



# **Estimation of Streamflow and Demand Data and Development of a REALM Model of Steels, Dixons and Pauls Creeks**

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Report prepared for Melbourne Water  
Final 2

February 2003

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# 1. Introduction

## 1.1 Background

Melbourne Water has the responsibility for developing Streamflow Management Plans (SFMPs) under the State Environment Protection Policy Waters of Victoria, Schedule F7, Waters of the Yarra catchment. In addition to this the State Government has identified streamflow management plans for priority streams as an initiative under the Victorian River Health Strategy. Streamflow Management Plans provide a framework by which water can be shared between water users and the environment.

A Streamflow Management Plan for the Steels, Dixons and Pauls Creeks Water Supply Protection Area is currently being developed. This catchment is located in the Yarra Valley and joins the Yarra River just upstream of the township of Yarra Glen. The catchment is unregulated and licensed water use and the effect of farm dams have impacted streamflows in the catchment. Use of water has reached a point where it may be stressing environmental health.

## 1.2 Purpose

To help the consultative committee to develop the Streamflow Management Plan (SFMP), Sinclair Knight Merz was engaged to develop a hydrological model of the Steels, Dixons and Pauls Creeks Water Supply Protection Area. The model will be used to order the thought processes needed to develop an SFMP. It will assist the consultative committee make judgements between flow sharing options, based on the impact to river flows and the reliability of supply to licensed water users.

This report is the first of a two-stage process. Stage 1 is the development of the hydrological model and some initial scenario modelling. Stage 2 will involve further scenario modelling, as devised by the consultative committee during negotiations.

## 1.3 Structure

The sections in this report have been arranged into two groups to cater for various audiences:

- Sections 1 to 4 present the findings in a non-technical format. They are aimed at members of the Steels, Dixons and Pauls Creeks Water Supply Protection Area community who may or may not have expertise in hydrological analysis.
- Sections 5 to 8 contain a technical description of the methodology used. They provide a transparent and defensible description of how the outcomes were derived.

## 2. The Steels, Dixons and Pauls Creeks Catchment

### 2.1 Catchment Description

Steels Creek rises near Kinglake and is joined by Dixons Creek before reaching the Yarra near Yarra Glen. Pauls Creek rises near Toolangi in the Great Dividing Range and joins the Yarra east of Yarra Glen. The streams generally flow south and there is a small urbanised area in the southwest of the Steels Creek catchment at the township of Yarra Glen. Dixons Creek flows into Steels Creek around 2.6 km upstream of where Steels Creek flows into the Yarra River. Pauls Creek is adjacent to Steels Creek and flows into the Yarra River upstream of Steels Creek. The catchments are long and narrow with a total area of approximately 95 km<sup>2</sup>. A map of the catchment is shown in Figure 2-1.

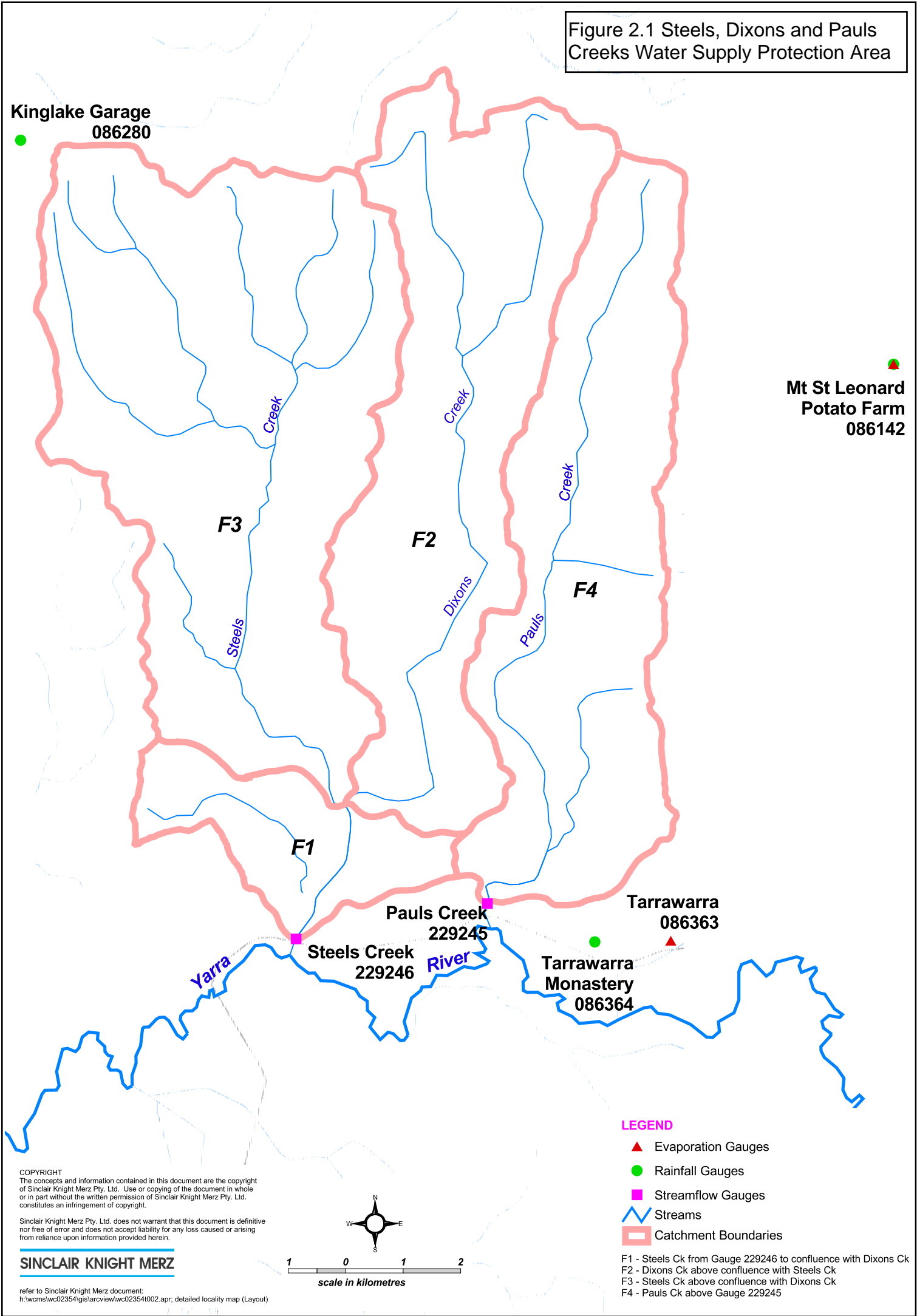
Water use licences within the catchment are generally for extraction of water from the waterways within the winter-fill period, for use throughout the year. There is also minimal domestic and stock use and extensive collection of water in farm dams.

The Steels, Dixons and Pauls Creeks Water Supply Protection Area has been divided into four subcatchments for this study. The subcatchments are described in Table 2.1 and shown in Figure 2-1.

■ **Table 2.1 – Steels, Dixons and Pauls Creeks subcatchment descriptions**

Subcatchment	Description	Area (km <sup>2</sup> )
Steels (Lower) [F1]	The Steels Creek catchment below the confluence with Dixons Creek and above the Steels Creek streamflow gauge 229246.	9.2
Dixons [F2]	Dixons Creek above the confluence with Steels Creek.	35.5
Steels (Upper) [F3]	The Steels Creek catchment above the confluence with Dixons Creek (NB: this does not include the Dixons Creek subcatchment).	50.5
Paul [F4]	Pauls Creek catchment above the Pauls Creek streamflow gauge 229245.	33.0

Figure 2.1 Steels, Dixons and Pauls Creeks Water Supply Protection Area



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refer to Sinclair Knight Merz document:  
 h:\wcm\swc02354\gis\arcview\wc02354t002.apr; detailed locality map (Layout)



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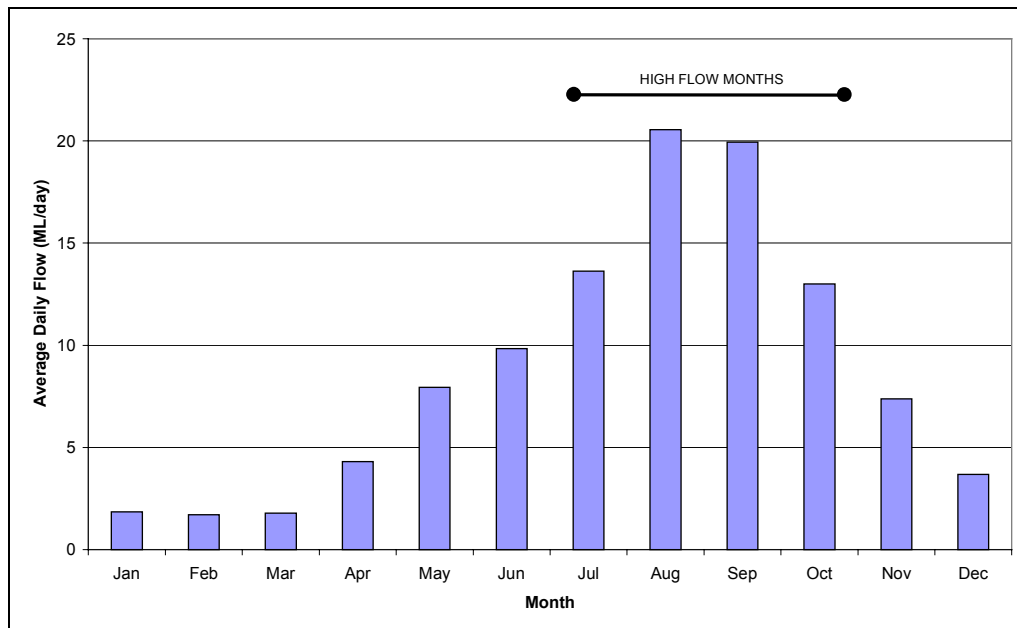
- ▲ Evaporation Gauges
- Rainfall Gauges
- Streamflow Gauges
- ▬ Streams
- ▭ Catchment Boundaries

F1 - Steels Ck from Gauge 229246 to confluence with Dixons Ck  
 F2 - Dixons Ck above confluence with Steels Ck  
 F3 - Steels Ck above confluence with Dixons Ck  
 F4 - Pauls Ck above Gauge 229245

## 2.2 Climate and Hydrology

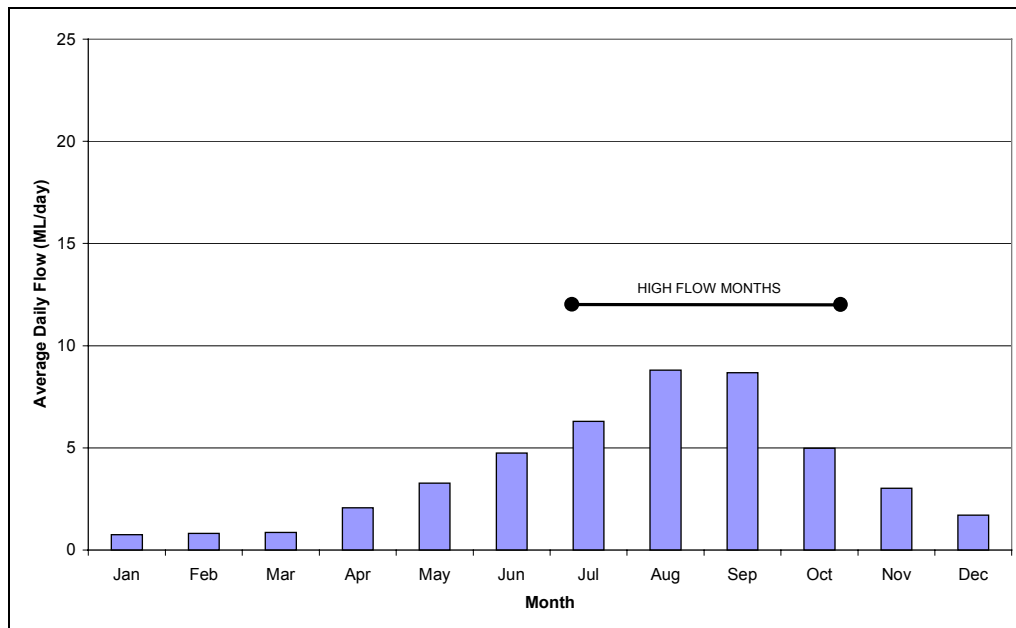
The Steels, Dixons and Pauls Creeks Water Supply Protection Area has a temperate climate. Rainfall varies across the catchment, with the lowest rainfall month occurring in February and the highest rainfall month occurring in the August to October period. Average monthly rainfall at Tarrawarra in the lower reaches of the catchment varies from 52 mm in February up to 88 mm in October. Average monthly rainfall at Mt St Leonard in the upper reaches of the catchment varies from as low as 70 mm in February up to 140 mm in August. The annual average evaporation is approximately 1,200 mm.

Streamflows in the catchment are seasonal and the daily average flows are lowest in the January to March period at around 2 ML/day in Steels Creek and 1 ML/day in Pauls Creek. Over the summer months, the watercourses often cease to flow. However, there are summer rainfall events that generate flows in the streams for small periods of time, resulting in the low average daily flows over the summer months. Streamflows are highest in August around 21 ML/day in Steels Creek and 9 ML/day in Pauls Creek. The average annual flow at the downstream point of Steels Creek is approximately 3,270 ML/annum and 1,430 ML/annum at the downstream point of Pauls Creek. Average daily flows for each month at the downstream point of the Steels Creek and Pauls Creek subcatchments are shown in Figure 2-2 and Figure 2-3 respectively.



NB: based on estimated current level of development flows over the period 1965 to 2001

■ **Figure 2-2 Average daily flows for each month at the outlet of Steels Creek.**



NB: based on estimated current level of development flows over the period 1965 to 2001

■ **Figure 2-3 Average daily flows for each month at the outlet of Pauls Creek.**

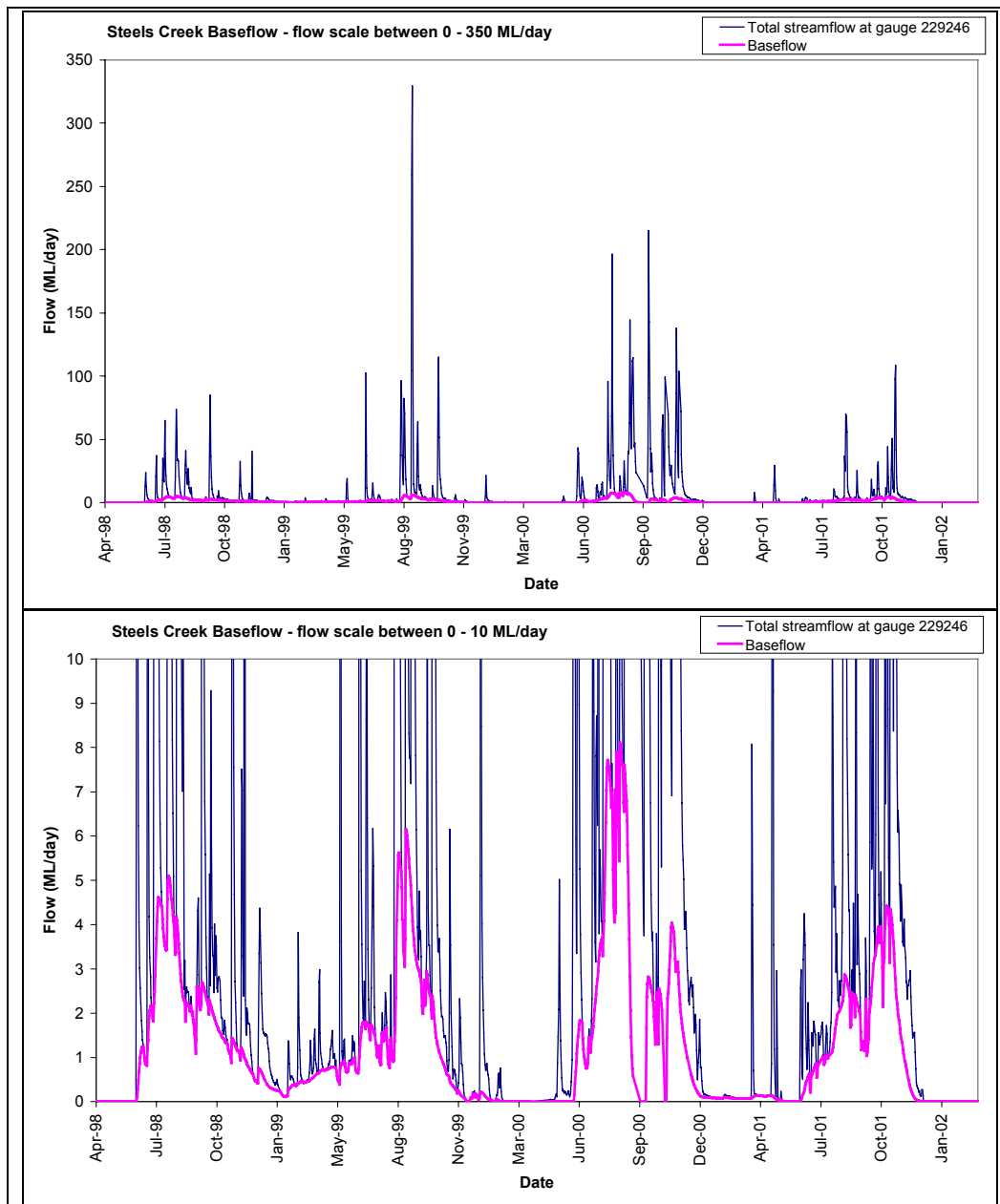
## 2.3 Hydrogeology

Topographically the catchment of Steels, Dixons and Pauls Creeks is highly undulating. The waterways in the catchment are defined by low lying areas that occur between a number of north south trending ridgelines, namely (from west to east) the Yarra Ridge, Brock Spur, the Pinnacles and the Paul Range. The creeks capture runoff from these ridgelines and divert flow south into the Yarra River, which then flows in a south- westerly direction.

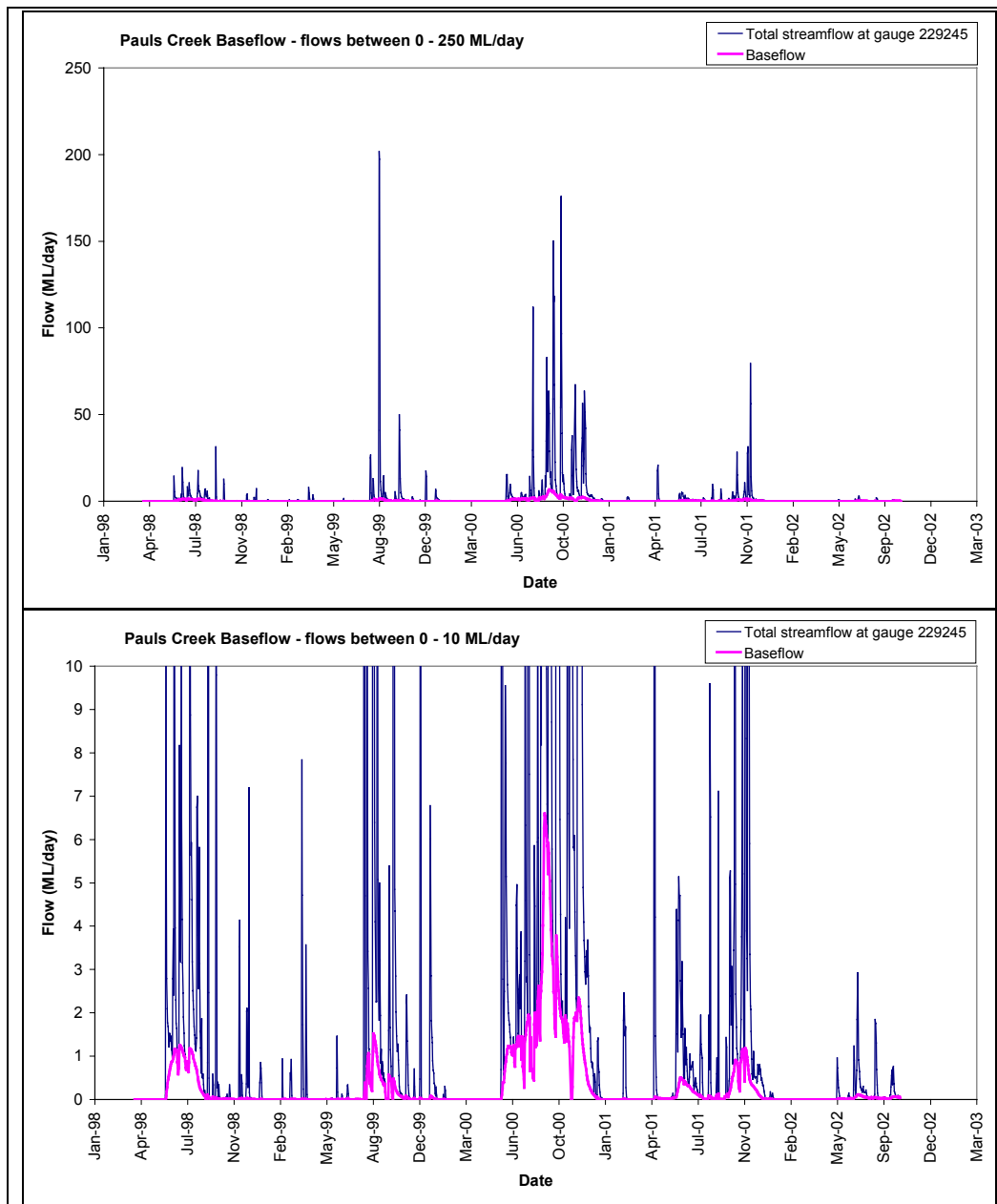
Underlying the catchment the geology consists of Lower Devonian and Silurian basement rocks comprising siltstone, sandstone and mudstone. Local intrusions of Upper Devonian aged quartz and/or feldspar porphyry occur in the south east of the catchment area. Quaternary aged river alluvium has been deposited along Steels, Dixons and Pauls Creeks.

Although there are many groundwater bores registered within the Steels, Dixons and Pauls Creeks Water Supply Protection Area there are currently no bores that have time series water level data available. The Steels Creek and Pauls Creek streamflow gauges have also not been surveyed, hence water level data collected at both sites is not relative to the elevation of the surrounding land. In the absence of groundwater monitoring bores in the catchment and the ability to link water levels at the streamflow monitoring sites to groundwater levels, a brief assessment of the influence of groundwater on surface water flows was made using a mathematical technique to separate the baseflow from the overland flow. The total surface water flow can be divided into a runoff component, which is generated entirely from overland flow, and a baseflow component, which is generated from the discharge of groundwater into the surface streams.

The mathematical technique used to assess baseflow volume is known as ‘recursive digital filtering’ (Lyne and Hollick, 1979; Nathan and McMahon, 1990). Figure 2-4 and Figure 2-5 illustrate the calculated baseflow in Steels and Pauls Creeks over the period of available streamflow record, 1998 and 2002. For clarity, each graph is presented twice, the first showing the full scale of flows and the second showing just the flows below 10 ML/day. The baseflow component is generated during high rainfall periods, which generally occur in the winter and spring months. Baseflow accounts for around 10 to 20% of the total streamflows. During these months, groundwater levels are assumed to be highest, generating groundwater movement towards the streams and enabling direct discharge into watercourses.



■ Figure 2-4 Total streamflow and the estimated baseflow in Steels Creek



■ Figure 2-5 Total streamflow and the estimated baseflow in Pauls Creek

## 2.4 Water Use

The majority of water use in the Steels, Dixons and Pauls Creeks Water Supply Protection Area is in the middle and lower reaches. The most common water use is for viticulture, and there are also areas of orchard, market gardens, pasture and turf. Of the 17 water use licences in the catchment, 16 are for winter-fill dam filling, which occurs during the winter-fill period (i.e. May to October inclusive). The remaining licence is for a stock and domestic diversion.

Farming in the catchment relies on off-stream and on-stream storages and farm dams. Farm dams are those dams filled primarily by rainfall runoff rather than by water pumped from Steels, Dixons or Pauls Creeks. The total volume of farm dams has been estimated from aerial photographs (Egis, 2001). Farm dams are used to store water for both stock and domestic use and irrigation. More detailed information on estimating the volume of farm dams is provided in Section 5.5. A summary of annual licences and estimated farm dam volumes is provided in Table 2-2.

■ **Table 2-2 Annual licences and estimated farm dam volumes in the Steels, Dixons and Pauls Creeks Water Supply Protection Area**

Subcatchment	Number of Licence Holders	Licence Volumes (ML)		Unlicensed Farm Dam Volumes (ML)
		Domestic & Stock (D&S)	Off-Stream/ On-Stream Dam Filling	
Steels (Upper)	3	-	240	175
Steels (Lower)	1	-	80	85
Dixons	7	2	209	433
Paul	6	-	154	352
<b>TOTAL</b>	<b>17</b>	<b>2</b>	<b>683</b>	<b>1,045</b>

## 3. Catchment Modelling

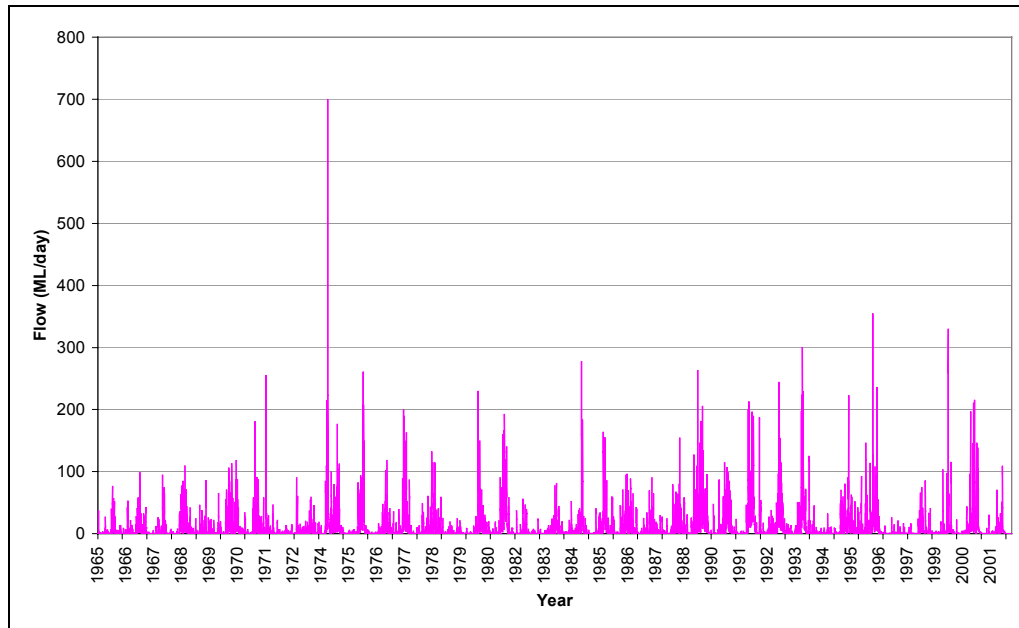
Streamflows are measured at two locations in the Steels, Dixons and Pauls Creeks Water Supply Protection Area – one on Steels Creek at the Healesville Yarra Glen Rd and one on Pauls Creek at the Healesville Yarra Glen Rd. These stations are shown in Figure 2-1. These measured streamflows, along with estimated farm dam impacts and any historic water use, can be used to build a model of streamflows through the rest of the catchment. This model can be used to test options for allocating and managing water licences. Changes in managing licences (scenarios) can be made in the model and the effect on the streamflows observed.

