TECHNICAL NOTE 2006/04

Department of Water, Land and Biodiversity Conservation

PRELIMINARY HYDROLOGICAL INVESTIGATIONS FOR THE DIVERSION OF FLOW FROM THE LOWER TO THE UPPER SOUTH EAST

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PURPOSE

A preliminary hydrological investigation of the potential volume and frequency of flows available for diversion from the Lower South East into the Upper South East has been undertaken for the Upper South East Dryland Salinity and Flood Management Program. The purpose of this technical note is to document the methodology and results of this assessment, together with additional information requirements for a more refined assessment.

INTRODUCTION

Streamflow in the South East of South Australia has historically moved from south to north. However, the construction of a drainage network in the Lower South East has broken the connectivity of this flow and hence altered the regional flow paths. As a result, the ecological systems in the Upper South East have suffered from reduced water availability.

Figure 1 shows the drains, watercourses, wetlands and regulators that form the system examined in this preliminary hydrological investigation, the objectives of which were to:

1. Calculate the potential flows for diversion north from Bool Lagoon to Drain E and the Marcollat Watercourse.
2. Calculate the potential flows for diversion north from Drain M at Callendale along the Bakers Range Watercourse.
3. Evaluate the possible hydrological benefits that the diversion of these flows may have on the wetlands along these northern systems.
4. Calculate the possible reductions in flow to Lake George resulting from possible diversions.

Limited flow data and information is available across the region. Data availability at those stations used in this analysis are presented in Table 1 and their locations shown in Figure 1.

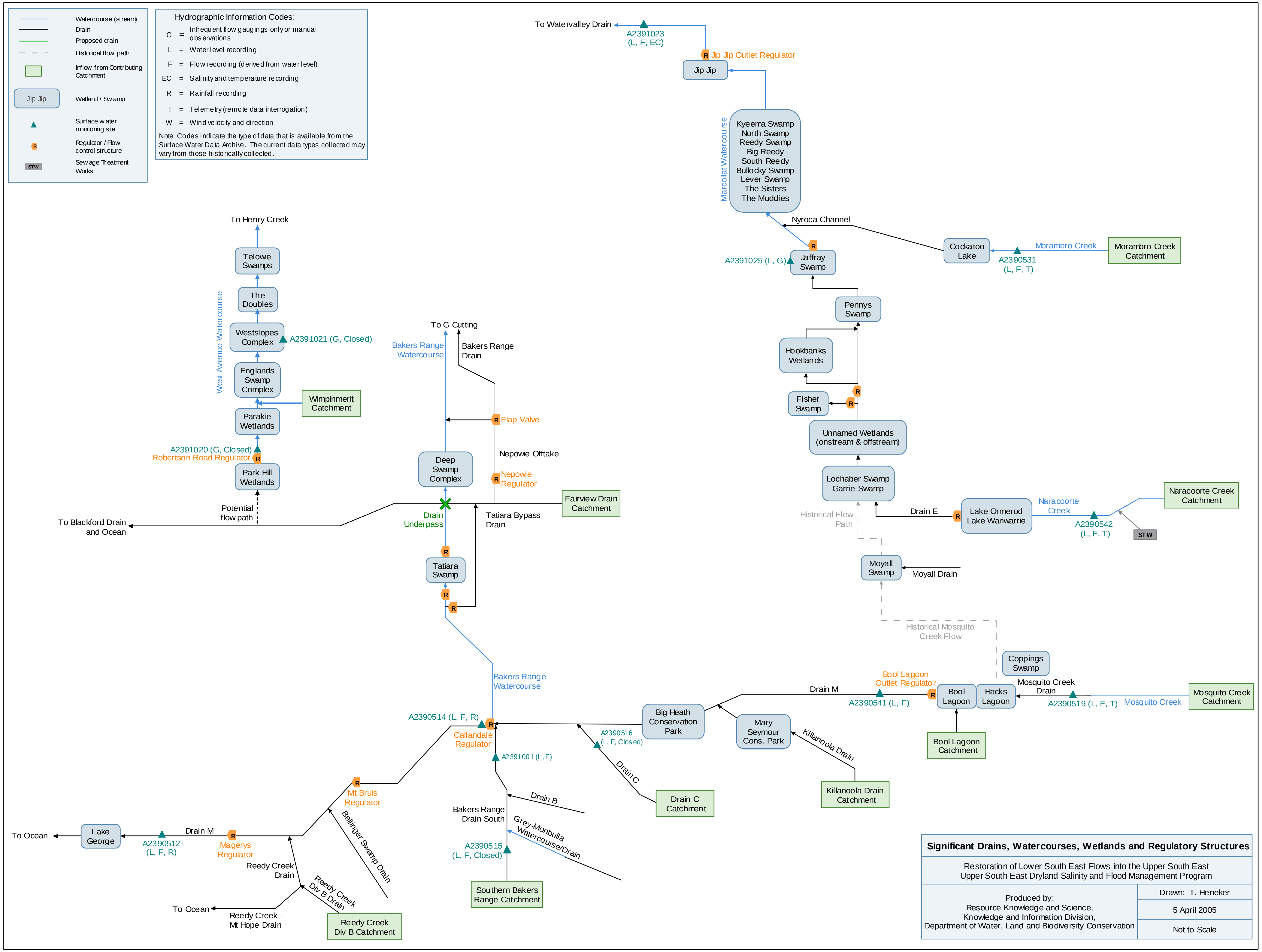


Figure 1 Significant Drains, Watercourses, Wetlands and Regulatory Structures.

Table 1 Available Water Level Data.

Site ID	Site Name	1970										1980										1990										2000				
A2390519	Mosquito Creek @ Struan		o	#	#	#	#	#	X	X	X	#	#	X	X	X	X	X	X	X	X	X	X	X	#	#	#	X	X	X	X	X	X	X	X	o
A2390541	Drain M @ D/S Bool Lagoon Outlet																o	X	X	#	o	X	o	X	X	X	X	X	X	X	X	X	X	o		
A2390514	Drain M @ Callendale		o	#	o	X	#	#	X	#	#	#	X	X	X	X	#	#	X	X	X	X	X	X	#	#	X	X	#	X	X	X	X	X	X	o
A2390512	Drain M @ Woakwine Amtd 5.1km		o	#	#	#	X	X	#	X	X	#	X	X	#	#	X	X	#	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	o
A2390516	Drain C @ Balma Carra		o	#	X	X	X	X	o	o																										
A2391001	Bakers Range South Drain @ Phillips Road																							u	u	u	u	u	u	u	u	u	u	o	o	
A2390515	Bakers Range South Drain @ Robe-Penola Road		o	o	#	X	#	X	#	#	X	X	X	X	X	#	X	X	o	X	X	X	X	X	o											
A2390556	Bakers Range Watercourse @ G Cutting																							o	o	X	#	X	X	o	o	#	#	#	o	
A2391023	Marcollat Watercourse @ Ballater Road Jip Jip																						o	X	X	#	X	X	X	X	#	#	#	#	o	
A2390542	Naracoorte Creek @ Naracoorte																o	#	#	X	#	#	X	X	X	#	#	X	X	X	X	X	X	X	X	o
A2390531	Morambro Ck @ Bordertown-Naracoorte Road Bridge							o	X	X	#	X	X	X	X	X	X	X	X	#	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	o

Notes:

1. Flow data can only be produced if a stage-discharge relationship is available.
2. Data Quality:
   - X Complete Year, Good Data.
   - # Complete Year, Some Estimated Data.
   - o Incomplete Year, Some Gaps or Missing Data.
   - u Unprocessed data.

DIVERSION FROM BOOL LAGOON

Mosquito Creek begins in Victoria, flowing into South Australia before discharging into Hack's Lagoon and subsequently Bool Lagoon. Water is currently released from Bool Lagoon through an outlet regulator into Drain M. Upstream of Hack's Lagoon, Mosquito Creek has a catchment area of approximately 1215 km^2 (Nitschke, 1984) and water historically flowed north from Hack's Lagoon, through Moyall Swamp and into Garrie Swamp. To supplement flows into Drain E and the Marcollat Watercourse, it would be necessary to reinstate this historical flow path. Environmental objectives are the purpose of such a reinstatement, therefore, construction works need to ensure that there is no compromise to local drainage.

Bool Lagoon has both drainage and conservation functions that are defined in the guidelines for the operation of the Bool Lagoon and Drain M regulators (Nitschke, 1984). It acts as a balancing storage for the system when inflow rates from Mosquito Creek are substantially greater than the capacity of Drain M. To meet drainage requirements, the operating guidelines recommend that the water level in the lagoon should be kept as low as practicable so that the maximum storage volume is available if required.

Under the National Parks and Wildlife Service, Bool Lagoon has been declared as a Game Reserve and Hack's Lagoon as a Conservation Reserve. In this function, Nitschke (1984) recommended that the water level within Bool Lagoon does not rise above a depth of 0.8 m. Depths in excess of this may result in bird breeding areas (particularly Ibis) being drowned. In addition, it is desirable that the lagoon not dry out in summer, although previous studies described in Nitschke (1984) suggested that there is insufficient inflow to prevent the lagoon drying out once every two years.

The current drainage and conservation requirements for Bool Lagoon need to be maintained. It should be noted that if there is an alternative flow path north to Drain E, it may be possible to retain additional water within Bool Lagoon for longer, while still maintaining the ability to store large events from Mosquito Creek when they occur. For this preliminary investigation, it was therefore concluded that any water historically released from Bool Lagoon would give a good indication of available water to push north into Drain E.

EXCESS FLOW AT BOOL LAGOON

The availability of excess flow at Bool Lagoon for redirection northwards was examined first. Annual data has been used for this purpose. No details of the capacity of the channel between Hack's Lagoon and Garrie Swamp are available. Therefore, only total annual volumes are required and intra-annual timing was not considered at this stage. The majority of inflow into Bool Lagoon occurs over a short period within winter and spring and when evaporation losses are lowest. Therefore, the lagoon is likely to fill and excess water become available primarily during this period. As a consequence, diversions northwards would most likely occur for one period during each year and channel capacity needs to be investigated as this will ultimately affect the total diversion northwards.

The relationship between the flow measured upstream of Bool Lagoon (A2390519) and flow measured downstream of the regulator (A2390541) is shown in Figure 2. A polynomial function fitted to the data was able to provide a reasonable estimate of this relationship. There were apparent errors in the data from 1992 and 1993, therefore, these values were excluded during the derivation of the curve. However, irrespective of these possible data errors and the fitted function, it appears that at an annual flow of least 20,000 ML from Mosquito Creek into Bool Lagoon occurs before water is released into Drain M. From this it was assumed that an annual inflow of 20,000 ML will generally satisfy the requirements of Bool Lagoon and that the remainder could be diverted north.

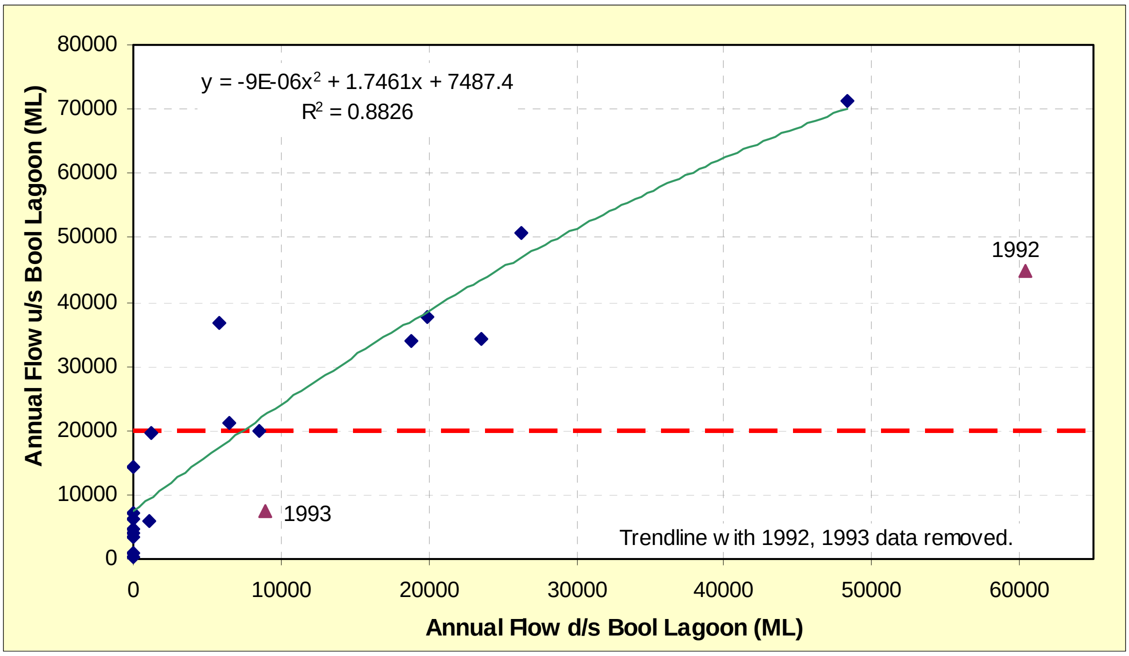


Figure 2 Relationship Between Bool Lagoon Inflow and Outflow.

The data from the station upstream of Bool Lagoon extends back to 1972. For this period, the relationship between average catchment rainfall and flow was examined and a Tanh function fitted to the data. This is a standard hyperbolic function that is often used as a simple rainfall to runoff or flow relationship, in particular, using rainfall data to infill or extend runoff data. Figure 3 shows this relationship between rainfall and flow.

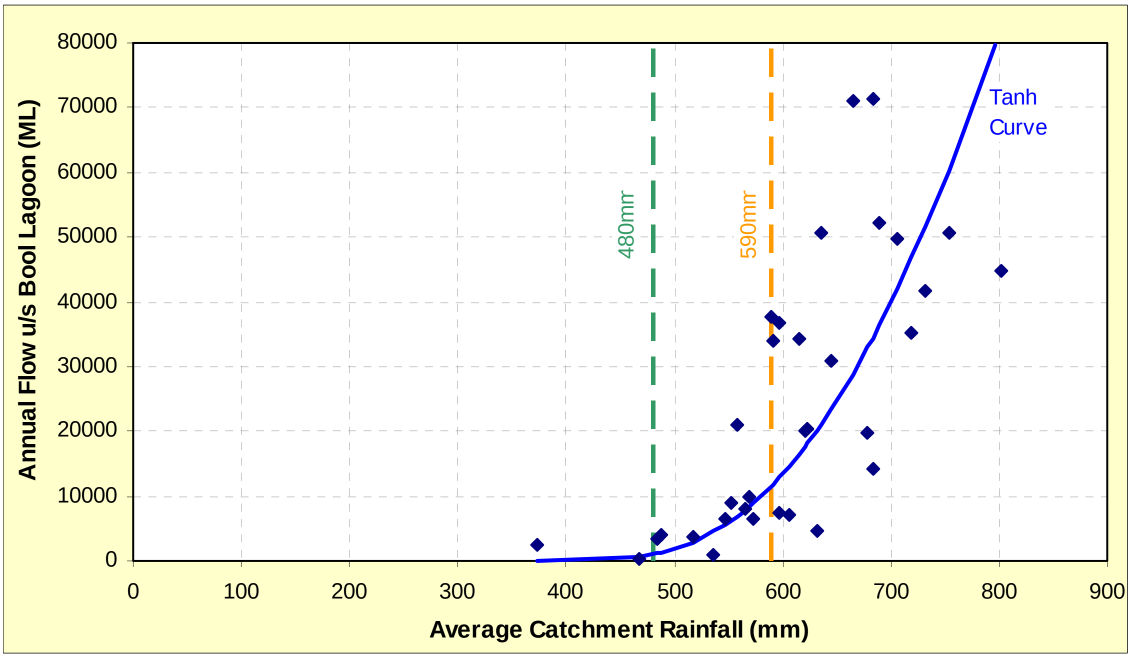


Figure 3 Relationship Between Catchment Rainfall and Inflow to Bool Lagoon.

A number of observations were made, in particular:

- Rainfall less than 480 mm tends to produce little, if any, flow into Bool Lagoon.
- As rainfall increases from 480 mm to 590 mm, flow increases to 10,000 ML.
- Flow increases quickly above 590 mm and the magnitude varies significantly. This variation is caused by a number of factors including the variation in the spatial and temporal distribution of rainfall, particularly over such a large catchment. The somewhat unpredictable response is often typical of catchments with a low coefficient of runoff.

While the Tanh function provides a reasonable representation of runoff when rainfall is less than 590 mm, it is unable to replicate the sharp increase in runoff that occurs once rainfall reaches 590 to 600 mm. In addition, due to the large variability of runoff for higher annual rainfalls, the Tanh function cannot provide meaningful estimates of runoff for these rainfalls.

Despite the high flow variability for higher rainfalls, the total volumes mostly exceed 20,000 ML, the estimated threshold for flow into Bool Lagoon before there is likely to be excess water available. Each year was then identified as one of three classes based on annual rainfall totals, in particular:

1. Class One: annual rainfall less than 480 mm.
2. Class Two: annual rainfall between 480 and 590 mm.
3. Class Three: annual rainfall greater than 590 mm and referred to as a wet year that is likely to produce significant runoff.

By classifying years based on rainfall in this way, an alternative method of analysis was able to assess the potential frequency of diversions. Figure 4 classifies inflows to Bool Lagoon since 1972.

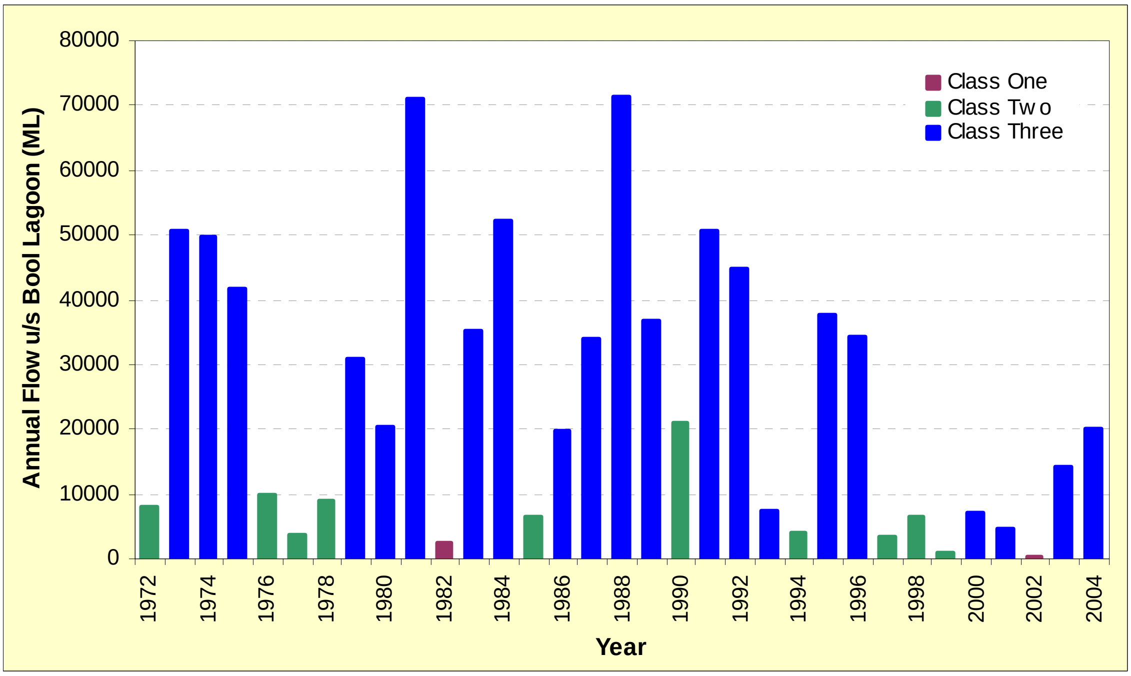


Figure 4 Classification of Bool Lagoon Inflow with Respect to Catchment Rainfall.

This, combined with the data from Figure 3, shows that:

- In 33 years of record there are 21 years (64%) with annual rainfall greater than 590 mm.
- Of these 21 years, 14 years had an inflow much greater than 20,000 ML and it is likely that water was released from Bool Lagoon.

- During three additional years Bool Lagoon may have contained enough storage to allow diversion.
- Of the 21 years with rainfall greater than 590 mm, available excess water was likely in 17 years (75%).
- Over 33 years of record, these 17 years equate to 50% or a potential return period of 1 in 2 years for diversions.

