portions of the Daly River. As shown in Figure 3-4, the HEC-RAS model extends 130km downstream from the gauge station located upstream of Dorisvale Crossing (140067) to the gauge station located 2km downstream of Beeboom Crossing (140042). Webster (2009) used this model to provide flow speeds, volumetric transport, and water depths to support the application of a biogeochemical model of the river to describe nutrient transport and transformations and the resulting primary production. The HEC-RAS model was used in **low flow steady state** conditions only.

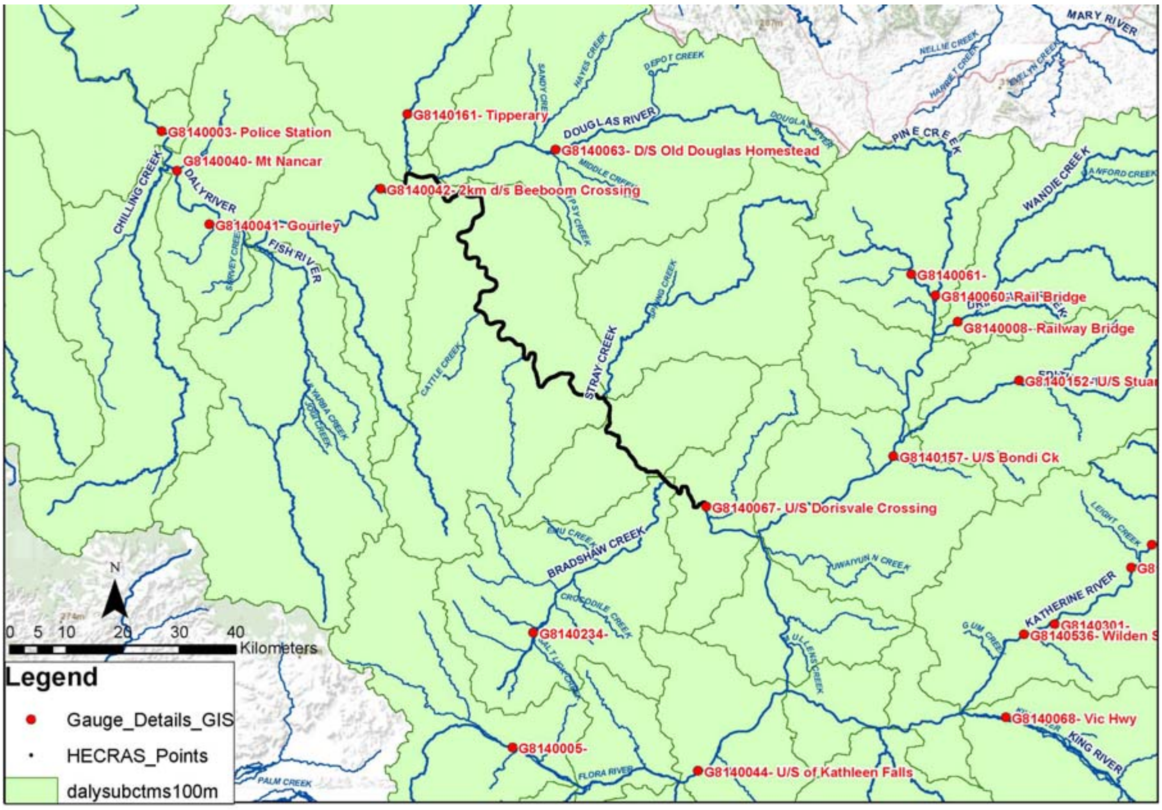

FIGURE 3-4 COVERAGE OF HEC-RAS & RMA MODELS

As HEC-RAS is a 1D hydraulic model, it requires input cross-sections to represent the flow shape of the river. Over the 130km reach in the Webster (2009) HEC-RAS model, only 65 surveyed cross-sections were available. This is insufficient to develop a hydraulic model. However, Webster (2009) also made use of a thalweg taken by Georges *et al* (2002) using a broad band RDI Acoustic Doppler Current Profiler (ADCP). Webster (2009) combined these data with widths of the water surface from Google Maps to derived estimated cross-sections along the 130km stretch. As Webster (2009) was interested in low flow simulations only, the cross-section definitions do not extend beyond the top-of-bank, as shown in Figure 3-5. Thus, at present, if the HEC-RAS model us used to model flows that exceed the top-of-bank, output will be unusable as it will be erroneous.