### 3.1 Model Description

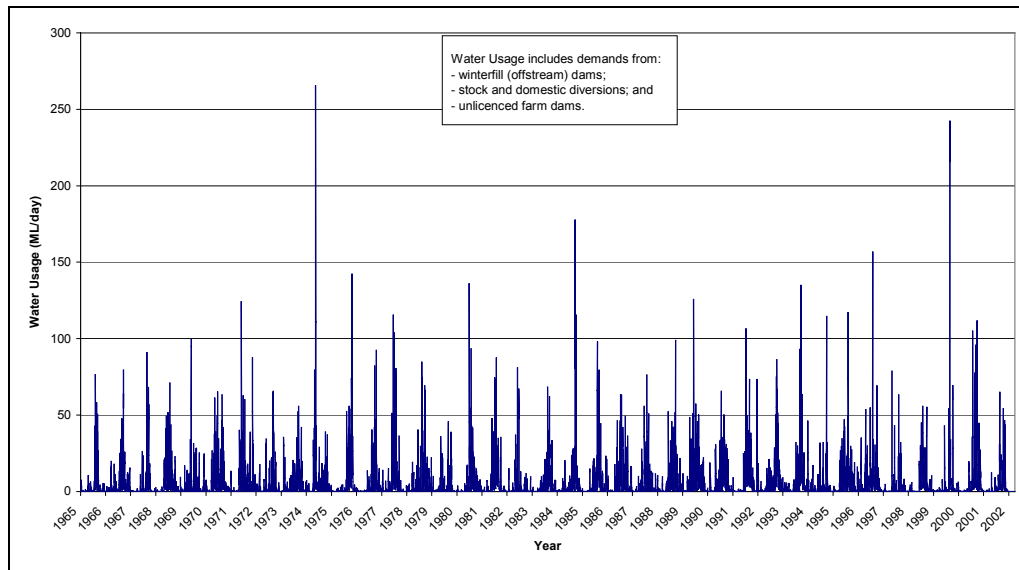
The Steels, Dixons and Pauls Creeks hydrological model simulates daily streamflows and daily water use throughout the catchment. The model was developed using REALM, a computer software package designed for modelling river systems.

The model has a number of features:

- ❑ The water supply protection area has been broken into four regions, as shown in Figure 2-1. This means that it is possible to specify different inflows and extractions in different subcatchments.
- ❑ The model runs from 1965 to 2001, thereby covering a range of climatic conditions. The results are therefore not biased by a limited number of wet or dry years.
- ❑ The model demands were derived based on a constant level of irrigation development over the period 1965 to 2001. This means that results are not affected by historic changes in the level of development in the catchment, and this enables us to test, at a statistically significant level, how different levels of irrigation development impact on streamflows in the catchment - i.e. we can see how the streamflow would have behaved under the range of climatic conditions experienced over the last 35 years with the current amount of water use. This can be used to help quantify anecdotal historical information provided by water users.
- ❑ The model estimates daily streamflows and water usage for each subcatchment, between 1965 and 2001. The water usage data can be used to determine reliability of supply. Example outputs are provided in Figure 3-1 and Figure 3-2.



■ **Figure 3-1 Estimated streamflows at the Steels Creek gauge assuming current level of development conditions from 1965 to 2001**



■ **Figure 3-2 Estimated water usage in the Steels, Dixons and Pauls Creeks catchment assuming current level of development conditions from 1965 to 2001**

### 3.2 Model Development

Several inputs and assumptions were needed to develop the hydrological model. These are summarised below, and described more fully in Sections 5 to 8.

## **Climatic Data**

In times when streamflows are not monitored, rainfall and evaporation data was used to predict streamflow. Firstly, rainfall or evaporation records were infilled and extended by making comparisons with records at nearby stations. It was then necessary to check rainfall for the presence of any unexplained trends, which can change how much rainfall is measured at a particular station and does not reflect the actual rainfall that occurred. Insufficient data exists to check for trend in evaporation. Secondly, the variation in rainfall and evaporation across the catchment was estimated from nearby stations. The main rainfall stations used for this study included those at Tarrawarra, Mt St Leonard and Kinglake Garage. The main evaporation stations used for this study include those at Mt St Leonard and Tarrawarra. These stations are shown in Figure 2-1.

Additional information on the derivation of climate inputs for the modelling is provided in Section 5.1 and 5.2.

## **Derivation of Demands**

The demand types in the Steels, Dixons and Pauls Creeks Water Supply Protection Area include all-year licences (stock and domestic) from the waterway, off-stream and on-stream (winter-fill) dams and farm dams, which collect rainfall and runoff.

Water demands were required for each subcatchment. No metered water use data was available, however water use licence volumes were known and a recent survey of licence holders in the Protection Area by Melbourne Water provided estimates of the maximum annual usage volume for 13 of the 17 diverters. This maximum usage estimate or the licence volume formed the basis for estimating annual water usage, the latter approach assumed that the entire licence volume is used. Seasonal variability in water use was estimated using the pattern of flows in the catchment within each year. The impact of farm dams on streamflows was based on the investigation undertaken by Egis (2001).

Additional information on the derivation of demands can be found in Section 6.

## **Streamflows**

Gauged streamflows at the Steels and Pauls Creeks gauges were available from April 1998 to September 2002, but were required to cover the period 1965 to 2001. An analysis was undertaken to determine the relationship between rainfall, evaporation and streamflow using the available streamflow data. This relationship was then used to predict streamflows when no gauged streamflow data were available. The extended and infilled streamflow records were then used to estimate streamflows at other points in the Steels, Dixons and Pauls Creeks subcatchments.

Additional information on the infilling of missing streamflow data, extending the available period of streamflow record to cover the period from 1965 to 2001, and estimating streamflows at other points in the catchment are provided in Section 7.

## 4. Reliability of Supply

The Resource Allocation Model (REALM) was chosen as a planning tool to assess the reliability of supply under current and future demand scenarios. REALM is an excellent tool for evaluating changes in the operation of streamflow and water supply systems as it has a high degree of flexibility and is able to simulate complex operating rules. REALM is also used by Melbourne Water and other rural water authorities to model urban water supply and irrigation districts.

REALM inputs include climate, streamflow, demand, discharges and management rules the streamflow system, such as any requirements to pass environmental flows at particular stream locations. A daily time step REALM model has been developed for the Steels, Dixons and Pauls Creeks catchment and used to simulate the demand and streamflow over the climatic period from 1965 to 2001 based on a number of scenarios (Section 4.1).

The model was calibrated using historic demands and streamflows. The assessment of the reliability of supply for water users was based on current and full level of development demands. Current level of development demands are based on the level of demands that currently occur within the catchment, 2002. Full level of development demands are based on potential future levels of development, full licence use.

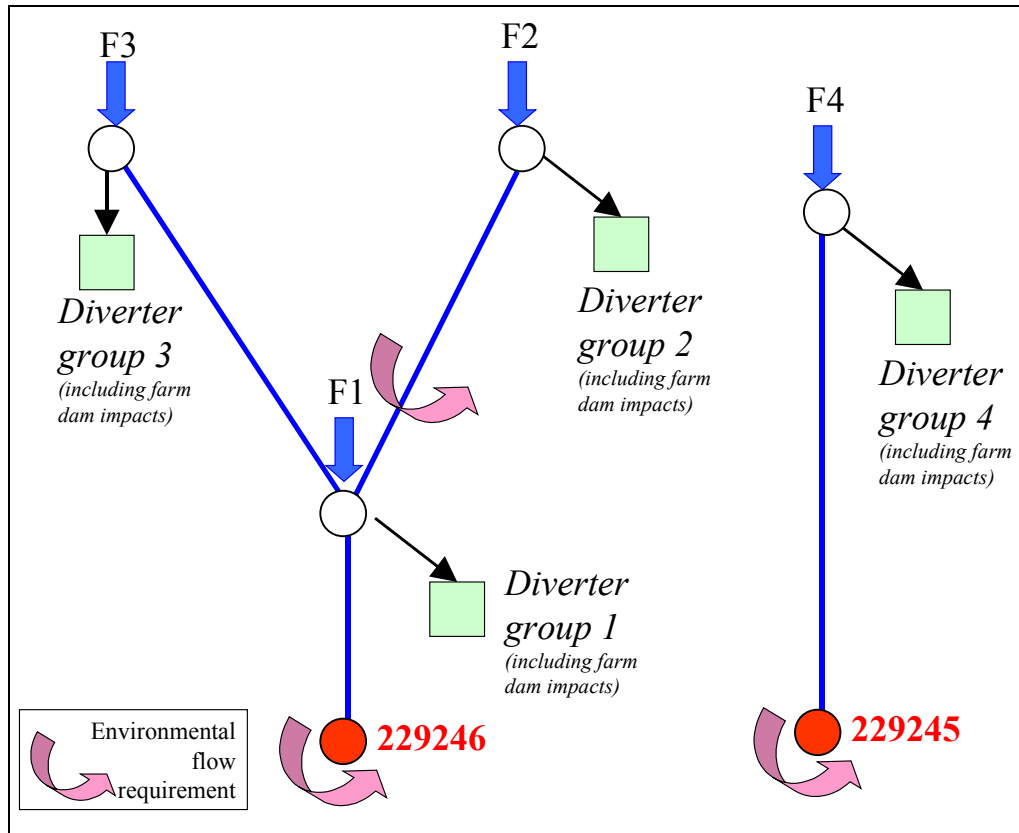
The current level of development scenarios investigate the streamflows and reliability of supply that would occur over the climatic period 1965 to 2001 if demands are constant at current levels of development. The full level of development scenarios investigate the streamflows and reliability of supply that would occur over the climatic period 1965 to 2001 if demands are constant at estimated full levels of development.

A schematic of the Steels, Dixons and Pauls Creeks REALM, showing the various inflows, points where environmental flows are to be specified, and demands in the catchment, is illustrated in Figure 4-1. The water use groups shown in the schematic have been simplified into one demand centre, however in the actual REALM system they have been broken down into three separate demand groups:

- Domestic and stock (all-year);
- Off-stream/on-stream winter-fill dams; and
- Farm dams.

The demands have been divided into separate demand groups as the pattern of usage varies considerably between the different types. It is also useful to have these demand groups separate to enable the model user to test how varying the level of demand of a particular demand type impacts on streamflows and the reliability of supply to the various water users. In Stage 2 of this project, management rules may be specified for each licence type individually.

The REALM system is set up to ensure that the environmental flow rules applied to the streamflows are met before any other water user demands are met.



■ Figure 4-1 Schematic of Steels, Dixons and Pauls Creeks REALM

### 4.1 Scenarios

A number of scenarios have been investigated for this project and these are described in Table 4-1. The environmental flow recommendations for the Steels, Dixons and Pauls Creeks Water Supply Protection Area at the sites shown in Figure 4-1 will be modelled in Stage 2.

■ Table 4-1 Steels, Dixons and Pauls Creeks REALM scenarios

Scenario	Purpose of Scenario	L.O.D. <sup>1</sup> Demands
Calibration	Calibration of the Steels, Dixons and Pauls Creeks REALM model based on historic catchment conditions.	Historic
1	To test reliability of supply to licensed water users based on the current level of development.	Current
2	To test the reliability of supply to licensed water users based on estimated full level of development.	Full
3	To test the reliability of supply to all water users at the Sustainable Diversion Limit (SDL) at sites F1 and F4.	S.D.L. <sup>2</sup>
4	To assess the impact on reliability of supply to licensed water users at sites F1 and F4 based on estimated full level of development and on implementing the SDL minimum flow thresholds over the licensed winter-fill period.	Full

Notes:

(1) L.O.D. stands for Level of Development

(2) S.D.L. stands for Sustainable Diversion Limit

**4.1.1 Sustainable Diversion Limits**

The Sustainable Diversion Limit (SDL) (SKM, 2002) is a tool to rapidly estimate the potential for water allocation from a catchment over the SDL winter-fill period (July to October). It is important to note that the SDL winter-fill period is different to the winter-fill period currently specified for licensed water users. The SDL encompasses all types of water use in a catchment, including licensed water users, urban water supply, farm dams or irrigation districts. It represents the limit beyond which there is an unacceptable risk that the environment may become degraded.

The overall intent for setting the allowable limit is that the flows after diversions must lie within the *natural range of flows* that occur under natural conditions. This means that although the flow volume in streams may not be equal to that which occurred under natural conditions, the frequency and magnitude of high flows in the stream are similar to that which occurred under natural flow conditions. Natural flow conditions are those that occurred prior to water use from streams in the catchment and the construction of farm dams.

The SDL (SKM, 2002) has specified four components for protecting the natural range of flows:

- 1) A winter-fill period over which diversions could occur, which has been defined as July to October inclusive (i.e. no diversions are allowed outside this period);
- 2) A minimum flow below which collection of water from the catchment should cease;
- 3) A maximum daily rate at which water can be extracted from a catchment; and
- 4) A maximum annual volume - Sustainable Diversion Limit - that can be extracted over the winter period, within the first three criteria.

In the Steels, Dixons and Pauls Creeks Water Supply Protection Area, Sustainable Diversion Limits have been estimated for three of the subcatchments (SKM, 2002) (Table 4-2). These limits were based on catchment characteristics, as the streamflow data was not available at the time the investigation was undertaken.

**Table 4-2 Sustainable Diversion Limits in the Steels, Dixons and Pauls Creeks**

SDL catchment	Catchment Description	SDL Maximum Annual Volume (ML)	Maximum Daily Extraction Rate (ML/day)	Minimum Flow Threshold (ML/day)
Dixons Creek	Dixons Creek above the confluence with Steels Creek	267	6.3	7.4
Steels Creek	The entire Steels Creek catchment (including Dixons Creek)	649 <sup>1</sup>	15.9 <sup>2</sup>	18.7
Pauls Creek	The entire Pauls Creek catchment	158	4.5	5.2

Notes:

- (1) The Maximum Annual Volume for Steels Creek without Dixons Creek is 382 ML/annum.
- (2) The Maximum Daily Extraction Rate for Steels Creek without Dixons Creek is 9.7 ML/day.

**4.1.2 Results of Scenario Modelling**

For each scenario the reliability of supply for water users was examined. A preliminary assessment has also been made of the impact of restrictions specified in the Drought Response Plan (Yarra Catchment) Private Diverters (Melbourne Water,

2001) on water users in the catchment. The DRP was not included in the model as the trigger for commencement of restrictions is a function of flow in the Yarra River, which is not available at current and future levels of development. This is discussed further in Section 4.2.6.

The following terms are used throughout the results section (Section 4.2) and brief explanations are provided:

- ❑ **UNRESTRICTED DEMAND:** the demand that would be met given an unlimited supply of water.
- ❑ **DEMAND MET:** the demand that can be met based on how much water is available. If there are environmental flow provisions in a catchment, the water available to meet demands is determined after environmental flows have been met. Or if it is desired to meet the SDL minimum winter flow threshold, then the water available to meet demands is determined after the SDL minimum flow threshold has been met.
- ❑ **SHORTFALL:** the difference between the demand met and the unrestricted demand.
- ❑ **NATURAL FLOWS:** the streamflow that would have occurred in a catchment before diversions, dams or other forms of regulation were implemented. Note this includes current level of land development (urbanisation, vegetation cover etc).
  - Current Level of development
  - Full level of development
- ❑ **HISTORIC DEMANDS:** historic demands are the demands for water that have occurred over time in a catchment. Changes in the level of demand occur as different crops may be put in that have different water requirements, new areas may become irrigated or additional licences are added. The types of demands in the catchment and how they were derived as inputs into the model are described in more detail in Section 6.
- ❑ **CURRENT LEVEL OF DEVELOPMENT DEMANDS:** these are the demands for water that are being seen at present in a catchment and are based on the current level of development, i.e. the current types and volumes of water use, such as the current number of farm dams harvesting water, the current area of irrigated crops or the current types of crops being irrigated. In the Steels, Dixons and Pauls Creek Water Supply Protection Area, the current level of development demands were based on catchment water use conditions in 2002.
- ❑ **FULL LEVEL OF DEVELOPMENT DEMANDS:** these are the estimated demands for water at some envisaged future level of development in a catchment. In the Steels, Dixons and Pauls Water Supply Protection Area this was taken to be when all licence volumes in the catchment were fully utilised, as under current conditions the maximum annual usage of some licensed water users is estimated to be below their license volume.

The following types of graphs are presented throughout the results section and brief explanations are provided:

- **FLOW DURATION CURVE:** a flow duration curve presents streamflows that have been ranked from the largest to the smallest and assigned a percentage based on the relative position of the flow against all other flows at the site. The percentage represents the proportion of time that a flow of a certain magnitude is exceeded. Flow duration curves are useful to compare flows between sites or modelling scenarios as they show how often cease to flow conditions occur, and what proportion of the time high or low flows are exceeded. The flow scale on the curves is presented on a logarithmic scale so as to enable easy distinction between flows in the low flow range.
- **TIME SERIES PLOTS:** time series plots illustrate how flows change over time. They are useful to compare when the timing of high flow or low flows occur between different sites or different modelling scenarios. The flow scale on these plots is sometimes shown on a logarithmic scale to enable low flows to be shown more clearly.
- **COLUMN PLOTS:** column plots show a cumulative value for a certain variable over a certain time period, for example the total volume of water that was diverted over the course of one year. These types of plots are useful as they can be used to demonstrate pictorially the proportion of say the total annual demand that was actually met in each year, i.e. one column shows the total demand and the overlying column shows the demand met.

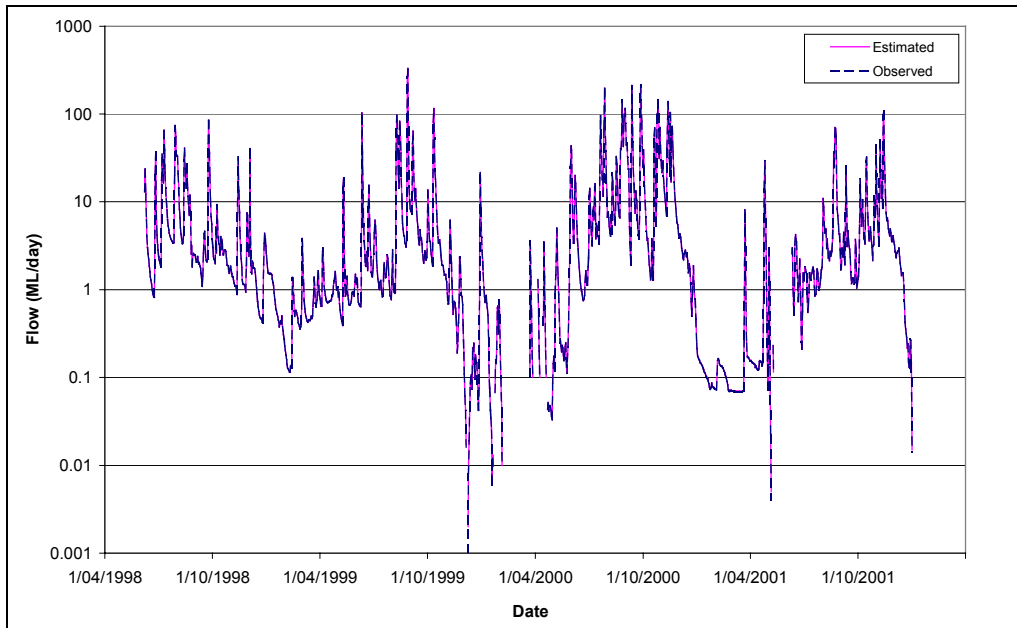
## 4.2 Results

### 4.2.1 Calibration

#### Historic level of development

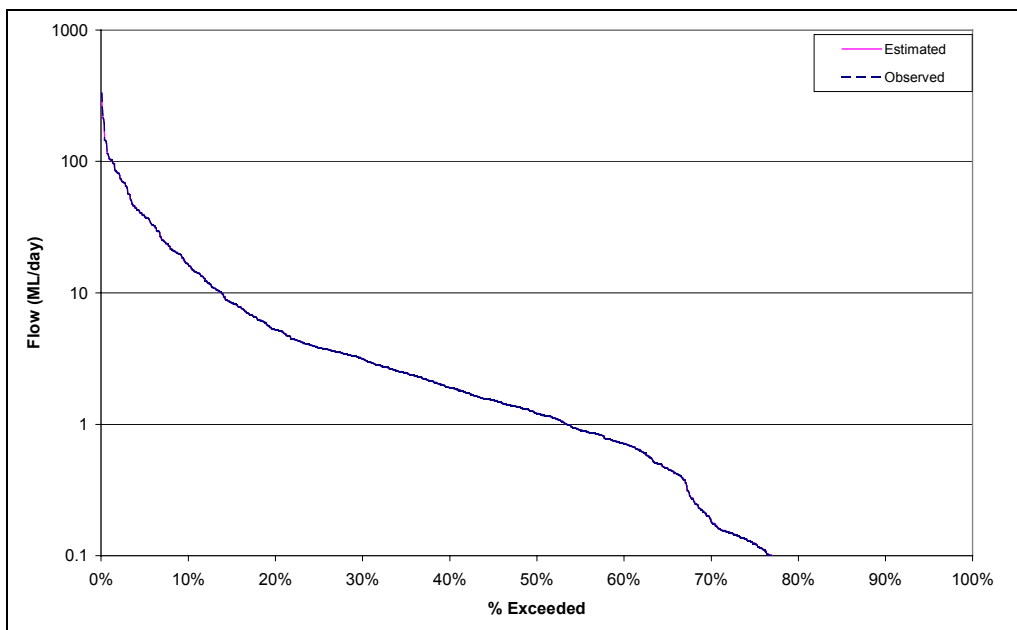
There are two calibration points in the Steels, Dixons and Pauls Creeks catchment. The first is the outflow from the Steels Creek Lower Subcatchment, which corresponds to the Steels Creek flow gauging station at Healesville Yarra Glen Rd (229246). The second is the outflow from the Pauls Creek Subcatchment, which corresponds to the Pauls Creek flow gauging station at Healesville Yarra Glen Rd (229245).

A comparison of the gauged (observed) and modelled (estimated) flows at the Steels Creek and Pauls Creek calibration points over the 1998 to 2001 period of record illustrates that the model outputs (Figure 4-2 and Figure 4-5) replicate the observed data.