If only rainfall classification is used to determine diversion potential, the frequency of diversion is 64% (21 out of 33 years), compared to the actual frequency of diversion based on recorded inflows which is 50% (17 out of 33 years). However, the differences equate to additional diversions during only 1 out of 10 years and as such, the classification of diversion potential based on rainfall is considered a reasonable approximation.

By using rainfall bounds as the determining factor for diversion years, it is then possible to extrapolate and estimate the longer term potential diversion frequencies. This analysis is shown in Table 2 using catchment rainfall from 1896. This shows that over 109 years of record, 60% are wet and would be likely to have provided an opportunity to divert flow north.

Table 2 Assessment of Bool Lagoon Inflow Based on Rainfall.

Period	Rainfall Classification			Runoff
	1	2	3	%Wet
1896-2004 (109 years)	12	29	68	62
1896-1971 (76 years)	10	19	47	62
1972-2004 (33 years)	2	10	21	64

The frequency of possible diversions to Drain E has been established above. Table 3 shows the frequencies of diversion volumes. These have been calculated using the recorded flow data downstream of Bool Lagoon from 1985 to 2004 and extrapolated to 1972 by assuming that all flow in excess of 20,000 ML entering Bool Lagoon is available for diversion.

Table 3 Frequency of Flow Volumes Available for Diversion to Drain E from Bool Lagoon.

Flow Available for Diversion (ML)	No. Years*	Frequency (years)
>10,000	13	4 in 10
>20,000	9	3 in 10
>30,000	5	2 in 10
>40,000	3	1 in 10
>50,000	2	0.5 in 10

*Period of analysis 1972 to 2004

ADDITIONAL FLOW TO DRAIN E

The diversion northwards of all excess water currently released from Bool Lagoon would add significantly to current inflows from Naracoorte Creek into Drain E. For this preliminary study, 500 ML of losses have been assumed between Bool Lagoon and Garrie Swamp; this can be refined after additional information is gathered. Therefore, it was assumed that no water would be diverted northwards unless there is more than 1000 ML of excess water available. The following analysis was conducted using the period with recorded Bool Lagoon release data (1985 to 2004).

Figure 5 shows the potential total annual inflows at Garrie Swamp, identifying the two sources of water. Using the model developed by Cresswell (2004), flow data from the Naracoorte Creek gauging station data was modelled through Lake Ormerod to determine the Naracoorte Creek component of the inflow to Garrie Swamp. This clearly shows that diversions from Bool Lagoon have the potential to enhance existing inflows and also to provide inflows in a number of years when no water spills from Lake Ormerod.

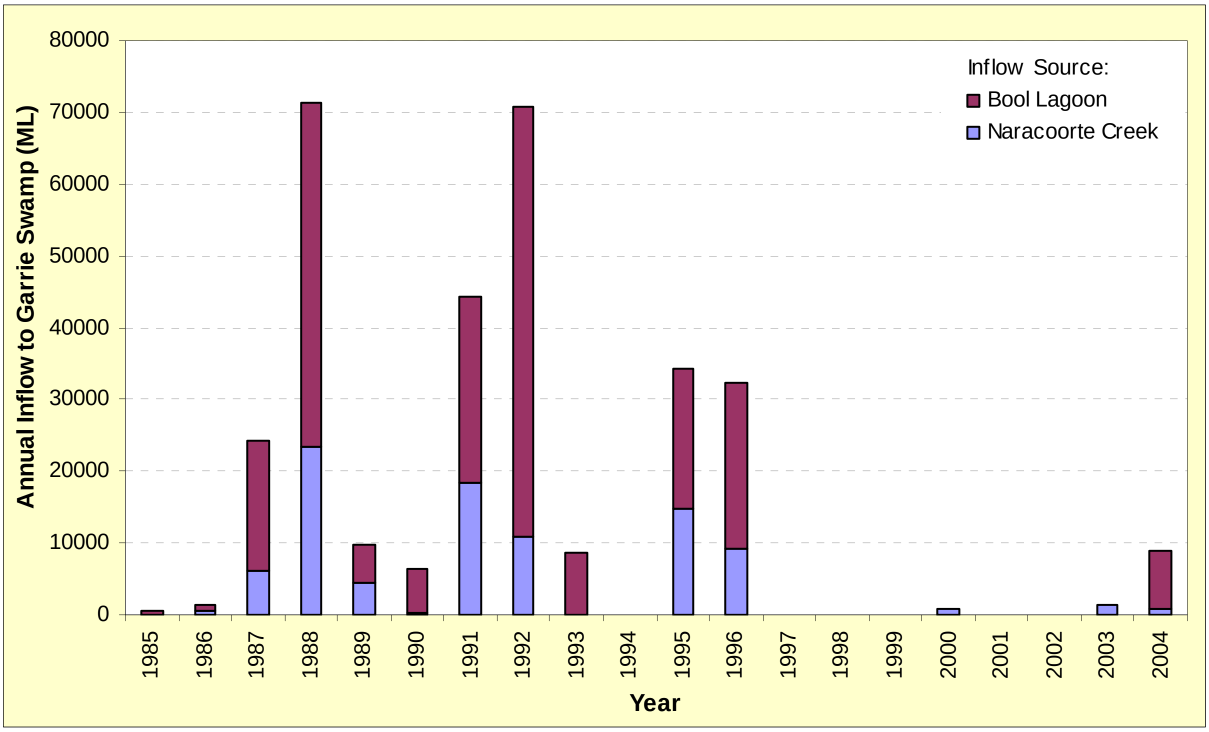


Figure 5 Potential Total Inflow into Drain E at Garrie Swamp.

Additional flow into Drain E would increase the turnover of water within all on-stream wetlands. Table 4 presents the estimated increases in the quantity and movement of flow throughout Drain E and the on-stream wetlands, together with the assumptions used in this analysis.

From this it can be seen that:

- Water is currently turned over within the wetlands at least once during 7 out of 19 years.
- Turnover would have been possible at least once during an additional 3 out of 19 years if water was diverted from Bool Lagoon.
- The increased turnover of water that would be possible is particularly significant in 6 of the 8 years when water has historically spilled from Jaffray Swamp. This would provide important flushing of the wetlands along this system.

Table 4 Water Turnover in Drain E Wetlands.

Year	Lake Ormerod Spill (ML)	Bool Lagoon Release (ML)	Potential Total Inflows to Drain E at Garrie Swamp (ML)	Jaffray Spill (ML)	Potential Jaffray Spill (ML)	Wetlands Turnover Without Bool Diversion	Wetlands Turnover With Bool Diversion
1985	0	1126	626	0	0	0	0
1986	672	1170	1342	0	0	0	0
1987	6066	18787	24353	4293	22080	1	6
1988	23489	48292	71281	28729	76021	7	19
1989	4411	5854	9765	6003	10857	2	3
1990	376	6512	6388	0	2627	0	1
1991	18434	26292	44226	30212	55504	8	14
1992	10837	60353	70690	16940	76293	4	19
1993	20	8991	8511	0	3991	0	1
1994	0	0	0	0	0	0	0
1995	14784	19919	34203	16064	34983	4	9
1996	9269	23511	32280	14614	37125	4	9
1997	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0
2000	947	0	947	1880	1880	0	0
2001	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0
2003	1438	0	1438	0	0	0	0
2004	969	8515	8984	0	7515	0	2

Assumptions

1. 500 ML of loss of diverted water between Bool Lagoon and Garrie Swamp
2. 500 ML of additional loss of diverted water between Garrie Swamp and Jaffray Swamp
3. Flow data from Naracoorte Creek is modelled through Lake Wanwarrie and Lake Ormerod to determine spill
4. Jaffray spill is modelled until 1994 when recording began
5. Potential total inflows to Drain E at Garrie Swamp
   = Spill from Lake Ormerod + Diversion Flow from Bool Lagoon - 500 ML losses
6. If Jaffray is spilling then all upstream wetlands assumed to be full
7. Potential spill at Jaffray:
   1) If Jaffray historically spilled:
      New Spill = Spill from Jaffray + Diversion Flow from Bool Lagoon - 1000 ML losses
   2) If Jaffray didn't historically spill: Use modelled data to determine how much extra water required to create spill at Jaffray
      New Spill = Diversion Flow from Bool Lagoon - 1000 ML losses - Water needed to create spill
8. Total volume of on-stream wetlands = 4000 ML (Giraudo, 2002)
9. Current turnover of water in wetlands = Jaffray Spill / Total wetland volume
10. Potential turnover of water in wetlands = Potential Jaffray Spill / Total wetland volume

ADDITIONAL FLOW TO MARCOLLAT WATERCOURSE

A similar analysis was conducted for the Marcollat Watercourse. The diversion of flow north from Bool Lagoon has the potential to increase the flows entering the Marcollat Watercourse at the Muddies wetland. The following analysis was conducted using the period with recorded Bool Lagoon Release data (1985 to 2004).

Figure 6 shows potential flow increases into the Muddies, identifying the three sources of water. Using the model developed by Cresswell (2004), flow data from the Morambro Creek gauging station was modelled through Cockatoo Lake to determine the Morambro Creek component of the inflow into the Muddies. This shows that diversions from Bool Lagoon have the potential to enhance the existing inflows and provide inflows in years when both Jaffray Swamp and Cockatoo Lake historically did not spill.

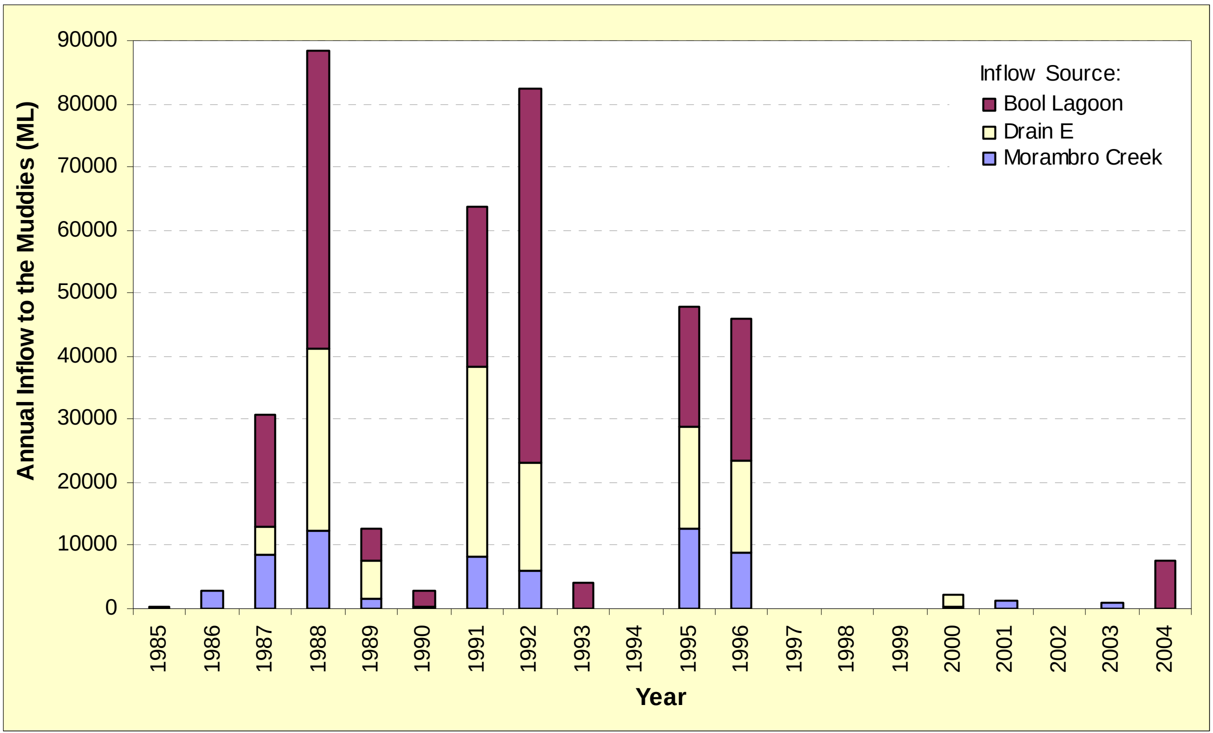


Figure 6 Potential Total Flow into Marcollat Watercourse at The Muddies.

Additional flow into the Marcollat Watercourse would also increase the turnover of water within all on-stream wetlands.

Table 5 presents the estimated increases in the quantity and movement of flow throughout the Marcollat Watercourse and the on-stream wetlands, together with the assumptions used in this analysis. From this it can be seen that:

- Water is turned over within the wetlands at least once during 7 out of 19 years.
- Turnover would have been possible at least once during an additional 2 out of 19 years if water was diverted from Bool Lagoon.
- The increased turnover of water that would be possible is particularly significant in 6 of the 10 years when water has historically spilled from Jip Jip. This would provide important flushing of the wetlands along this system.

Table 5 Water Turnover in Marcollat Watercourse Wetlands.

Year	Cockatoo Lake Spill (ML)	Bool Lagoon Release (ML)	Potential Jaffray Spill (ML)	Potential Total Inflows to Marcollat Watercourse (ML)	Jip Jip Spill (ML)	Potential Jip Jip Spill (ML)	Wetlands Turnover Without Bool Diversion	Wetlands Turnover With Bool Diversion
1985	298	1126	0	298	0	0	0	0
1986	2785	1170	0	2785	0	0	0	0
1987	8579	18787	22080	30659	8849	25636	2	6
1988	12411	48292	76021	88432	38855	85146	9	20
1989	1678	5854	10857	12535	6400	10254	2	2
1990	210	6512	2627	2837	43	1670	0	0
1991	8129	26292	55504	63633	36132	60424	8	14
1992	6120	60353	76293	82413	17113	75466	4	18
1993	129	8991	3991	4120	21	3012	0	1
1994	0	0	0	0	0	0	0	0
1995	12736	19919	34983	47719	26187	44105	6	10
1996	8793	23511	37125	45918	20074	41585	5	10
1997	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0
2000	399	0	1880	2279	17	0	0	0
2001	1254	0	0	1254	0	0	0	0
2002	0	0	0	0	0	0	0	0
2003	1065	0	0	1065	0	0	0	0
2004	47	8515	7515	7562	0	6515	0	2

<u>Assumptions</u>

1. 1000 ML of loss of diverted water between Bool Lagoon and Jaffray Swamp
2. 1000 ML of additional loss of diverted water between Jaffray Swamp and Jip Jip
3. Flow data from Morambro Creek is modelled through Cockatoo Lake to determine spill
4. Jip Jip spill is modelled until 1991 when recording began
5. Potential total inflows to Marcollat Watercourse at the Muddies
   = Spill from Cockatoo Lake + Potential Spill from Jaffray Swamp
6. If Jip Jip is spilling then all upstream wetlands assumed to be full
7. Potential spill at Jip Jip:
   1) If Jip Jip historically spilled:
      New Spill = Spill from Jip Jip + Potential Spill from Jaffray Swamp - 1000 ML losses
   2) If Jip Jip didn't historically spill: Use modelled data to determine how much extra water required to create spill at Jip Jip
      New Spill = Potential Spill from Jaffray - 1000 ML losses - Water needed to create spill at Jip Jip
8. Total volume of on-stream wetlands = 4300 ML (Giraudo, 2002)
9. Current turnover of water in wetlands = Jip Jip Spill / Total wetland volume
10. Potential turnover of water in wetlands = Potential Jip Jip Spill / Total wetland volume

DIVERSION TO BAKERS RANGE WATERCOURSE

The Southern Bakers Range Watercourse (including Drains A and B), Drain C and the Killanoola Drain have a combined catchment area of approximately 1105 km^2 (Clark and Kotwicki, 1992), which has historically produced significant flows. These have primarily been re-directed down Drain M to Lake George and the ocean since the late 1960s. Figure 7 details the design capacities of the Callendale Regulator, Drain M and Bakers Range Watercourse. Because of these constraints, some uncontrolled diversion of flow north into the Bakers Range Watercourse upstream of the Callendale Regulator has occurred during high flows (B. Puddy, SEWCDB, *pers. comm.*, 2003). In addition, the regulator has been operated to induce this northern flow during a number of years. Only limited details of these diversions are currently available.

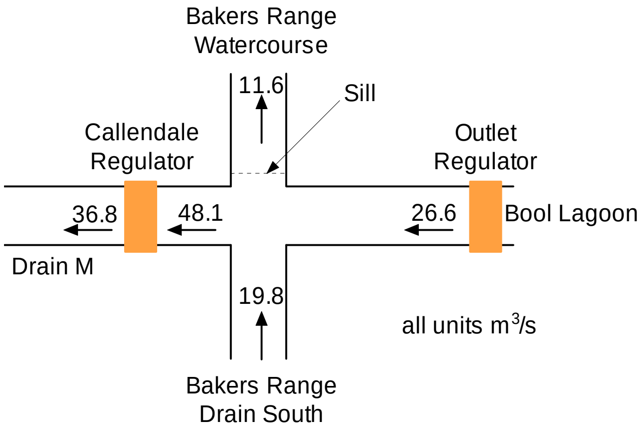


Figure 7 Design Capacities of Callendale Regulator, Drain M and Bakers Range Watercourse.

The channel constraints of the Bakers Range Watercourse restrict inflow and hence volumes that can be diverted to a maximum of 11.6 m^3/s. The daily mean and maximum flows at the gauging station downstream of Callendale Regulator (A2390514) were compared. The daily maximum flows showed reasonable consistency with the daily mean flows, that is, the difference between the two values was generally small. Larger differences occurred primarily when the mean flow was low and the maximum flow was less than the threshold flow of 11.6 m^3/s. Therefore, for the analysis undertaken here, the mean daily flows were used. A mean flow of 11.6 m^3/s corresponds to approximately 1000 ML/day. Using this value, the analysis was conducted at an annual time scale in terms of total available flow. Two scenarios were considered, namely:

1. Diversion at Callendale with no diversion to Drain E (1972 to 2004).
2. Diversion at Callendale with maximum diversions to Drain E (1985 to 2004).

DIVERSION ONLY AT CALLENDALE

The sole diversion of water northwards along Bakers Range Watercourse from Callendale was evaluated first. A 1000 ML minimum annual diversion was assumed as smaller flows north are likely to have limited benefit due to potential losses. The length of the channel between Callendale and Fairview Drain is similar to the distance between Bool Lagoon and the Marcollat Watercourse, for which a 1000 ML loss was assumed. This estimation can be revised if more information becomes available.

Unlike the availability of excess water at Bool Lagoon that generally occurs for a short period only once during a year, available flow at Callendale can occur more than once and for a longer period. Water is not able to be stored in Drain M at Callendale for extended periods as it is in Bool Lagoon. Therefore, operational considerations need to be taken into account when calculating the potential diversion volumes. It was assumed that flow would primarily be diverted during higher flow events and months to minimise losses as a proportion of total flow.

An arbitrary value of 0.5 m^3/s (equivalent to 43 ML/day) was assumed as a minimum threshold for the start and finish of any diversions. The hydrograph in Figure 8 can be used to explain this analysis. Once flow at Callendale reaches 43 ML/day as shown by the minimum diversion line, redirection of flow into Bakers Range Watercourse would begin. Diversion of all inflow to Callendale in excess of 43 ML/day would continue until the flow rate reached a maximum of 1000 ML/day, as shown by the maximum diversion line. The part of the hydrograph above this maximum diversion line would flow down Drain M. Once the flow from an event recedes to 43 ML/day, the diversions are assumed to cease and all flow passes Callendale and down Drain M.