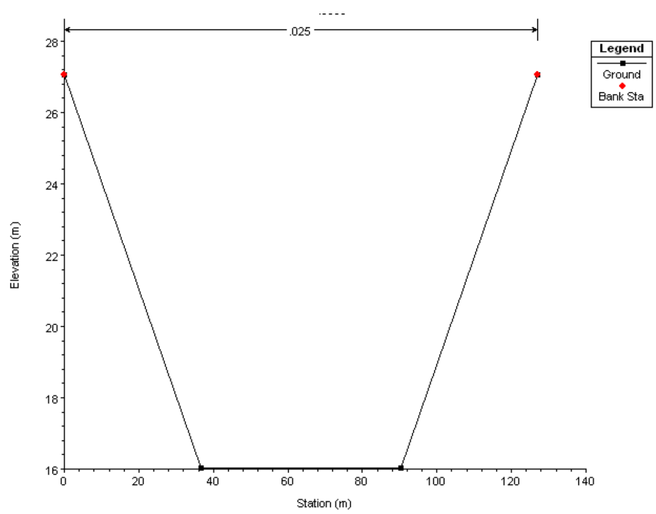

FIGURE 3-5 TYPICAL TRAPEZOIDAL HEC-RAS CROSS-SECTION

An example of longitudinal output at a steady-state low flow of 19.5m3/s (as used by Webster, 2009) is shown in Figure 3-6.

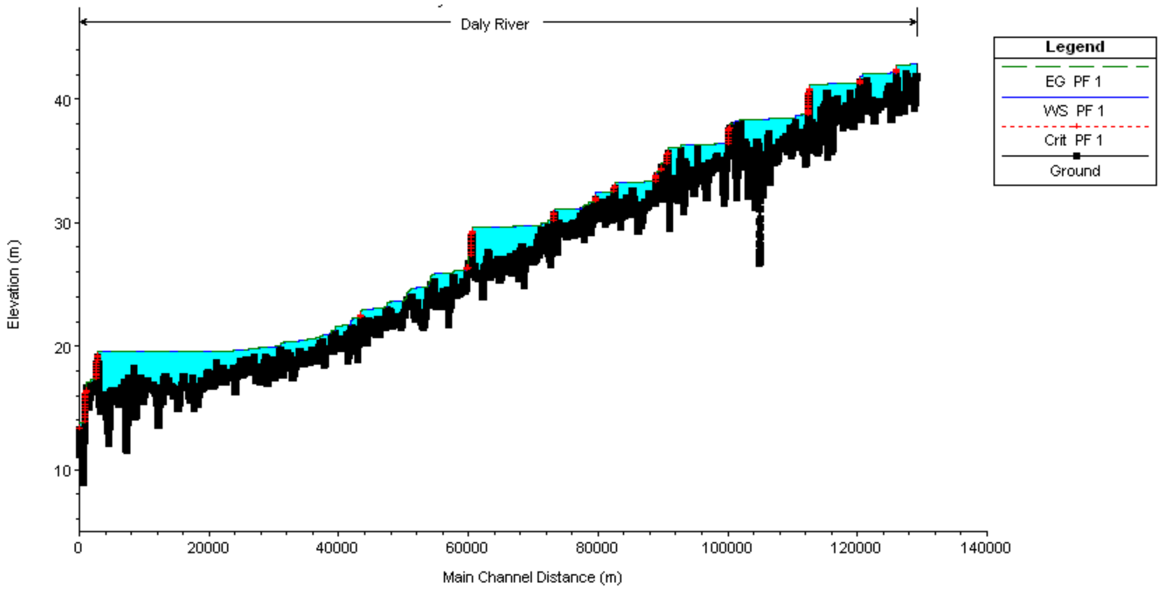

FIGURE 3-6 LONGITUDINAL HEC-RAS WATER PROFILE FOR UNSTEADY FLOW

P1.4 has trialled the use of this HEC-RAS model with unsteady flows with success. At present, this trial is continuing with a gauge-derived and MSE predicted flow time-series. The P1.4 team is considering the use of HEC-RAS as a tool for predicting velocities based on predicted flows. However, it does have some limitations including accuracy of cross-sections, limit of cross-sectional extent and ability to model 'leaking' of pools at low flows through riffles. This latter limitation may have a significant impact upon both pool size and velocity during low flows.

3.4.2 RMA-10 3D HYDRAULIC MODEL

RMA-10 is a 3D finite element hydrodynamic & water quality model. It has been developed by Professor Ian King from the Water Research Laboratory in NSW.