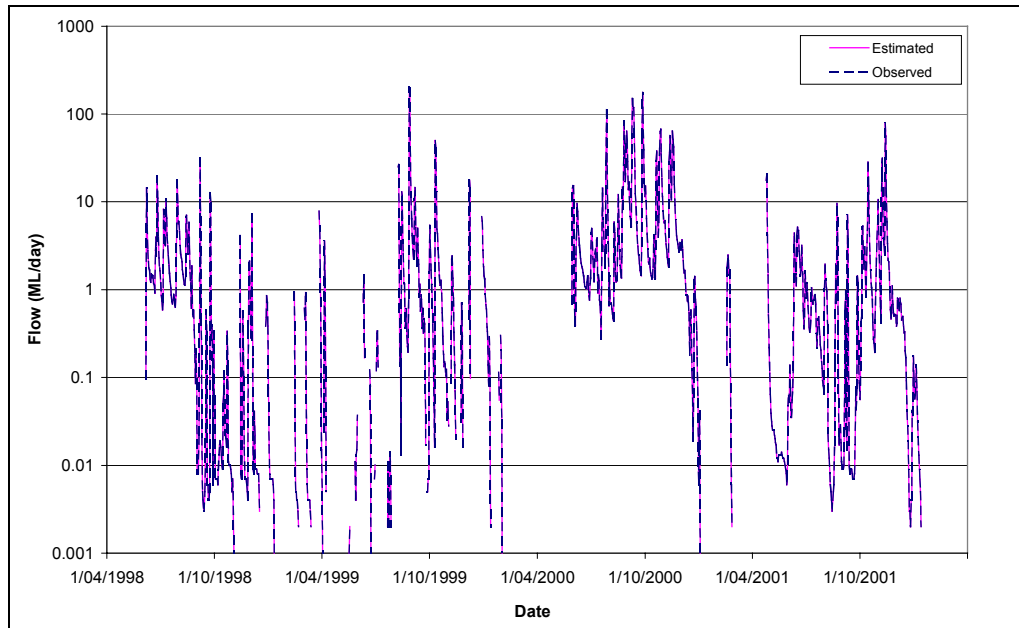


NB: flow scale is shown in the logarithmic domain

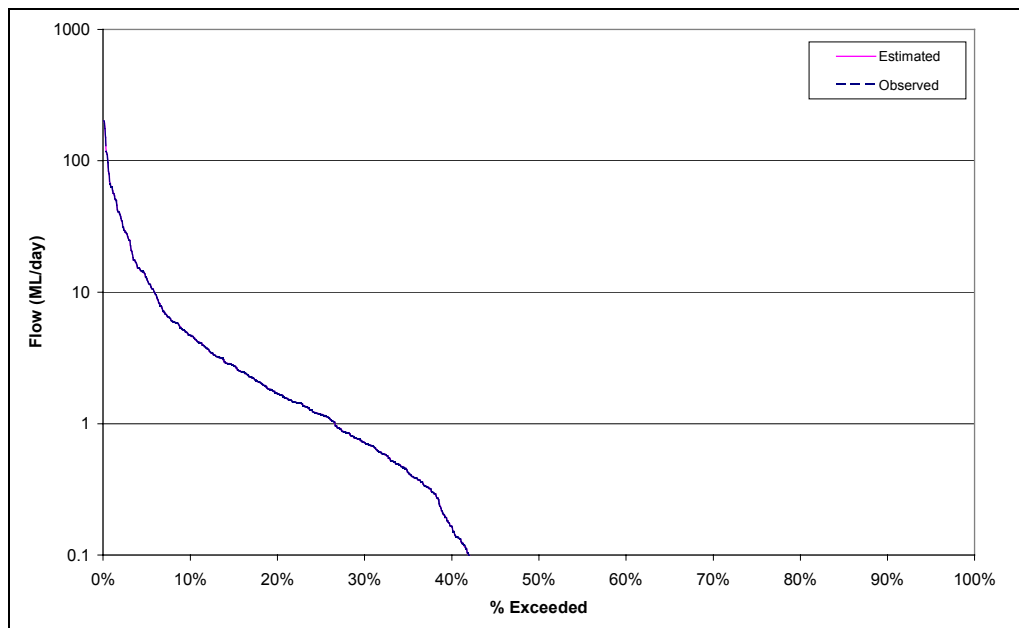
■ **Figure 4-2 Time series of gauged (observed) and modelled (estimated) flows at Steels Creek (229246)**



■ **Figure 4-3 Flow duration curves of gauged and modelled flows at Steels (229246)**



■ **Figure 4-4 Time series of gauged and modelled flows at Pauls Creek (229245)**



■ **Figure 4-5 Flow duration curves of gauged and modelled flows at Pauls (229245)**

Under historic conditions, the REALM model estimates that no shortfalls occur over the 1965 to 2001 simulation period. However, anecdotal evidence suggests that there have been periods in the Steels, Dixons and Pauls Creeks catchment where shortfalls have occurred, i.e. licensed water users have not been able to extract all of their licence volumes (*pers. comm.*, Melbourne Water). The lack of shortfalls predicted by the model under historic conditions is a result of the methods used to derive the

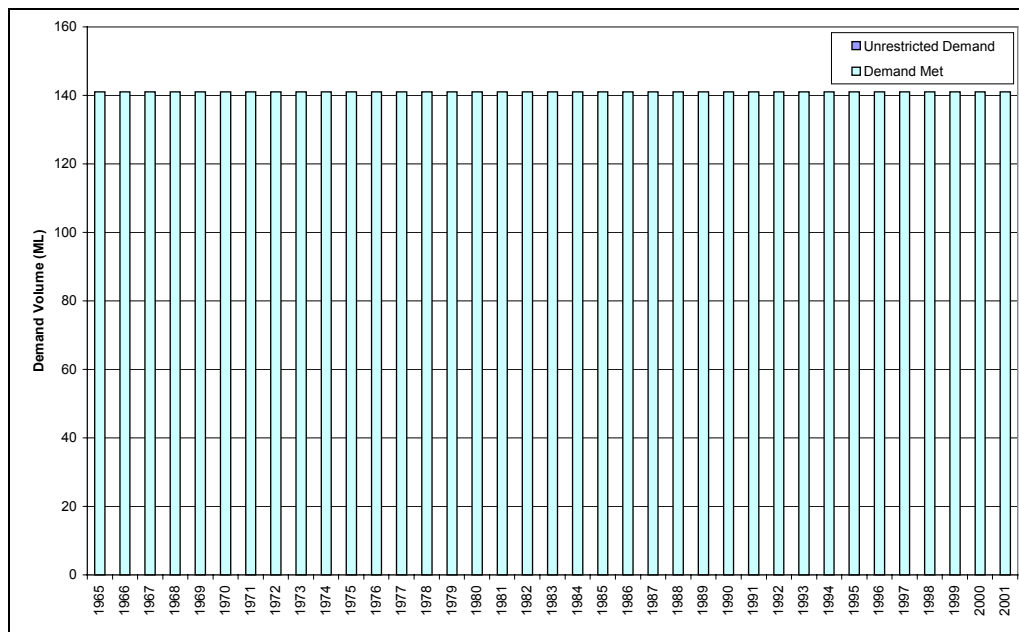
inflows to the model in the absence of actual water usage data. This is discussed in more detail in Section 7.

The historic and current conditions have been modelled using the same demand data the plots showing the number of weeks of shortfalls and the demand met versus the unrestricted demand is provided in the results for Scenario 1 (Section 4.2.2).

#### 4.2.2 Scenario 1

##### Current level of development

Under Scenario 1, there are no demand shortfalls in the Steels, Dixons or Pauls Creek catchment. Figure 4-6 compares the unrestricted demands in each year to the demand met for the Pauls Creek Subcatchment. Note that in this graph the unrestricted demand equals the demand met, so it is not possible to see the unrestricted demand columns. Farm dam usage is not displayed on these graphs, as farm dams will not be shortfalled in the event of inadequate streamflows, as farm dams collect rainfall runoff before it reaches the waterways. The unrestricted demand is the same in each year as a result of the methodology applied to derive the demand time series for input into the REALM model (Section 7).

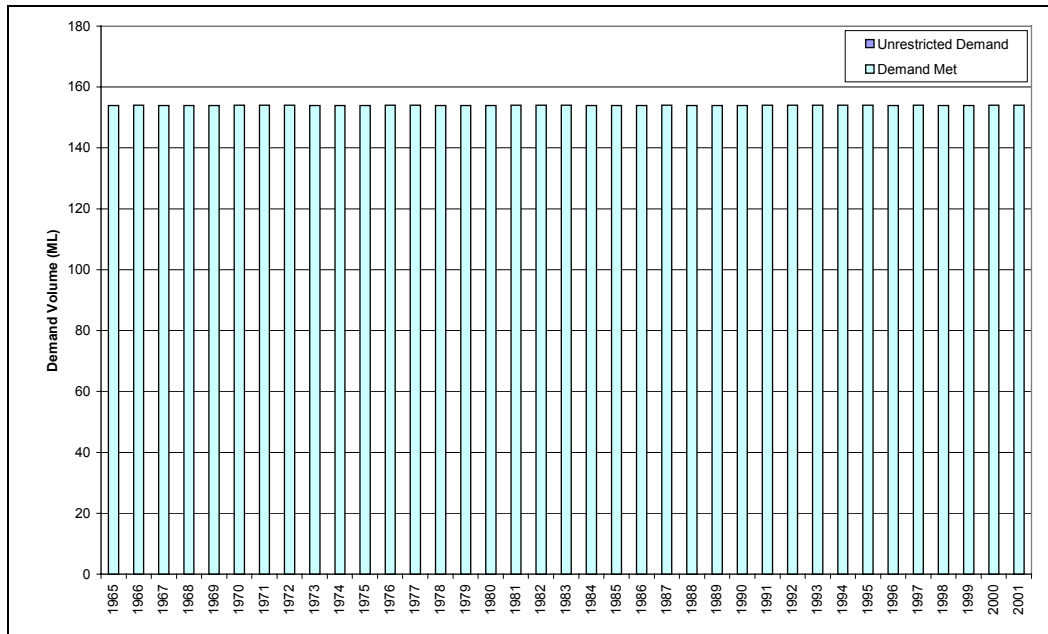


■ Figure 4-6 A comparison of the unrestricted demand and the demand met in the Pauls Creek Subcatchment (F4) under Scenario 1

### 4.2.3 Scenario 2

#### Full level of development

Under Scenario 2, there are no demand shortfalls in the Steels, Dixons or Pauls Creek catchment. Figure 4-7 compares the unrestricted demands in each year to the demand met for the Pauls Creek Subcatchment. Note that in this graph the unrestricted demand equals the demand met, so it is not possible to see the unrestricted demand columns.



■ Figure 4-7 A comparison of the unrestricted demand and the demand met in the Pauls Creek Subcatchment (F4) under Scenario 2

#### 4.2.4 Scenario 3

##### Sustainable Diversion Limit

Under Scenario 3, the REALM model was set up to extract up to the SDL maximum annual volumes in the three specified SDL catchments (Table 4-2) in accordance with the SDL rules, namely:

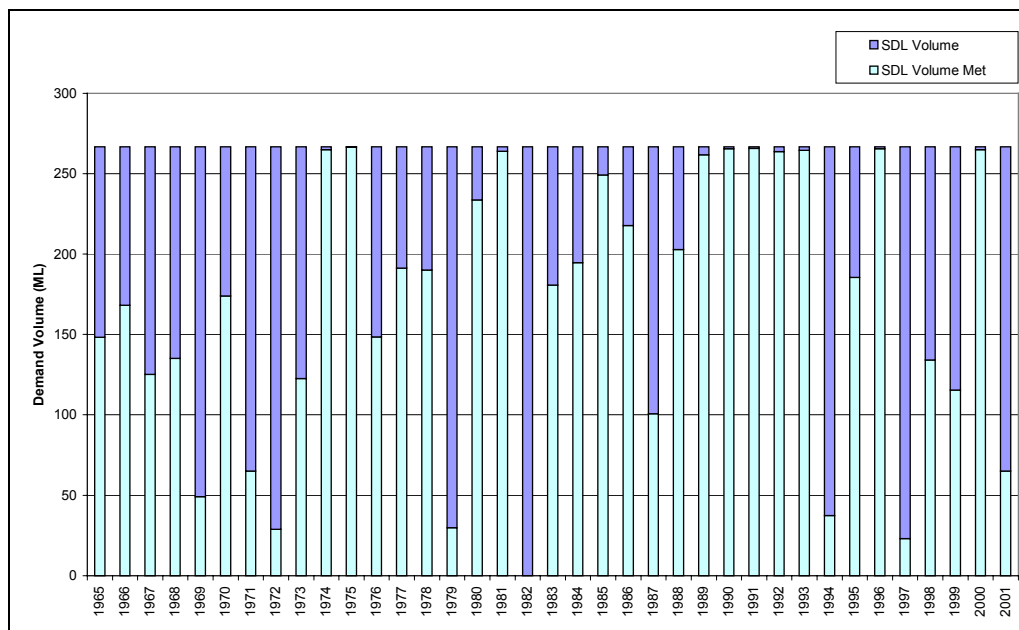
- extraction rates were not to exceed the maximum diversion rate specified; and
- streamflows were not to drop below the minimum flow threshold (unless inflows to the catchment were not sufficient to meet these minimum flow requirements).

Under this scenario, the different types of demands in the catchment are not differentiated between, as the scenario is trying to test whether or not the SDL maximum annual volume can be extracted from the catchment given the minimum flow thresholds and the maximum daily diversion rates. The SDL maximum annual volume encompasses all water use within a catchment, which means that in the Steels, Pauls and Dixons Water Supply Protection Area, water use by licensed water users and farm dams is governed by the SDL rules.

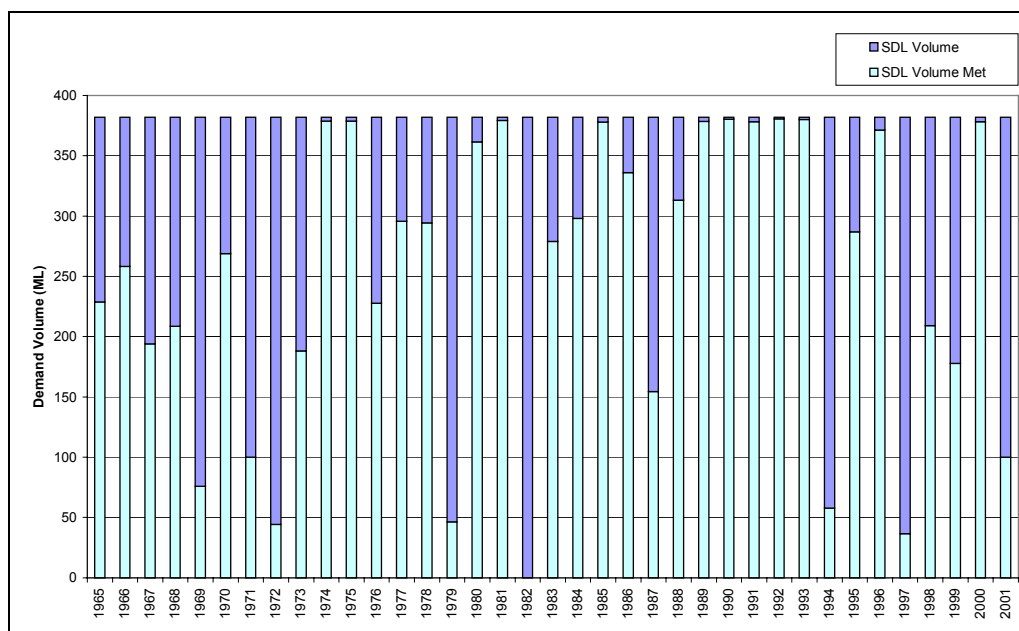
Figure 4-8 compares the SDL maximum annual volume in each year to the volume extracted (demand met) for the Dixons Creek SDL Catchment. With the introduction of Sustainable Diversion Limits in Dixons Creek, the SDL maximum annual diversion volume can be met in 5 out of the 37 years from 1965 to 2001, with an average shortfall in the SDL volume of 100 ML/annum. The volume met in many years (for example 1982 or 1979) is significantly lower than the SDL maximum annual diversion volume.

It was assumed that the SDL volume was met if the volume extracted in any year was within 1% of the SDL maximum annual diversion volume. This assumption was necessary, as the way in which the REALM model was set up did not enable an exact volume extraction. The rules governing the diversion of water relied on the iterative accounting processes within REALM. The water is available to be diverted, however small iteration imbalances prevent the water from being diverted.

Figure 4-9 compares the SDL maximum annual volume in each year to the volume extracted (demand met) for the Steels Creek SDL Catchment. With the introduction of Sustainable Diversion Limits in Steels Creek, the SDL maximum annual diversion volume can be met in 9 out of the 37 years from 1965 to 2001, with an average shortfall in the SDL volume of 133 ML/annum. It was assumed that the SDL volume was met if the volume extracted in any year was within 1% of the SDL maximum annual diversion volume. The volume met in many years (for example 1982 or 1979) is significantly lower than the SDL maximum annual diversion volume.



■ Figure 4-8 A comparison of the unrestricted demand and the demand met in the Dixons Creek SDL Catchment (F2) under Scenario 3



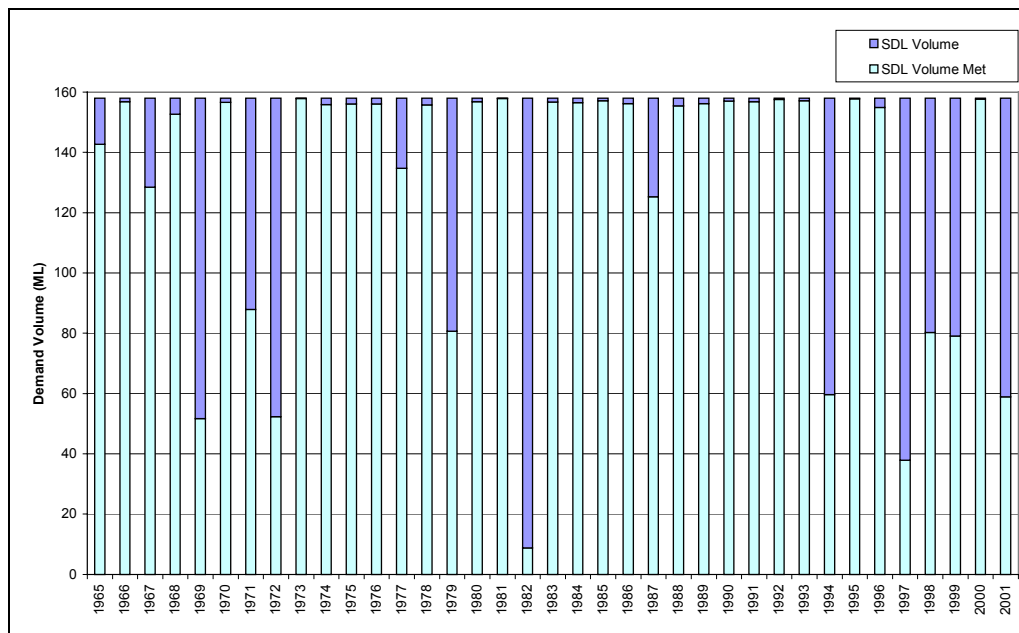
■ Figure 4-9 A comparison of the unrestricted demand and the demand met in the Steels Creek SDL Intermediate Catchment (F1+F3) under Scenario 3

Figure 4-10 compares the SDL maximum annual volume in each year to the volume extracted (demand met) for the Pauls Creek SDL Catchment. With the introduction of Sustainable Diversion Limits in Pauls Creek, the SDL maximum annual diversion volume can be met in 14 out of the 37 years from 1965 to 2001, with an average shortfall in the SDL volume of 30 ML/annum. It was assumed that the SDL volume was met if the volume extracted in any year was within 1% of the SDL maximum

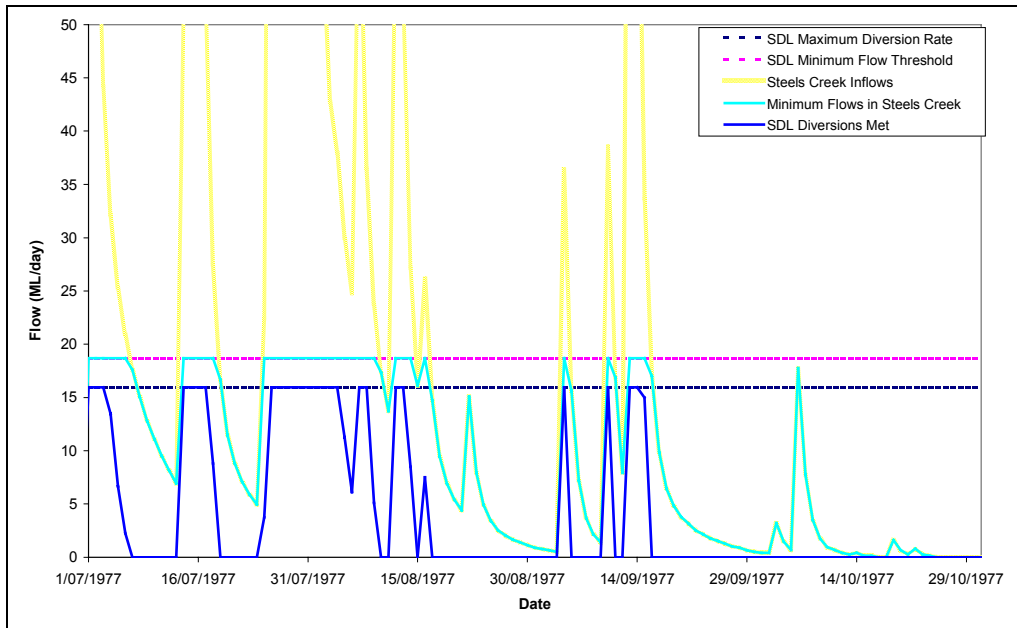
annual diversion volume. The volume met in many of these years (for example 1982 or 1979) is significantly lower than the SDL maximum annual diversion volume.

Figure 4-11 shows how the inflows over the 1977 SDL winter period (July to October inclusive) affect the way in which water can be diverted under the SDL constraints. The time series show the maximum diversion rate and the minimum flow threshold as constant values. The actual minimum flow and the demand supplied within the SDL constraints are also shown. When streamflows drop below the minimum flow threshold, diversion ceases and all streamflows make up the minimum flow requirements. Daily diversions can never exceed the maximum daily diversion rate and can only occur when the minimum flow in the stream is greater than the minimum flow threshold.

The results from this scenario show that there appears to be considerable uncertainty surrounding the SDL figures for the Steels, Dixons and Pauls Creek catchments that were derived from catchment characteristics. However, there is also uncertainty in the streamflow estimation and this is discussed in more detail in Section 7.3. As the SDL figures for the Protection Area are only guidelines, it is advised that they be refined as part of the Streamflow Management Plan process.



■ **Figure 4-10 A comparison of the unrestricted demand and the demand met in the Pauls Creek SDL Catchment (F4) under Scenario 3**



■ Figure 4-11 Steels Creek SDL for the winter period in 1977

**4.2.5 Scenario 4**

**Full level of development (with SDL minimum flow thresholds implemented over the winter-fill period)**

Under Scenario 4, the unrestricted demand in all subcatchments cannot be met in all years (i.e., there is a shortfall in demands). Table 4-3 provides the number and duration of shortfalls in each subcatchment under Scenario 4.

■ **Table 4-3 Number and duration of shortfalls by subcatchment under Scenario 4**

Subcatchment	Total number of years of shortfalls	Average shortfall duration (days)	Range in shortfall duration (days)
Steels (Upper)	37	8	1 - 96
Dixons	37	12	1 - 84
Steels (Lower)	37	8	1 - 96
Pauls	37	3	1 - 41

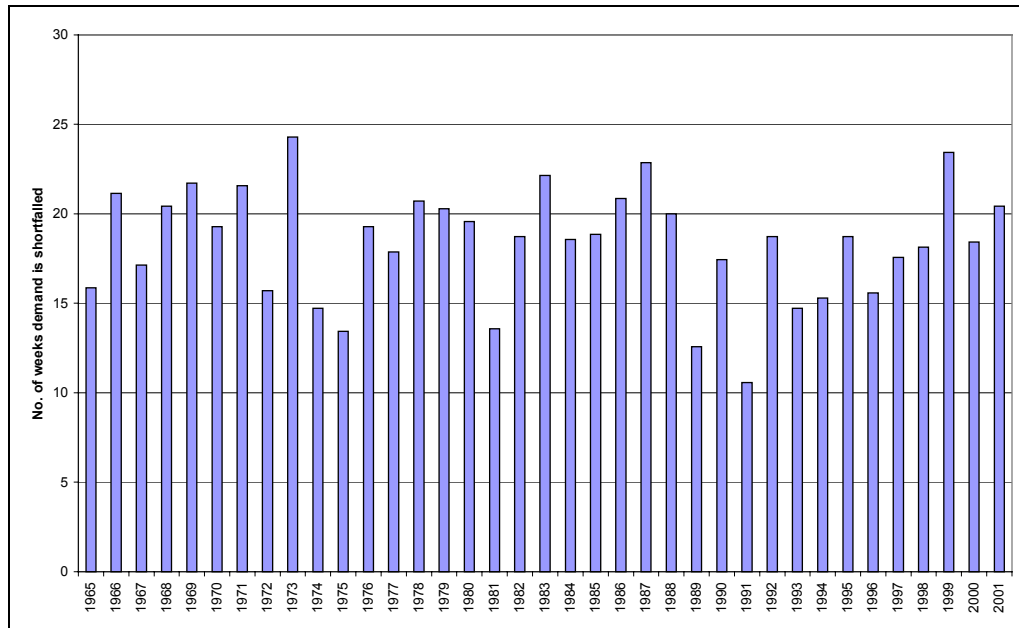
Figure 4-12 illustrates the number of weeks in each year where demands cannot be fully met and Figure 4-13 compares the unrestricted demands in each year to the demand met for the Steels Creek Upper Subcatchment.

Figure 4-14 illustrates the number of weeks in each year where demands cannot be fully met and Figure 4-15 compares the unrestricted demands in each year to the demand met for the Dixons Creek Subcatchment. In the Dixons Creek Subcatchment the shortfall duration range is greater, which reflects the need to satisfy the minimum flow threshold for Dixons Creek and also to pass flows from this subcatchment to satisfy minimum flow thresholds in the Steels Creek Lower Subcatchment.

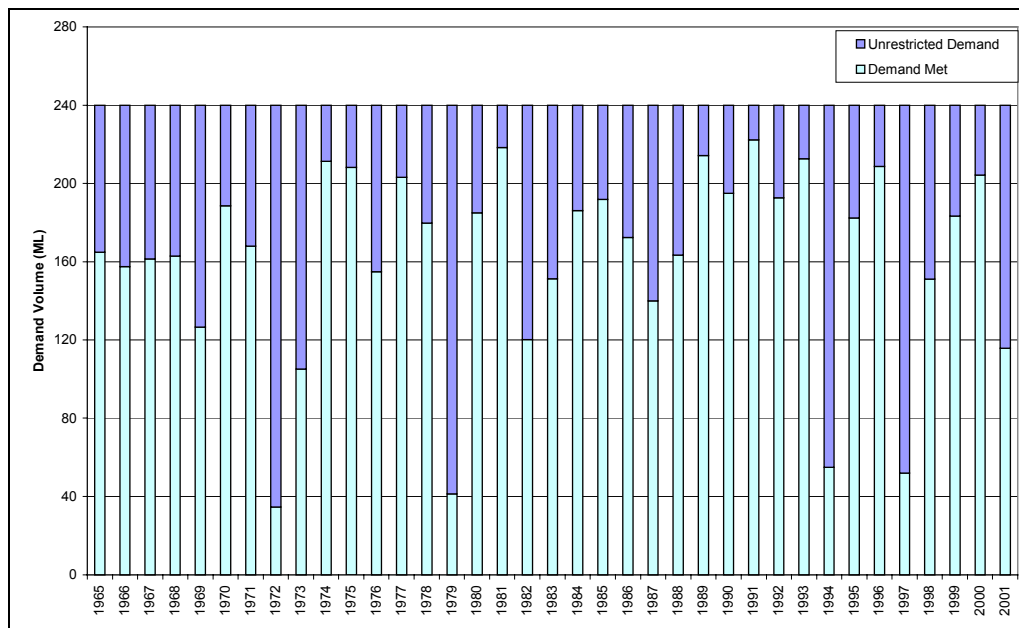
Figure 4-16 illustrates the number of weeks in each year where demands cannot be fully met and Figure 4-17 compares the unrestricted demands in each year to the demand met for the Steels Creek Lower Subcatchment.

Figure 4-18 illustrates the number of weeks in each year where demands cannot be fully met and Figure 4-19 compares the unrestricted demands in each year to the demand met for the Steels Creek Lower Subcatchment.