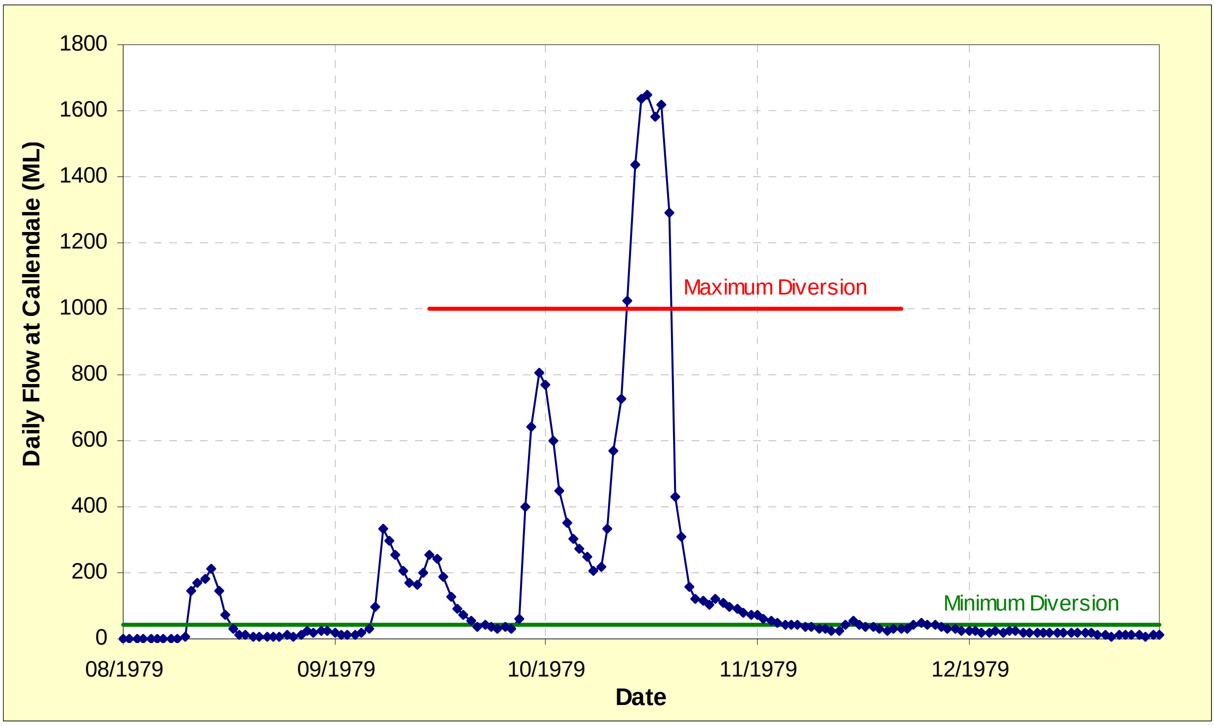


Figure 8 Hydrograph Describing Possible Diversion Rules.

Figure 8 also showed that the flow through Callendale may fluctuate above and below the minimum diversion rate over a year. It has been assumed that the rules behind the diversion of flow into Bakers Range Watercourse would aim to minimise post-diversion losses and hence ensure that real environmental benefits are delivered. Therefore, it is likely that there would be little benefit in diverting short or isolated flow sequences even if they are above the minimum diversion rate. Conversely, if two or more events occur closely together in time but the flow recedes below the minimum threshold between these events, diversions will potentially cease during this period.

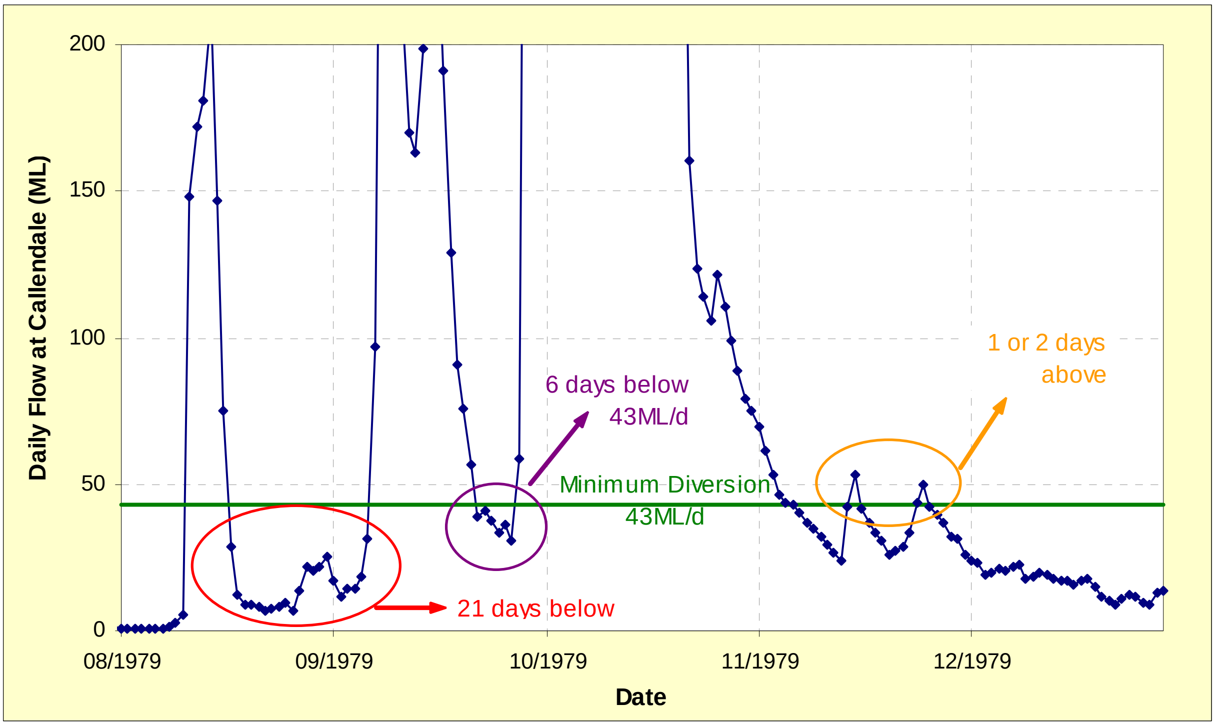


Figure 9 Interpretation of Diversion Rules.

Figure 9 shows those flows less than 200 ML/day from the hydrograph in Figure 8, highlighting three situations where diversion rules have had to be assumed. The following outlines how these situations have been evaluated to determine potential diversion frequencies:

- Flow exceeded the minimum rate of 43 ML/day for six days in August, but following this there were 21 days of below minimum flow. The total flow from this event was not particularly high and, because of its isolation from subsequent flows, diversion of these may not provide significant environmental benefits as losses are likely to be high. During this analysis, these types of events were removed and not used to determine potential frequencies of diversions from the historical data.
- The second double-peaked event in September was followed by a much larger event (also double peaked) that began at the end of September and continued until early November. Between these events the hydrograph receded and there were six days where the flow was less than 43 ML/d. Because the flow remained close to the threshold and the below minimum diversion period was short, it was considered that both events would be diverted. While those flows below the threshold were not included in the diversion volume, future operating rules may determine to divert these if it is possible to predict an ensuring event.

- There were two smaller peaks in November where the flow rate rose above the minimum diversion flow. However, because there were only one or two days above 43 ML/d, these were removed from the analysis because they are unlikely to be diverted.

Based on the outlined assumptions, Figure 10 shows that a large proportion of the flow at Callendale could be diverted. The total height of the columns equals the current flows passing Callendale. The "Bakers Range Watercourse" (maroon) flow component is the potential diversion volume to Bakers Range, leaving only the "Drain M" (blue) component to pass. These potential flows generally comprise more than 95% of the potential flow for diversion based solely on a maximum flow rate (no minimum threshold), that is, flows less than 43 ML/day account for less than 5% of the total flow. Table 6 then shows the frequencies of total flow volumes available for diversion.

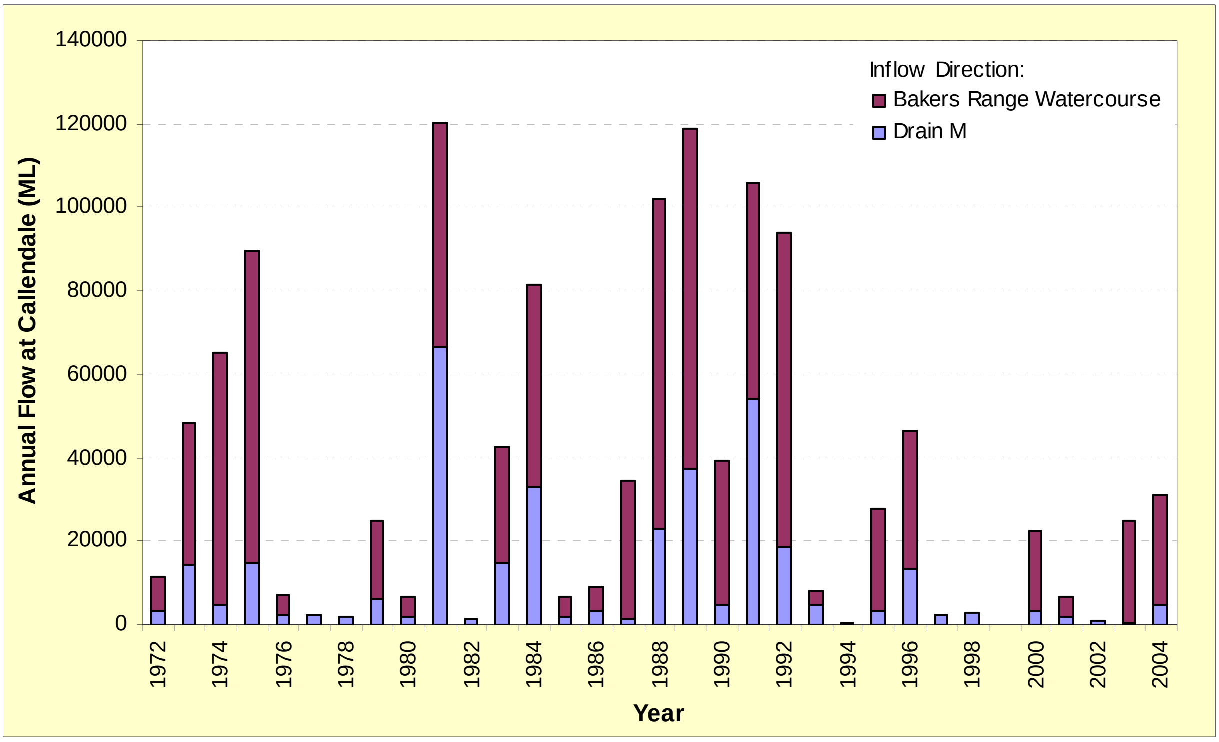


Figure 10 Potential Diversion of Flow at Callendale.

Table 6 Frequency of Available Flow Volumes for Diversion at Callendale without Bool Lagoon Diversions.

Flow Available for Diversion (ML)	No. Years*	Frequency (years)
>10,000	18	5 in 10
>20,000	16	5 in 10
>30,000	12	4 in 10
>40,000	8	2 in 10
>50,000	7	2 in 10

*Period of analysis 1972 to 2004

The analysis provided an estimate of the total volumes and diversion frequencies, assuming the arbitrary use of a minimum diversion threshold of 43 ML/day. However, the number of diversion days is also important. Constrictions exist along Bakers Range Watercourse and the drains and watercourses that provide links to other parts of the system. These may limit the proportion of water diverted each day from Callendale that can be directed into a particular environmental asset such as the wetlands along the West Avenue Watercourse. Hence, if large volumes of flow only occur over a small number of days, it may not be physically possible to meet the flow requirements of those systems where the water is being directed. While these constrictions and their impact on flow have not been documented here, an analysis of the number of flow diversion days has been carried out.

It may also be desirable to adjust the minimum diversion level to allow more flow to pass down Drain M thereby increasing the likelihood that only significant flow volumes would be diverted. Figure 8 highlighted a possibility that occurs frequently throughout the historical data, that is, although the minimum flow (43 ML/day) has been reached, the event that follows is short or a large volume is not available. By waiting until a higher minimum diversion flow is reached, there may be more confidence in assuming that a particular event will provide significant volumes to divert. However, if the minimum diversion is set too high, significant environmental benefits may be lost, but this is highly dependent on the hydrograph in any particular year. Figure 11 to Figure 13 show the potential volumes available at Callendale by assuming varying minimum diversion thresholds during three representative years (1996, 1991 and 1987) and the number of days over which these flows occurred. In Figure 11 for example, if a minimum diversion flow of 43 ML/day is assumed then there would have been the potential to divert 32700 ML over 86 days. In the case of a 100 ML/day flow, the potential diversion would have been 32300 ML over 80 days. These figures highlight the potential for extended periods of flow diversion into Bakers Range as well as demonstrating the influence of the minimum flow diversion threshold on total diversions. Appendix A presents hydrographs for all other years from 1972 to 2004.

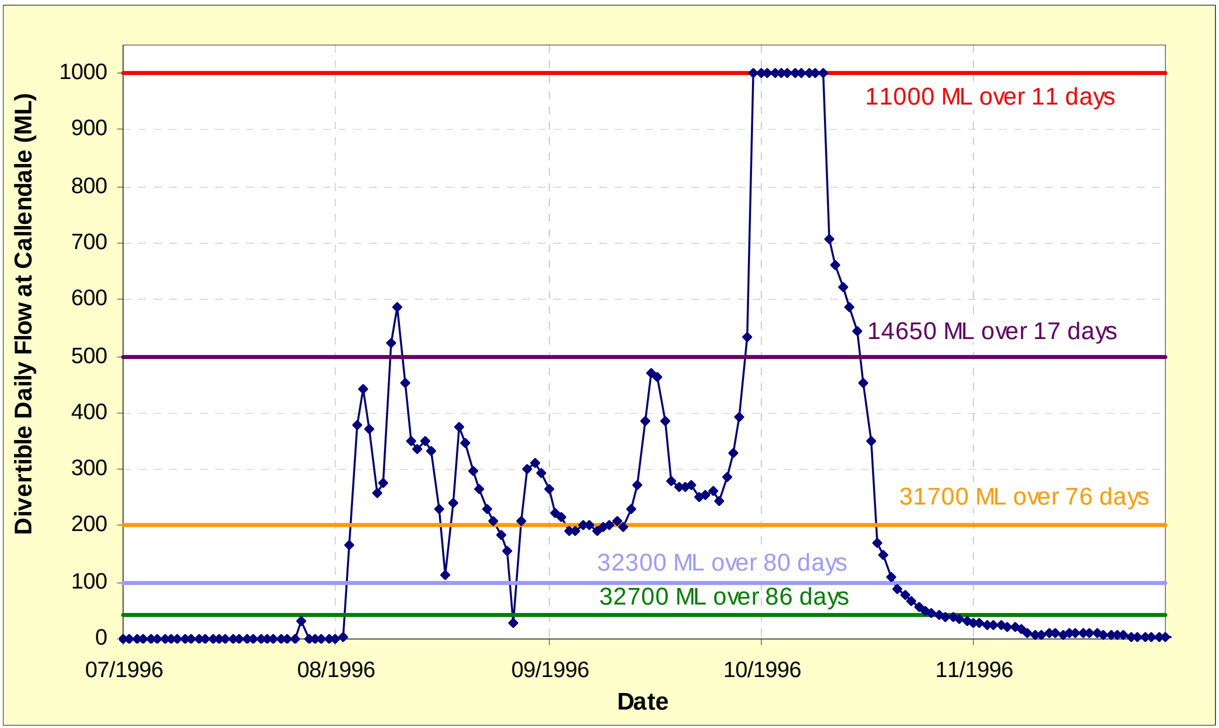


Figure 11 Hydrograph Showing 1996 Potential Diversions at Callendale.

In Figure 11, the flows in August and September essentially fluctuate between 200 ML/day and 500 ML/day. As such, by increasing the minimum diversion flow from 200 ML/day to 500 ML/day, there is a diversion reduction of 17050 ML (54%) and 59 diversion days. In contrast, the 1991 hydrograph shown in Figure 12 has a much longer period where flows are greater than

1000 ML/day. Therefore, as the minimum diversion flow increases, relative reductions in flows and diversion days are less. Flows at Callendale during 1987, as shown in Figure 13, remained below 1000 ML/d. No diversions would therefore have occurred if the minimum rate was set at 1000 ML/day. However, the potential for significant diversion volumes and periods remains high even if the minimum rate was set at 500 ML/day.

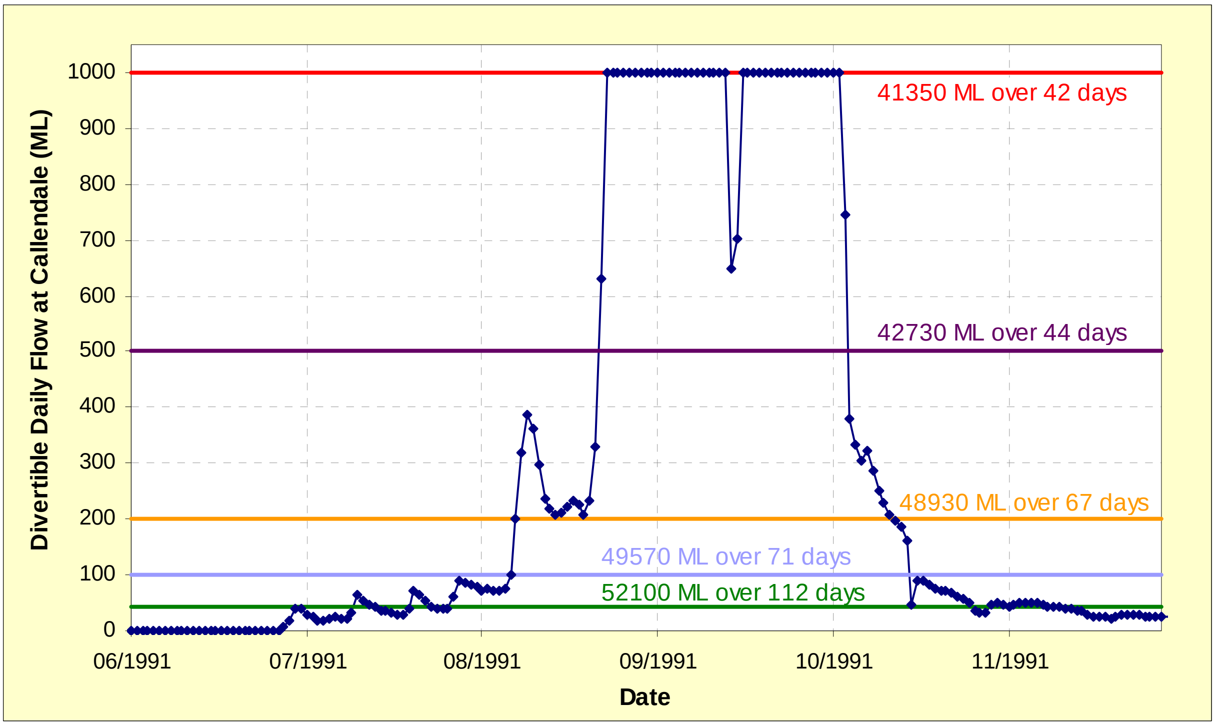


Figure 12 Hydrograph Showing 1991 Potential Diversions at Callendale.

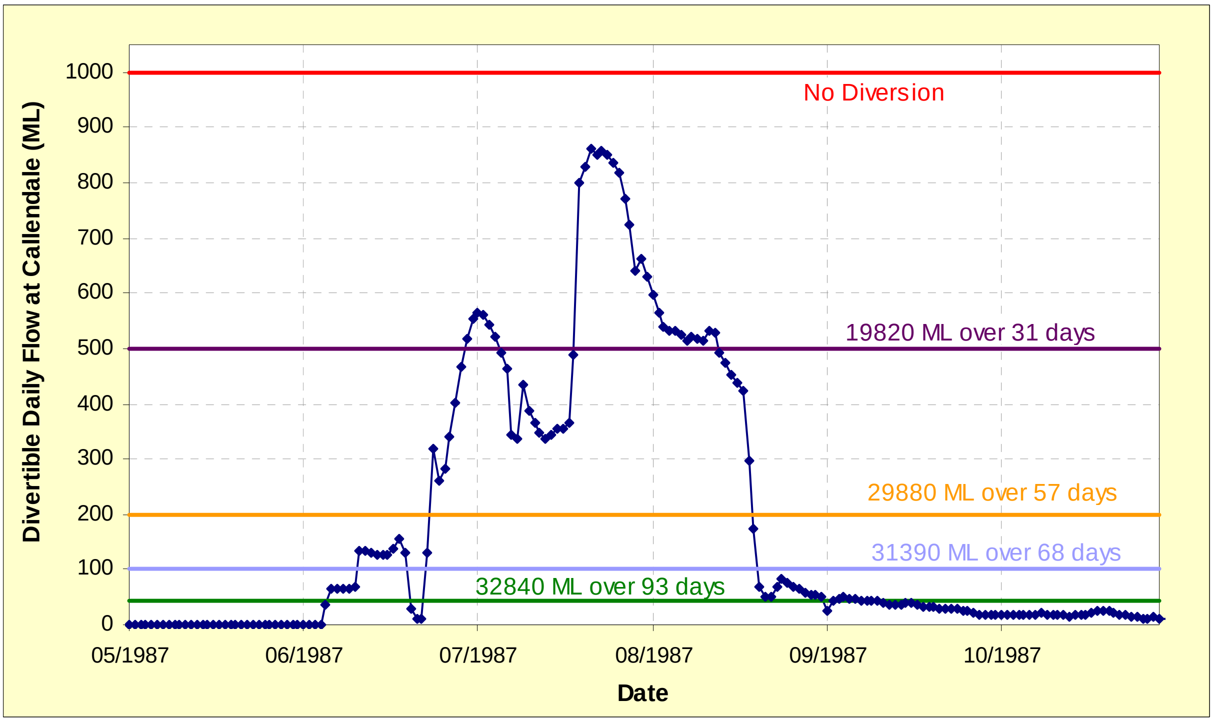


Figure 13 Hydrograph Showing 1987 Potential Diversions at Callendale.