Project 4.2 of TRaCK has developed an RMA-10 model over the 130km stretch shown in Figure 3-4. The RMA-10 model requires that the "flow shape" of the river is defined in 3D rather than with 1D cross-sections. That is, RMA-10 requires a DEM to represent the river channel. Project 4.2 invested time into defining a DEM of the river both above and below water using the same 65 cross-sections and thalweg used by Webster (2009). Project 4.2 also used Google Maps to assist with this process.

Project 4.2 has developed this RMA-10 model to estimate sediment transport rates in this portion of the river. As such, they are less concerned with low flows and more interested in bank-full flows where maximum sediment transport occurs.

P1.4 is interested in the RMA model at this stage in relation to its DEM of the river channel. P1.4 is in communication with Project 4.2 to determine if the DEM will be of any use in better defining the pools, riffles and associated velocities.

3.5 CALIBRATION

Model calibration is the process of comparing model predictions to measured variables, making adjustments to the model and/or inputs until the model is able to replicate real world behaviour, within the bounds of data uncertainty and model capability.

P1.4 is in the initial stages of calibrating the Daly catchment water model using the datasets described in the previous sections. Functionality has been added to the MSE GUI to allow calibration to be undertaken within the MSE system. Full calibration of this catchment water model will only be possible once groundwater behaviour and floodplain inundation have been successfully modelled. The following sections provide preliminary indications of how calibration data will be used, functionality of the calibration software module, and examples of calibration runs.

3.5.1 USING CALIBRATION DATA

As described previously, daily rainfall and potential evapotranspiration (PET) data are required inputs for the hydrologic component (SIMHYD) of the catchment water model. However, they are also a member of the calibration "dataset" when being used to calibrate the model to historical records.

The primary historical record that is used to calibrate water models is flow. Calibration to flow occurs when a time series of *measured*[1] flow is compared with the time series of flow *predicted* by the model. Calibration aims to minimise the differences between the *measured* flow and the *predicted* flow. One means of minimising this difference is to adjust the model parameters (within realistic bounds) to allow the predicted flow to better reflect the measured flow. However, it is important to note that the process of calibration may also lead to the modeller questioning the schematisation of the model and/or the accuracy of the measured input data itself. Further information on flow data, rating curves and accuracy is provided in Section 2.2.

Measured flow at a particular location is compared to predicted flow from within the model at the same location.

3.5.2 CALIBRATION SOFTWARE MODULE

Within the MSE software, the calibration software module is designed to assist with the calibration of the catchment water model. It allows a measured flow gauge station to be selected along with a corresponding subcatchment and flows from each compared directly using the charting tool in the Graphical User Interface (GUI). Model parameters for each functional unit within each subcatchment are presented within the GUI. These are able to be changed individually, within the subcatchment, across functional unit groupings, or across sub-catchments. An example of the Parameter screen within the calibration module is shown in Figure 3-7. Model output includes daily time-series and scatter plots of measured and predicted flows, summed daily flows, ratio of measured and predicted summed flow, RMS, and the Nash-

[1] Flow is **not** directly measured; it is derived from recorded water level. This is explained further in Section 2.2. However, for the purpose of distinguishing between a real world flow and a modelled flow, the terminology of *measured* flow (derived from measurements in the field) and predicted flow (output results predicted by a water model) is adopted here.

Sutcliffe Efficiency Coefficient. An example of the Run screen within the calibration module is shown in Figure 3-8.