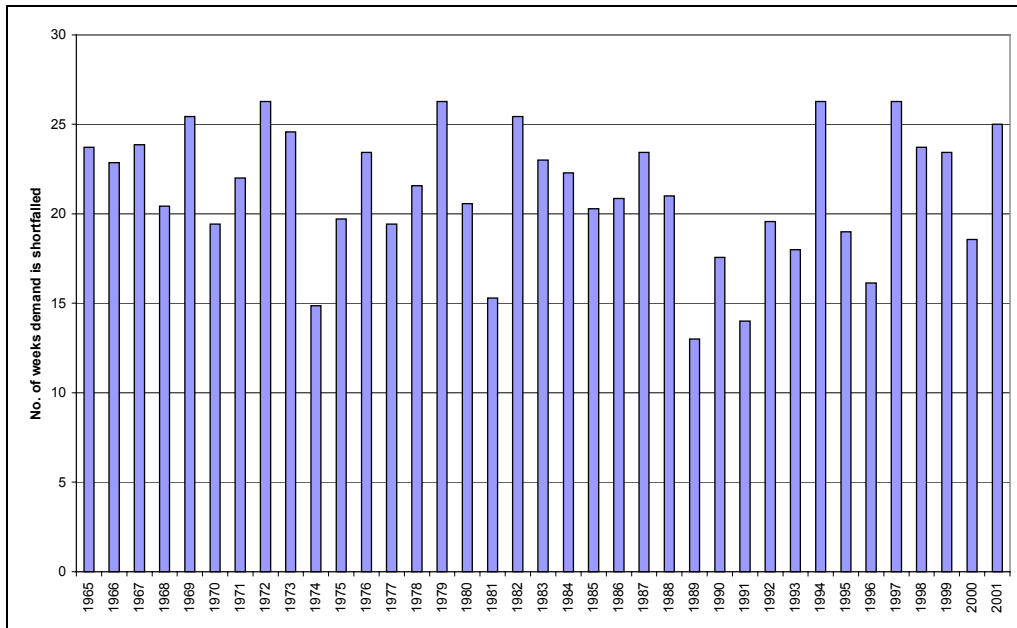
The introduction of SDL minimum flow thresholds over the licensed winter-fill period (May to October inclusive) with demands at the full level of development, would result in considerable shortfalls and loss of reliability of supply to all water users in the catchment. This scenario assumes that farm dams receive all of the water that they would collect based on the demands/impact estimated using the farm dam impact model (Section 6.3) (i.e. farm dams do not have the infrastructure necessary to pass runoff to satisfy instream flow requirements). Under full level of development conditions without the SDL minimum flow thresholds implemented licensed water user demands can be met in all years.



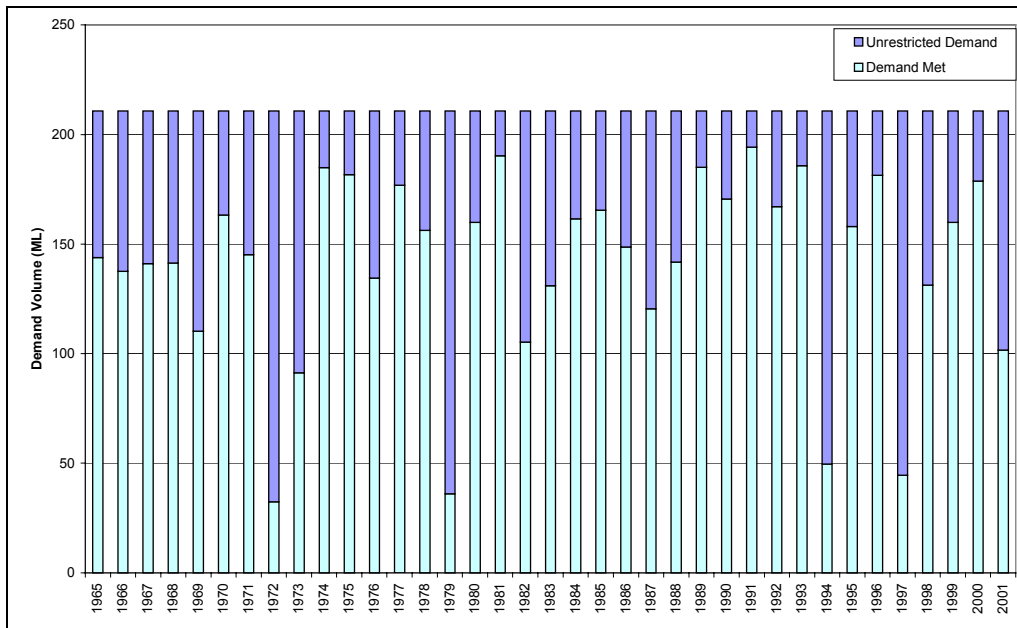
■ Figure 4-12 Number of weeks where demands cannot be fully met in the Steels Upper Subcatchment (F3) under Scenario 4



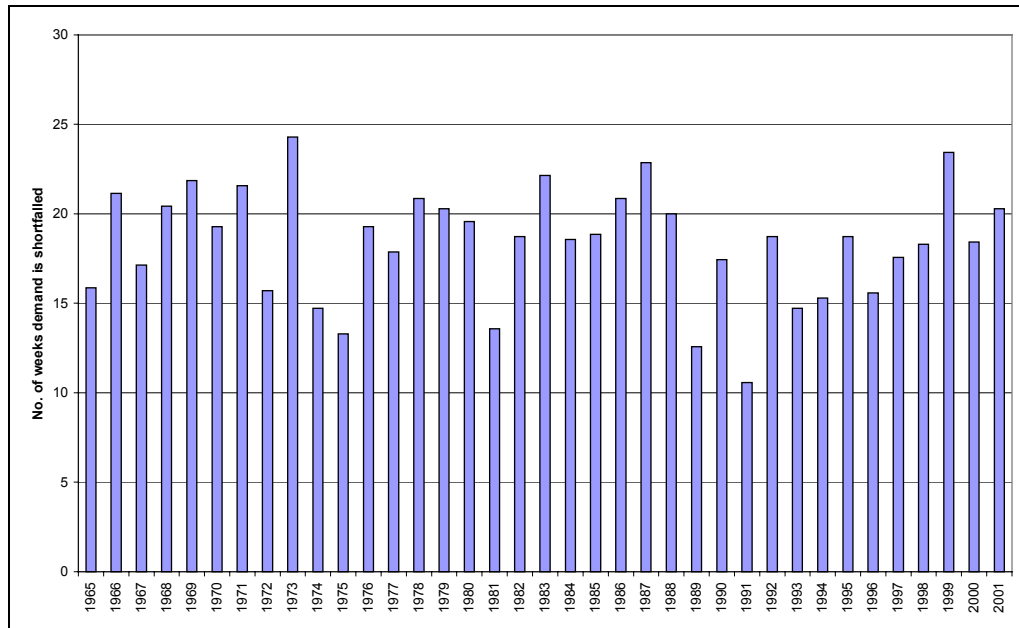
■ Figure 4-13 A comparison of the unrestricted demand and the demand met in the Steels Upper Subcatchment (F3) under Scenario 4



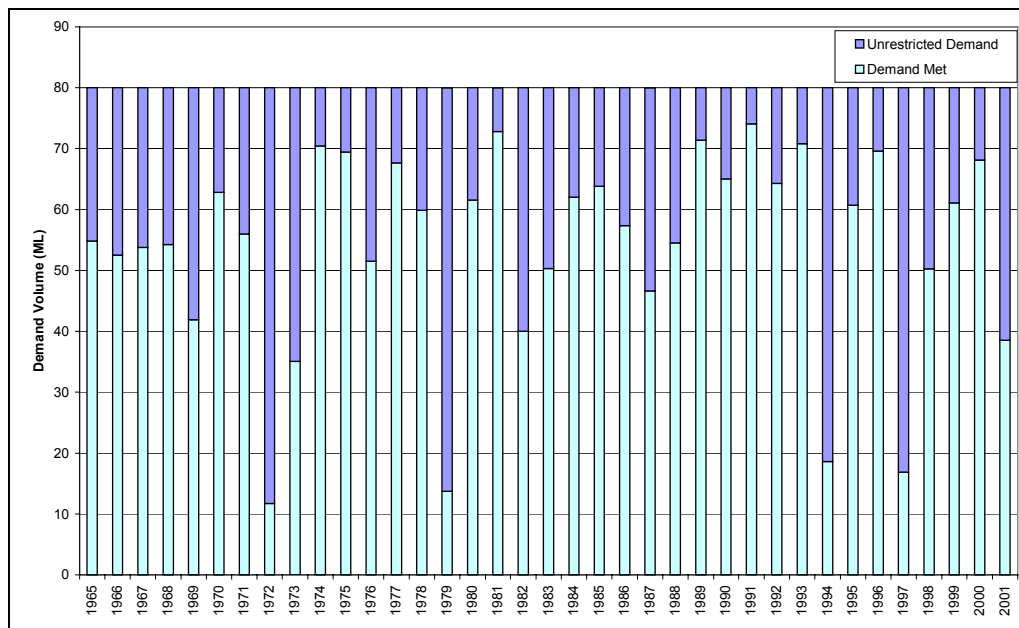
■ Figure 4-14 Number of weeks demands cannot be fully met in the Dixons Creek Subcatchment (F2) under Scenario 4



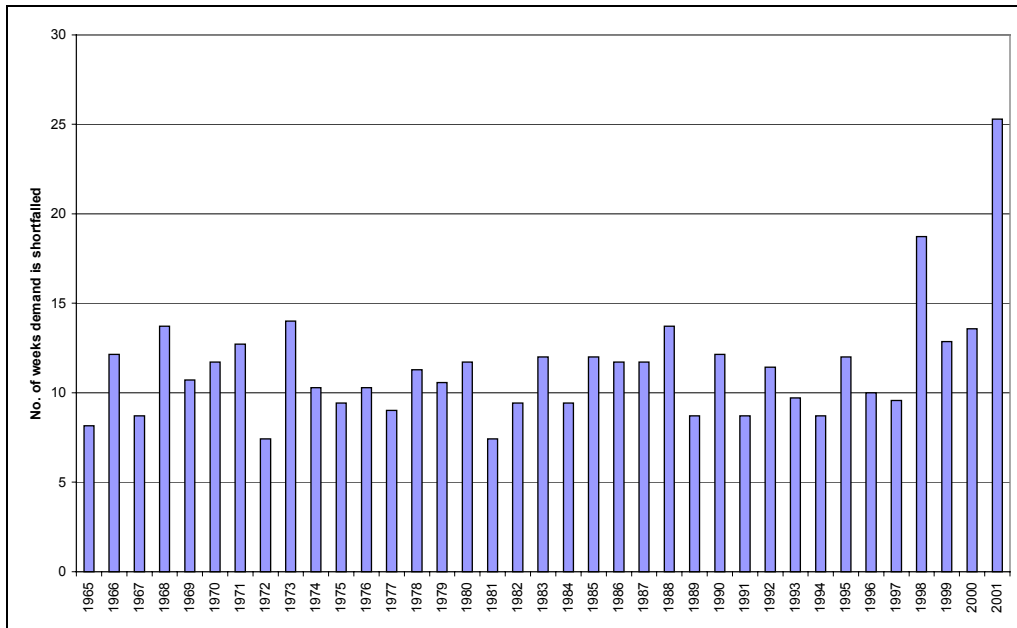
■ Figure 4-15 A comparison of the unrestricted demand and the demand met in the Dixons Creek Subcatchment (F2) under Scenario 4



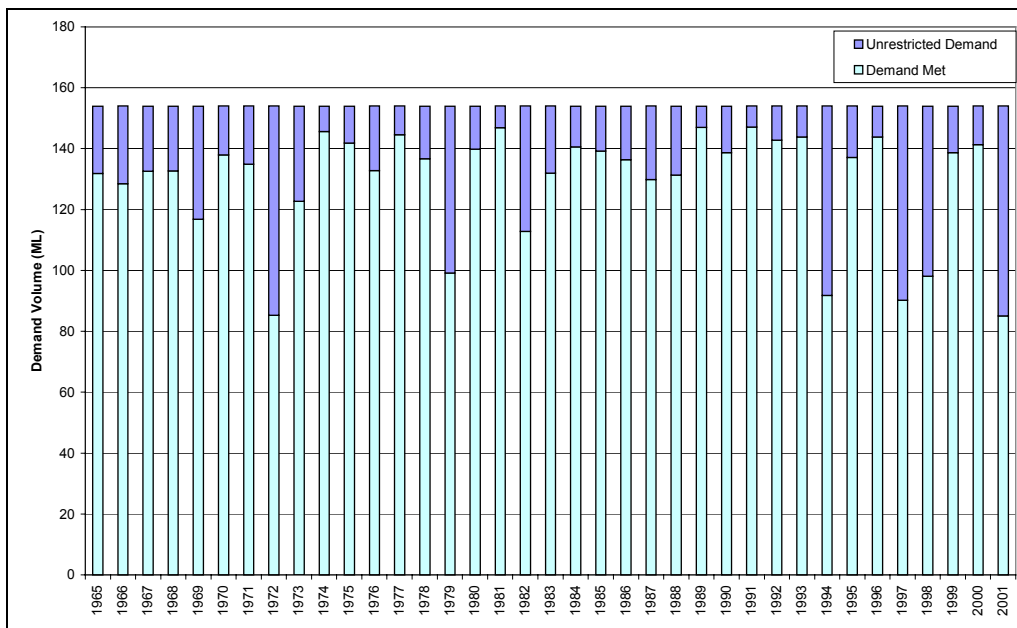
■ Figure 4-16 Number of weeks demands cannot be fully met in the Steels Lower Subcatchment (F1) under Scenario 4



■ Figure 4-17 A comparison of the unrestricted demand and the demand met in the Steels Lower Subcatchment (F1) under Scenario 4



■ Figure 4-18 Number of weeks demands cannot be fully met in the Pauls Creek Subcatchment (F4) under Scenario 4



■ Figure 4-19 A comparison of the unrestricted demand and the demand met in the Pauls Creek Subcatchment (F4) under Scenario 4

#### 4.2.6 Drought Response Plan

The *Drought Response Plan (Yarra Catchment) Private Diversions* (Melbourne Water, 2001) provides three restriction levels for private diverters based on flows in the Yarra River at Warrandyte (Table 4-4). Based on the types of licensed water users in the Steels, Dixons and Pauls Creeks Water Supply Protection Area, the impact on diverters as a result of restrictions being implemented in the Yarra Basin is minimal.

■ **Table 4-4 Private diverter restrictions (after Melbourne Water, 2001)**

Restriction Level	Warrandyte Flow (7 day rolling average, ML/day)	Summary of Restrictions Specified in DRP (please see the DRP for the complete descriptions)
1	375	Diverters to implement drought contingency plans or otherwise conserve water.
2	300	<u>Domestic and Stock:</u> Diversions are banned where alternative supplies exist.  <u>Winter-fill:</u> No restrictions provided water is drawn from reserves of stored water.
3	200	<u>Domestic and Stock:</u> Diversions are banned where alternative supplies exist.  <u>Winter-fill:</u> No restrictions provided water is drawn from reserves of stored water.

Since implementation of the Drought Response Plan (DRP) in 1998, restrictions have been enacted three times (*pers. comm.*, Melbourne Water, Table 4-5). These restrictions would have had little impact on the licensed water users in the Steels, Dixons and Pauls Creeks Water Supply Protection Area as the majority of licences (16 out of 17) are for winter-fill dam filling (i.e. during the winter-fill period) and none of the restrictions were enacted during the winter-fill period.

■ **Table 4-5 Restrictions in the Yarra Basin**

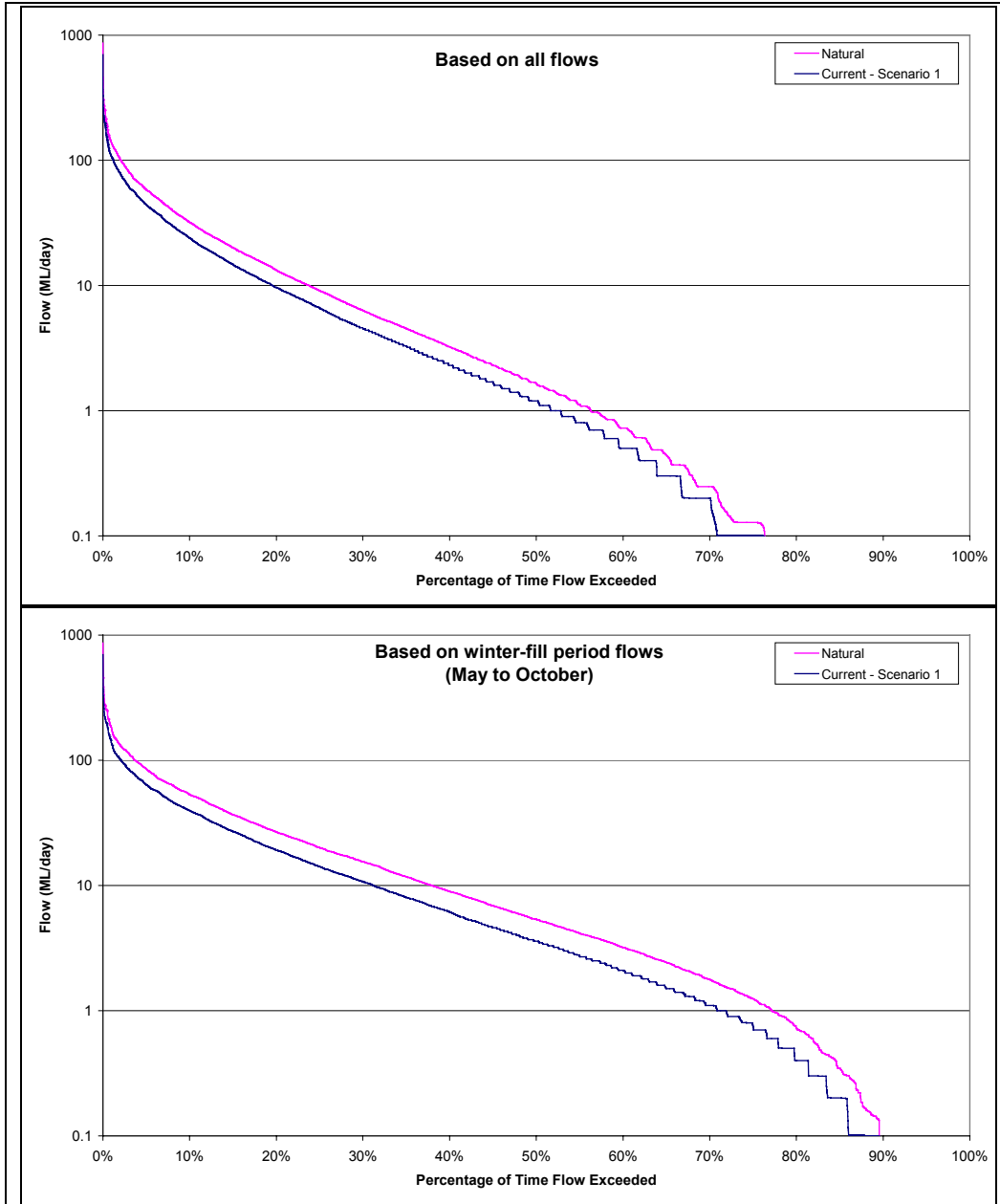
Date of Restriction	Level of Restriction	Warrandyte Flow
11 January 1998	2	245 ML/day
6 March 2000	1	274 ML/day
26 March 2000	2	266 ML/day

#### 4.3 Flow Comparison

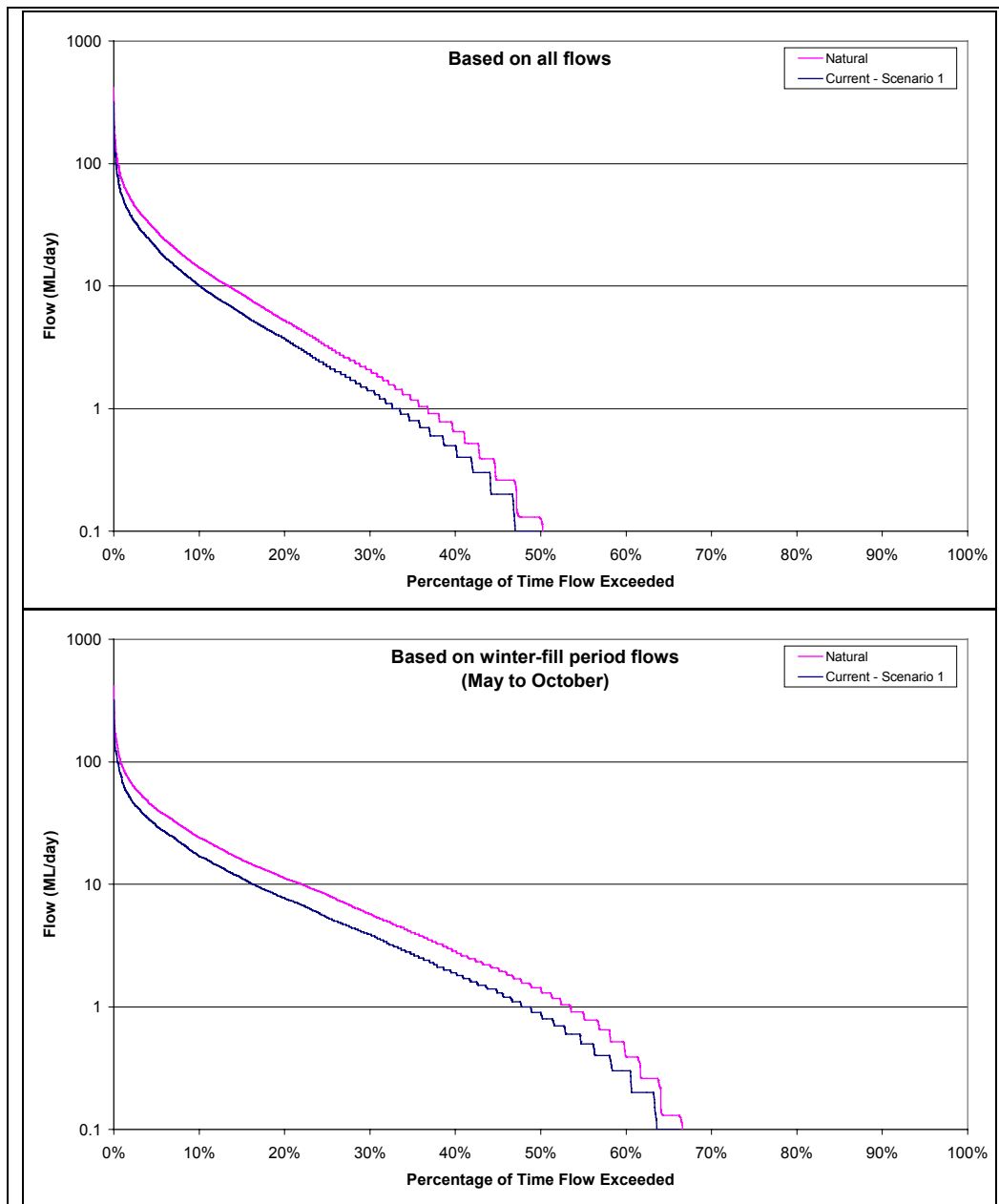
Under current level of development conditions (Scenario 1), estimated natural flows in all subcatchments have been reduced due to licensed water use and farm dams. This is demonstrated in Figure 4-20 and Figure 4-21, which show *flow duration curves* for flows under natural and current level of development conditions in the Steels Creek and Pauls Creek catchments respectively.

Figure 4-20 shows that in the Steels Creek catchment flows over all ranges were higher under natural conditions than under the current level of development conditions. For example the flows that are exceeded 20% of the time (Proportion of Time Flow Exceeded = 20%) under natural conditions were around 13 ML/day. However, under the current level of development conditions, the flows that are

exceeded 20% of the time have been reduced to around 10 ML/day. Similarly, in the Pauls Creek catchment (Figure 4-21) flows over all ranges were higher under natural conditions, with flows that are exceeded 20% of the time reduced from 5 ML/day under natural conditions to 4 ML/day under the current level of development conditions.