Analysis of the potential impact on volumes, diversion frequencies and number of diversion days for varying minimum diversion flows was undertaken for the period 1972 to 2004. Table 7 shows the potential volumes that could be diverted into Bakers Range Watercourse at Callendale assuming a number of minimum thresholds and the number of days over which these diversions would have taken place. These indicate that there is the potential for significant diversions even as the threshold flow is increased, particularly up to a minimum threshold of 200 ML/day. Table 8 shows the frequencies of total flow volumes that would have been available for diversion for the different minimum flow diversion thresholds.

Table 7 Potential Diversions of Flow Currently Passing Callendale.

Year	Minimum Flow Threshold for Diversion to Bakers Range (ML)									
	43 ML/day		100 ML/day		200 ML/day		500 ML/day		1000 ML/day	
	Volume (ML)	#Days	Volume (ML)	#Days	Volume (ML)	#Days	Volume (ML)	#Days	Volume (ML)	#Days
1972	7911	31	7317	22	6192	14	3278	4	0	0
1973	33884	95	31408	58	30176	49	25023	29	21359	23
1974	60565	126	59129	107	53153	67	51334	62	13000	13
1975	74479	212	70305	139	65251	104	44407	49	30779	31
1976	4656	35	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0
1979	18819	55	17824	41	16768	33	8297	9	7000	7
1980	4912	48	0	0	0	0	0	0	0	0
1981	53411	97	52134	74	48913	53	46599	47	45931	46
1982	0	0	0	0	0	0	0	0	0	0
1983	27777	102	22981	54	20622	35	15550	16	15000	15
1984	48348	76	47175	58	46672	54	44390	47	40000	40
1985	5137	40	3339	15	0	0	0	0	0	0
1986	5861	43	0	0	0	0	0	0	0	0
1987	32843	93	31393	68	29883	57	19816	31	0	0
1988	79192	139	78427	127	75750	109	59342	64	44000	44
1989	81070	153	80572	145	75142	107	55658	59	51075	52
1990	34661	66	34099	57	32243	45	27707	33	12000	12
1991	52117	112	49574	71	48928	67	42728	44	41353	42
1992	75456	161	74109	140	70584	113	51932	59	39691	40
1993	3345	47	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0
1995	24374	31	24251	29	24251	29	23466	27	11823	12
1996	32696	86	32307	80	31712	76	14655	17	11000	11
1997	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0
2000	19096	88	17888	71	13330	39	0	0	0	0
2001	4732	49	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0
2003	24351	97	21251	52	19635	41	11327	16	0	0
2004	26514	80	25163	61	21387	34	17420	19	14412	15

Table 8 Frequency of Flow Volumes under Varying Minimum Flow Thresholds Available for Diversion at Callendale without Bool Lagoon Diversions.

Flow Available for Diversion (ML)	No. Years*	Frequency (years)
43 ML/day Threshold		
>10,000	18	5.5 in 10
>20,000	16	5 in 10
>30,000	12	3.5 in 10
>40,000	8	2.5 in 10
>50,000	7	2 in 10
100 ML/day Threshold		
>10,000	18	5.5 in 10
>20,000	16	5 in 10
>30,000	12	3.5 in 10
>40,000	8	2.5 in 10
>50,000	6	2 in 10
200 ML/day Threshold		
>10,000	18	5.5 in 10
>20,000	15	4.5 in 10
>30,000	11	3 in 10
>40,000	8	2.5 in 10
>50,000	5	1.5 in 10
500 ML/day Threshold		
>10,000	16	5 in 10
>20,000	11	3 in 10
>30,000	8	2.5 in 10
>40,000	8	2.5 in 10
>50,000	4	1 in 10
1000 ML/day Threshold		
>10,000	14	4 in 10
>20,000	8	2.5 in 10
>30,000	7	2 in 10
>40,000	4	1 in 10
>50,000	1	0.5 in 10

*Period of analysis 1972 to 2004

CONCURRENT DIVERSIONS AT CALLENDALE AND BOOL LAGOON

In the previous analysis it was assumed that diversion into the Upper South East would occur solely via the Bakers Range Watercourse. The effect on available water at Callendale from a reduction in releases of water from Bool Lagoon was then considered. Figure 14 shows the total annual flow at the Callendale gauging station, downstream of the Callendale Regulator, identifying two sources of water. In most years, the majority of the recorded flow is from the southern Bakers Range Watercourse, Drain C and the Killanoola Drain.

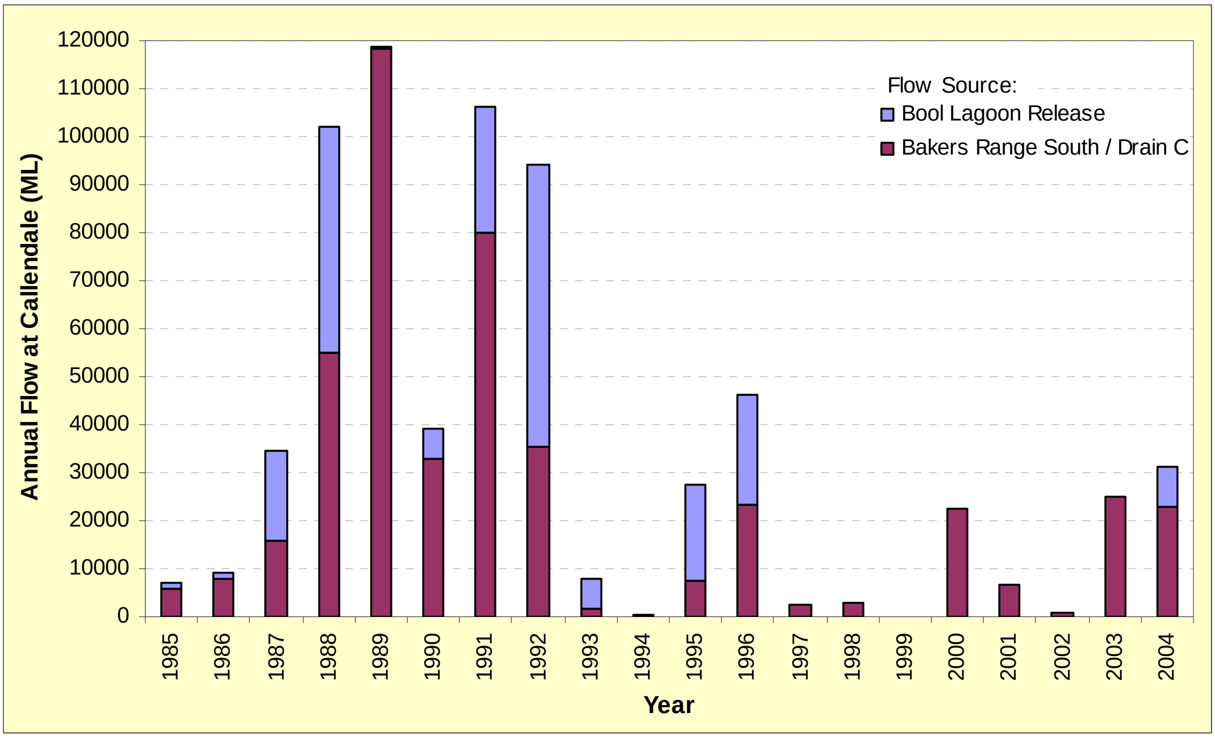


Figure 14 Flow Sources and Proportions at Callendale.

Drain M flows through the Big Heath Conservation Park, with a diversion channel to direct a proportion of the flow into the park, which has a total storage capacity of approximately 4000 ML (M. de Jong, SEWCDB, *pers. comm.*, 2005). While the basic characteristics and storage capacity of the Big Heath Conservation Park have been estimated, the proportion and timing of flows entering the park are not able to be established at this time. This presents difficulties when determining the source proportions of the flow arriving at Callendale. The recorded release from Bool Lagoon would be reduced by losses before it reaches Callendale. These losses were estimated and then added to the difference between the flow at Callendale and releases from Bool Lagoon. This provided an estimate of the flow originating from the Bakers Range Watercourse, Drain C and Killanoola Drain catchments. These calculated values can be revised when more details are known. Releases from Bool Lagoon and hence water available for diversion at Callendale are only quantifiable for the period 1985 to 2004. Therefore, only data during this period has been used for any analysis involving the combined diversions to Bakers Range and Drain E.

Figure 15 shows the proportion of flow available under current conditions at Callendale that could be diverted into Bakers Range Watercourse if the full amount of excess water at Bool Lagoon was diverted into Drain E and assuming a 43 ML/day minimum threshold at Callendale. If the maximum diversions were undertaken then the "Drain M" (blue) flow direction component would be the total flow to pass Callendale. The "Drain E" (yellow) component represents the flow diverted north from Bool Lagoon (that previously would have reached Callendale) and the "Bakers Range Watercourse" (maroon) component represents the flow diverted north from Callendale along Bakers Range Watercourse. Only the period 1985 to 2004 could be evaluated because it was not possible to determine flow rates at Callendale prior to 1985 without recorded outflow data for Bool Lagoon. No spill occurred from Bool Lagoon in 1994 or between 1997 and 2003, hence there is no diversion to Drain E as it was assumed that the water requirements of Bool Lagoon were not satisfied.

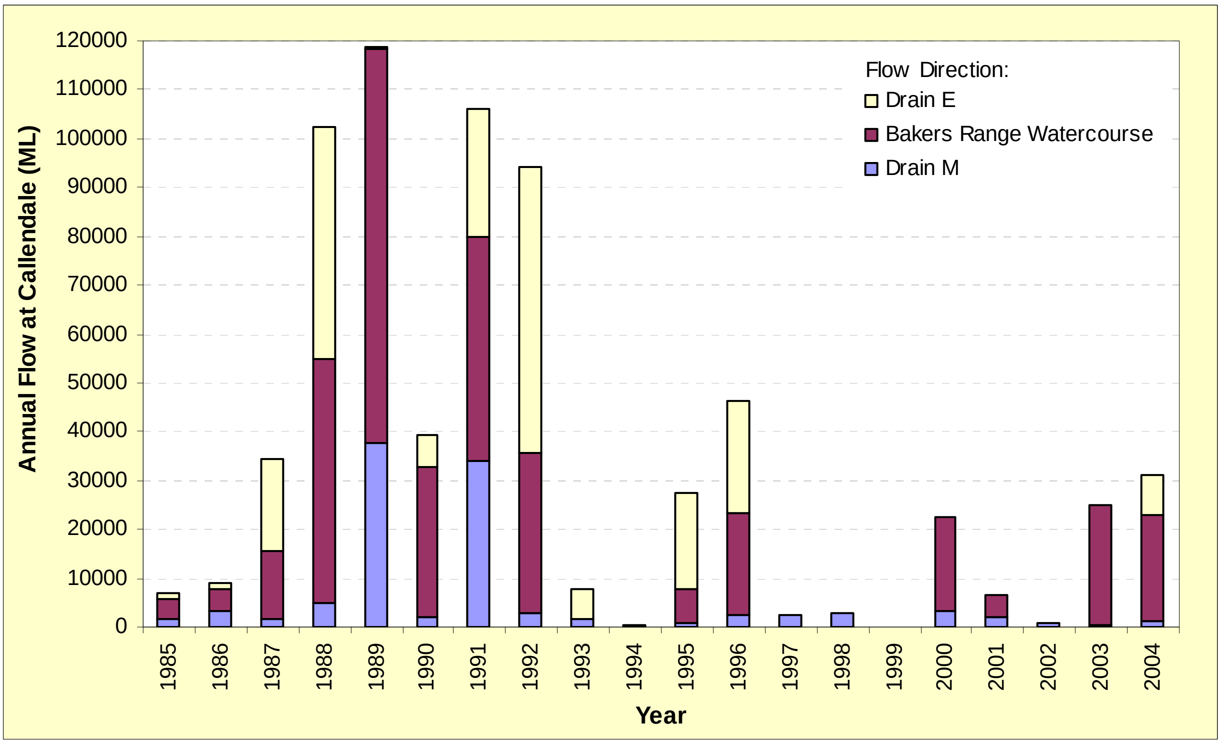


Figure 15 Potential Diversions of Total Flow Passing Callendale Under Current Conditions.

Table 9 shows the relative frequency of water available for diversion with a 43 ML/day diversion threshold. The frequency of diversion volumes of at least 10,000 ML is only slightly lower when flow is diverted from Bool Lagoon into Drain E than when sole diversions into Bakers Range Watercourse occur. The reduction in the frequency of higher volume diversions is more significant.

Table 9 Frequency of Flow Volumes Available for Diversion at Callendale with Bool Lagoon Diversions.

Flow Available for Diversion (ML)	No. Years*	Frequency (years)
>10,000	10	5 in 10
>20,000	8	4 in 10
>30,000	5	2.5 in 10
>40,000	3	1.5 in 10
>50,000	1	0.5 in 10

*Period of analysis 1985 to 2004

Higher total volumes available for diversion are generally dependent on the number of high flow days. Figure 16 and Figure 17 demonstrate this by comparing the flow at Callendale available for diversion (maximum diversion 1000 ML/day) with and without diversions occurring from Bool Lagoon into Drain E for 1992 and 1996.

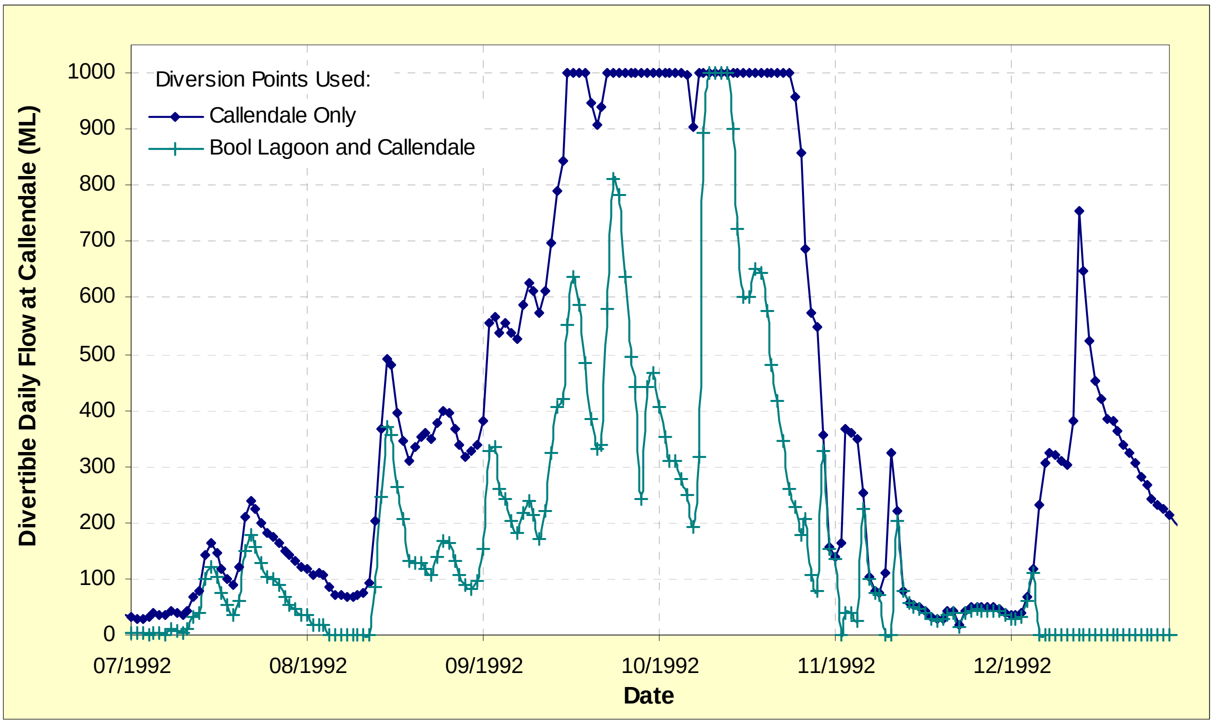


Figure 16 Comparisons of 1992 Potential Diversions at Callendale when Single or Multi-Diversion Points are Used.

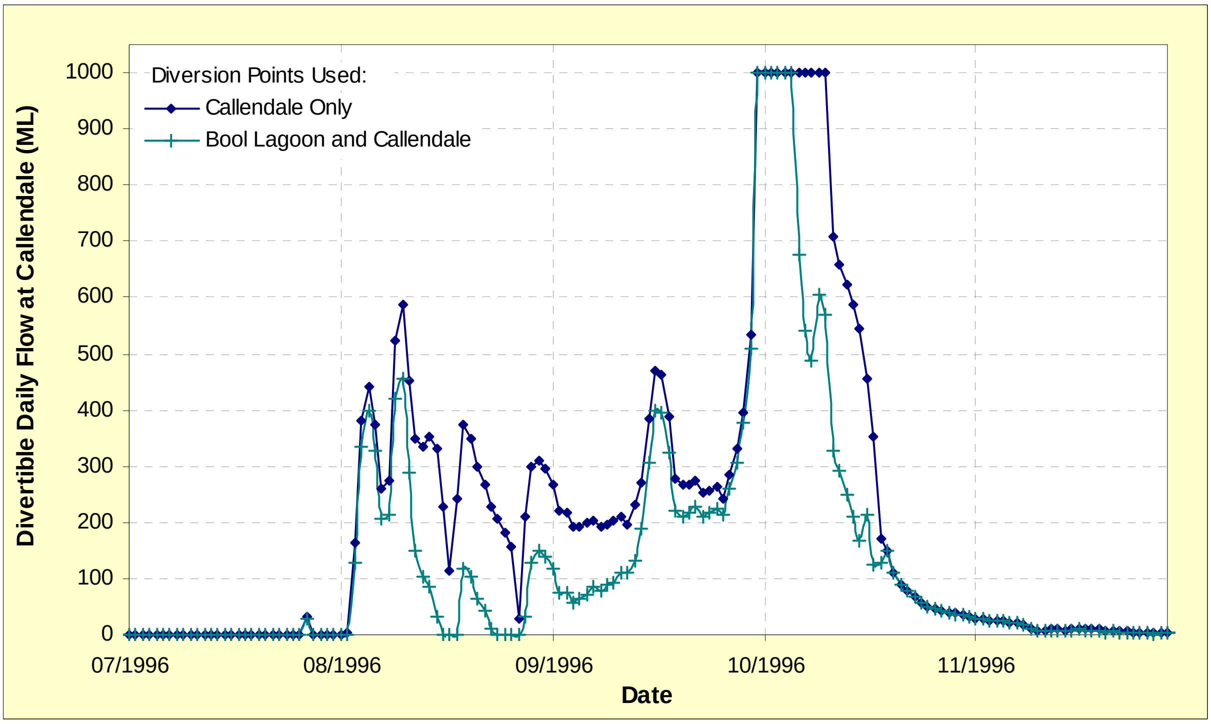


Figure 17 Comparisons of 1996 Potential Diversions at Callendale when Single or Multi-Diversion Points are Used.

In both Figure 16 and Figure 17, the results indicate that the peak flow events were highly dependent on the water spilling from Bool Lagoon. In such years, it would be vital to consider the benefits of diversions to each of Drain E and Bakers Range as a single diversion point may have to be chosen.

Table 10 shows how total volumes and diversion frequencies are affected for a number of assumed minimum flow diversion thresholds and the number of days over which these diversions would have taken place. Table 11 then shows the frequencies of total flow volumes available for diversion for the different minimum flow diversion thresholds. From this it appears that there would be very limited diversion potential at Callendale if diversions were undertaken from Bool Lagoon in conjunction with a high minimum threshold diversion flow. Finally, Table 12 shows the differences between the sole diversion of flow into Bakers Range Watercourse and the diversion in conjunction with those from Bool Lagoon into Drain E.