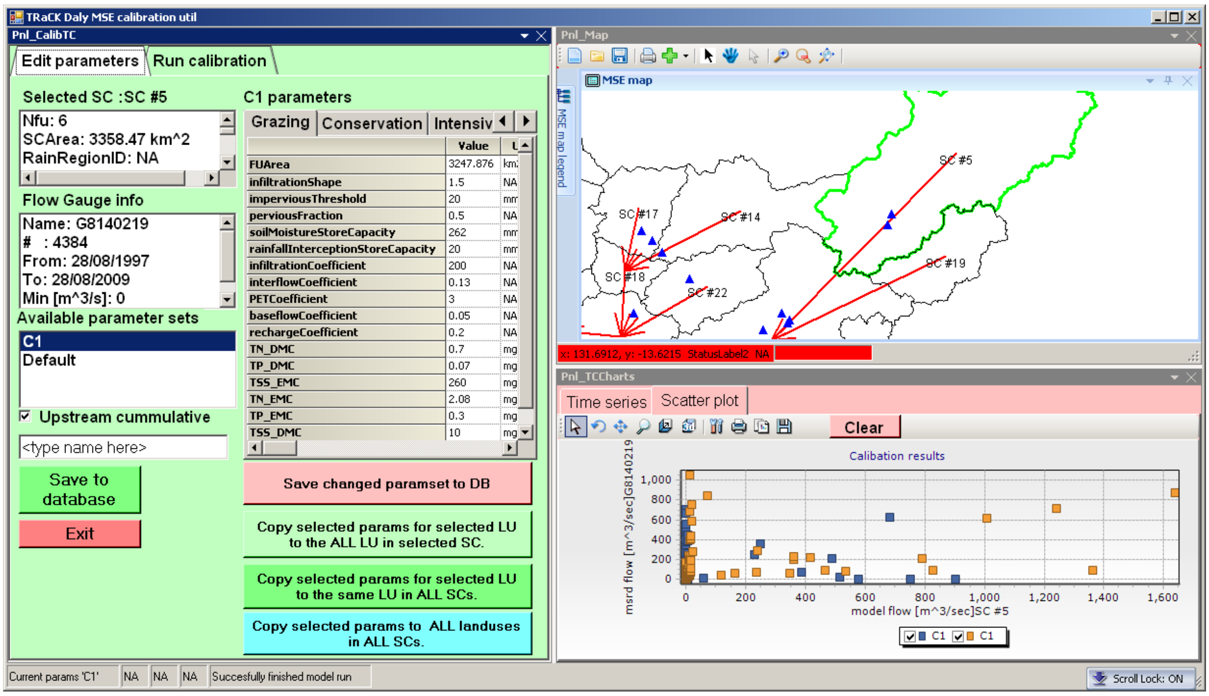

FIGURE 3-7 EXAMPLE OF THE CALIBRATION PARAMETER SCREEN WITHIN THE MSE SOFTWARE

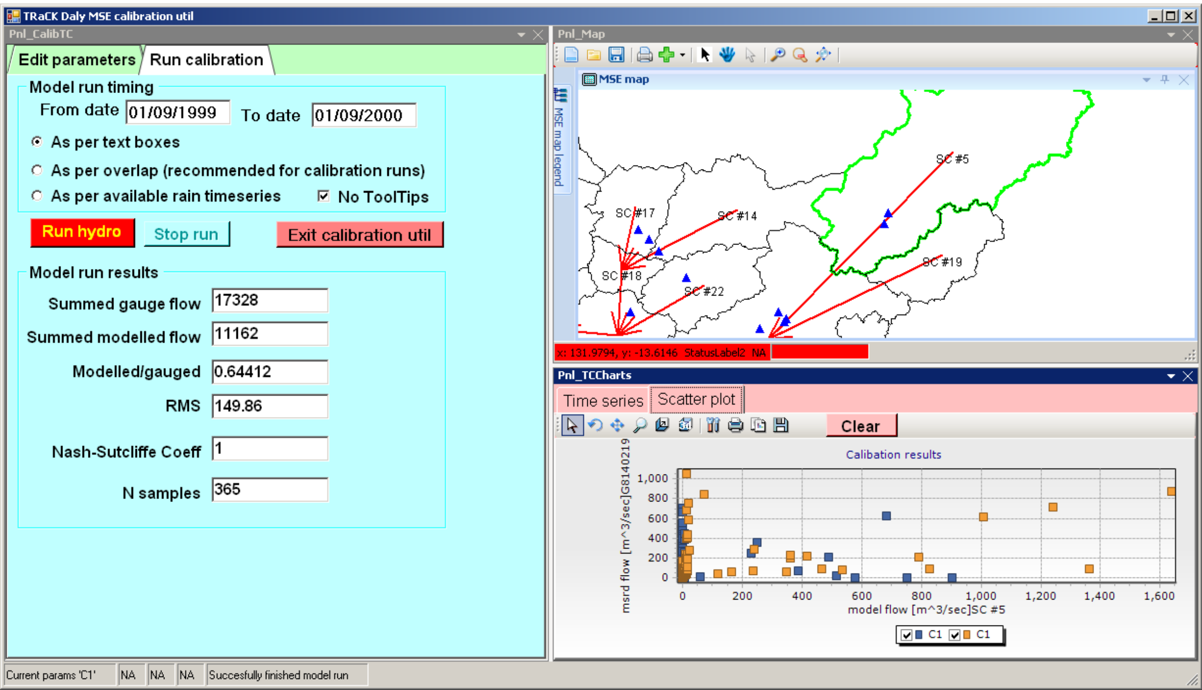

FIGURE 3-8 EXAMPLE CALIBRATION RUN SCREEN WITHIN THE MSE SOFTWARE

3.5.3 PRELIMINARY OUTPUTS SHOWING INFLUENCE OF PARAMETER SELECTION

To demonstrate the influence of the parameters on model output, a number of simulations have been undertaken and flow outputs compared. These outputs are for subcatchment #14 compared with flow data from gauge G8140008, which is on the Fergusson River at the Rail

Bridge. The simulation has been undertaken over a demonstration 5 year period from 1994 to 1999.