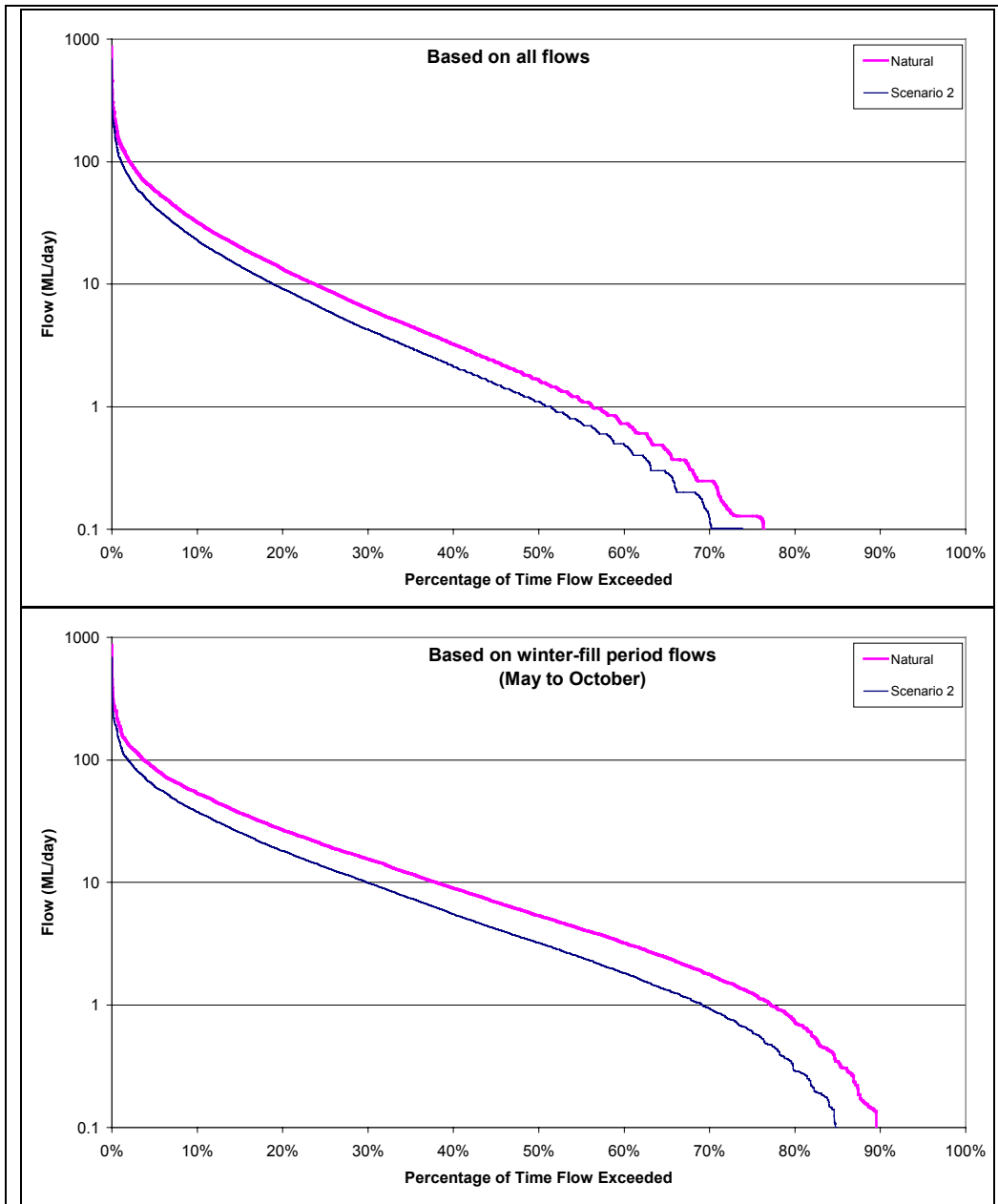


■ Figure 4-20 Steels Creek catchment flow duration curves under natural and current conditions (Scenario 1)

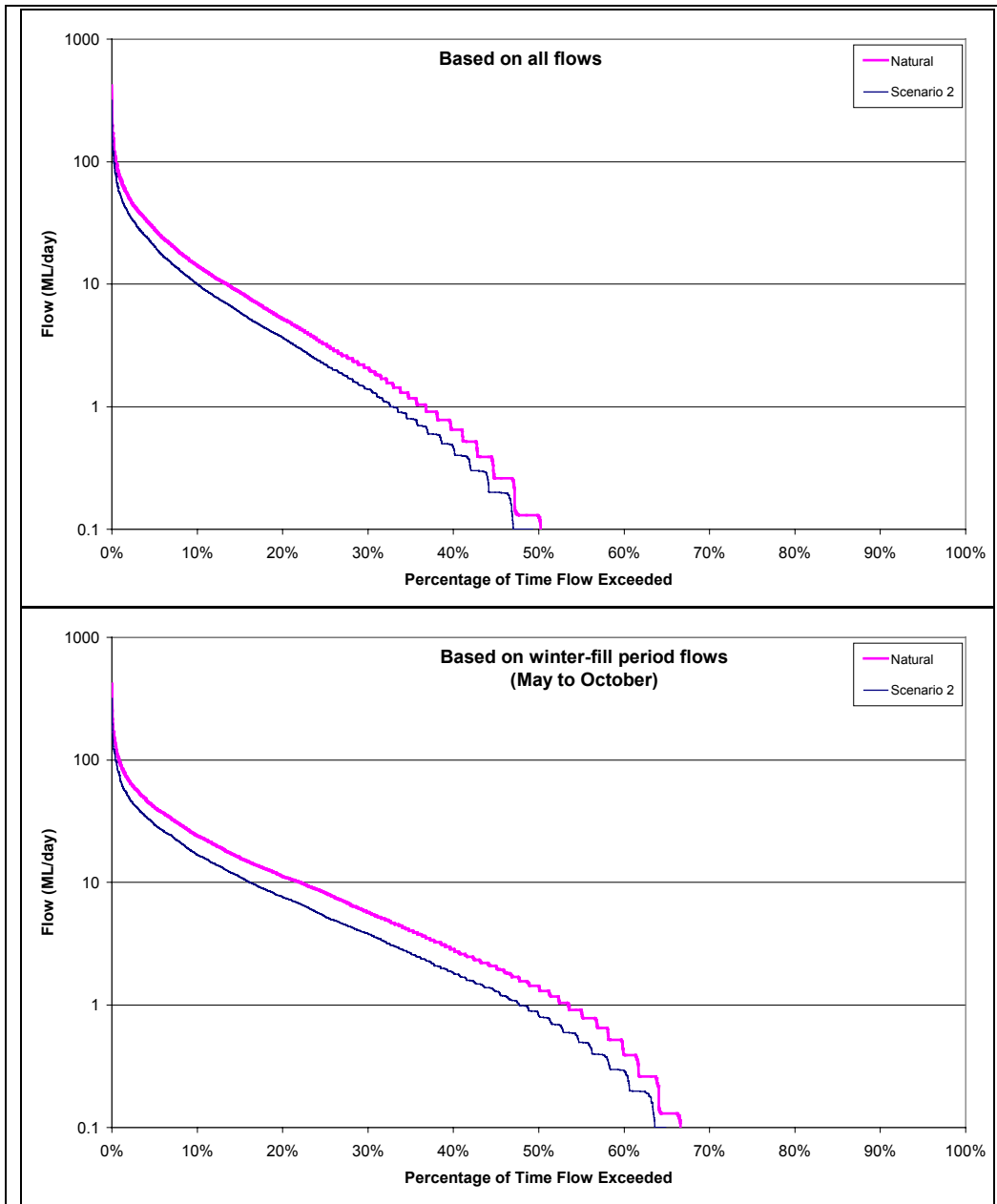


■ **Figure 4-21 Pauls Creek catchment flow duration curves under natural and current conditions (Scenario 1)**

Under full level of development conditions (Scenario 2) the flows in the Steels Creek and Pauls Creek catchments (Figure 4-22 and Figure 4-23) are reduced even further below the natural flow conditions. Flows exceeded 20% of the time in the Steels Creek catchment are reduced from 13 ML/day under natural conditions to around 9 ML/day under current conditions. In the Pauls Creek catchment under full level of development conditions, flows that are less than the flow exceeded around 2% of the time are unchanged with respect to current level of development conditions. Flows above this point have been only marginally reduced below the current level of development conditions.

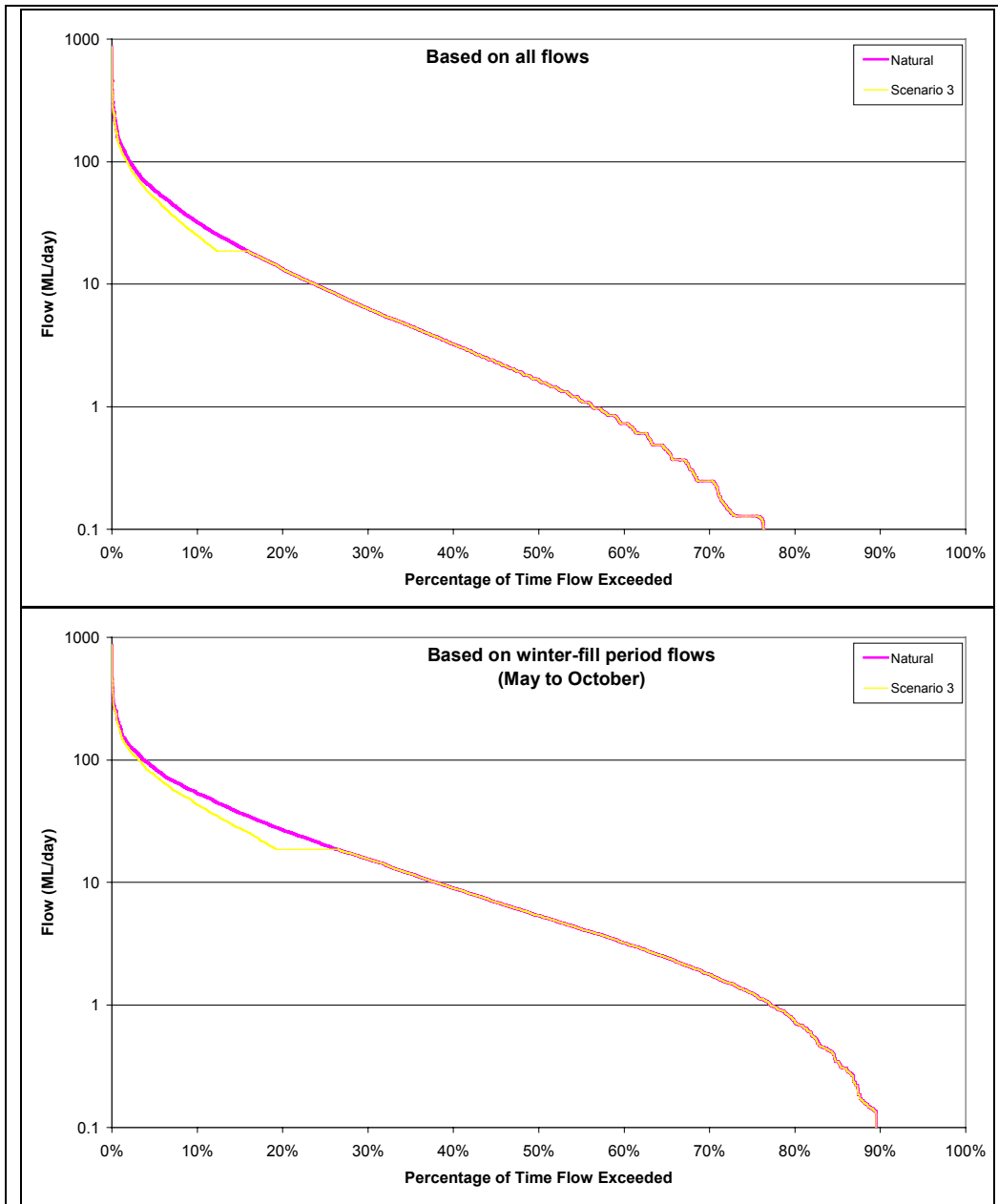


■ Figure 4-22 Steels Creek catchment flow duration curves under natural and full level of development conditions (Scenario 2)

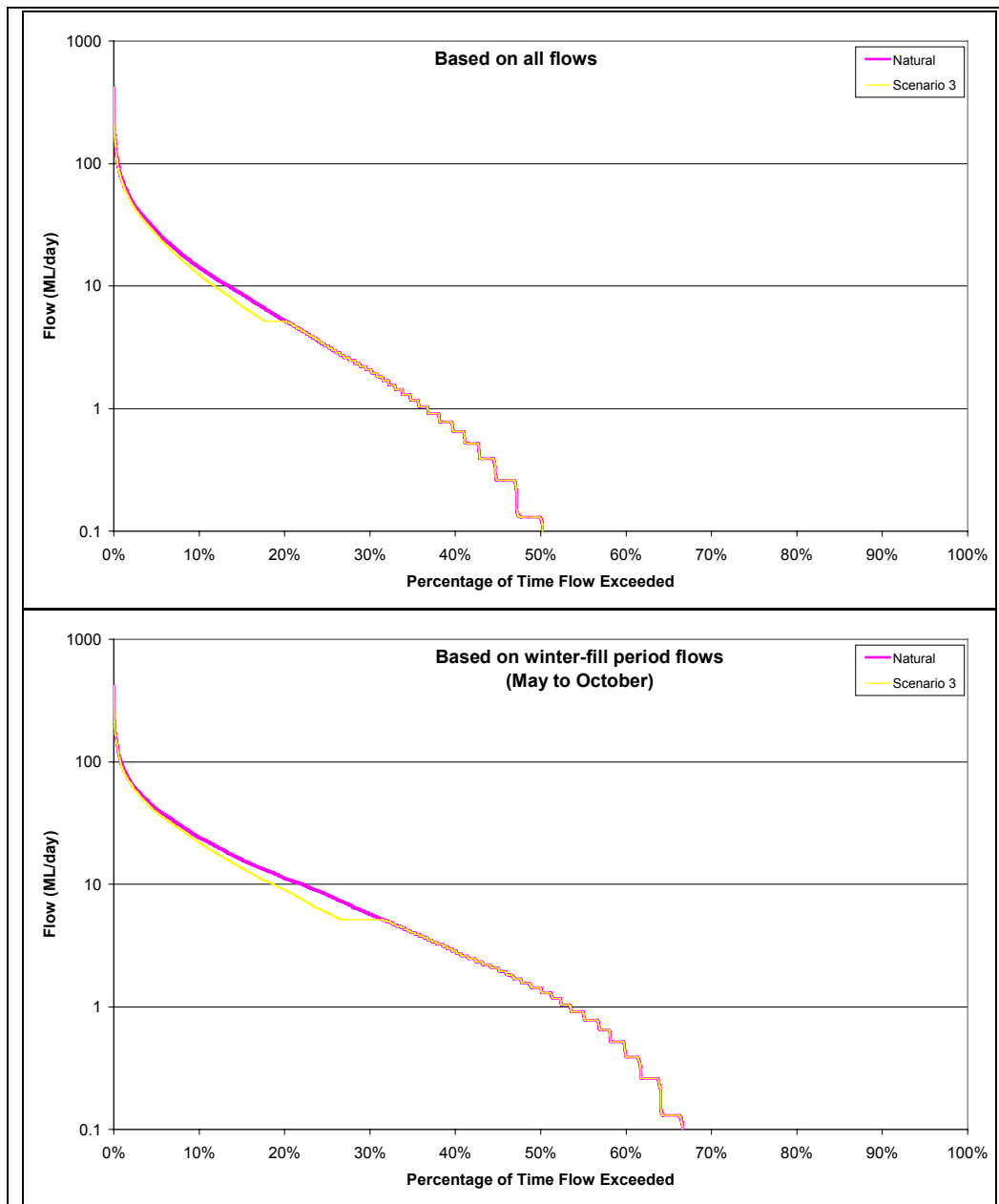


■ **Figure 4-23 Pauls Creek catchment flow duration curves under natural and full level of development conditions (Scenario 2)**

With the implementation of the Sustainable Diversion Limit under Scenario 3, flows in Steels Creek greater than 18.67 ML/day (the flow exceeded around 16% of the time) have been reduced (Figure 4-24). Flows below this are equivalent to the natural flow conditions. Similarly in Pauls Creek catchment flows below the SDL minimum flow threshold of 5.16 ML/day (flows exceeded around 20% of the time) are the same under natural conditions or with the SDL rules in place (Figure 4-25). Flows greater than 5.16 ML/day have been reduced.



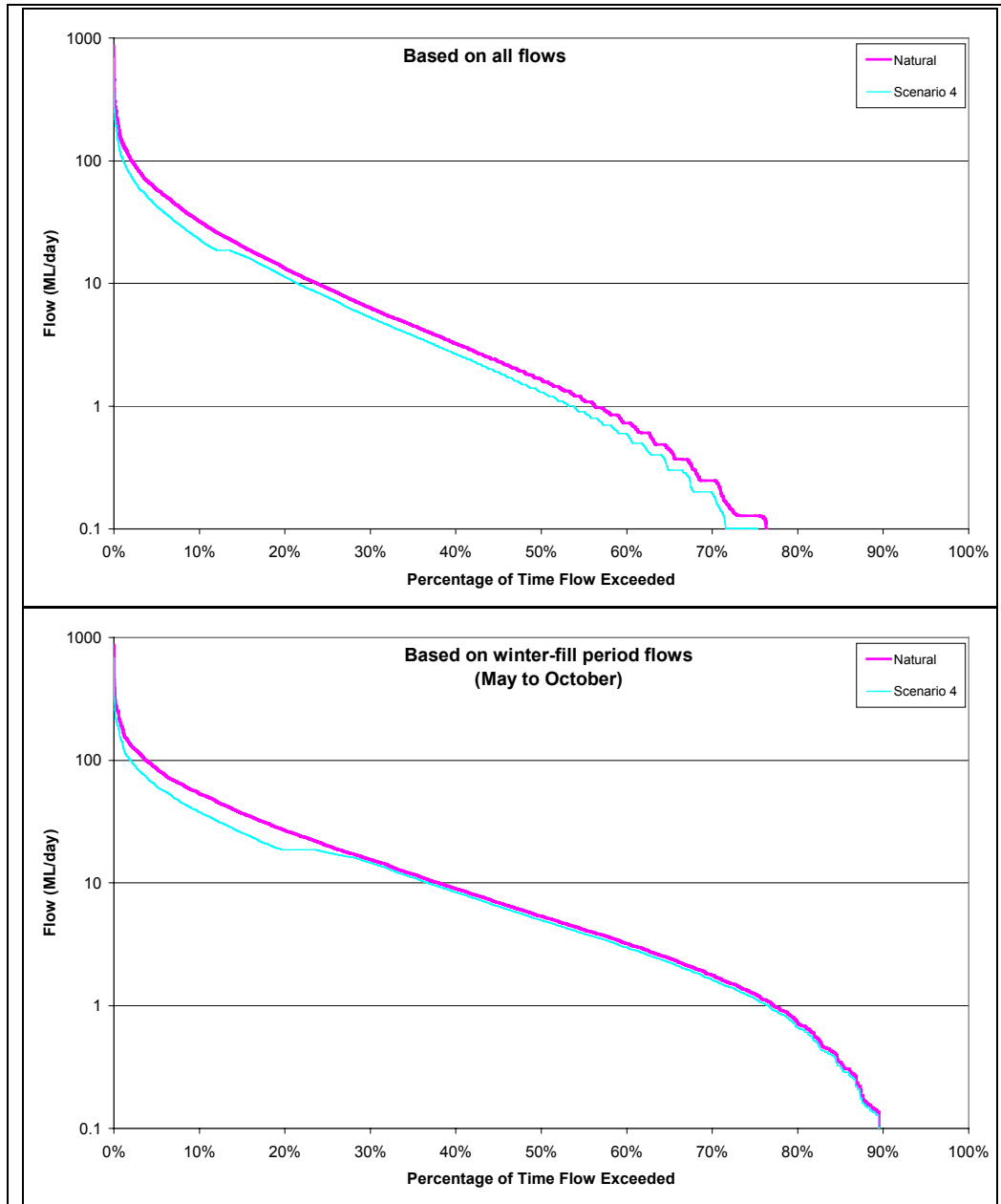
■ Figure 4-24 Steels Creek catchment flow duration curves under natural and SDL conditions (Scenario 3)



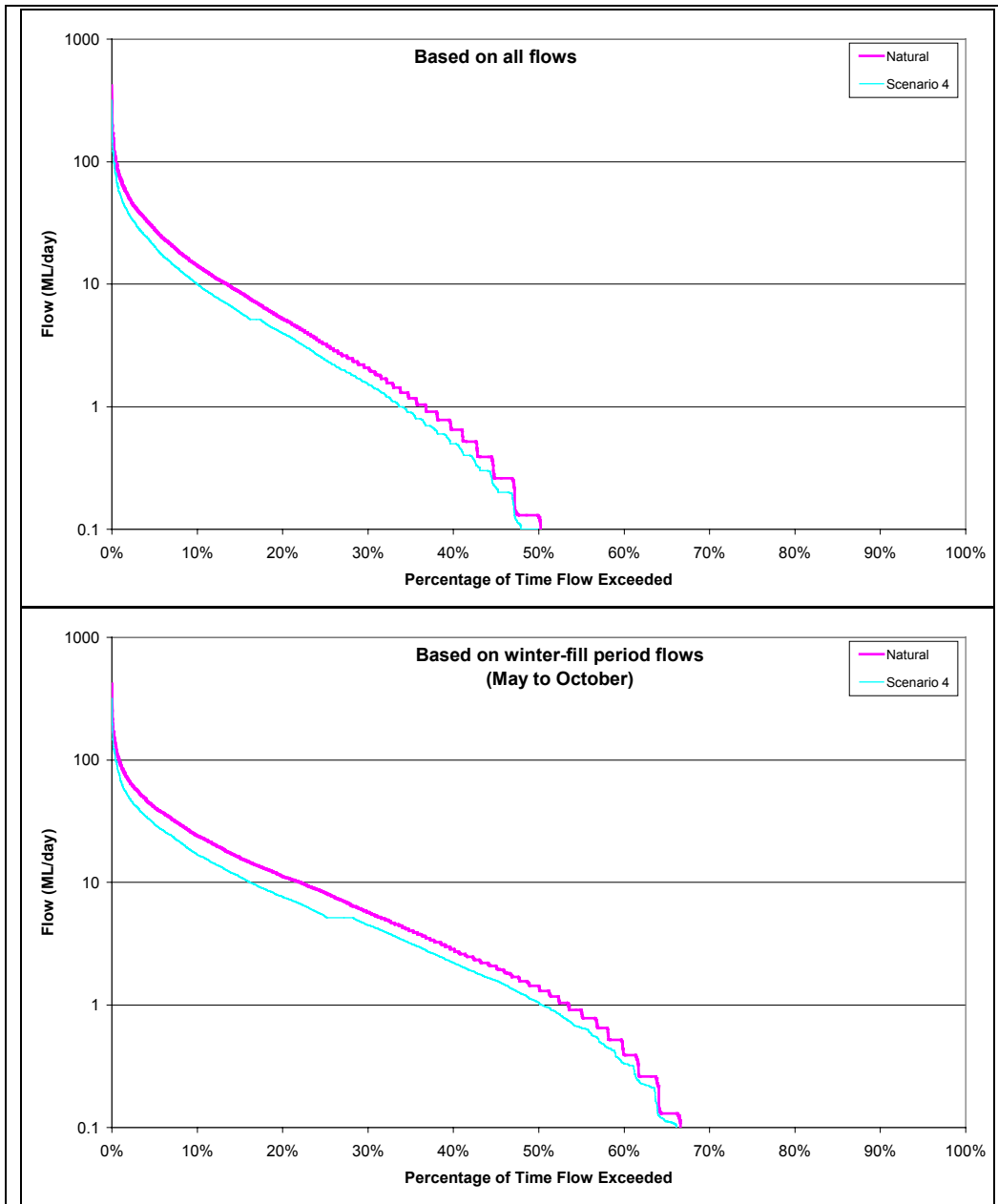
■ **Figure 4-25 Pauls Creek catchment flow duration curves under natural and SDL conditions (Scenario 3)**

Under Scenario 4 full level of development demands are implemented along with the SDL minimum flow thresholds. However these minimum flow thresholds are implemented over the licensed winter-fill period, i.e. May to October. In Steels Creek (Figure 4-26) flows that are above the SDL minimum flow threshold of 18.67 ML/day are reduced in a similar manner to flows under Scenario 2. However below the threshold, flows are higher than under Scenario 2 or current level of development conditions. They are also not equal to that which occurred under natural conditions, such as occurred in Scenario 3, as stock and domestic and farm dam demands occur outside the winter-fill period. In Scenario 3 water use is only allowed over the SDL winter-fill period of July to October when the minimum flow thresholds are in place.

The same pattern is seen in the flow duration curves for Pauls Creek under Scenario 4 (Figure 4-27).



■ Figure 4-26 Steels Creek catchment flow duration curves under natural and full level of development conditions with SDL minimum flow thresholds implemented (Scenario 4)



■ Figure 4-27 Pauls Creek catchment flow duration curves under natural and full level of development conditions with SDL minimum flow thresholds implemented (Scenario 4)

## 4.4 Summary

Five different scenarios (including historic) have been modelled for the Steels, Dixons and Pauls Creeks catchment, the results for which have been presented in the preceding sections. Table 4-8 summarises the results of each scenario.

No demand shortfalls were found to occur under the historic conditions. This is contrary to anecdotal evidence, which suggests that diverters have not been able to extract their licence volumes in all years. The method used to determine natural flows, which are inputs into the REALM model of the catchment, assumed that the licence volume equalled the current demand and the historic usage in the catchment from year to year. This assumption was necessary, as there is no data available on actual usage in the catchment. The methodology applied for determining the demands for the winter-fill dam filling licences and the stock and domestic licence was consistent with methodologies adopted in other similar studies.

Under current and full level of development scenarios no demand shortfalls were found to occur in the catchment.

Under full level of development conditions with SDL minimum flow thresholds implemented over the licensed winter-fill period, licensed water users in all subcatchments experience demand shortfalls in all years, compared with no shortfalls in the absence of SDL minimum flow thresholds.

Sustainable Diversion Limits have been specified for the Dixons Creek, Steels Creek and Pauls Creek catchments and were based on catchment characteristics and the application of regional relationships, as actual streamflow data was not available at the time that the investigation was undertaken. The SDL rules include specifying:

- 1) The winter-fill months when diversion is allowed (i.e. July to October inclusive);
- 2) A maximum annual diversion volume;
- 3) A maximum daily diversion rate; and
- 4) A minimum flow threshold below which diversion must cease.

With the SDL rules implemented, all water users in the Steels, Dixons and Pauls Creeks Water Supply Protection Area are only able to extract the combined SDL annual maximum volumes in 22% of years (i.e. the overall reliability of supply throughout the Protection Area is 22%). These results indicate that the SDL rules for these catchments may not be appropriate and require careful consideration and potentially review before adoption in the Streamflow Management Plan. The SDL rules were based on regional relationships, which may not adequately reflect the conditions in the study catchment. Hence there are potentially significant error bounds around the SDL estimates. However, it is also important to consider that it was not possible to obtain a good rainfall runoff model fit for the streamflow data in Steels Creek or Pauls Creek, and that there may also be error bounds around the infilled and extended streamflow data for the catchment. Further discussion on the reliability of the estimation of streamflow data is provided in Section 7.3.

Streamflows in the Steels, Dixons and Pauls Creeks catchment under current levels of development are lower across all flow ranges than flows under natural conditions. There is not a significant reduction in flows if demands are increased to the full level of development conditions.