Table 10 Potential Diversions of Flow Passing Callendale In Conjunction With Diversions to Drain E from Bool Lagoon.

Year	Minimum Flow Threshold for Diversion to Bakers Range (ML)									
	43 ML/day		100 ML/day		200 ML/day		500 ML/day		1000 ML/day	
	Volume (ML)	#Days	Volume (ML)	#Days	Volume (ML)	#Days	Volume (ML)	#Days	Volume (ML)	#Days
1985	4355	39	2601	15	0	0	0	0	0	0
1986	4717	34	0	0	0	0	0	0	0	0
1987	14051	85	12598	58	7495	27	0	0	0	0
1988	49762	133	48383	112	41952	68	29624	36	17314	18
1989	80818	153	80050	142	75142	107	55658	59	51075	52
1990	30823	66	30261	57	28404	45	23869	33	0	0
1991	45827	100	43804	70	42776	63	37881	44	28000	28
1992	32785	114	30069	81	26602	60	14182	19	0	0
1993	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0
1995	6669	31	6546	29	4117	14	0	0	0	0
1996	21034	79	16005	41	14951	33	9386	12	6000	6
1997	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0
2000	19096	88	17888	71	13330	39	0	0	0	0
2001	4732	49	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0
2003	24351	97	21251	52	19635	41	11327	16	0	0
2004	21442	80	19766	57	16343	34	10846	15	0	0

Note: No spill occurred from Bool Lagoon in 1994 or between 1997 and 2003, hence the values for these years are identical to those for the sole diversion to Bakers Range.

Table 11 Frequency of Flow Volumes under Varying Minimum Flow Thresholds Available for Diversion at Callendale with Bool Lagoon Diversions.

Flow Available for Diversion (ML)	No. Years*	Frequency (years)
43 ML/day Threshold		
>10,000	10	3 in 10
>20,000	8	2.5 in 10
>30,000	5	1.5 in 10
>40,000	3	1 in 10
>50,000	1	0.5 in 10
100 ML/day Threshold		
>10,000	10	3 in 10
>20,000	6	2 in 10
>30,000	5	1.5 in 10
>40,000	3	1 in 10
>50,000	1	0.5 in 10
200 ML/day Threshold		
>10,000	9	3 in 10
>20,000	5	1.5 in 10
>30,000	3	1 in 10
>40,000	3	1 in 10
>50,000	1	0.5 in 10
500 ML/day Threshold		
>10,000	7	2 in 10
>20,000	4	1 in 10
>30,000	2	0.5 in 10
>40,000	1	0.5 in 10
>50,000	1	0.5 in 10
1000 ML/day Threshold		
>10,000	3	1 in 10
>20,000	2	0.5 in 10
>30,000	1	0.5 in 10
>40,000	1	0.5 in 10
>50,000	1	0.5 in 10

*Period of analysis 1985 to 2004

Table 12 Reduction in the Potential Diversions to Bakers Range Due to Diversions to Drain E.

Year	Minimum Flow Threshold for Diversion to Bakers Range (ML)									
	43 ML/day		100 ML/day		200 ML/day		500 ML/day		1000 ML/day	
	Volume (ML)	#Days	Volume (ML)	#Days	Volume (ML)	#Days	Volume (ML)	#Days	Volume (ML)	#Days
1985	782	1	738	0	0	0	0	0	0	0
1986	1144	9	0	0	0	0	0	0	0	0
1987	18793	8	18795	10	22388	30	19816	31	0	0
1988	29430	6	30044	15	33799	41	29718	28	26686	26
1989	252	0	522	3	0	0	0	0	0	0
1990	3838	0	3838	0	3838	0	3838	0	12000	12
1991	6290	12	5769	1	6152	4	4847	0	13353	14
1992	42671	47	44040	59	43982	53	37750	40	39691	40
1993	3345	47	0	0	0	0	0	0	0	0
1994	-	-	-	-	-	-	-	-	-	-
1995	17705	0	17705	0	20133	15	23466	27	11823	12
1996	11661	7	16302	39	16761	43	5269	5	5000	5
1997	-	-	-	-	-	-	-	-	-	-
1998	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-
2000	-	-	-	-	-	-	-	-	-	-
2001	-	-	-	-	-	-	-	-	-	-
2002	-	-	-	-	-	-	-	-	-	-
2003	-	-	-	-	-	-	-	-	-	-
2004	5072	0	5397	4	5044	0	6574	4	14412	15

Note: No spill occurred from Bool Lagoon in 1994 or between 1997 and 2003, hence there is no difference between these values and those for the sole diversion to Bakers Range.

ADDITIONAL FLOW TO WEST AVENUE WATERCOURSE

The West Avenue wetlands are generally considered to be of high environmental value and significance within the Upper South East. Historically these wetlands received significant flows from the region south of Drain M including the Bakers Range Watercourse. Since construction of the Blackford, Jacky White and Fairview Drains, the local catchment area has become the single source of inflow (Vivian, 2004) and the wetlands are in danger of degradation due to a lack of significant flows. As a result, the design of the Bald Hill Drain (adjacent to the West Avenue Watercourse) will consider a connection to the Fairview Drain. This would allow the diversion of flow from the southern watercourses and drains into West Avenue.

Diversion of flow from Bakers Range to West Avenue is limited to 195 ML/day, which is the channel capacity of Fairview Drain. Because of the importance of the West Avenue Watercourse and wetlands, the analysis undertaken has assumed a maximum possible diversion of flow to this system, that is, 195 ML/day would be diverted if available. Figure 18 and Figure 19 show the hydrographs for the potential diversion into Bakers Range Watercourse for 1988 and 1996, assuming diversions are only carried out at Callendale and there are no diversions from Bool Lagoon into Drain E. The portion of this hydrograph that could potentially be diverted into West Avenue is also shown. Losses from Callendale to the Fairview Drain have not been included in the calculation of this hydrograph. Irrespective of this, they provide a good indication of the periods over which diversions could take place.

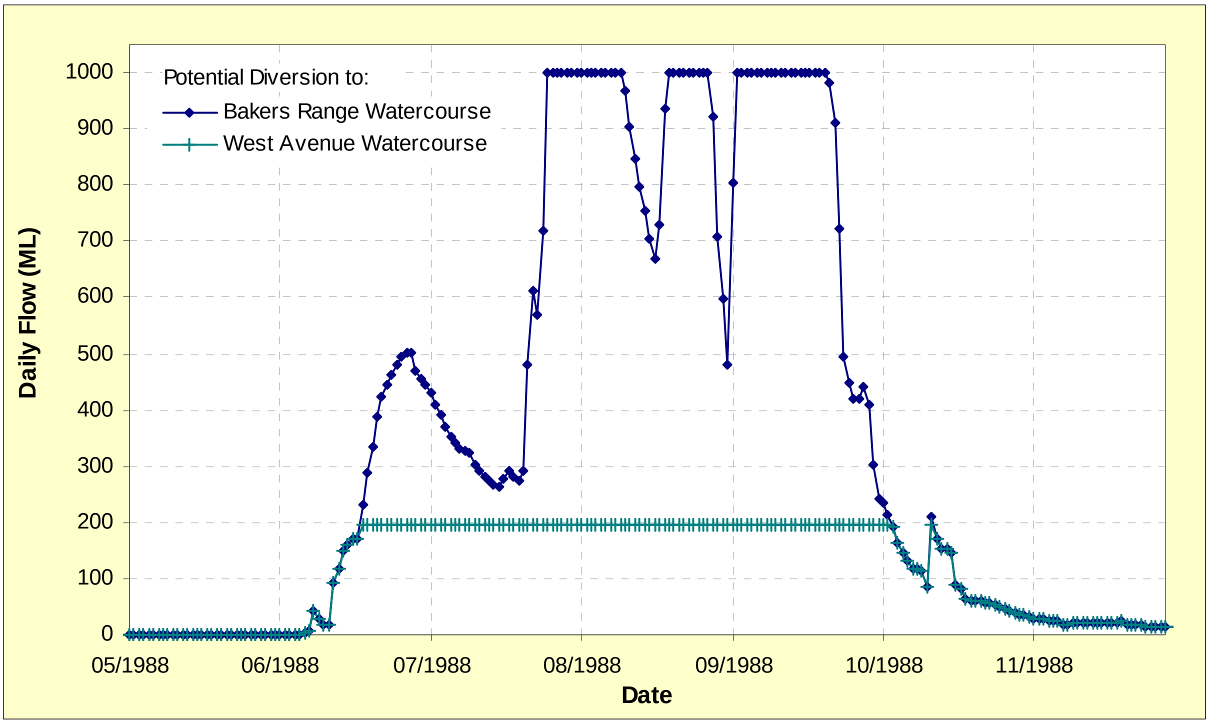


Figure 18 Potential Diversions into Bakers Range and West Avenue in 1988 using Callendale Diversion Point Only.

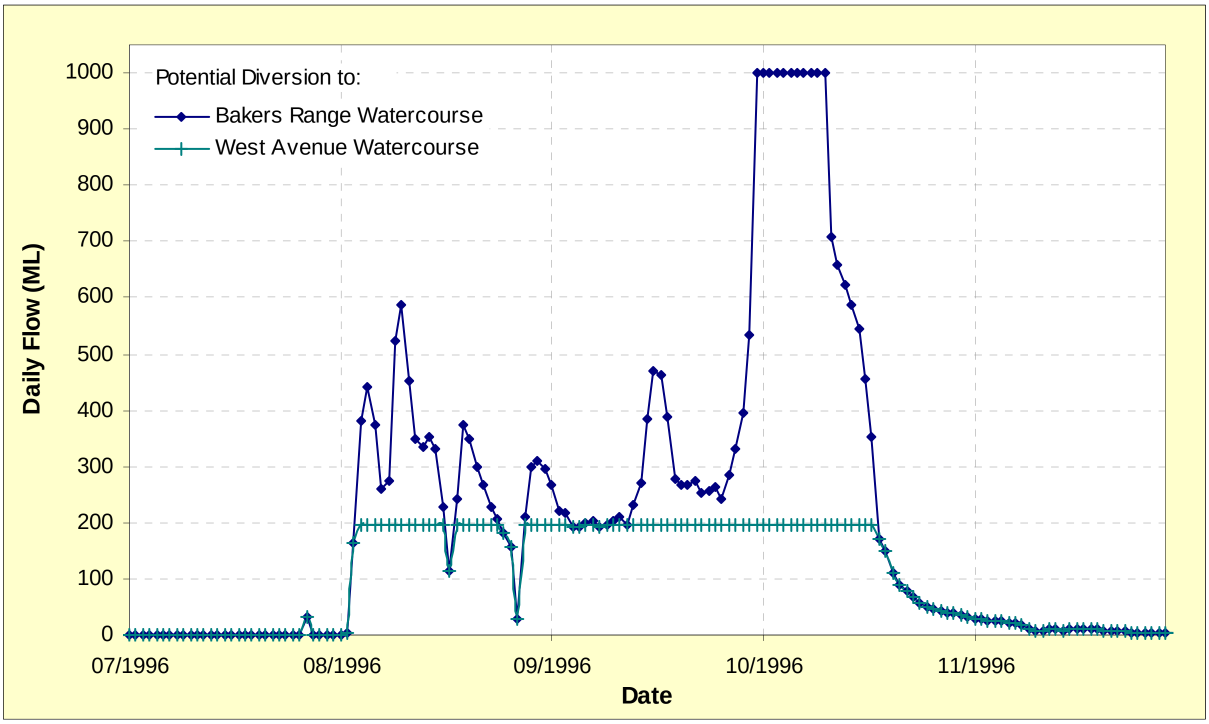


Figure 19 Potential Diversions into Bakers Range and West Avenue in 1996 using Callendale Diversion Point Only.

It is difficult to estimate the current turnover of water within the West Avenue wetlands as the recorded flow information along this watercourse is limited in both quality and quantity. Vivian (2004) stated that there has been no flow through the Wimpinmerit Gap since construction of the Fairview Drain such that local runoff entering the wetlands flows only from the immediately adjacent ranges and flats. An estimate of local runoff can be calculated using a catchment area of 181 km^2 (Clark and Kotwicki, 1992) with a typical runoff coefficient for the region of 0.05. Using rainfall over the period 1972 to 2004, this produces a mean runoff value of only 4880 ML per year. Giraudo (2002) estimated the storage capacity of the West Avenue wetlands as 5600 ML, such that under current flow conditions the wetlands are unlikely to even overflow during a average rainfall year. This is supported by anecdotal evidence that very little or no flow from Little Telowie Swamp has occurred over the last eight years and particularly since the Fairview Drain was constructed in 1999. However, because these estimates of current conditions are extremely unreliable, only the potential additional wetland turnovers (those above current conditions) have been estimated for each year during the period 1972 to 2004 for diversions solely to Bakers Range, and the period 1985 to 2004 for combined diversions to Bakers Range and Drain E.

Table 13 presents the estimated increases in the quantity and movement of flow through the West Avenue Watercourse and wetlands above current flow conditions. Turnover of water within the wetlands would not only provide important environmental flows but would also allow flushing through this system. The analysis was conducted for the two diversion scenarios from Callendale (diversion of flow into Bakers Range with and without diversions to Drain E from Bool Lagoon).

Table 13 Water Turnover in West Avenue Wetlands.

Year	Sole Diversion to Bakers Range				Diversion to Bakers Range and Drain E			
	Diversion to Bakers Range (ML)	Diversion to West Avenue (ML)	Proportion to West Avenue	Additional Wetlands Turnover	Diversion to Bakers Range (ML)	Diversion to West Avenue (ML)	Proportion to West Avenue	Additional Wetlands Turnover
1972	7911	4448	0.56	1	-	-	-	-
1973	33884	13204	0.39	2	-	-	-	-
1974	60565	20453	0.34	4	-	-	-	-
1975	74479	29504	0.40	5	-	-	-	-
1976	4656	3416	0.73	1	-	-	-	-
1977	0	0	0	0	-	-	-	-
1978	0	0	0	0	-	-	-	-
1979	18819	8430	0.45	2	-	-	-	-
1980	4912	3923	0.80	1	-	-	-	-
1981	53411	14773	0.28	3	-	-	-	-
1982	0	0	0	0	-	-	-	-
1983	27777	13458	0.48	2	-	-	-	-
1984	48348	12206	0.25	2	-	-	-	-
1985	5137	3934	0.77	1	4355	3874	0.89	1
1986	5861	4814	0.82	1	4717	3717	0.79	1
1987	32843	14075	0.43	3	14051	11736	0.84	2
1988	79192	24680	0.31	4	49762	21070	0.42	4
1989	81070	26742	0.33	5	80818	26528	0.33	5
1990	34661	11194	0.32	2	30823	11194	0.36	2
1991	52117	16251	0.31	3	45827	15305	0.33	3
1992	75456	26904	0.36	5	32785	17122	0.52	3
1993	3345	3345	1.00	1	0	0	0	0
1994	0	0	0	0	0	0	0	0
1995	24374	5778	0.24	1	6669	4986	0.75	1
1996	32696	15497	0.47	3	21034	11413	0.54	2
1997	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0
2000	19096	13363	0.70	2	19096	13363	0.70	2
2001	4732	3906	0.83	1	4732	3906	0.83	1
2002	0	0	0	0	0	0	0	0
2003	24351	12708	0.52	2	24351	12708	0.52	2
2004	26514	11754	0.44	2	21442	11726	0.55	2

Assumptions

1. 1000 ML/day (11.6 m^3/s) maximum diversion rate from Callendale
2. 1000 ML of loss between Callendale and Fairview Drain from total diverted flow
3. 195 ML/day channel capacity of Fairview Drain to potential connection with proposed Bald Hill Drain
4. Maximum diversion of 195 ML/day to West Avenue when available
5. Total volume of on-stream wetlands = 5600 ML (Giraudo, 2002)
6. Potential additional turnover of water in wetlands = (Diverted Volume - Losses) / Total wetland volume

The results from Table 13 show that:

Sole Diversion to Bakers Range

- It may have been possible for the water within the wetlands to be turned over at least once during 25 out of 33 years (75% or 3 in 4 years).
- A significant turnover (3 to 5 times) may have been possible during 10 out of 33 years (30% or 3 in 10 years).

Diversion to Bakers Range and Drain E

- Turnover within the wetlands would have been possible at least once during 14 out of 19 years (75% or 3 in 4 years).
- During 11 out of the 14 years between 1985 and 2004 when diversions at Callendale would have been possible, there was generally little difference in the potential volumes diverted to West Avenue in 8 of these years (75% or 3 in 4 years). This indicates that diverting water to Drain E may not heavily impact on the diversion of flow to West Avenue and the two diversion points could be jointly operated.

It was stated above that because of the importance of the West Avenue Watercourse and wetlands, the analysis undertaken assumed a maximum possible diversion of 195 ML/day to this system if available. However, there are also number of important wetlands on the Bakers Range Watercourse north of Fairview Drain, including the Deep Swamp Complex. In some years it may be preferable to divert less flow to West Avenue, allowing more water to flow through and turnover water within the Bakers Range wetlands.

IMPACT ON FLOW TO LAKE GEORGE

Community opposition to a reduction in flow to Lake George from Drain M is considered one of the main factors against redirecting flow from the Lower South East into the Upper South East. Figure 20 shows the proportions of flow at Woakwine, considered representative of the inflow to Lake George, from the catchments upstream and downstream of Callendale. The downstream catchment proportion contributes a mean annual flow of 22300 ML compared to the upstream catchment which produces a mean annual flow of 36000 ML. Therefore, if significant volumes of water were diverted prior at Callendale, the mean annual flows entering Lake George are likely to be reduced by an average of 50%. This reduction would be greater in higher rainfall and hence flow years.

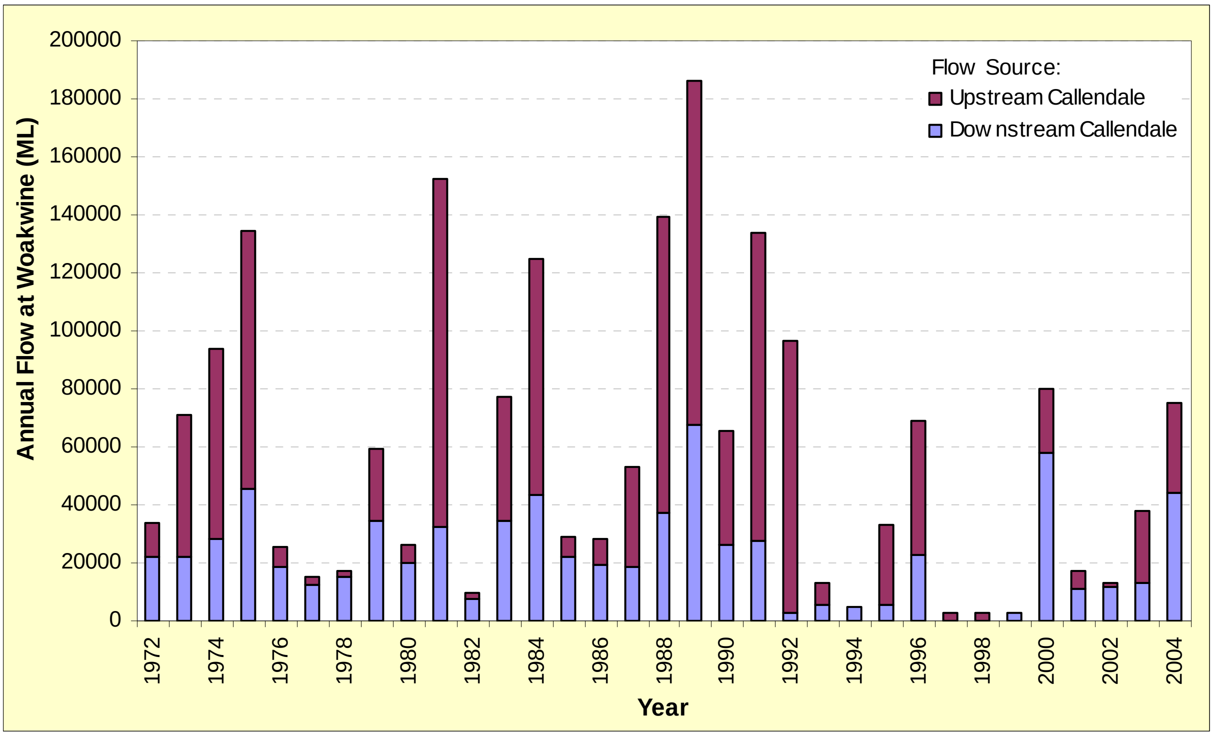


Figure 20 Proportion of Flow at Woakwine from Catchments Upstream and Downstream of Callendale.