Simulation 1: Default parameters

As shown in Figure 3-9 and Figure 3-10, predicted modelled flows for Simulation 1 are too low in comparison with the measured flows. Figure 3-9 indicates that the summed modelled flow over the simulation period is around 31,000m³/s compared to around 48,000m³/s for the gauged (measured) flow.

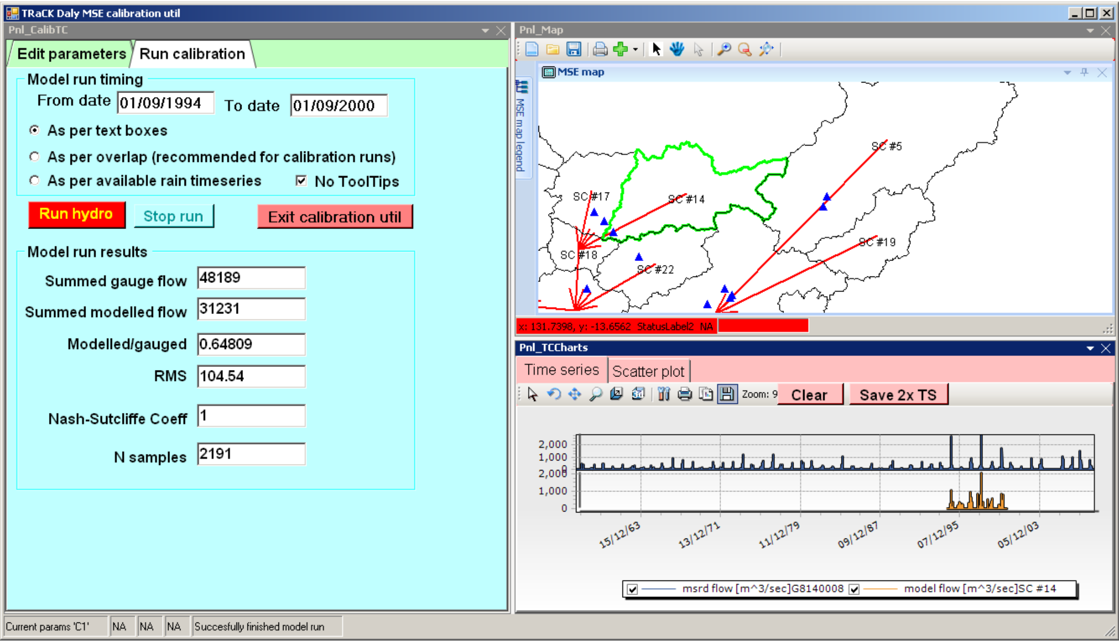

FIGURE 3-9 RUN SCREEN FOR SIMULATION 1 (DEFAULT PARAMETERS)