■ **Table 4-6 Summary of scenario modelling results**

Scenario	Purpose of Scenario	Total number of years of shortfalls				Average shortfall duration (days)			
		Steels Upper	Steels Lower	Dixons	Pauls	Steels Upper	Steels Lower	Dixons	Pauls
Calibration	Calibration of the Steels, Dixons and Pauls Creeks REALM model based on historic catchment conditions.	0	0	0	0	N/A	N/A	N/A	N/A
1	To test reliability of supply to licensed water users based on the current level of development.	0	0	0	0	N/A	N/A	N/A	N/A
2	To test the reliability of supply to licensed water users based on estimated full level of development.	0	0	0	0	N/A	N/A	N/A	N/A
3 <sup>1,2</sup>	To test the reliability of supply to all water users at the Sustainable Diversion Limit (SDL) at sites F1 and F4.	28	28	30	23	N/A	N/A	N/A	N/A
4	To assess the impact on reliability of supply to licensed water users at sites F1 and F4 based on estimated full level of development and on implementing the SDL minimum flow thresholds over the licensed winter-fill period.	37	37	37	37	8	8	12	3

Notes:

- (1) An Average Shortfall Duration cannot be obtained for Scenario 3, as a daily demand time series is not available under this scenario. The demands were set up in the REALM system to attempt to extract the SDL maximum daily diversion rate, if streamflow conditions and timing under the SDL permitted.
- (2) Shortfalls to supply the SDL maximum annual diversion volume were determined to occur if the volume met was greater than 1% from the SDL annual. Shortfalls were also based on the calendar year rather than the financial year as for all other scenarios.

## 5. Data Collation and Preparation

### 5.1 Rainfall

Rainfall data was required from 1965 to 2001 to estimate farm dam impacts and to estimate streamflows in the absence of recorded streamflow. In a previous investigation undertaken by Egis (2001) that assessed the impact of farm dams on streamflows in the Steels, Dixons and Pauls Creek catchment, monthly streamflows were required as inputs to the TEDI (Tool for Estimating Dam Impact) model from 1970 to 2000. This period did not cover the required period of record for input into the REALM model and the goodness of fit of these estimated streamflows were not considered adequate to be used on a daily basis. Hence it was necessary to re-derive the streamflows over the required period of record using a rainfall runoff model.

Although significant periods of recorded rainfall data near the Protection Area are available, some records contained missing data and periods where the measurement was accumulated over several days. It was also necessary to check the data for the presence of any unexplained trends. All rainfall data was obtained from the Bureau of Meteorology. The preparation of rainfall data is described below.

#### *Location of Rainfall Gauges*

The key rainfall gauges used in this study are shown in Figure 2-1.

#### *Disaggregation*

The method used to disaggregate accumulated periods was that proposed by Porter and Ladson (1993), which assumes the influence of nearby stations is inversely proportional to their distance from the gauge for which the accumulated data is to be disaggregated (the focal gauge). This safeguards against the uncertainty of using data from a single station. As the time required for this procedure is large, an automated procedure has been developed.

#### *Infilling of Missing Data*

An automated procedure has also been developed for the process of infilling missing data. This procedure calculates the correlation between the focal and nearby gauges. The gauge with the highest correlation that has data concurrent with the missing period is used for infilling. The hyetograph of the selected nearby station is adjusted by the ratio of the concurrent mean annual rainfalls of the two stations and used to infill the missing period. A summary of the rainfall sites surrounding the study catchment and the data availability is contained in Table 5-1.

■ **Table 5-1 Rainfall gauging station details**

Station Number	Location	Period of Record Available	Proportion Missing
086142	Mt St Leonard	1953 - 2002	0.2%
086280	Kinglake Garage	1969 - 1988	5.8%
086364	Tarrawarra Monastery	1986 - 2002	7.0%

Two of these rainfall stations do not cover the entire modelling period (1965-2001). The pattern of daily rainfalls over the concurrent period at the three rainfall sites is relatively similar, however the magnitude of rainfall varies considerably. Mt St

Leonard (086142) receives the greatest amount of rainfall, whilst Tarrawarra Monastery (086364) receives the lowest rainfall. Based on the similarity in the pattern of rainfall between the sites, the extensive infilling that would be required at two of the sites, and the purpose that the rainfall data was to be used for, the Mt St Leonard (086142) rainfall record was adopted for use in the extension of streamflow data using the rainfall runoff model. Hence extension of the rainfall record at this site was not required.

The average monthly rainfall inputs required for the TEDI model that were derived by Egis (2001) were adopted for use in rerunning the TEDI model with the revised streamflows. Further information on the assessment of farm dam impacts is provided in Section 6.3.

*Removal of Trend*

The rainfall data sets were checked for stationarity (i.e. absence of trend) by plotting a double mass curve of each annual data series against a nearby known “high quality” rainfall gauge (Yan Yean, 086131), as identified by the Bureau of Meteorology. Upon analysis it was found that none of the data sets required de-trending.

## 5.2 Evaporation

Evaporation data was required to estimate farm dam impacts and to estimate streamflows in the absence of recorded data. The monthly average evaporation data that was derived by Egis (2001) for the rainfall-runoff modelling and farm dam impact assessments for the Steels, Dixons and Pauls Creek catchment was adopted for use in this study (Table 5-2).

■ **Table 5-2 Average monthly evaporation (after Egis, 2001)**

Evap (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TEDI	263.6	230.3	210.3	105.4	82	58.9	68.7	86.4	102.8	140.8	183.4	260.8
AWBM	194.1	169.9	143.8	83.3	57.8	41.6	48.2	63.2	79.7	114.9	143	182.3

A summary of the evaporation data used to derive the Egis (2001) average monthly evaporation figures used in this study is provided in Table 5-3.

■ **Table 5-3 Evaporation gauging station details.**

Rainfall Station	Location	Period of Record Available	Proportion missing
086363	Tarrawarra	1987 - 2000	45%
086142	Mt St Leonard	1965 - 2000	51%

## 5.3 Streamflow

There are two streamflow gauging stations in the Water Supply Protection Area (Table 5-4), with periods of missing data at both sites and differing levels of data quality. Of note are thirty days of missing flow data at the Steels Creek site (229246) around March and April of 2000. Approximately 22% of the data at Pauls Creek (229245) and 29% of the data at Steels Creek (229246) have quality codes greater than 99. The quality code is used to indicate the accuracy of the data. Quality codes between 1 and 99 are allocated to good reliable data, while quality codes from 100 to 150 are

allocated to estimated data of lower reliability. Data with quality codes of greater than 150 have been categorised as “missing data”.

■ **Table 5-4 Streamflow gauging stations in the Steels, Dixons and Pauls Creeks Catchment**

Station ID	Station Name	Period of Available Record	Proportion of missing data
229245	Pauls Creek at Healesville Yarra Glen Rd	April 1998 to March 2002	0.2%
229246	Steels Creek at Healesville Yarra Glen Rd	April 1998 to March 2002	3.0%

## 5.4 Water Use Licenses

Melbourne Water provided diversion license information for Steels, Dixons and Pauls Creeks. The licenses were divided into the four subcatchments used in the REALM model, as shown in Table 5-5.

■ **Table 5-5 Assignment of diverters to subcatchments**

Subcatchment	Waterway	Private Diverter Type	Licensed Annual Volume (ML)
Steels Creek (Lower)	Steels Creek	Off-Stream Dam Filling	80
<i>Total Steels Creek (Lower)</i>			<i>80</i>
Steels Creek (Upper)	Steels Creek	Off-Stream Dam Filling	115
	Steels Creek	Off-Stream Dam Filling	15
	Tributaries of Steels Creek	On-Stream Dam Filling	110
<i>Total Steels Creek (Upper)</i>			<i>240</i>
Dixons Creek	Dixons Creek	Domestic & Stock	2
	Dixons Creek	Off-Stream Dam Filling	35
	Dixons Creek	Off-Stream Dam Filling	45
	Dixons Creek	Off-Stream Dam Filling	7
	Dixons Creek	Off-Stream Dam Filling	80
	Dixons Creek	Off-Stream Dam Filling	6
	Tributary of Dixons Creek	On-Stream Dam Filling	36
<i>Total Dixons Creek</i>			<i>211</i>
Pauls Creek	Pauls Creek	Off-Stream Dam Filling	16
	Pauls Creek	On-Stream Dam Filling	3
	Pauls Creek	Off-Stream Dam Filling	7
	Pauls Creek	Off-Stream Dam Filling	105
	Pauls Creek	Off-Stream Dam Filling	8
	Pauls Creek	Off-Stream Dam Filling	15
<i>Total Pauls Creek</i>			<i>154</i>
<b>TOTAL ALL SUBCATCHMENTS:</b>			<b>685</b>

## 5.5 Farm Dam Volumes

Farm dam volumes for the Steels, Dixons and Pauls Creeks Water Supply Protection Area were supplied by Egis (2001). The dam volumes had been estimated from their surface area as shown on aerial photographs, using the relationship derived by Good and McMurray (1997):

$$V = \frac{(A)^{1.4}}{22727}$$

**Equation 1**

Where:

V = volume in ML

A = area in km<sup>2</sup>

Farm dam impacts were divided into the four subcatchments used in the REALM model. Table 5-6 shows the farm dam volumes by subcatchment. Egis (2001) farm dam impacts were derived over the period 1970 to 2000. Hence it was necessary to re-derive the farm dam impacts over the 1965 to 2001 period using the extended streamflows derived for this investigation. No other changes were made to the TEDI models prepared by Egis (2001), however an additional model was required for the Steels Creek (Lower) subcatchment, as this area had not been included in the original farm dam impact assessment.

■ **Table 5-6 Farm dam volumes on a subcatchment basis**

Subcatchment	Farm Dam Volumes (ML)
Steels Creek (Upper)	175
Steels Creek (Lower)	85
Dixons Creek	433
Pauls Creek	352
<b>Total Volume</b>	<b>1,045</b>

## 6. Derivation of Demands

Demand time series at different levels of development were required for this project:

- ❑ Historic demands were required to assist in the calculation of inflows, and as input to the REALM calibration run. Historic licensed demands were taken to be licenses active over the period of gauged flows in the catchment (1998 to 2002). All licences in the catchment were active over this period and hence the *Estimate of Maximum Annual Usage* as provided by licensed water users in the survey was adopted as the historic demand.
- ❑ Current level of development demands were required as input to the REALM scenario runs. The current level of development demands were based on the results of the water use survey conducted in November 2001 by Melbourne Water. The current demands were adopted as historic for the Steels, Dixons and Pauls Creeks Water Supply Protection Area.
- ❑ Full level of development demands were also required as input to the REALM scenario runs. The full level of development demands were calculated by assuming that all licence volumes were fully utilised.

No data is available on the actual usage of licensed water users and as such assumptions were made regarding historic/current and full level of development demands. Table 6-1 provides a summary of the license volume in each subcatchment and the volumes adopted for historic, current and full level of development conditions.

■ **Table 6-1 Licence volumes, historic, current and full level of development annual demands**

Subcatchment	Licensed Volume (ML)	Historic (ML)	Current level of development (ML)	Full level of development (ML)
Dixons Creek	211	165.5	165.5	211
Steels Creek (Upper)	240	170	170	240
Steels Creek (Lower)	80	55	55	80
Pauls Creek	154	141	141	154
<b>TOTAL</b>	<b>685</b>	<b>531.5</b>	<b>531.5</b>	<b>685</b>

At each level of development, the following types of demands were estimated:

- ❑ Domestic and stock;
- ❑ Off-stream/on-stream dam filling (winter-fill); and
- ❑ Farm dams.

The derivation of each type of demand is described below.

## 6.1 Off-stream/ On-stream Dams

Winter-fill (off-stream and on-stream dams) demands were derived on the assumption that licence holders would only divert during the winter-fill period (May to October inclusive). It was also assumed that licence holders diverted one hundred percent of the historic, current or full level of development volumes, which were based on either the license volume or the *Estimate of Maximum Annual Usage* provided in the licensed water user survey information. The water use pattern over the winter-fill period was based on the pattern of streamflows that occurred in each of the winter-fill months.

## 6.2 Domestic and Stock

Domestic and stock demands were assumed to be equal to the diversion licence volume. The rate of extraction was assumed to be uniform throughout the year.

## 6.3 Farm Dams

For this study the hydrologic impact of farm dams in each subcatchment was modelled individually using the model Tool for Estimating Dam Impacts (TEDI). The model inputs for each subcatchment were the partial natural inflows (historic streamflows adjusted for off-stream/on-stream dams and domestic and stock usage).

Other model inputs had been derived in the farm dam impact study (Egis, 2001) including:

- ❑ The number and volume of farm dams in the Steels, Dixons and Pauls Creeks Water Supply Protection Area;
- ❑ The threshold dam volume between stock and domestic and irrigation dams (threshold volume = 16 ML);
- ❑ Irrigation demand patterns and annual demand volumes;
- ❑ Stock and domestic demands and annual demand volumes;
- ❑ Monthly rainfall and evaporation data;
- ❑ The proportion of irrigation farm dam volume withdrawn each year as annual demand (demand factor = 2);
- ❑ Farm dam size distribution; and
- ❑ Upstream catchment area for farm dams of 5 ML and 100 ML in size.

The Egis (2001) TEDI model was adjusted based on the area of each of the four subcatchments and the volume of farm dams within each subcatchment. As it was necessary to re-derive the rainfall-runoff model to estimate streamflows on a daily basis, new streamflow input files were also derived for the TEDI models. In order to obtain daily natural flows for each subcatchment, the monthly output from TEDI (i.e. the partial natural flow plus the impact of farm dams) was disaggregated to a daily time series based on the pattern daily flows from the partial natural flow series. Hence to obtain the farm dam impact or farm dam demands the daily partial natural flow was subtracted from the natural flow series.

The estimate of farm dam impacts in the Protection Area only looked at unlicensed dams, which is standard for farm dam impact assessments. However, it has been noted that some of the off-stream dams in the catchment have significant catchment

area (*pers. comm.*, Melbourne Water) and these off-stream dams may be collecting rainfall runoff in addition to diversions from waterways. Unfortunately at present there is no information available on the catchment areas of these off-stream dams and, as such, it has not been possible to consider the potential additional water use that these dams may have for water in the Protection Area.

## 6.4 Sustainable Diversion Limit Demands

For Scenario 3, in which the SDL rules were applied, the daily demands in the REALM model were set at the maximum daily diversion rate for each of the SDL catchments. The total diversions from the creeks were then capped at the SDL maximum annual diversion limit specified for each catchment. The diversion period for this scenario was only over the SDL winter period, i.e. July to October inclusive. This is different to the current licensed winter-fill period of May to October inclusive.

## 6.5 Summary

Three daily demand data sets were derived for input into REALM at historic/current and full levels of development. For the relevant subcatchment (denoted in brackets) these series were:

- Off-stream/ on-stream dam extractions (F1, F2, F3 and F4);
- Extractions for domestic and stock (F2); and
- Farm dam impacts (F1, F2, F3 and F4).

A maximum daily demand data set was derived for the Sustainable Diversion Limit scenario, Scenario 3 (F1+F3, F2 and F4). This demand data set replaced the three daily demand data sets listed above. The maximum daily demand for the Steels Upper and Steels Lower subcatchments was specified as one value in the SDL project (SKM, 2002), as these catchments form an intermediate catchment. An intermediate catchment is the portion of the catchment that does not include the upstream SDL subcatchment, in this case Dixons Creek.

## 7. Derivation of Inflows and Losses

Natural streamflows were derived for each subcatchment based on adjustments made to gauged streamflows. There are two streamflow gauges within the Steels, Dixons and Pauls Creeks Water Supply Protection Area (Table 5-4).

Before the gauged streamflows could be used, it was necessary to check the data for any unexplained trend and extend the data to cover the period 1965 to 2001. The streamflows at both gauges were then extended using the HYDROLOG rainfall runoff model (refer Section 7.3), and transposed to other locations in the catchment.

### 7.1 Time-lag, Losses and Flow Attenuation

Streamflows as they progress from the upper part of a catchment to the lower part of a catchment may be influenced by the following factors:

- ❑ **TIME LAG:** A time lag is the delay that occurs when a flow peak travels to a point further downstream. Time lag can vary from less than one day in small catchments to several days or weeks in larger catchments.
- ❑ **LOSSES:** As flow travels from one point in a stream to a downstream point, there is the potential for losses to occur as a result of infiltration or evaporation.
- ❑ **FLOW ATTENUATION:** Flow attenuation is used to describe the way in which a flow peak changes shape as it progresses from upstream in the catchment to downstream. For example the flow peak in the upper part of a catchment may be very narrow with large flows, however as the flow peak travels downstream the magnitude of this peak may decrease and the peak may take longer to pass a specific site. It is also possible that the flow peak does not change shape as it progresses downstream.

To investigate the occurrence of time lag, losses and flow attenuation on streamflow in a catchment, it is generally necessary to have two streamflow monitoring sites on the same stream, i.e. one upstream and one downstream. In the Steels, Dixons and Pauls Creek catchment there is only one monitoring site in the Steels Creek subcatchment and one monitoring site in the Pauls Creek subcatchment. Hence it was necessary to look for two monitoring sites on the same stream in an adjacent catchment with similar characteristics.

Two sites in the Diamond Creek catchment were provided for this investigation (Table 7-1), as Diamond Creek has similar catchment characteristics to Steels Creek (SKM, 2002) and has two streamflow monitoring sites on the same stream. These sites, in relation to the Steels, Dixons and Pauls Creeks Water Supply Protection Area are illustrated in Figure 7-1.

■ **Table 7-1 Diamond Creek monitoring sites**

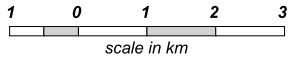
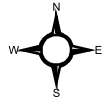
Station ID	Station Name	Period of Available Record	Proportion of missing data
229223	Diamond Creek @ Diamond Creek	June 1976 to September 1993	0%
229619	Diamond Creek @ Hurstbridge	January 1978 to October 2002	4%

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## SINCLAIR KNIGHT MERZ

refer to Sinclair Knight Merz document:  
h:\wcm\wc02354\gis\arcview\wc023541002.apr; extended locality map (Layout)



### LEGEND

- Streamflow Gauges
- Lakes and Reservoirs
- ~ Streams
- Catchment Boundaries
- Major Roads
- Railway Lines

F1 - Steels Ck from Gauge 229246 to confluence with Dixons Ck  
F2 - Dixons Ck above confluence with Steels Ck  
F3 - Steels Ck above confluence with Dixons Ck  
F4 - Pauls Ck above Gauge 229245

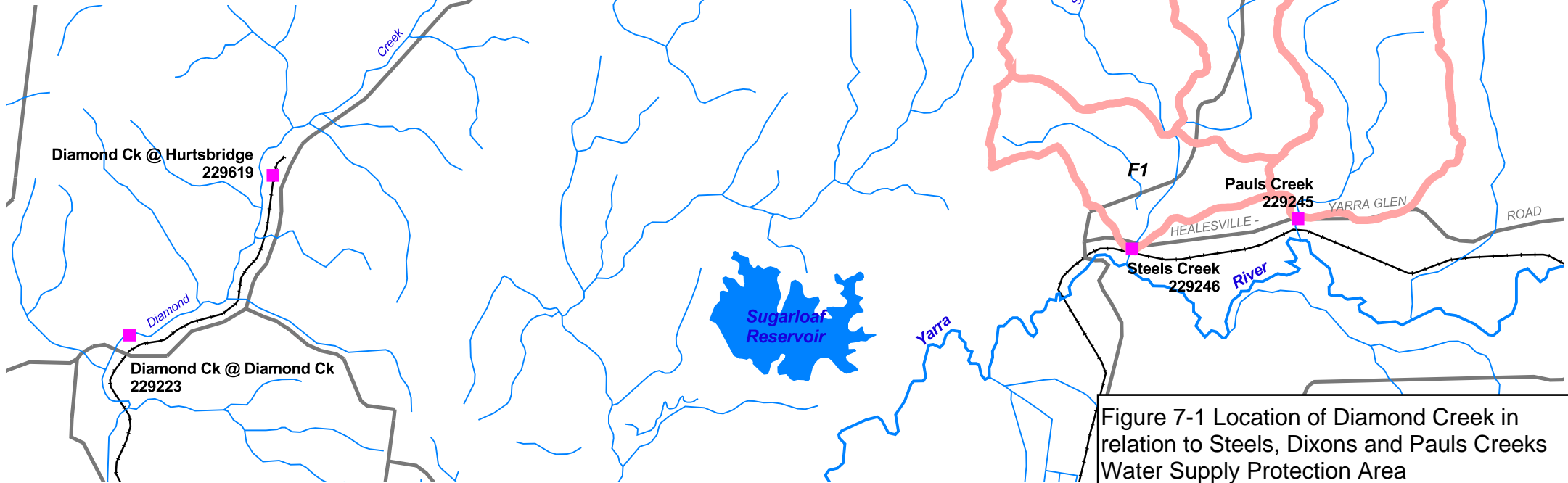
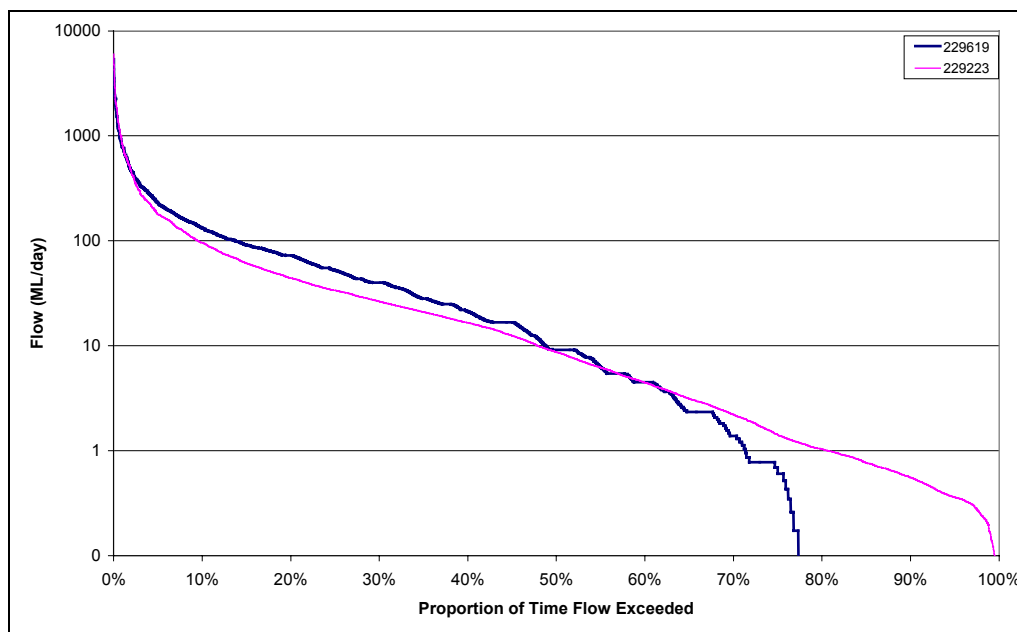


Figure 7-1 Location of Diamond Creek in relation to Steels, Dixons and Pauls Creeks Water Supply Protection Area

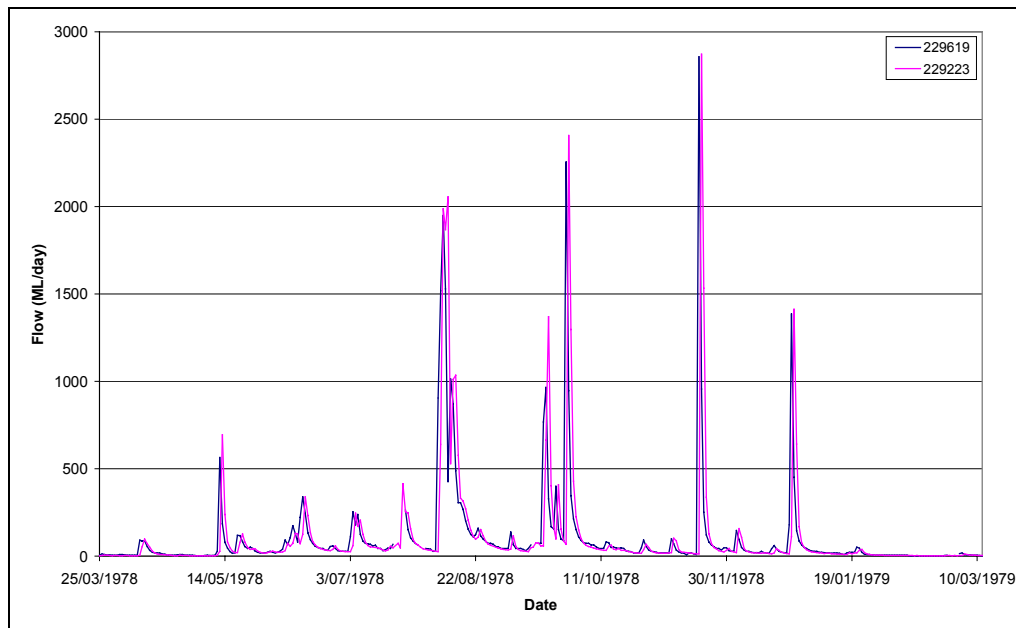
The two Diamond Creek flow monitoring sites have potential problems associated with the low flow data that may affect the estimation of time lag, losses and attenuation. Historically the Hurstbridge gauging station (229619) was used as a flood warning station and until 12 months ago did not read low flows very accurately (*pers. comm.*, Melbourne Water). The period of concurrent record at the two Diamond Creek sites is prior to this more accurate low flow rating being established. The Diamond Creek at Diamond Creek gauging station (229223) has very good quality data, however the flows are influenced by urban runoff, which tends to sustain the low flows at this point (*pers. comm.*, Melbourne Water).

Figure 7-2 illustrates the differences in the flow duration curves for the upstream site at Hurstbridge (229619) and the downstream site at Diamond Creek (229223). The curves show that the low flows at the Diamond Creek gauge are sustained considerably passed the cease to flow point at the Hurstbridge site. The curve for the Hurstbridge site is not as smooth as the Diamond Creek site, especially in the lower flow range, which suggests that the data is of poorer quality. Although there are problems with the flows at these two sites, they are still considered to be adequate to assess time lag, losses and flow attenuation in the Steels, Dixons and Pauls Creeks catchment given the lack of suitable data within this catchment.



■ **Figure 7-2 Flow duration curves for Diamond Creek flows at 229619 and 229223 over the period 1978 to 1993.**

The lag time for flows in Steels Creek between the confluence of Steels and Dixons Creek and the end point of the REALM model (i.e. the gauge on Steels Creek, 229246) was investigated by looking at the timing of hydrograph peaks at the two Diamond Creek streamflow sites. Figure 7-3 illustrates the flows at the two Diamond Creek sites over a short period of record.