The Reedy Creek Div B Drain currently flows into the Reedy Creek-Mt Hope Drain, then into Mullins Swamp and Lake Frome before entering the ocean (M. Talanskas, SEWCDB, *pers. comm.*, 2005). The installation of a regulator to redirect this flow into Drain M and then to Lake George could be investigated to compensate for any upstream flow diversions. The environmental requirements of Mullins Swamp and Lake Frome would also need to be considered.

Table 14 shows the reduction in flows to Lake George that may occur if the maximum volumes available were diverted at Bool Lagoon and/or Callendale. These are then presented in Figures 21 to 23 together with the percentage decreases in flow resulting from each scenario.

Table 14 Impact of Diversion Scenarios on Lake George.

Year	Historical Flow to Lake George (ML)	Bool Lagoon Diversion		Bakers Range Diversion		Bool Lagoon and Bakers Range Diversion		
		Flow to Drain E (ML)	Adjusted Flow to Lake George (ML)	Flow to Bakers Range (ML)	Adjusted Flow to Lake George (ML)	Flow to Drain E (ML)	Flow to Bakers Range (ML)	Adjusted Flow to Lake George (ML)
1972	33571	0	33571	7911	25660	-	-	-
1973	70883	30807	40076	33884	37000	-	-	-
1974	93739	29788	63951	60565	33174	-	-	-
1975	134789	21619	113171	74479	60310	-	-	-
1976	25750	0	25750	4656	21094	-	-	-
1977	14931	0	14931	0	14931	-	-	-
1978	16989	0	16989	0	16989	-	-	-
1979	59322	11023	48299	18819	40503	-	-	-
1980	26522	0	26522	4912	21610	-	-	-
1981	152521	51130	101391	53411	99110	-	-	-
1982	9326	0	9326	0	9326	-	-	-
1983	77275	15090	62185	27777	49498	-	-	-
1984	124511	32133	92378	48348	76163	-	-	-
1985	29101	1126	27975	5137	23964	1126	4355	23647
1986	28442	1170	27272	5861	22581	1170	4717	22668
1987	53105	18787	34318	32843	20262	18787	14051	20328
1988	139416	48292	91125	79192	60225	48292	49762	42253
1989	186236	5854	180382	81070	105166	5854	80818	105166
1990	65734	6512	59221	34661	31072	6512	30823	28398
1991	133523	26292	107231	52117	81406	26292	45827	61408
1992	96490	60353	36137	75456	21034	60353	32785	5280
1993	13335	8991	4344	3345	9991	8991	0	6989
1994	5023	0	5023	0	5023	0	0	5023
1995	33145	19919	13227	24374	8772	19919	6669	6572
1996	68772	23511	45260	32696	36076	23511	21034	24800
1997	2196	0	2196	0	2196	0	0	2196
1998	2934	0	2934	0	2934	0	0	2934
1999	2537	0	2537	0	2537	0	0	2537
2000	79996	0	79996	19096	60900	0	19096	60900
2001	17490	0	17490	4732	12758	0	4732	12758
2002	12872	0	12872	0	12872	0	0	12872
2003	37703	0	37703	24351	13353	0	24351	13353
2004	75207	8515	66692	26514	48693	8515	21442	45250

A reduction of the inflow to Lake George that only considers diversions from Bool Lagoon into Drain E is shown in Figure 21. If the maximum diversions were undertaken then the "Drain M" (blue) flow direction component would be the total flow to pass Callendale. The "Drain E" (yellow) component represents the flow diverted north from Bool Lagoon, and the "Bakers Range Watercourse" (maroon) component represents the flow diverted north from Callendale along Bakers Range Watercourse. Releases from Bool Lagoon and hence water available for diversion has been estimated for the period from 1972 to 1984. It is highly likely that releases only occurred in 7 out of these 13 years. The releases were estimated as any excess volume over an annual inflow into Bool Lagoon of 20,000 ML. The water requirements of the Big Heath Conservation Park were not considered in this investigation, but would need to be evaluated if releases from Bool Lagoon were undertaken.

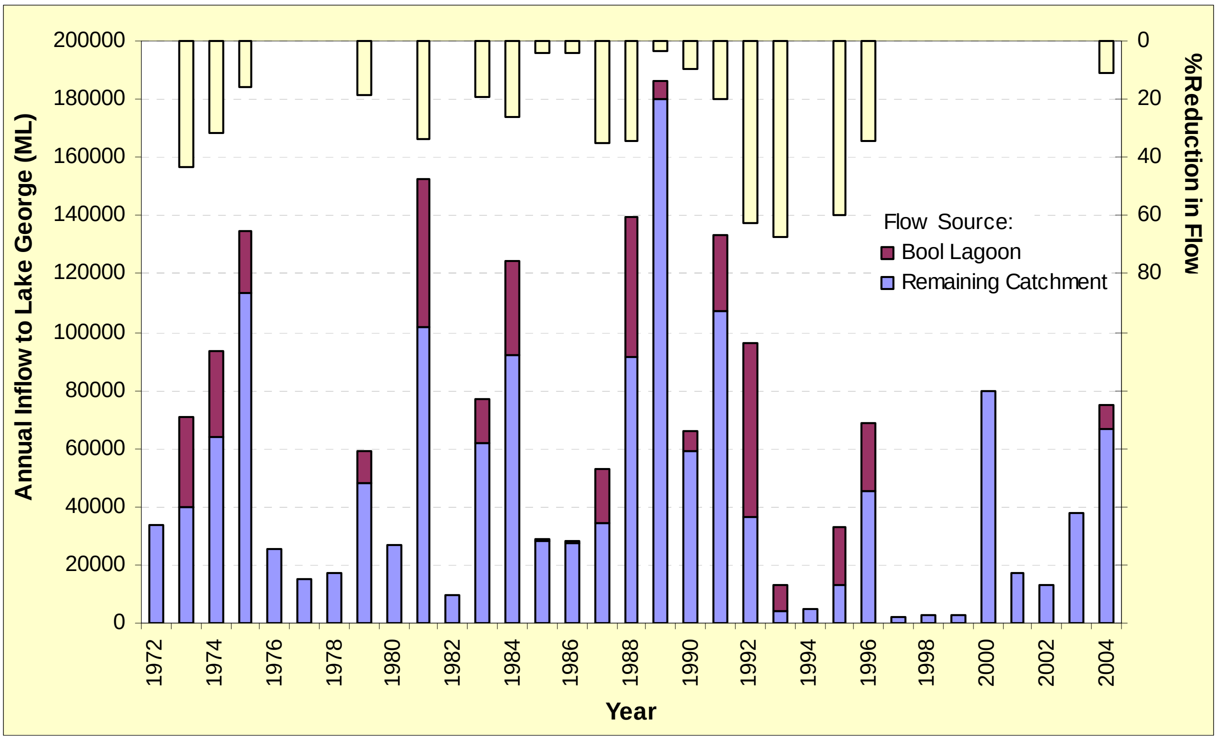


Figure 21 Annual Flow to Lake George with Diversions from Bool Lagoon.

Figure 22 shows the likely annual inflows to Lake George and reductions from current flows for the period 1972 to 2004 if diversions were only conducted at Callendale into Bakers Range Watercourse. The total height of the "flow component" columns equals the current total inflow to Lake George. The reduction in this flow from diversion to Bakers Range is equal to the "Bakers Range Diversion" (maroon) component and hence the adjusted inflow to Lake George is equal to the "Remaining Catchment" (blue) component. The percentage reduction in flow due to this diversion is also shown. Because larger volumes of flow have the potential to be diverted north, the impact on flows into Lake George increases under this scenario.

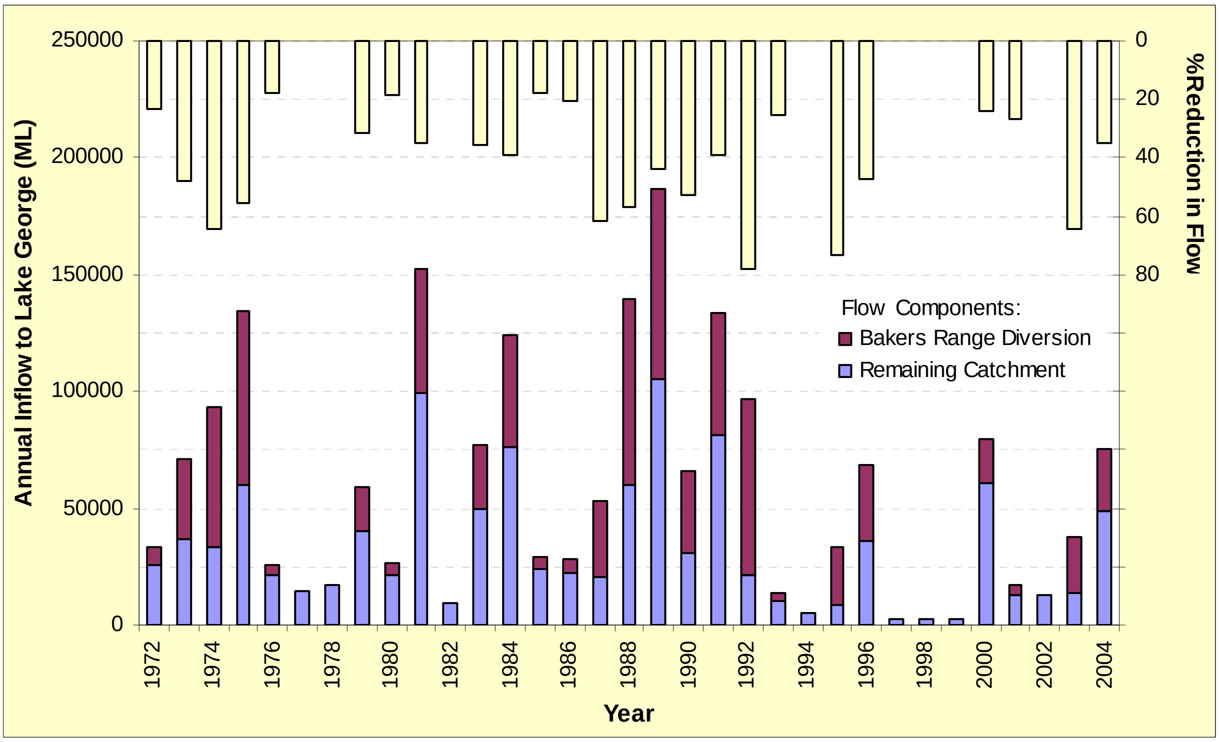


Figure 22 Annual Flow to Lake George with Diversions from Callendale.

Finally, Figure 23 shows the impact on flows to Lake George if water was diverted from both Bool Lagoon and Callendale. Again, the total height of the "flow component" columns equals the current total inflow to Lake George. If water was diverted from Bool Lagoon, the volume entering Lake George would reduce by the "Bool Lagoon Diversion" (green) component of this current inflow. Conversely, if flow was diverted to Bakers Range Watercourse, the volume entering Lake George would reduce by the "Bakers Range Diversion" (maroon) component. Therefore, if diversions at both locations were conducted, the new inflow to Lake George would be equal to the "Remaining Catchment" (blue) component of the current total flow. The percentage reduction in flow assuming diversions from both locations is also provided. While it was only possible to examine this scenario for the period 1985 to 2004, it shows little difference to the impact of diverting flow into Bakers Range Watercourse alone. This is because any flow not diverted at Bool Lagoon is likely to be diverted at Callendale instead. If it is only possible to divert at one point, the relative importance of the Drain E and Bakers Range systems would need to be examined to determine which diversion point is preferable.

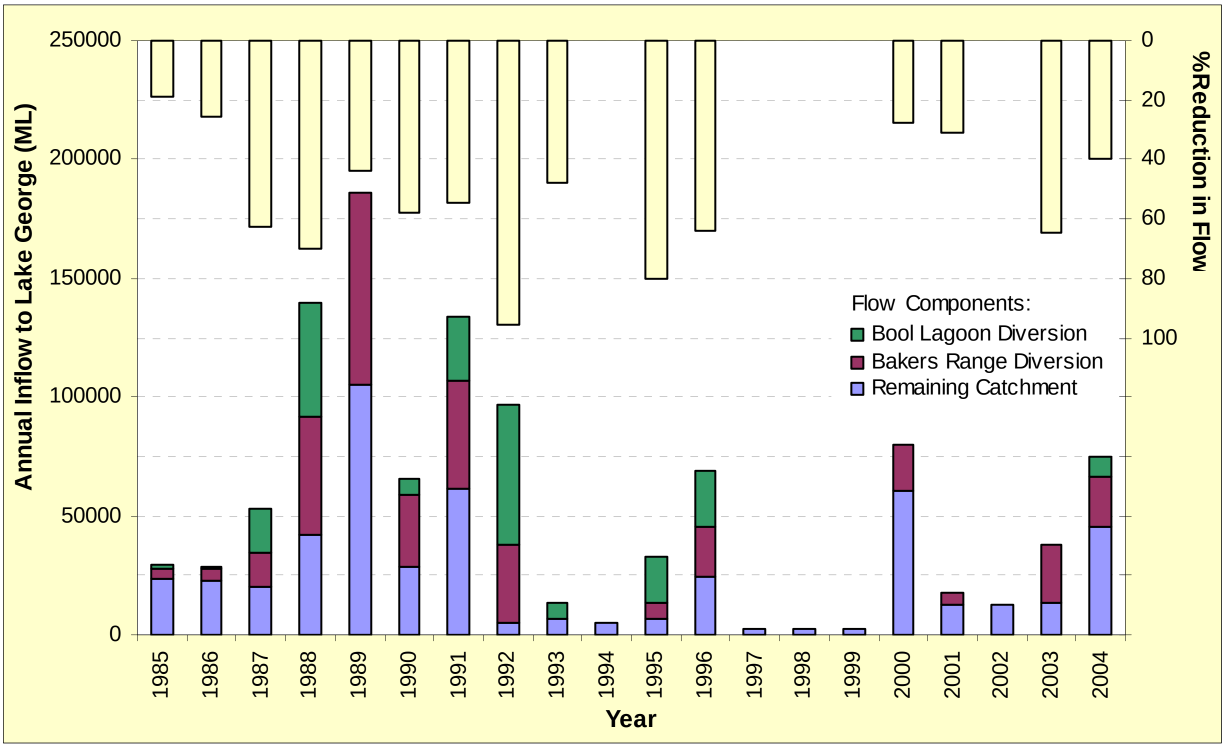


Figure 23 Annual Flow to Lake George with Diversions from Bool Lagoon and Callendale.

CONCLUSIONS AND RECOMMENDATIONS

This preliminary hydrological investigation has attempted to provide a guide to the potential volume and frequency of flows available for diversion from the Lower South East into the Upper South East. Two diversion points were investigated, namely from Bool Lagoon north along the old Mosquito Creek channel into Drain E, and from Callendale along the Bakers Range Watercourse. Figure 24 details the results of this investigation.

It has been shown that diversions to both Drain E and Bakers Range could provide valuable environmental flows to these systems. Diversions to Drain E from Bool Lagoon would greatly enhance the wetlands along both Drain E and the Marcollat Watercourse. Because the current drainage and conservation requirements for Bool Lagoon need to be maintained, it should be noted that if there is an alternative flow path north to Drain E, it may be possible to retain additional water within Bool Lagoon for longer, while still maintaining the ability to store large events from Mosquito Creek when they occur.

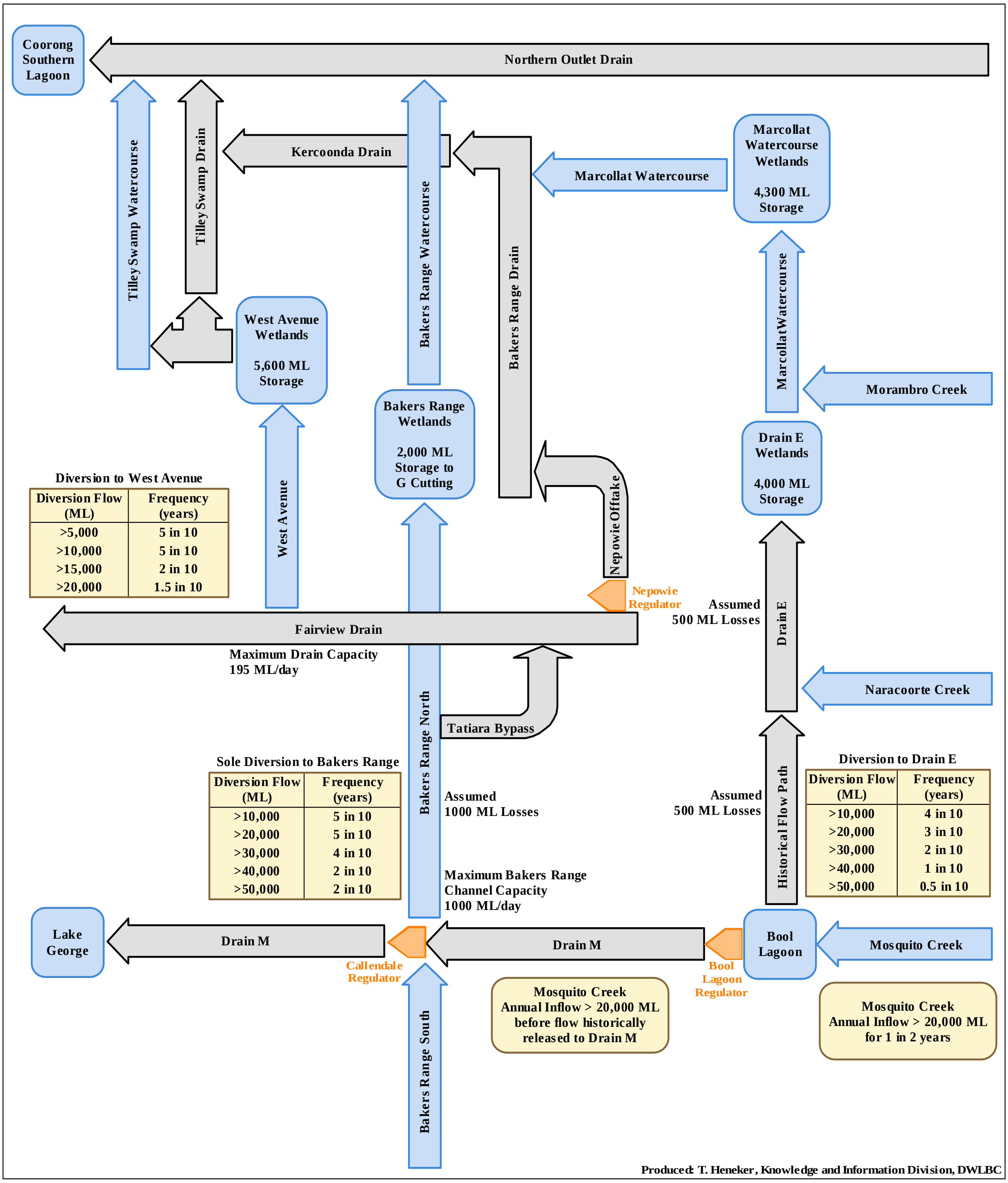
Diversions into the Bakers Range Watercourse at Callendale have the potential to be diverted to the West Avenue Watercourse (via Fairview Drain), providing much needed flows for the wetlands in this system. Wetlands on the Bakers Range Watercourse north of Fairview Drain would also benefit.

There is only limited water available for diversion and some wetland systems such as West Avenue are likely to be considered a higher priority than others in the Upper South East. However, although a decision on flow diversion priorities will be required, this preliminary study has shown that, in certain circumstances, diverting water into Drain E does not significantly reduce the available water for diversion to West Avenue.

The impact on Lake George in terms of reduced inflow from such diversions has also been considered. However, the impact of these reductions in terms of water level and ecology within Lake George has not been considered within this investigation.