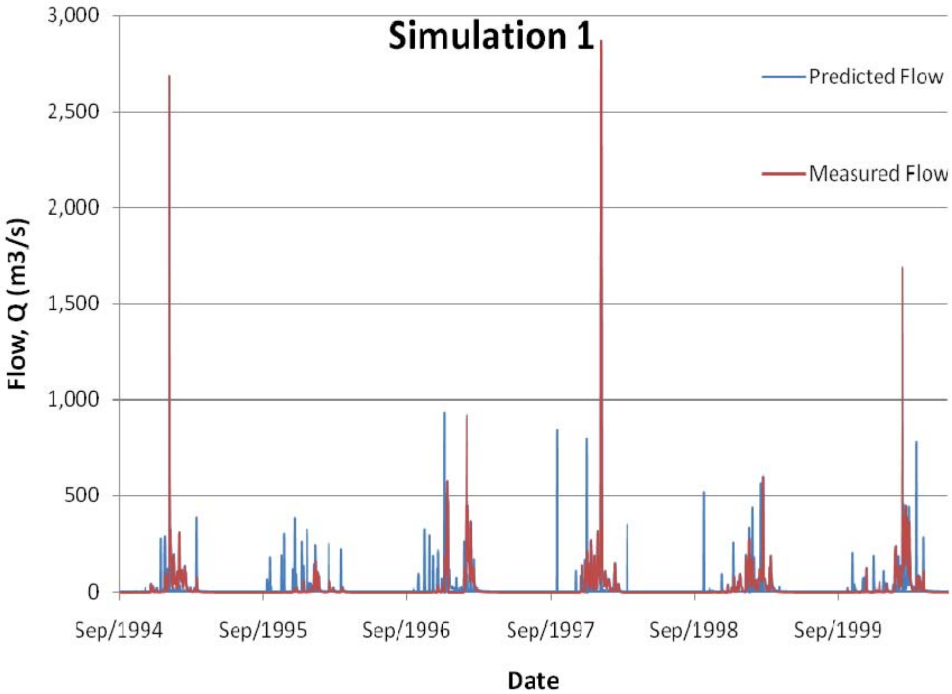

FIGURE 3-10 COMPARISON OF DAILY FLOWS: SIMULATION 1

Simulation 2: Decrease Infiltration Coefficient

To demonstrate the influence of parameters on results, the infiltration coefficient is reduced from 200 to 45. The results are provided in Figure 3-11 and Figure 3-12. The sum of peak flows over the period is around 47,000m³/s compared to around 48,000m³/s for the gauged (measured) flow. Thus, reducing the infiltration coefficient improves the sum of peak flows.

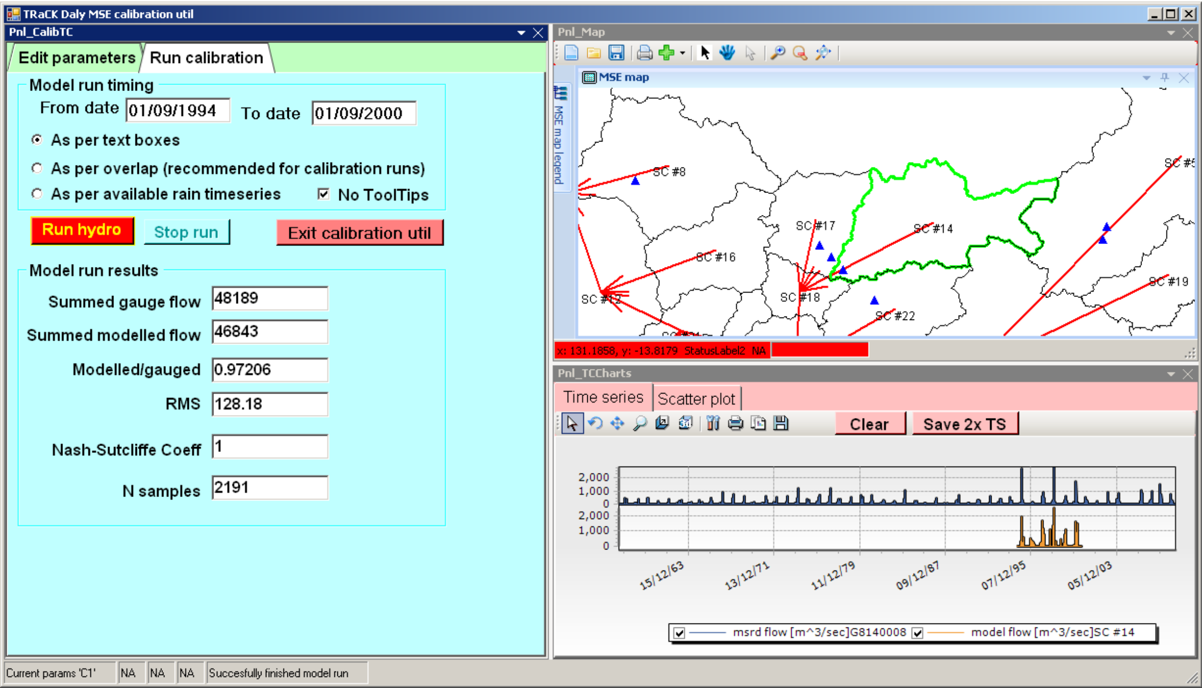

FIGURE 3-11 RUN SCREEN FOR SIMULATION 2 (LOWERED INFILTRATION COEFFICIENT)