■ **Figure 7-3 Hydrograph peaks**

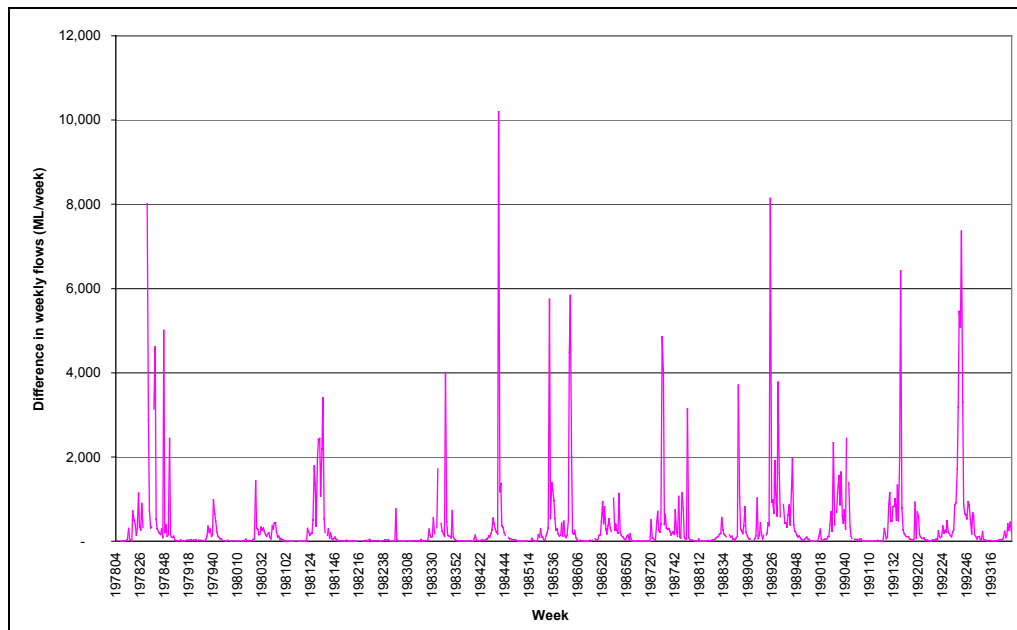
Generally the time lag in flows between the upstream Hurstbridge site and the downstream Diamond Creek site is around one day, however there are a small number of lag periods for some of the lower flow peaks or low flow periods that are around 2 days. The stream distance between the two Diamond Creek gauges is roughly 6 km. The distance between the confluence of Dixons and Steels Creeks, and the gauge 229246 is roughly 2.7 km. Based on these distances it is likely that the lag in the Steels Creek catchment is less than one day for streamflows travelling between the confluence of Steels and Dixons Creek and the gauge 229246. However, this analysis is based on the assumed similarity between Diamond Creek and Steels Creek and should be reviewed if additional information becomes available.

A comparison of the streamflow time series (Figure 7-3) was also used to assess whether significant flow attenuation occurred between the Hurstbridge and Diamond Creek flow sites. The hydrographs were found to have very similar rising and falling limbs and very little change in the magnitude of peak flows, i.e. similar shapes. This indicates that flow attenuation is insignificant in the Diamond Creek catchment. Based on the assumption that the Diamond Creek catchment is similar to the Steels Creek catchment, flow attenuation was not included in the Steels, Dixons and Pauls Creeks REALM system.

Losses in streamflow were investigated by subtracting the weekly flows at Hurstbridge from weekly flows at Diamond Creek. A negative value indicates either a loss in streamflows or a gauging error. Figure 7-4 illustrates the weekly difference in flows between the Diamond Creek sites and shows that all weekly differences are positive, i.e. no negative inflows (losses) occurred.

In general losses are assessed on a weekly basis rather than a daily basis as small errors in flow measurements and the potential for different lag times over different flow ranges can indicate losses to have occurred that may not have. Given the concerns over the quality of the data from the two Diamond Creek gauges, the weekly

basis for this assessment is considered appropriate. Based on zero losses being observed between the Diamond Creek streamflow gauging sites and the assumption that Diamond Creek is similar to Steels Creek, no losses have been included in the Steels, Dixons and Pauls Creek REALM. This assessment assumes that the period of concurrent record at the Diamond Creek sites (i.e. 1978 to 1993) is comparable with the period of available record at the Steels and Pauls Creeks sites. This should be reviewed if data becomes available within the study catchments.



■ Figure 7-4 Investigation of losses occurring in Diamond Creek

## 7.2 Trend Analysis

The removal of trend from streamflow data is important for farm dam impact modelling, as it is necessary to have a stationary flow time series to assess the impact of a set level of farm dam development. Downward trends in streamflows may be a result of an increase in the number of farm dams in a catchment, which would intercept more surface runoff.

Unfortunately only four years of streamflow data exists at the Steels and Pauls Creeks gauges. This does not provide an adequate length of record to undertake trend analyses and provide an acceptable level of statistical significance in the assessment.

## 7.3 Infilling and Extension

As part of the impact of farm dams study Egis (2001) infilled and extended the Steels and Pauls Creeks streamflow data using the rainfall runoff model AWBM. Unfortunately this data did not cover the entire period of record required for this study and the goodness of fit of the estimated data was not satisfactory for the use in a daily model. This is of particular importance if the data is required in low flow analyses. Hence, the parameters and calibration used by Egis (2001) could not be used in this investigation.

The rainfall runoff modelling was re-derived using the rainfall runoff model HYDROLOG, as this model has additional features that make it more flexible in the estimation of streamflows. An attempt was made to improve the AWBM model fit on a daily time step, however this was unsuccessful.

The values of variables used for the HYDROLOG calibration and a brief description of their function in the model are provided in Table 7-2. The climatic input to the model was rainfall recorded at Mt St Leonard (gauge 086142) and the mean monthly evaporation prepared by Egis (2001) (a combination of Mt St Leonard 086142 and Tarrawarra 086363). Rainfall inputs to both the Steels Creek and Pauls Creek HYDROLOG models required factoring downwards, with a rainfall factor of 0.55 being used in both cases.

■ **Table 7-2 Variables used in the HYDROLOG rainfall runoff model**

Parameter	Description	Steels Creek (229246)	Pauls Creek (229245)
ADS	Fraction depressional area	0	0
COEFF	Maximum infiltration parameter	170	120
CRAK	Groundwater diversion parameter	0.17	0.5
DSC	Depression store capacity	0	0
EMAX	Maximum plant evapotranspiration rate	7	8.9
HK1	Linear g/water parameter	0.04	0.2
HK2	Exponential groundwater parameter	0	0
HK3	Exponent in groundwater function	0	0
INSC	Interception store capacity	2	1.5
SMSC	Soil store capacity	100	120
SQ	Infiltration function parameter	0.3	1
SUB	Interflow diversion parameter	0.178	0.15
VCOND	Deep leakage coefficient	0.1	0.3
INIHS	Initial soil store level	80	0
INIHG	Initial groundwater store level	0	0
SDK	Daily streamflow recession	0.6	1

The HYDROLOG estimated streamflows are compared with the observed streamflow data in Figure 7-5 to Figure 7-9. Figure 7-5 displays flow duration curves of the observed and estimated daily data, while Figure 7-6 to Figure 7-9 compares the data in time series plots. Figure 7-10 compares the cumulative flows of observed and estimated data over time. Note that all calibration plots have estimated data removed from periods corresponding to missing observed data.

The goodness of fit of the HYDROLOG estimated data to the gauged data at both streamflow gauges is provided in Table 7-3.

■ **Table 7-3 Goodness of fit of observed streamflows versus estimated streamflows from HYDROLOG**

Goodness of Fit Measures	Steels Creek (229246)	Pauls Creek (229245)
Coefficient of Determination ( $R^2$ )	0.32	0.24
Coefficient of Efficiency (CE)	0.24	0.20
% Difference in Mean Daily Flows	3.4%	3.3%

The fit of the HYDROLOG estimated data to the observed streamflow data is poor, however on a daily basis the estimated flows represent the observed data better than the Egis (2001) AWBM estimates, which were generated to be used on a monthly

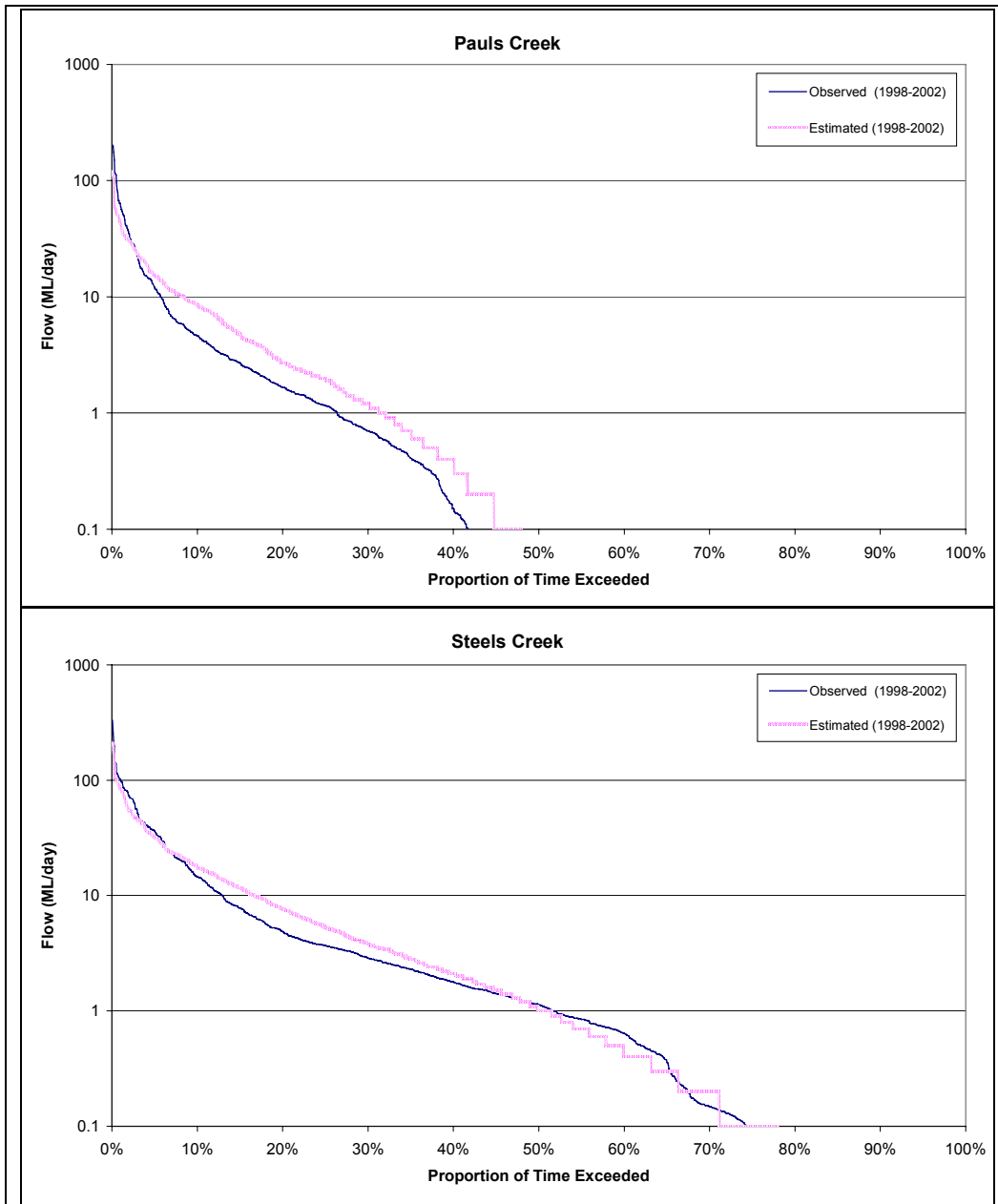
basis. The Egis (2001) AWBM estimated streamflows are compared with the observed streamflow data and the streamflows estimated for this study using HYDROLOG in Figure 7-11 to Figure 7-12.

The poor fit of the HYDROLOG estimated data to the observed streamflow data is most likely a result of the rainfall being unrepresentative or characteristics of the catchment that cannot be adequately represented in a rainfall runoff model. Potential explanations for the poor fit of the estimated and observed data includes:

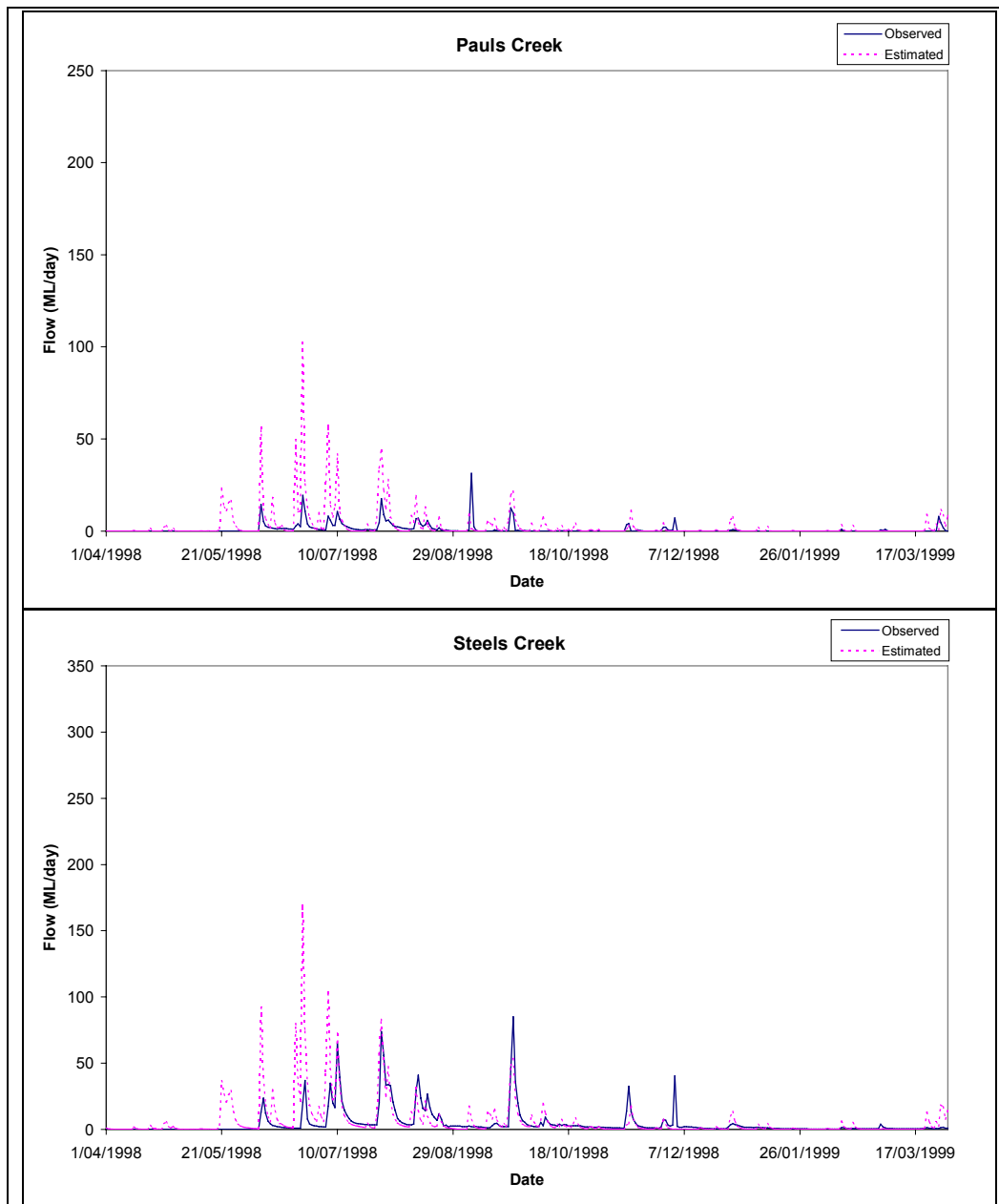
- Both streamflow sites are located close to the Yarra River and there is the potential for backup effects from the Yarra to influence streamflows. This has only occurred on a limited number of occasions over the period of available record. However there is the potential for localised groundwater fluctuations in response to Yarra River levels that may influence the base flow recorded at the Steels and Pauls Creeks monitoring sites.
- There are a number of dams on tributaries, particularly in the Pauls Creek catchment, which will intercept flows and alter the rainfall runoff relationship, as some of the streamflow will be stored rather than being passed downstream. Evaporation from these dams will also change the rainfall runoff relationship. In order to eliminate these effects, the streamflow gauges would need to be placed upstream of the majority of these dams.
- The rainfall site used in the rainfall runoff modelling can influence the fit of the relationship, as although the sites have similar patterns they are not always identical. Several different rainfall time series were input into the rainfall runoff model, including the Egis (2001) generated rainfall time series and the Tarrawarra Monastery (086364) rainfall gauge, in order to obtain an improved fit between the observed and the estimated streamflow data. However none of the rainfall data provided an improved fit over the Mt St Leonard (086142) rainfall gauge. To eliminate any uncertainty in the rainfall data used in the rainfall runoff modelling would require new rainfall gauges to be put in place inside the catchment.

The poor fit of the rainfall runoff model introduces a degree of uncertainty in the extended streamflow data records that are used as input into the REALM model. This has implications for the reliability of supply estimations and the impact of minimum flow thresholds on the streamflows in the catchment. The uncertainty in the data will also be an important consideration in the development of environmental flow recommendations, which are currently being undertaken using the flow data determined for this study.

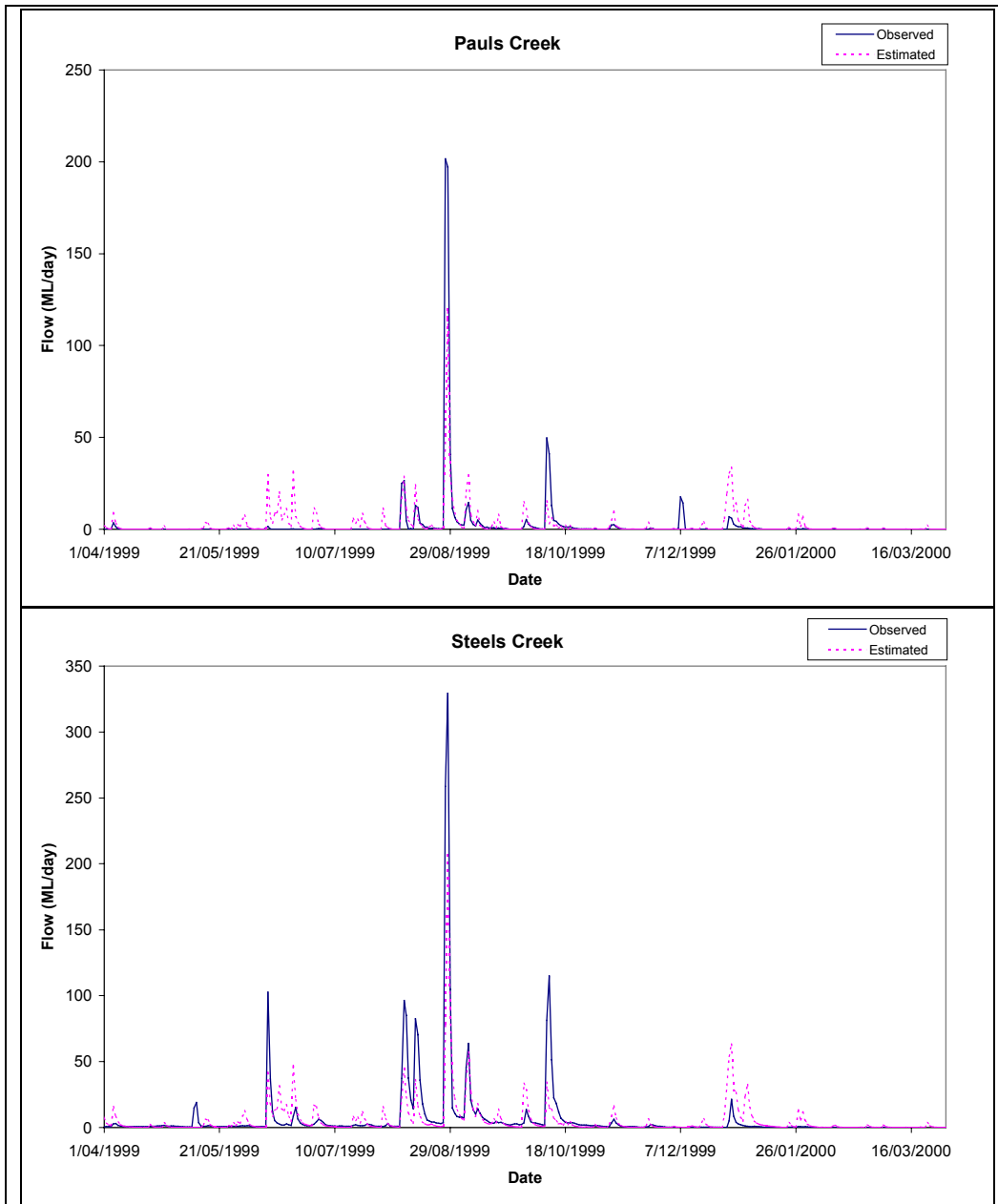
It is strongly recommended that the rainfall runoff modelling be revisited after a number of years of further data collection.



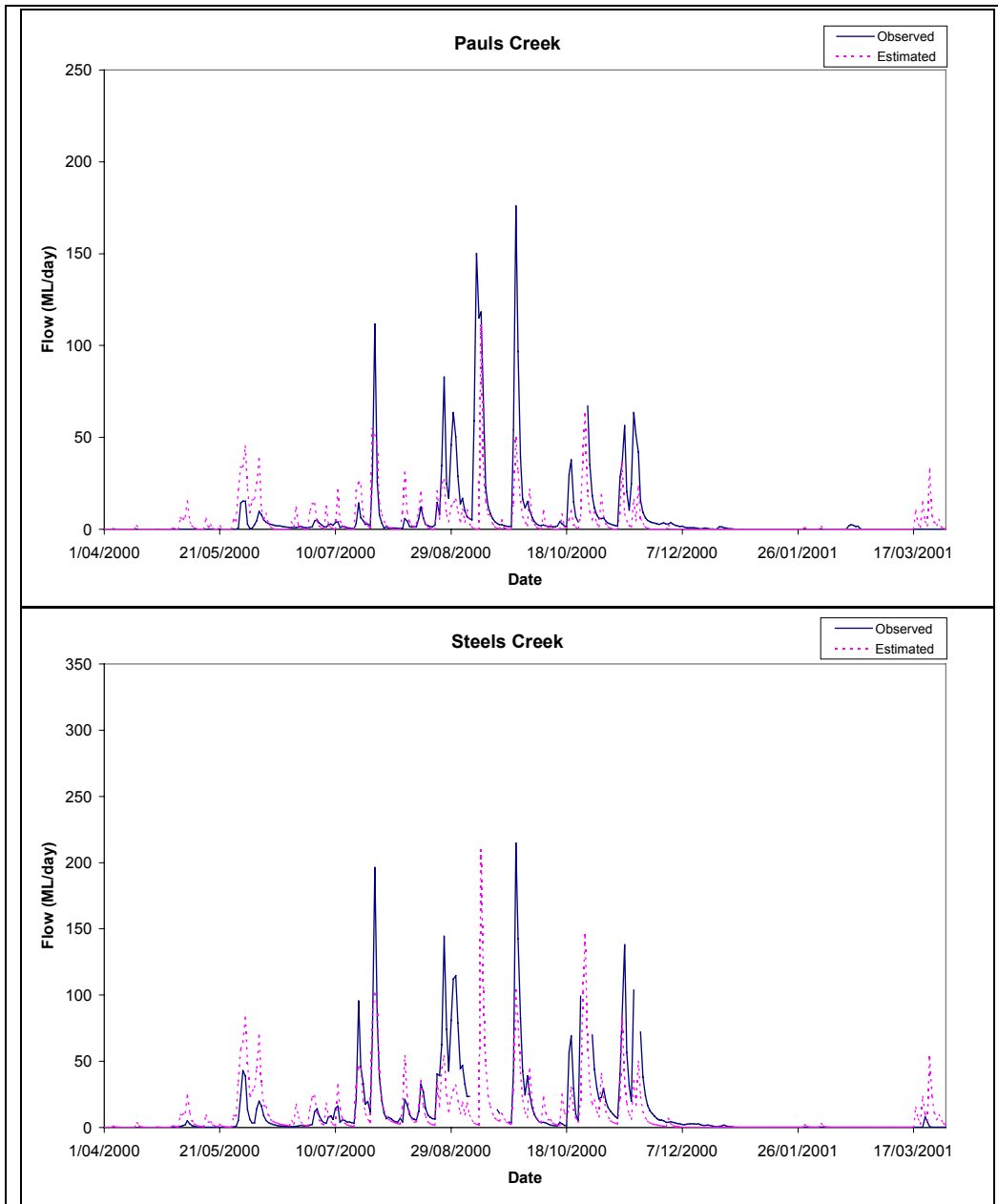
■ Figure 7-5: Flow duration curves of observed and estimated daily flows