Large deficiencies in available hydrological data and operational information currently preclude more than this preliminary analysis. However, the results show the potential to significantly supplement flows in the Upper South East. It is highly recommended that a feasibility study be conducted to further investigate the potential of flow diversions and refine the estimates presented here. Before such a feasibility is undertaken, it is imperative that a number of issues be considered and information gathered to facilitate such a detailed study. These include (but are not limited to):

- Diversion from Bool Lagoon:
  - Collect any historical Bool Lagoon water level data (gauge board readings).
  - Verify Bool Lagoon water level to volume relationship (Nitschke, 1984) to allow modelling of this storage. This should allow an estimation of the inflow from the Seymour and Robertson Drains and hence a better estimation of the total inflow.
  - Obtain details of the operation of Bool Lagoon outlet regulator to allow a better estimate of historical releases during the period of inflow records.
  - Review existing ratings at all gauging stations.
  - Obtain details of any historical flow diversions through the old Mosquito Creek channel as detailed in Bool Lagoon Operation Guidelines (Nitschke, 1984).
  - Verify location and capacity of the Mosquito Creek and Straun Relief Drains and quantify the impact on recorded inflows at the gauging station A2390519.



Diversion to West Avenue

Diversion Flow (ML)	Frequency (years)
>5,000	5 in 10
>10,000	5 in 10
>15,000	2 in 10
>20,000	1.5 in 10

Sole Diversion to Bakers Range

Diversion Flow (ML)	Frequency (years)
>10,000	5 in 10
>20,000	5 in 10
>30,000	4 in 10
>40,000	2 in 10
>50,000	2 in 10

Diversion to Drain E

Diversion Flow (ML)	Frequency (years)
>10,000	4 in 10
>20,000	3 in 10
>30,000	2 in 10
>40,000	1 in 10
>50,000	0.5 in 10

Figure 24 Water Resource Availability for Diversion from the Lower South East into the Upper South East.

- Obtain accurate capacities and volume to surface area relationships for the wetlands along Drain E and the Marcollat Watercourse to facilitate more accurate modelling of diverting water through these systems.
- Determine likely characteristics of an upgraded historical Mosquito Creek channel to better estimate losses.

- Diversion from Callendale:
  - Obtain details of the operation of Callendale Regulator and periods when flow has historically been diverted into Bakers Range Watercourse.
  - Complete the processing of water level data from gauging station A2391001 on the southern Bakers Range Watercourse.
  - Obtain accurate capacities and volume to surface area relationships for the wetlands along Bakers Range Watercourse to facilitate modelling of diverting water into this system.
  - Obtain accurate capacities and volume to surface area relationships for the wetlands along West Avenue Watercourse to facilitate modelling of diverting water into this system.
  - Determine the characteristics and storage capacity of the Big Heath Conservation Park and Mary Seymour Conservation Park.
  - Consider a minimum threshold value for the diversion of water north along Bakers Range Watercourse from Callendale.
- Impact on Lake George:
  - Obtain details of the Lake George Regulator operations and any operating rules.
  - Obtain the operational history of the Mt Bruis and Magerys Regulators to enable calculation of flow delays and losses.
  - Calculate potential increase in flow at Woakwine from diversion of the Reedy Creek Div B Drain into Drain M via the Reedy Creek-Mount Hope Drain.

APPENDIX A POTENTIAL DIVERSIONS AT CALLENDALE

This appendix presents the potential volumes during the years 1972 to 2004 available for diversion into Bakers Range Watercourse at Callendale when this is the sole diversion point. These figures highlight the potential for extended periods of flow diversion into Bakers Range as well as demonstrating the influence of the minimum flow diversion threshold on total diversions and the number of days. Those years when no flow was available for diversion at any threshold flow have been excluded.

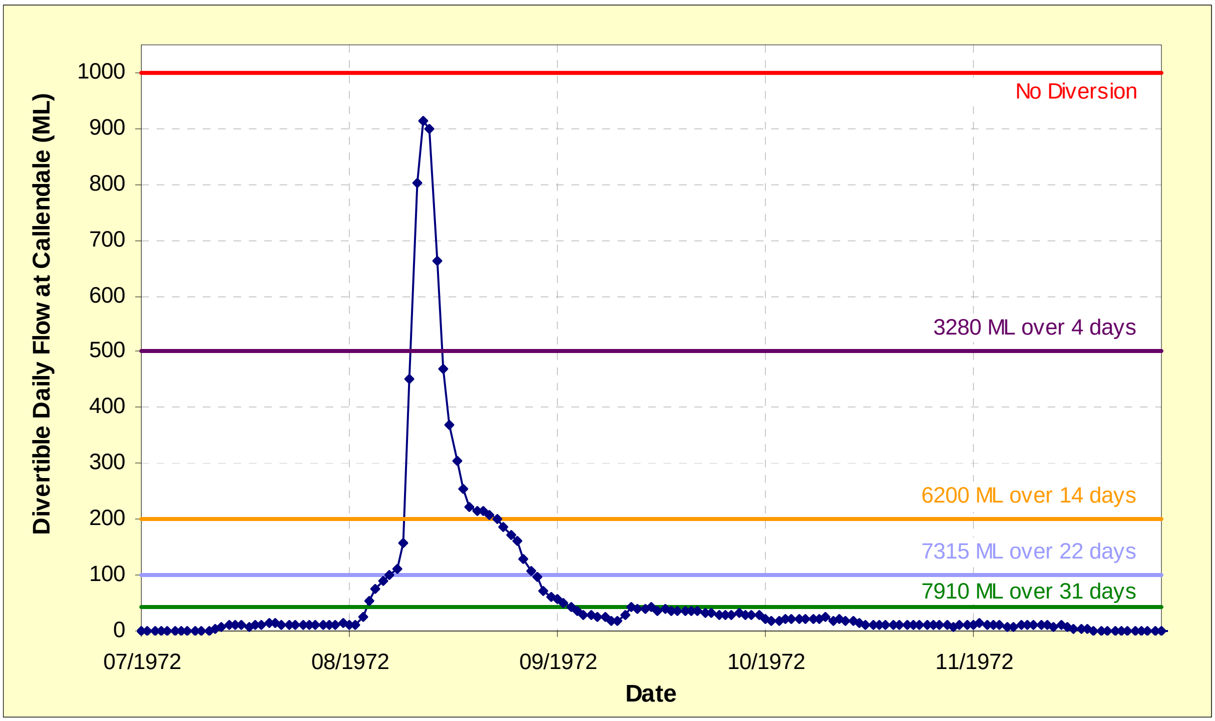


Figure A.1 Hydrograph Showing 1972 Potential Diversions at Callendale.

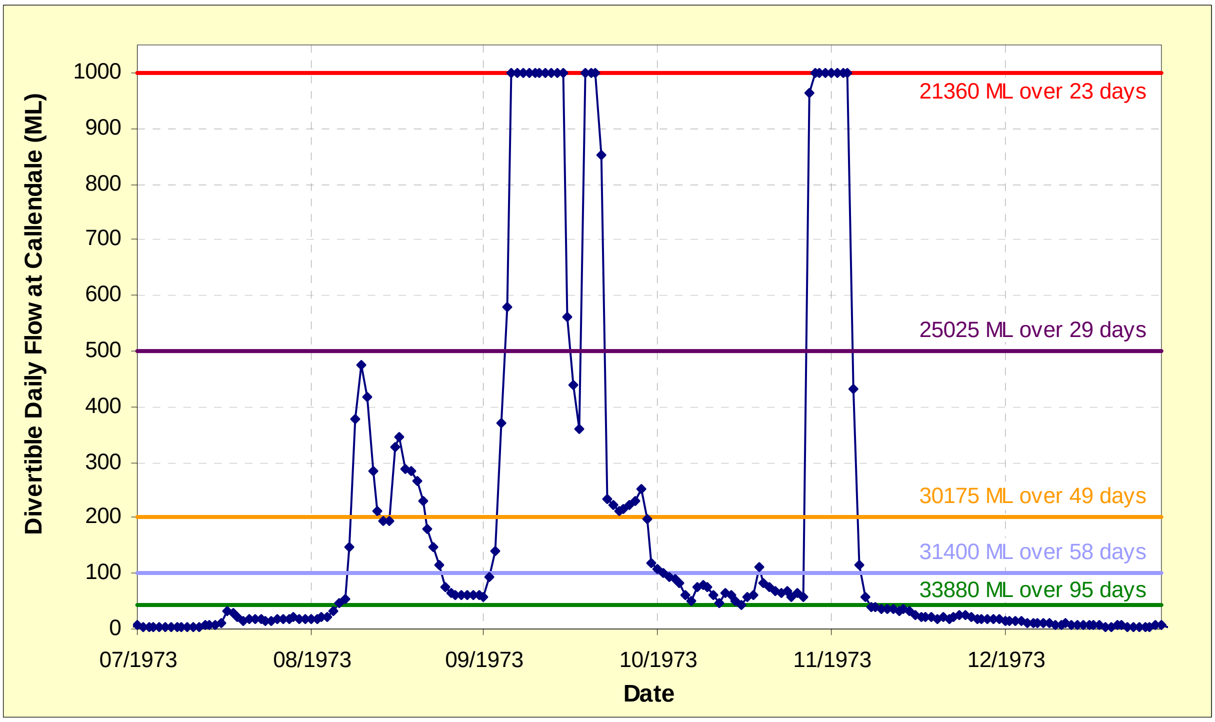


Figure A.2 Hydrograph Showing 1973 Potential Diversions at Callendale.

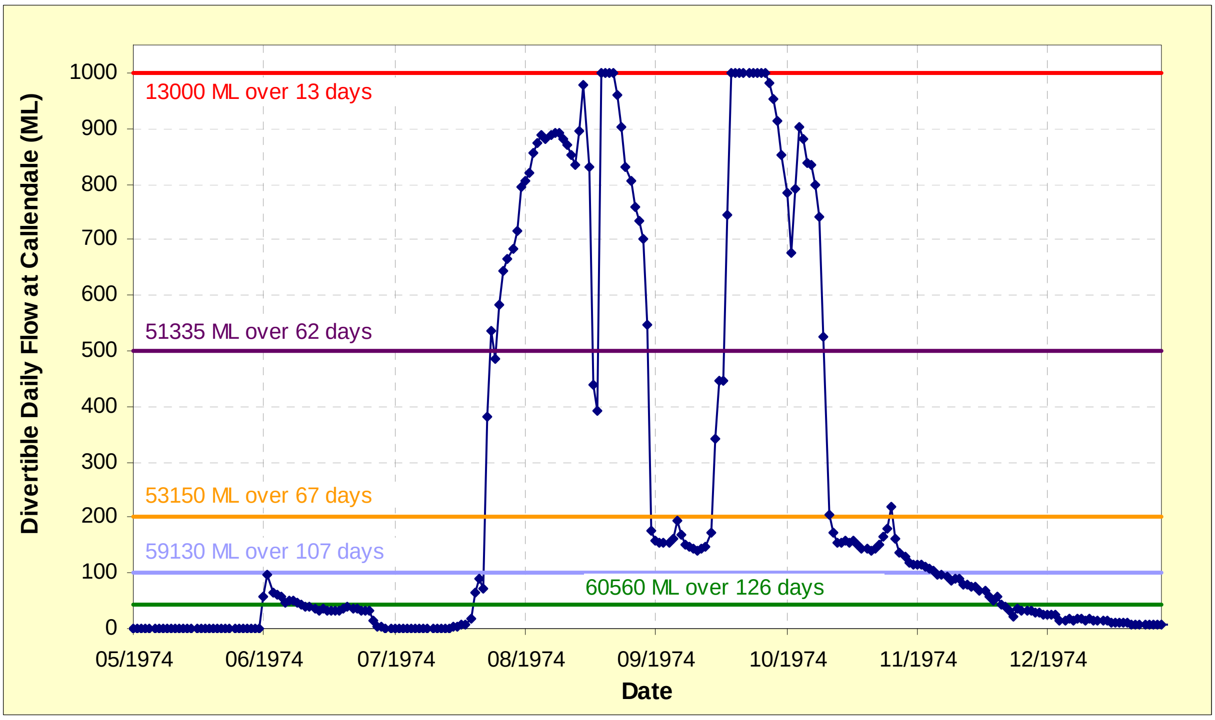


Figure A.3 Hydrograph Showing 1974 Potential Diversions at Callendale.

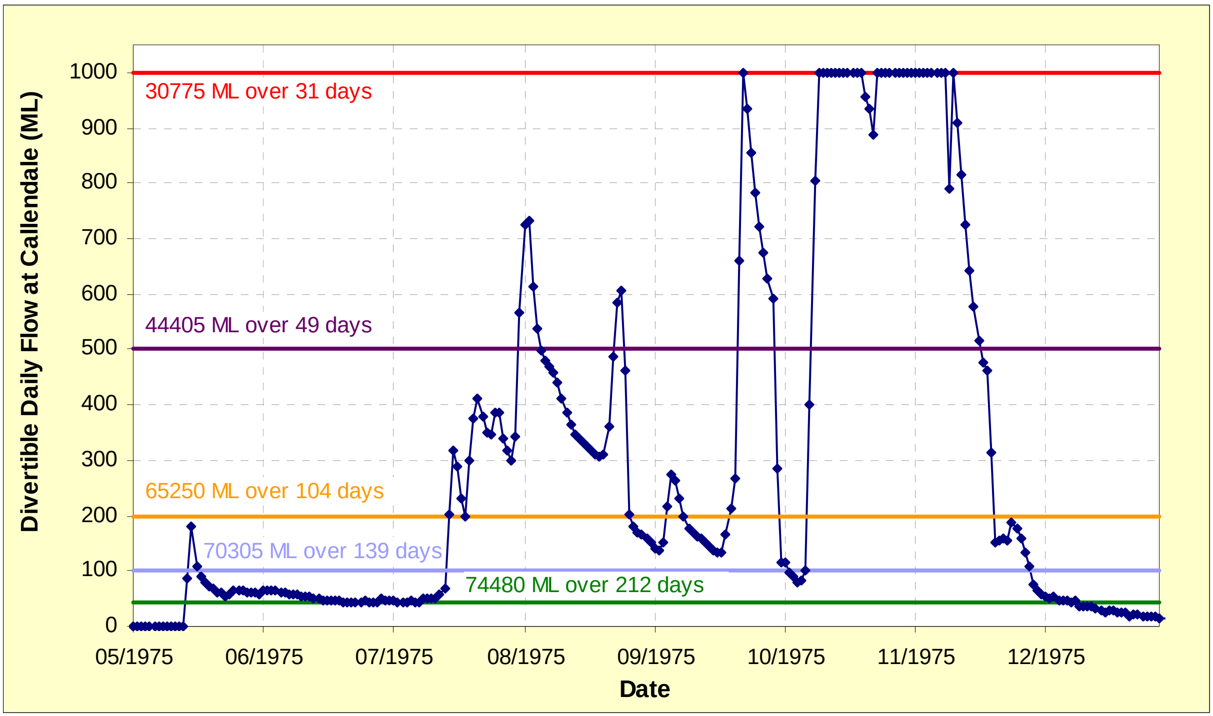


Figure A.4 Hydrograph Showing 1975 Potential Diversions at Callendale.

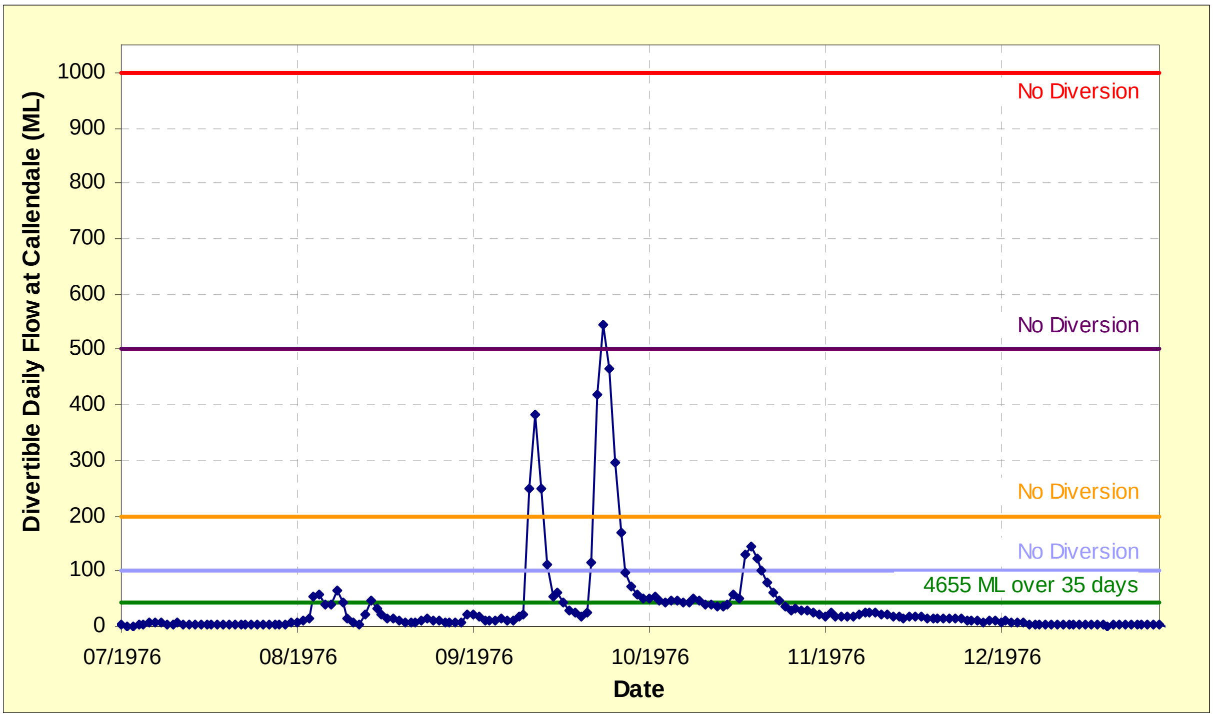


Figure A.5 Hydrograph Showing 1976 Potential Diversions at Callendale.

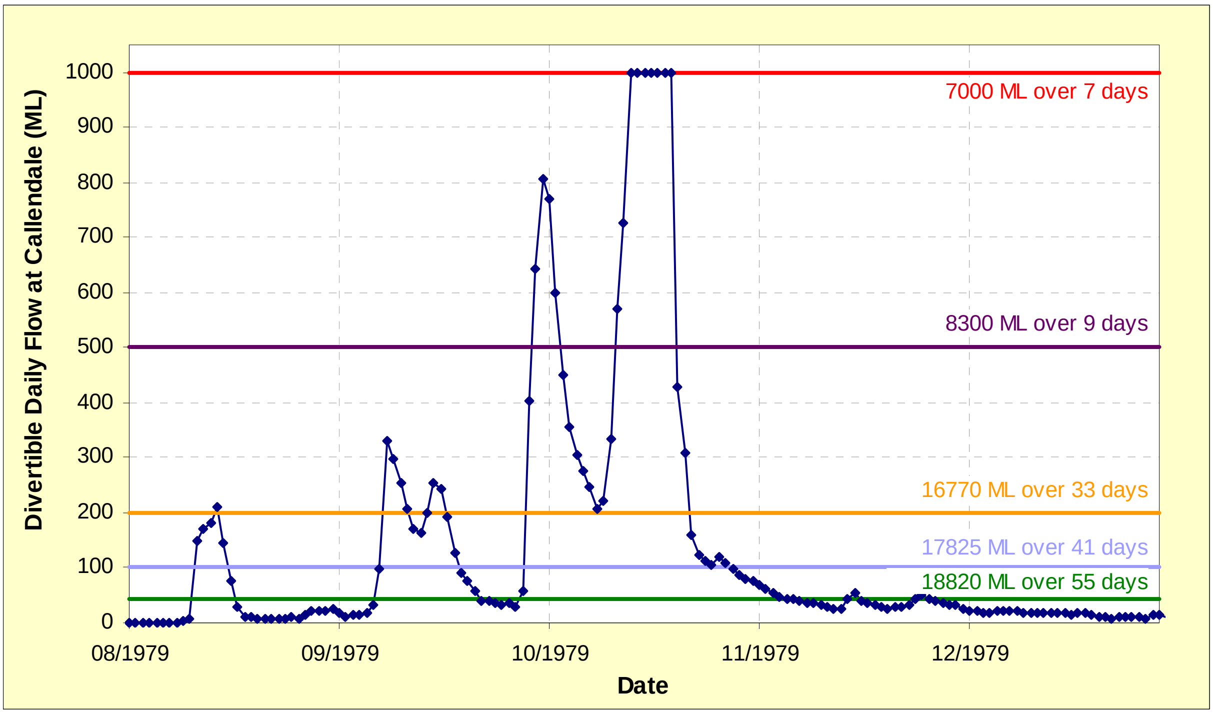


Figure A.6 Hydrograph Showing 1979 Potential Diversions at Callendale.