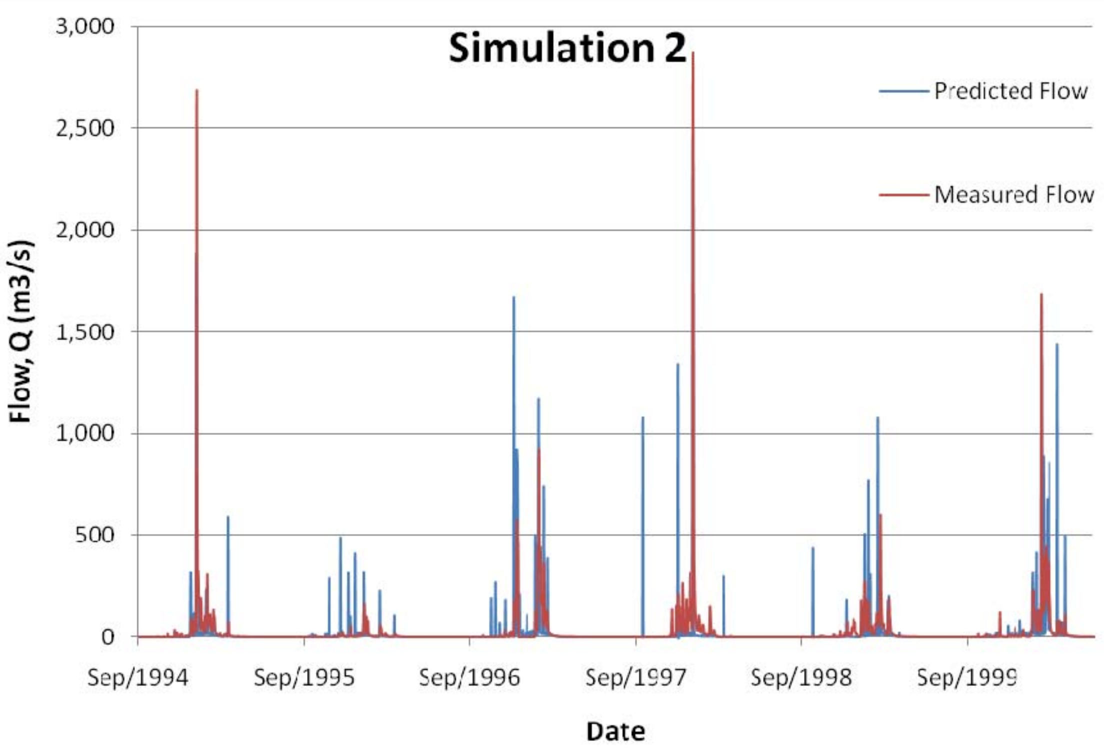

FIGURE 3-12 COMPARISON OF DAILY FLOWS: SIMULATION 2

While this simple example demonstrates some of the functionality of the calibration module and the influence of one parameter on predicted modelled output, it is but a small fraction of the overall calibration process. Calibration also requires that the model is able to *sufficiently* replicate the shape and timing of the measured flow hydrographs. The term sufficiently is an important term to define in this context: the calibration results are sufficient to allow the model to perform simulations with an accuracy fit for purpose.

4 CONCLUSION

TRaCK Project 1.4 has successfully developed a spatially explicit catchment water model, linked with constituent models. Calibration of this model is currently underway for the Daly River catchment. Datasets required for this purpose have been investigated and collated. Calibration of the catchment water model may lead to some refinements to the model as the relative importance of the groundwater behaviour and floodplain losses are better understood. The model will allow water strategy and scenario evaluation to be undertaken within the MSE framework.

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APPENDIX A: SUMMARY OF CLIMATE DATA OPTIONS FOR USE WITH C2C-MSC

The following summarises the options available as at February 2010 for obtaining climate data (specifically daily rainfall and PET) across the Daly River catchment. Costs are also provided for other areas.

OPTION 1: ORIGINAL RAIN GAUGE DATA

Appendix A provides a summary of available long-term rain gauges within the three TRaCK subject catchments.

Advantages	• Original data – can be assured of its applicability to that point • 16 gauges throughout catchment
Disadvantages	• Limited by having only six (6) long-term gauges (with period of record >20 years) (Moliere, 2008) • Only four (4) of these rainfall gauges represent distinct separate areas of the catchment (Katherine Upper, Katherine Town, Douglas River, Daly River Town) • Each rainfall station dataset will need to be assessed for quality and poor data removed where apparent • May not overlap with evaporation data (?) • Need to obtain evaporation data separately
Cost	Minimal
Previous Uses	NRETAS (2000), Katherine River Flood Study. Data from both daily and pluviograph rain gauges within the Katherine River catchment were collected to allow calibration of the URBS hydrologic model. This was an historical event-driven calibration.