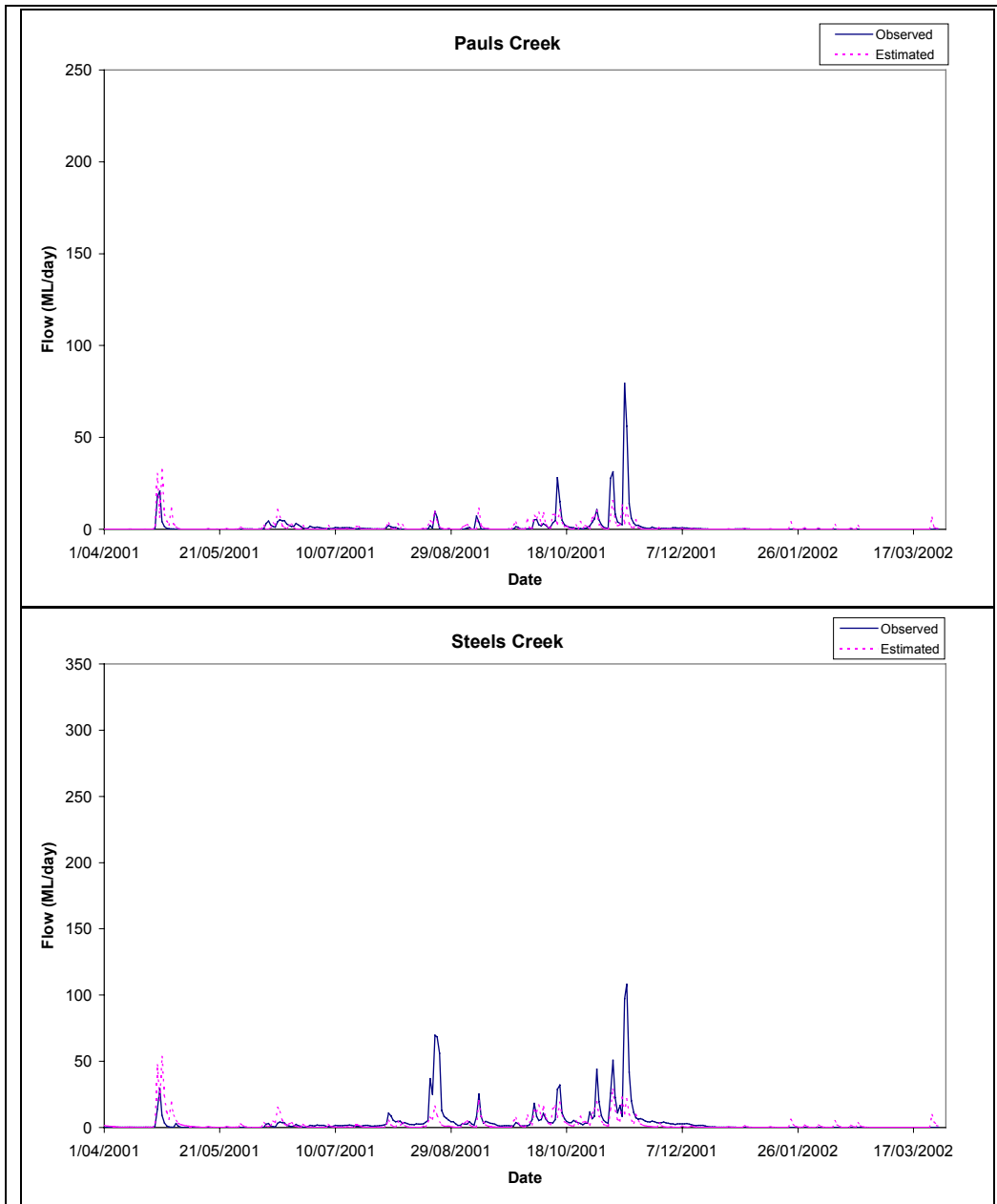
■ Figure 7-6 Time Series of observed and estimated daily flows (period 1/04/1998 to 31/03/1999)



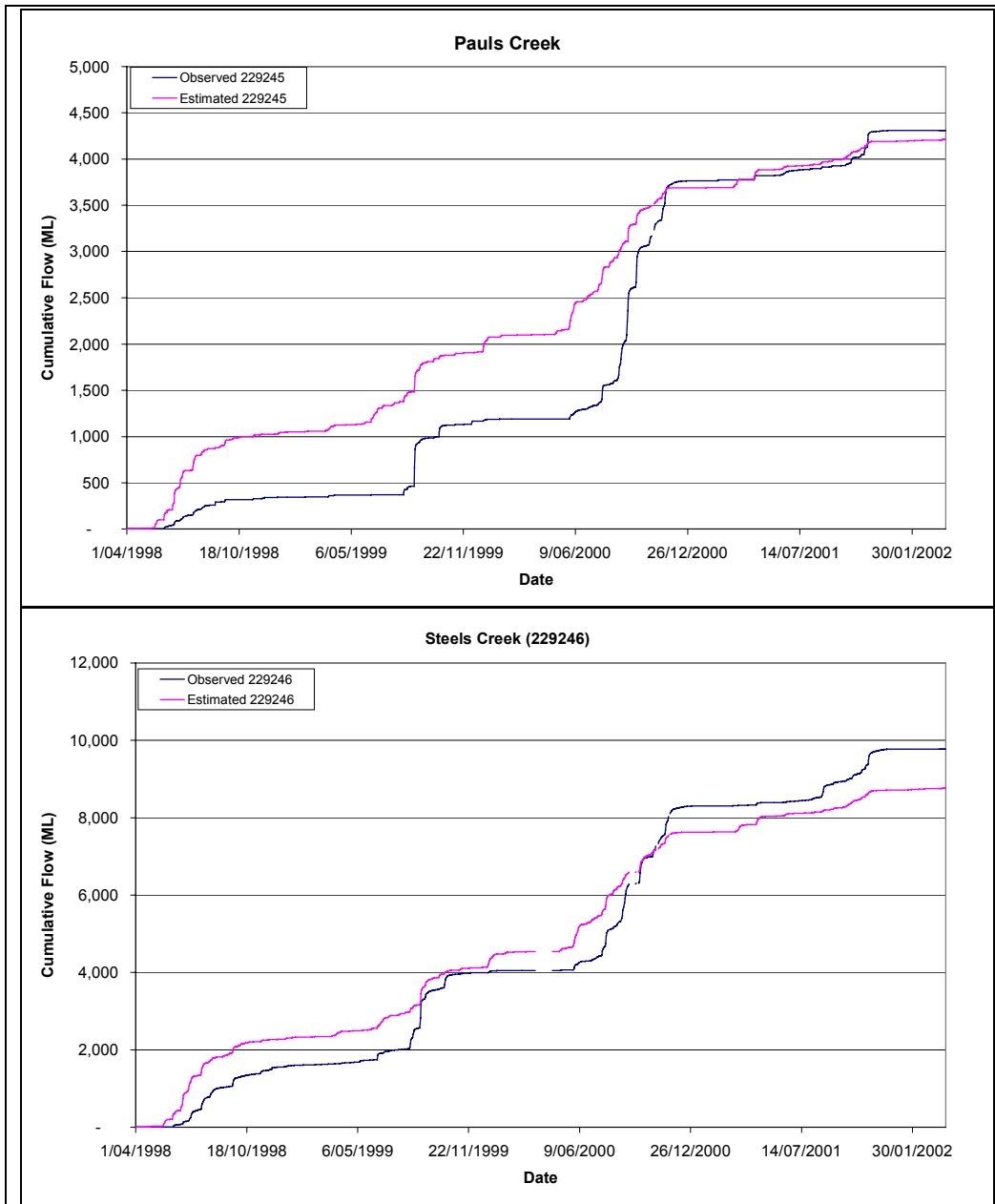
■ Figure 7-7 Time Series of observed and estimated daily flows (period 1/04/1999 to 31/03/2000)



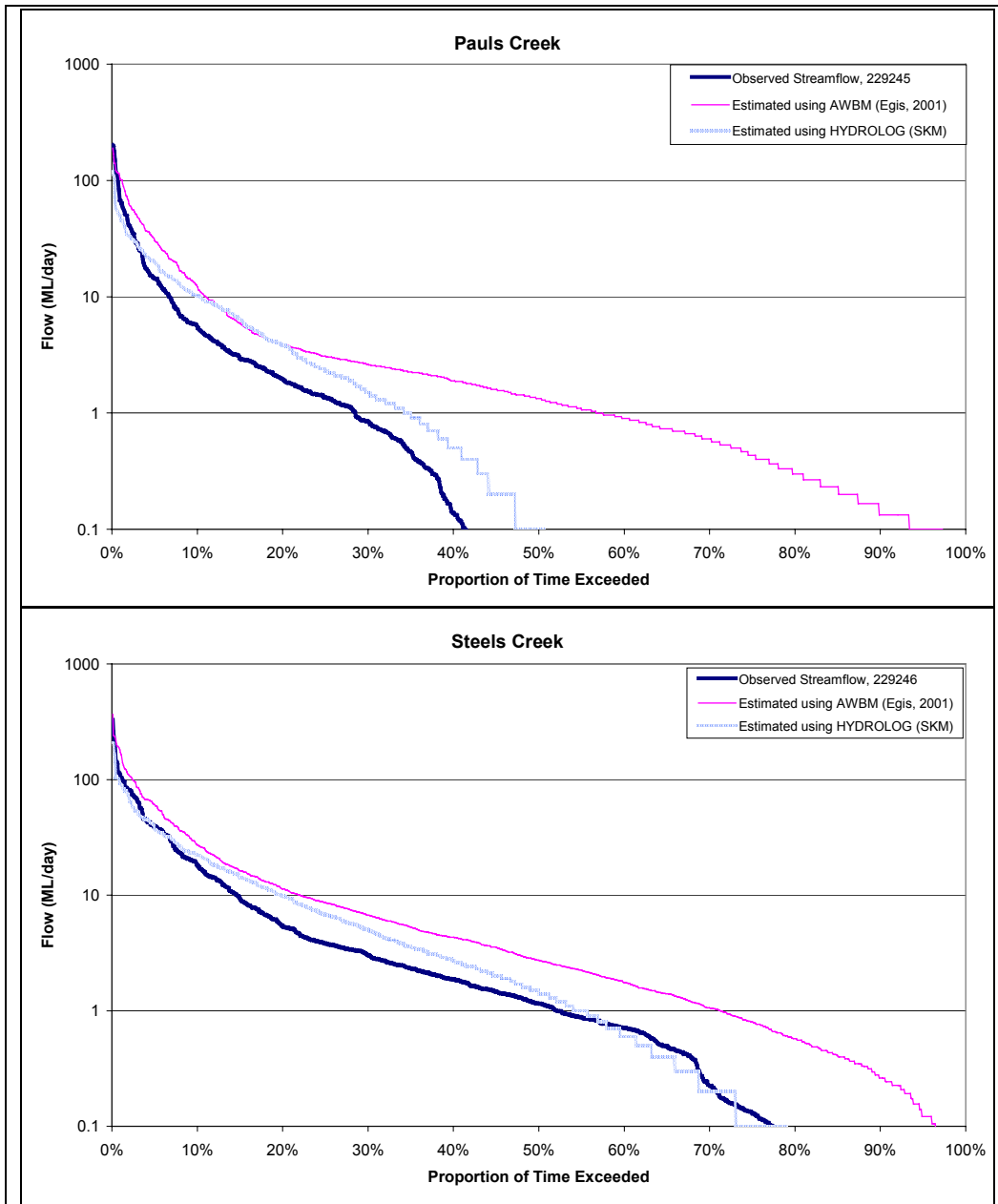
■ Figure 7-8 Time Series of observed and estimated daily flows (period 1/04/2000 to 31/03/2001)



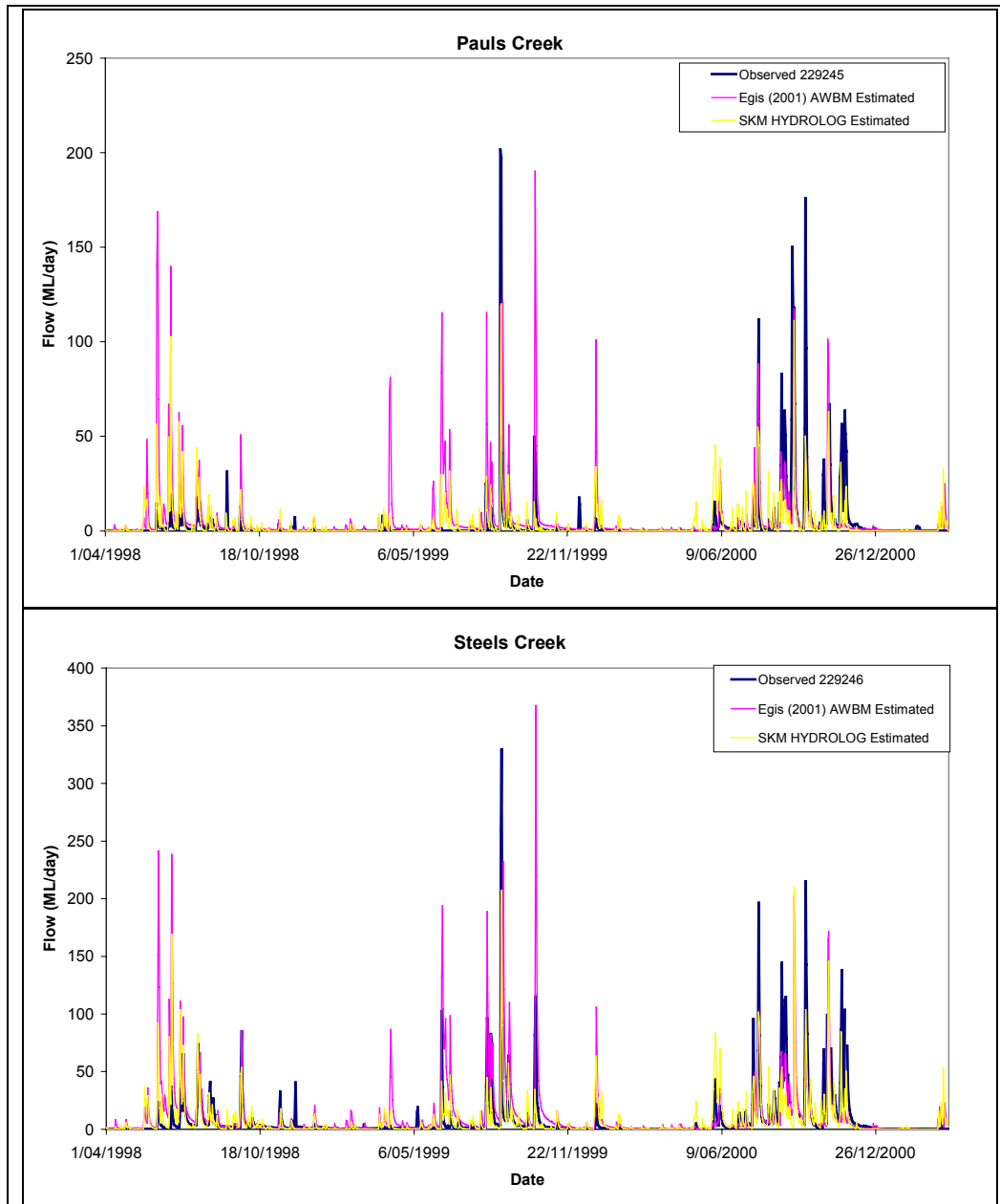
■ Figure 7-9 Time Series of observed and estimated daily flows (period 1/04/2001 to 31/03/2002)



■ Figure 7-10 Mass Curves of observed and estimated flow



■ Figure 7-11 Flow duration curves of observed and estimated streamflows by SKM and Egis (2001)



■ **Figure 7-12 Time series of observed and estimated streamflows by SKM and Egis (2001)**

## 7.4 Transposition of Streamflows

In the Steels Creek catchment, estimates of streamflows were required at the gauge site (229246) and also for the Dixons Creek subcatchment and the Steels Creek Upper subcatchment (i.e. above the confluence with Dixons Creek). Streamflows at the gauge 229246 were transposed to the other points in the Steels Creel catchment using the following transposition equation (Equation 2) (Alexander, 1972):

$$Flow_x = Flow_y \times \left( \frac{Area_x}{Area_y} \right)^{0.7}$$

**Equation 2**

Where:

Flow<sub>x</sub> = the flow in the subcatchment that you would like to obtain flows for;

Flow<sub>y</sub> = the flow at the gauged catchment;

Area<sub>x</sub> = the area of the subcatchment that you would like to obtain flows for; and

Area<sub>y</sub> = the areas of the gauged catchment.

This method was used rather than a direct ratio of areas as a direct ratio of areas will generally underestimate streamflows at a certain point in the catchment.

## 7.5 Inflow methodologies

### 7.5.1 Derivation of F1 Inflow

Inflow to the Steels Creek Lower Subcatchment, F1, does not include flows generated above the confluence of the Steels and Dixons Creeks. Only flows that are generated below the confluence are included in this flow, which is known as an interflow. The interflow F1 was determined by transposing the gauged flows at the Steels Creek gauge (229246) to the confluence of the Steels and Dixons Creek using the transposition relationship described in Section 7.4. This transposed flow was then subtracted from the gauged flow at 229246 to obtain the interflow. Demands in the subcatchment were then added to the interflow to obtain the natural interflow in the Steels Creek Lower Subcatchment. The demands in the F1 subcatchment include winter-fill private diversions and farm dam impacts.

$$F1 = 229246_{GAUGED} - 229246_{GAUGED} \times \left( \frac{(A2 + A3)}{(A1 + A2 + A3)} \right)^{0.7} + LD1 + FD1$$

**Equation 3**

Where:

229246<sub>GAUGED</sub> = gauge flows at Steels Creek (229246);

A1 = area of the Steels Creek Lower Subcatchment;

A2 = area of the Dixons Creek Subcatchment;

A3 = area of the Steels Creek Upper Subcatchment

LD1 = winter-fill private diversion demands; and

FD1 = farm dam demands.

The subcatchments and subcatchments areas are shown in Figure 7-13.

### 7.5.2 Derivation of F2 Inflow

Inflow to the Dixons Creek Subcatchment, F2, was determined by transposing the gauged flows at the Steels Creek gauge (229246) to the confluence of Steels and Dixons Creek and then factoring this flow on the ratio of areas between Dixons Creek and Steels Creek Upper Subcatchment. Demands in the subcatchment were then added to the transposed flow to obtain the natural flows in the Dixons Creek Subcatchment. The demands in the F2 subcatchment include winter-fill private diversions, stock and domestic and farm dam impacts.

$$F1 = \left[ 229246_{GAUGED} \times \left( \frac{(A2 + A3)}{(A1 + A2 + A3)} \right)^{0.7} \right] \times \left[ \frac{A2}{(A2 + A3)} \right] + SD2 + LD2 + FD2$$

**Equation 4**

Where:

229246<sub>GAUGED</sub> = gauge flows at Steels Creek (229246);  
 A1 = area of the Steels Creek Lower Subcatchment;  
 A2 = area of the Dixons Creek Subcatchment;  
 A3 = area of the Steels Creek Upper Subcatchment  
 SD2 = stock and domestic licensed water user demands;  
 LD2 = winter-fill licensed water user demands; and  
 FD2 = farm dam demands.

### 7.5.3 Derivation of F3 Inflow

Inflow to the Steels Creek Upper Subcatchment, F3, was determined by transposing the gauged flows at the Steels Creek gauge (229246) to the confluence of Steels and Dixons Creek and then factoring this flow on the ratio of areas between Steels Creek Upper Subcatchment and the Dixons Creek Subcatchment. Demands in the subcatchment were then added to the transposed flow to obtain the natural flows in the Dixons Creek Subcatchment. The demands in the F3 subcatchment include winter-fill private diversions and farm dam impacts.

$$F1 = \left[ 229246_{GAUGED} \times \left( \frac{(A2 + A3)}{(A1 + A2 + A3)} \right)^{0.7} \right] \times \left[ \frac{A3}{(A2 + A3)} \right] + LD3 + FD3$$

**Equation 5**

Where:

229246<sub>GAUGED</sub> = gauge flows at Steels Creek (229246);  
 A1 = area of the Steels Creek Lower Subcatchment;  
 A2 = area of the Dixons Creek Subcatchment;  
 A3 = area of the Steels Creek Upper Subcatchment  
 LD3 = winter-fill licensed water user demands; and  
 FD3 = farm dam demands.

### 7.5.4 Derivation of F4 Inflow

Inflow to the Pauls Creek Subcatchment, F4, was determined by adding the demands in the catchment to the gauged flow data. The demands in the Pauls Creek Subcatchment include winter-fill private diversions and farm dam impacts.

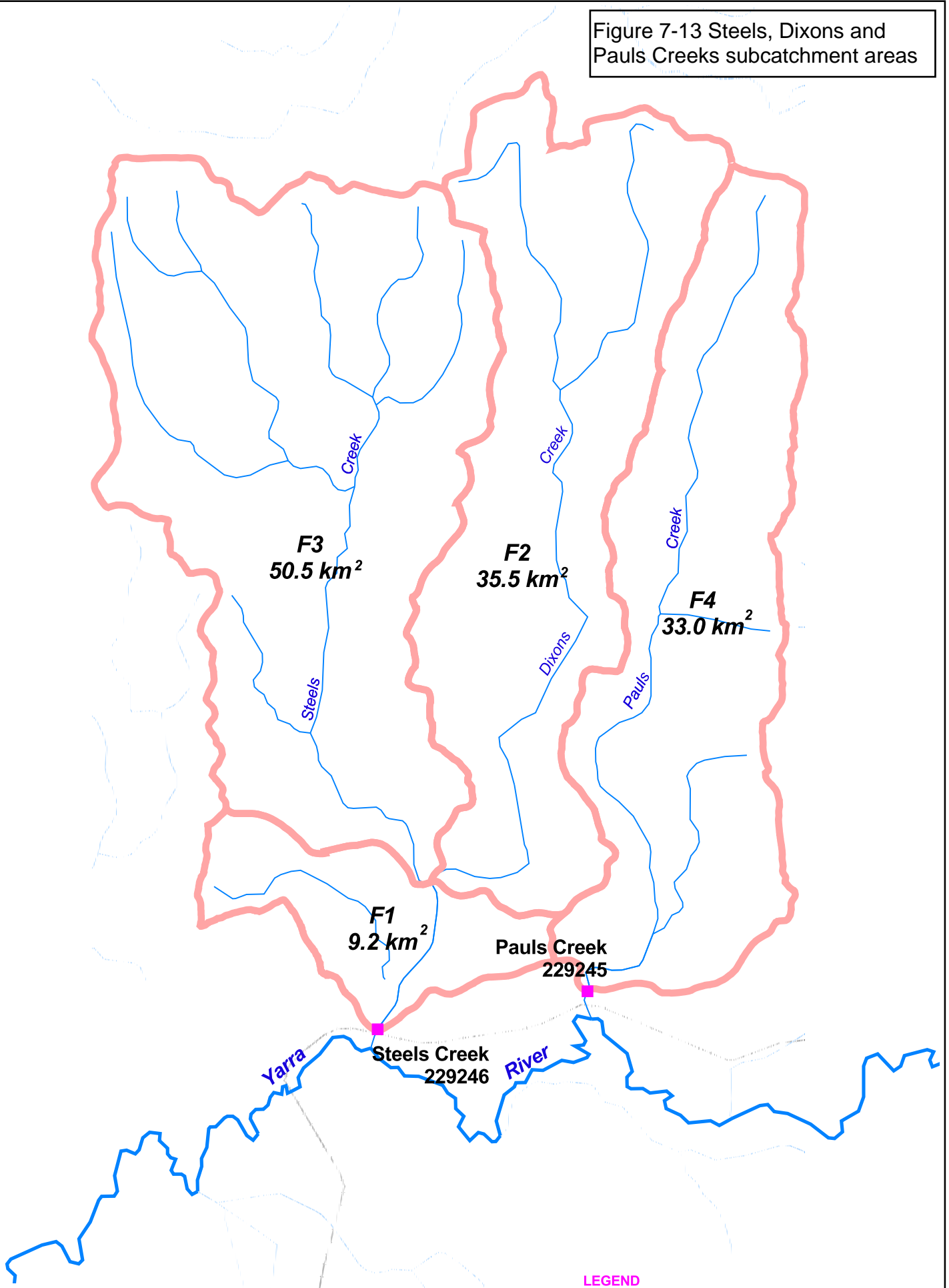
$$F1 = 229245_{GAUGED} + LD4 + FD4$$

**Equation 6**

Where:

229245<sub>GAUGED</sub> = gauge flows at Pauls Creek (229246);  
 LD4 = winter-fill licensed water user demands; and  
 FD4 = farm dam demands.

Figure 7-13 Steels, Dixons and Pauls Creeks subcatchment areas

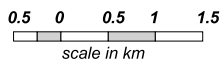
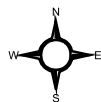


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refer to Sinclair Knight Merz document:  
h:\wcm\swc02354\gis\arcview\wc02354\002.apr: subcatchment areas (Layout)



**LEGEND**

- Streamflow Gauges
- Streams
- Catchment Boundaries

F1 - Steels Ck from Gauge 229246 to confluence with Dixons Ck  
 F2 - Dixons Ck above confluence with Steels Ck  
 F3 - Steels Ck above confluence with Dixons Ck  
 F4 - Pauls Ck above Gauge 229245

## 8. References

Alexander, G.N. (1972) *Effect of catchment area on flood magnitude*. Journal of Hydrology, 16, pp225-240.

Egis (2001). *Steel's, Dixon's, and Paul's Creeks Farm Dams Impact Assessment*. Report prepared for Melbourne Water, June 29 2001.

Good, M. and McMurray, D (1997) *The Management of Farm Dams and their Environmental Impact in the Mount Lofty Ranges* ANCOLD Seminar "Dams and the Environment" Water Resources Group, South Australian Department of Environment and Natural Resources.

Lyne, V. and Hollick, M. (1979) *Stochastic time-variable rainfall-runoff modelling*. Hydrology and Water Resources Symposium, Institution of engineers Australian National Conference, Publication number 79/10, pp. 89-93.

Melbourne Water (2001). *Drought Response Plan (Yarra Catchment) Private Diverters*. Final Version November 2001.

Nathan, R.J. and McMahon, T.A. (1990) *Evaluation of automated techniques for baseflow and recession analyses*, Water Resources Research, 26(7), pp. 1565-73.

Porter, J.W. and Ladson, A.R. (1993) *An application of fixed-area rainfall reduction factors*. Hydrology and Water Resources Symposium 993, Newcastle, Australia. IEAust. Nat. Conf. Publication No. 93/14: 273-279

Sinclair Knight Merz (2002) *Sustainable Diversions Limit Project - Recommendations for Sustainable Diversions Limits over Winterfill Periods in Unregulated Victorian Catchments (January 2002)*. Report prepared for the Department of Natural Resources and Environment (SKM project number WC01569).

### Personal Communication

Steve Nicol, Melbourne Water. Personal communication regarding potentially significant catchment areas of off-stream dams in the Steels, Dixons and Pauls Creeks catchment. November 2002.

Simone Gunn, Melbourne Water. Personal communication regarding restriction periods in the Yarra Basin. November 2002.

Simone Gunn, Melbourne Water. Personal communication regarding anecdotal evidence of shortfalls in the Steels, Dixons and Pauls Creek catchment. January 2003.

Simone Gunn, Melbourne Water. Personal communication regarding data quality of Diamond Creek flow gauging stations. January 2003.