OPTION 2: PATCHED POINT DATASET (PPD)

Patched Point Data (PPD) is produced by SILO & Qld DERM. A PPD uses original Bureau of Meteorology measurements for a particular meteorological station, but with interpolated data used to fill ("patch") any gaps in the observation record. PPD is available for both evaporation and daily rainfall data.

Advantages	• Extends common period of record for each climate gauge. • Poor quality data has already been removed • Uses original data where available • Available for both evaporation & rainfall (all climate variables) • Available from 1889. However, the applicability of anything prior to 1970 would need to be considered.
Disadvantages	• Gaps are filled via the interrogation of interpolated spatial surfaces. The interpolated surfaces may or may not bear any resemblance to the actual rainfall that occurred. The relevance of the surface will be dependent upon the gauge data used to develop the surface. Thus, relevance is hidden from the user. DERM has advised that they may be able to supply information on the gauges (location, data quality) actually used to create the surfaces but this is not a standard product. • Limited by the number of climate gauges operational and included in PPD analysis. More investigation is needed into where the stations included in the PPD are located and over what dates the original data is available. Estimate that about 10 PPD gauges are available across the Daly catchment and potentially more in surrounding catchments. • Cost
Cost	One climate station $145.40 NT Set - $1091 (yearly update = $273) WA Set - $5102 (yearly update = $1,273) Qld Set - $5102 (yearly update = $1,273) Australian Set - $17,503 (yearly update = $4,374) (Source: http://www.derm.qld.gov.au/silo/misc/charges.html & personal comm. Dec 2009)

OPTION 3: DATA DRILL

The Data Drill accesses grids of data interpolated from Bureau of Meteorology point observations. Interpolations are calculated by splining and kriging techniques. Further details of interpolation methods are provided in Appendix B. The data in the Data Drill are all synthetic; there are no original meteorological station data left in the calculated grid fields.

Advantages	• Can select data drill points anywhere throughout catchment. • Poor quality data from climate stations has already been removed • Data drills provide all 6 climate variables from 1889 (again relevance of anything prior to 1970 would need to be considered due to sparsity of operational gauges before this time)
Disadvantages	• Data drill is totally synthetic - no original meteorological data is left in product. • Limited by the number of climate gauges used in developing interpolation surfaces. The interpolated surfaces may or may not bear any resemblance to the actual rainfall that occurred. The relevance of the surface will be dependent upon the gauge data used to develop the surface. Thus, relevance is hidden from the user. DERM has advised that they may be able to supply information on the gauges (location, data quality) actually used to create the surfaces but this is not a standard product.
Cost	10 Data Drills (min=10) $144 Additional drill (per drill) = $14.40 (Source: http://www.derm.qld.gov.au/silo/misc/charges.html & personal comm. Dec 2009)
Previous Uses	NRETAS & URS (2008), 'Integrated Hydrologic Modelling of the Daly River Catchment'. Data drill for this study was needed to calibrate the NAM hydrologic model developed by DHI Australia. Data drill was obtained at 10 sites throughout the Daly River catchment.

OPTION 4: INTERPOLATED SILO GRIDDED DATA POINTS

Interpolated climate data is available on a standard 0.05 degree grid across Australia (within the boundaries of the Patched Point Data Sets). These data are based on the same interpolated surfaces used by the Data Drill. Interpolations are calculated by splining and kriging techniques. Further details are provided in Appendix B. The gridded data are all synthetic; there are no original meteorological station data left in the calculated grid fields.

Advantages	• Thorough coverage • Poor quality data from climate stations has already been removed • Can provide all 6 climate variables from 1889 (again relevance of anything prior to 1970 would need to be considered due to sparsity of operational gauges before this time)
Disadvantages	• Cost • Gridded data is totally synthetic - no original meteorological data is left in product. • Limited by the number of climate gauges used in developing interpolation surfaces. The interpolated surfaces may or may not bear any resemblance to the actual rainfall that occurred. The relevance of the surface will be dependent upon the gauge data used to develop the surface. Thus, relevance is hidden from the user. DERM has advised that they may be able to supply information on the gauges (location, data quality) actually used to create the surfaces but this is not a standard product.
Cost	NT (Rainfall Only) - $34,680 NT (all variables) - $41,624 Australia (Rainfall Only) - $110,950 Australia (all variables) - $138,757 (Source: http://www.derm.qld.gov.au/silo/misc/charges.html & personal comm. Feb 2010)
Previous Uses	CSIRO (2009) North Australia Sustainable Yields (NASY) Project, CSIRO Water for a Healthy Country Flagship

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