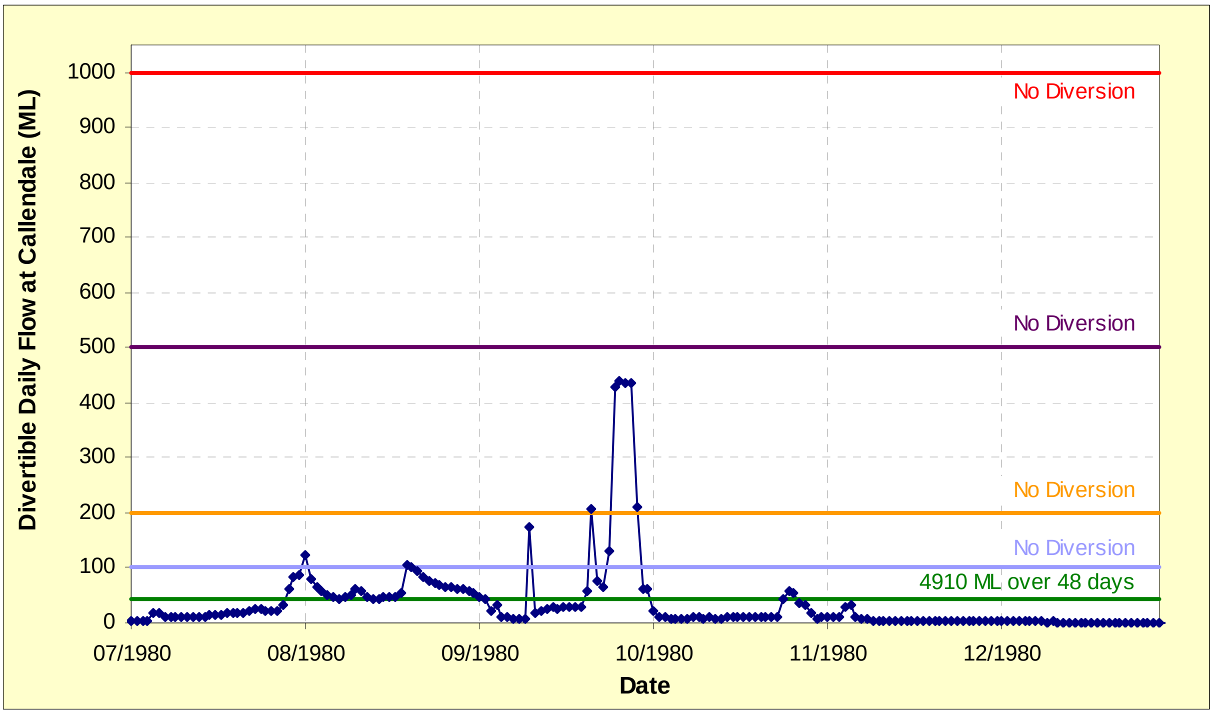


Figure A.7 Hydrograph Showing 1980 Potential Diversions at Callendale.

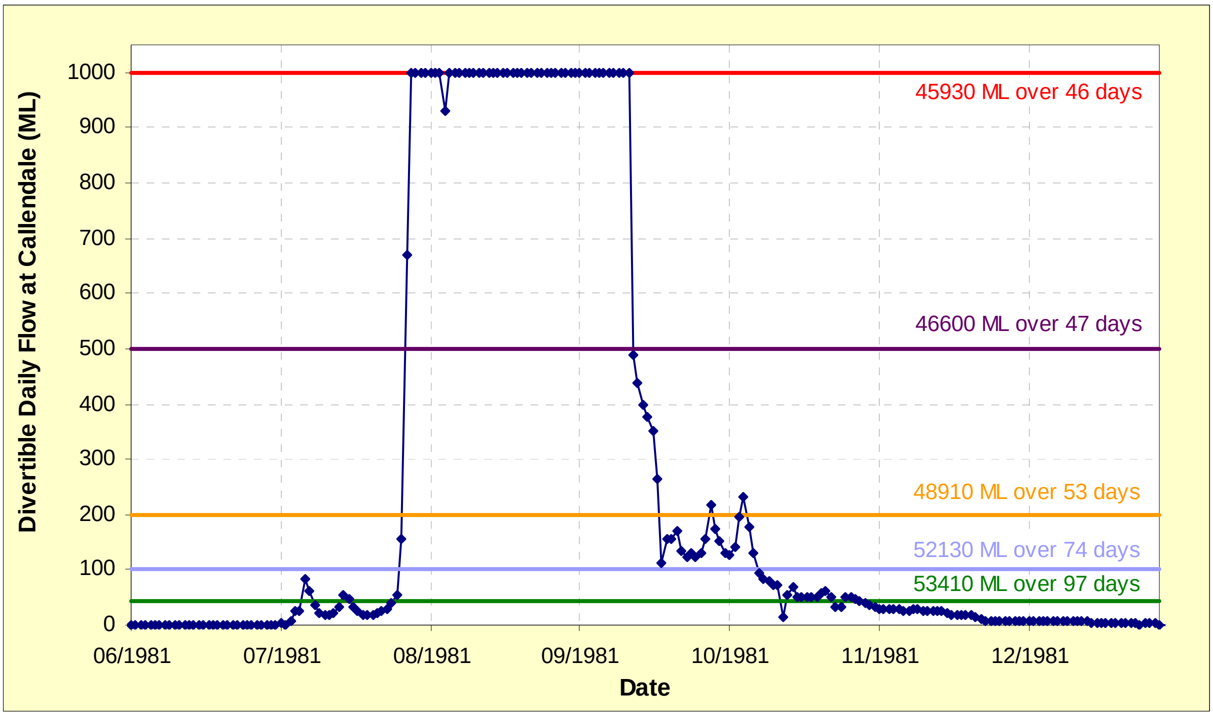


Figure A.8 Hydrograph Showing 1981 Potential Diversions at Callendale.

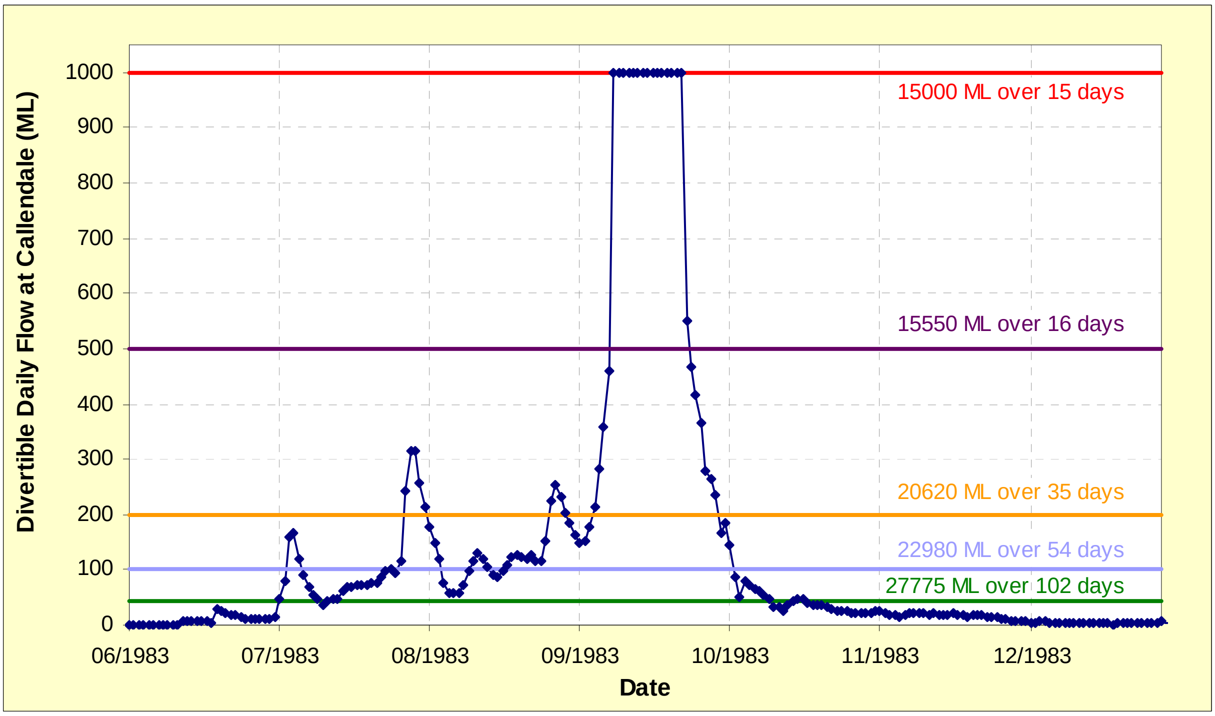


Figure A.9 Hydrograph Showing 1983 Potential Diversions at Callendale.

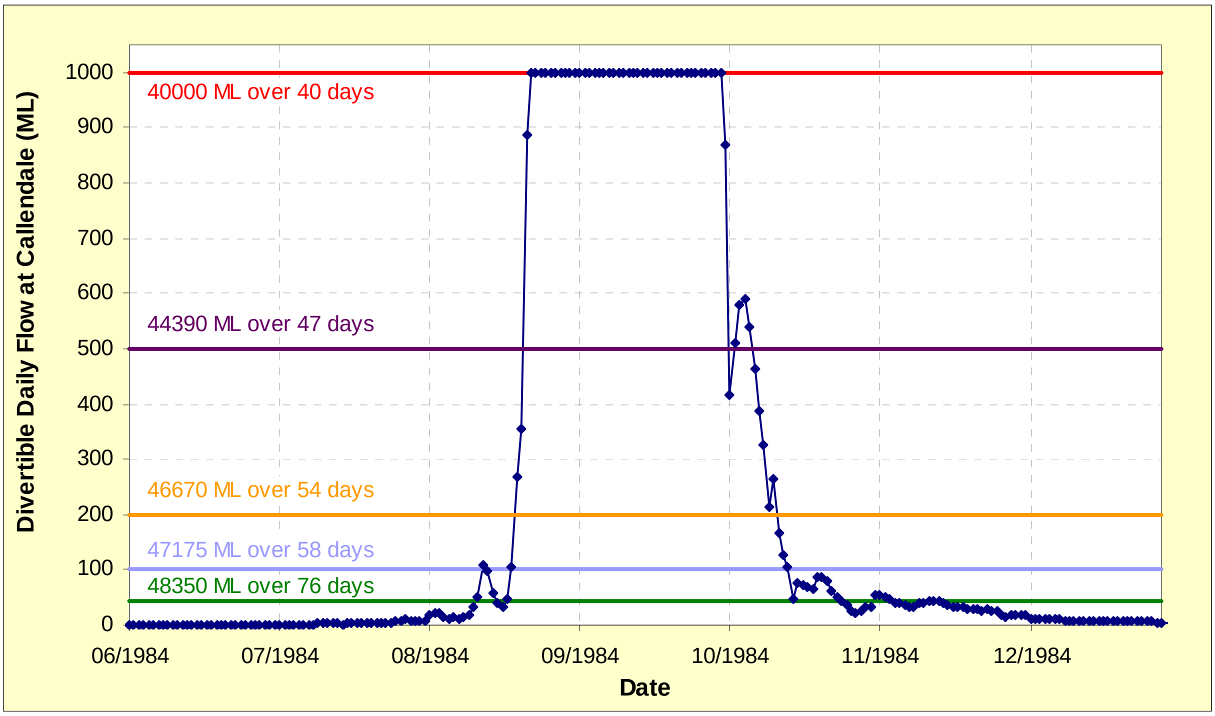


Figure A.10 Hydrograph Showing 1984 Potential Diversions at Callendale.

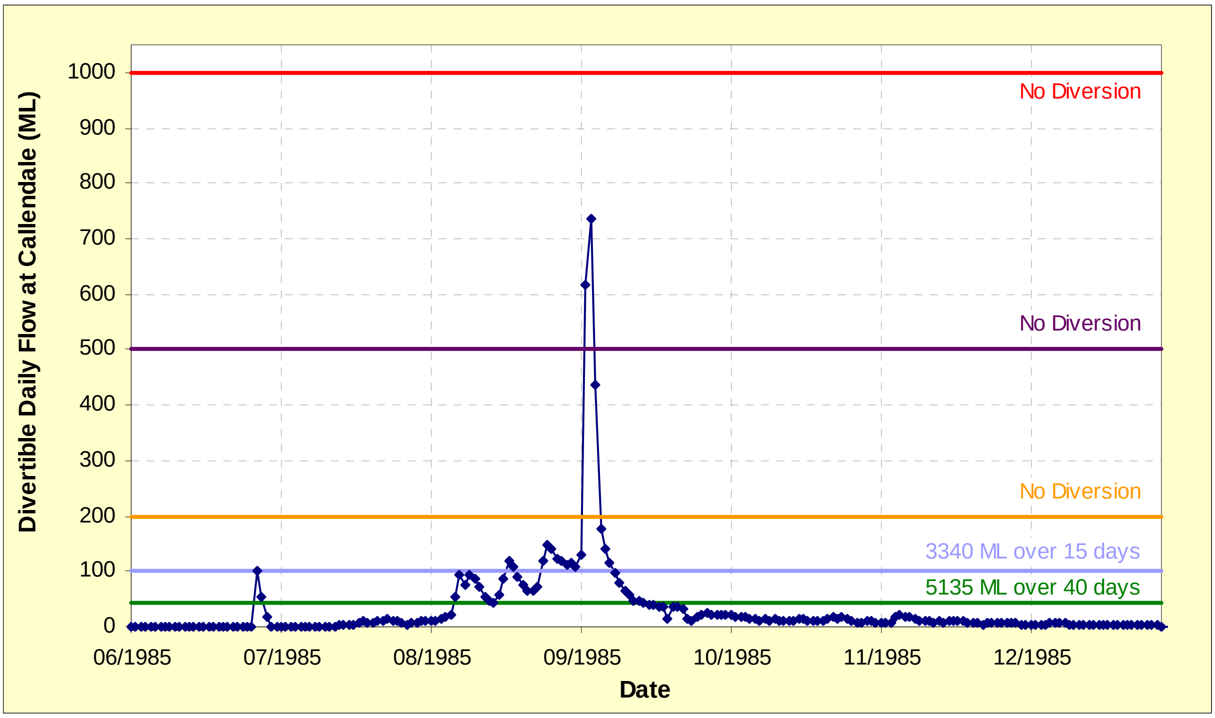


Figure A.11 Hydrograph Showing 1985 Potential Diversions at Callendale.

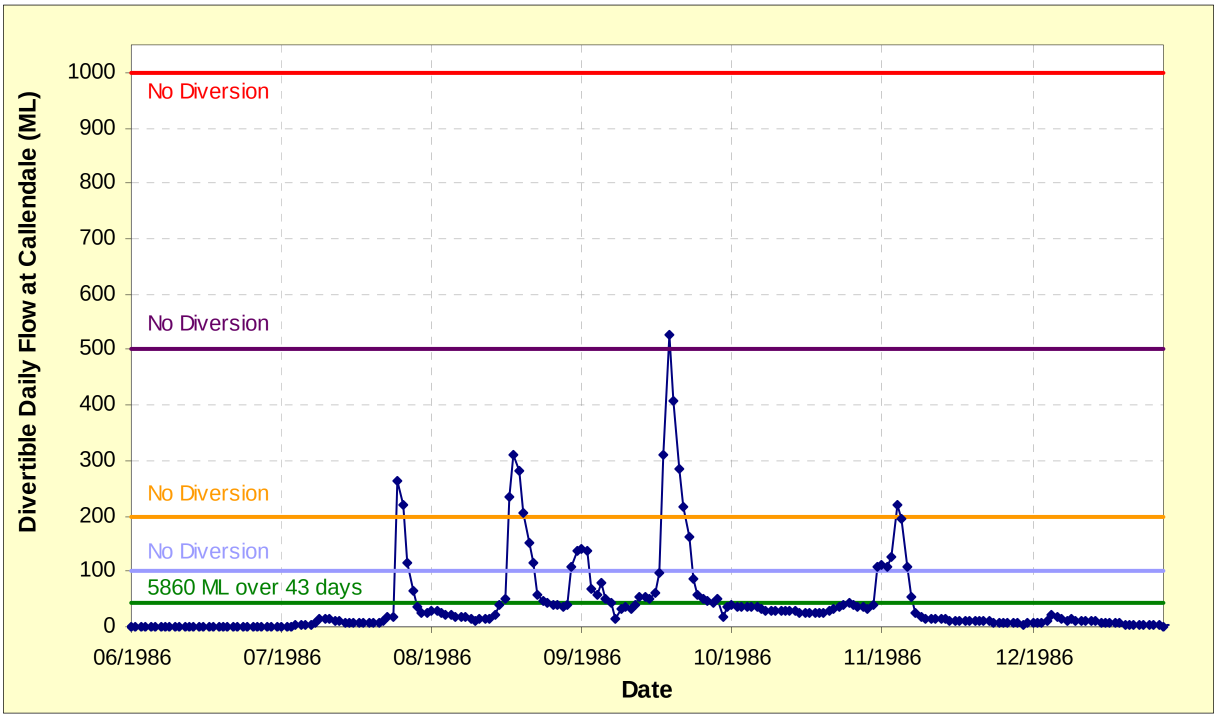


Figure A.12 Hydrograph Showing 1986 Potential Diversions at Callendale.

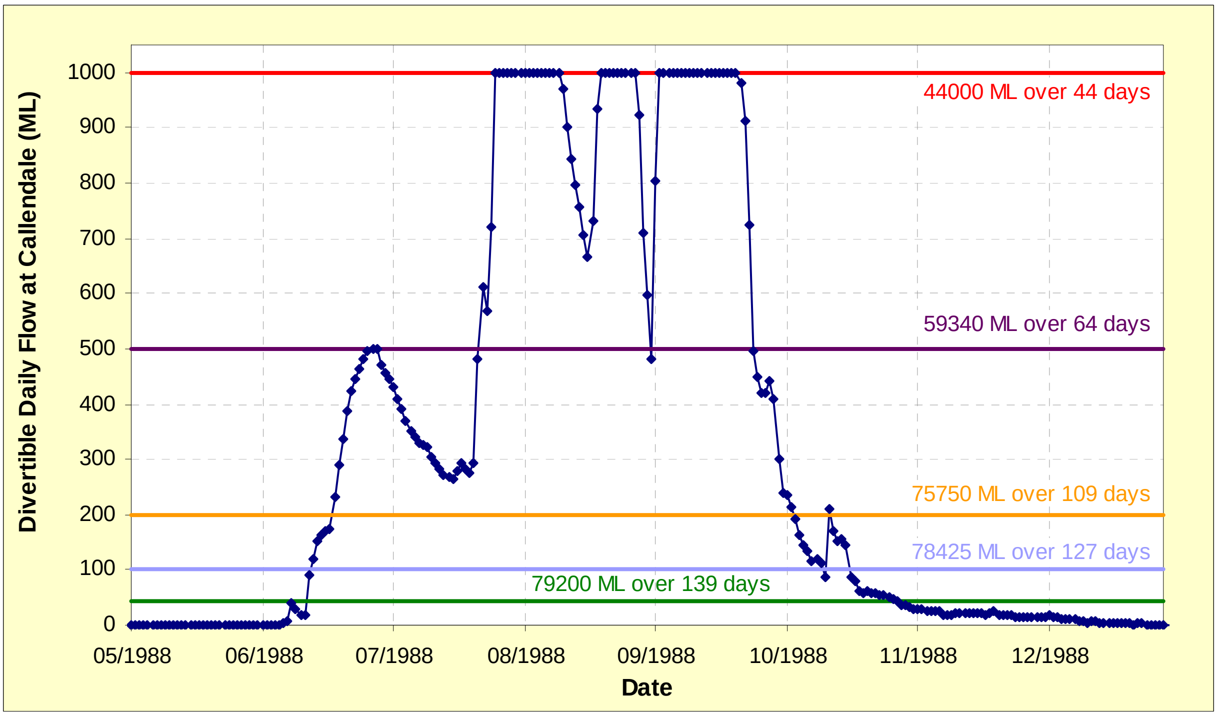


Figure A.13 Hydrograph Showing 1988 Potential Diversions at Callendale.

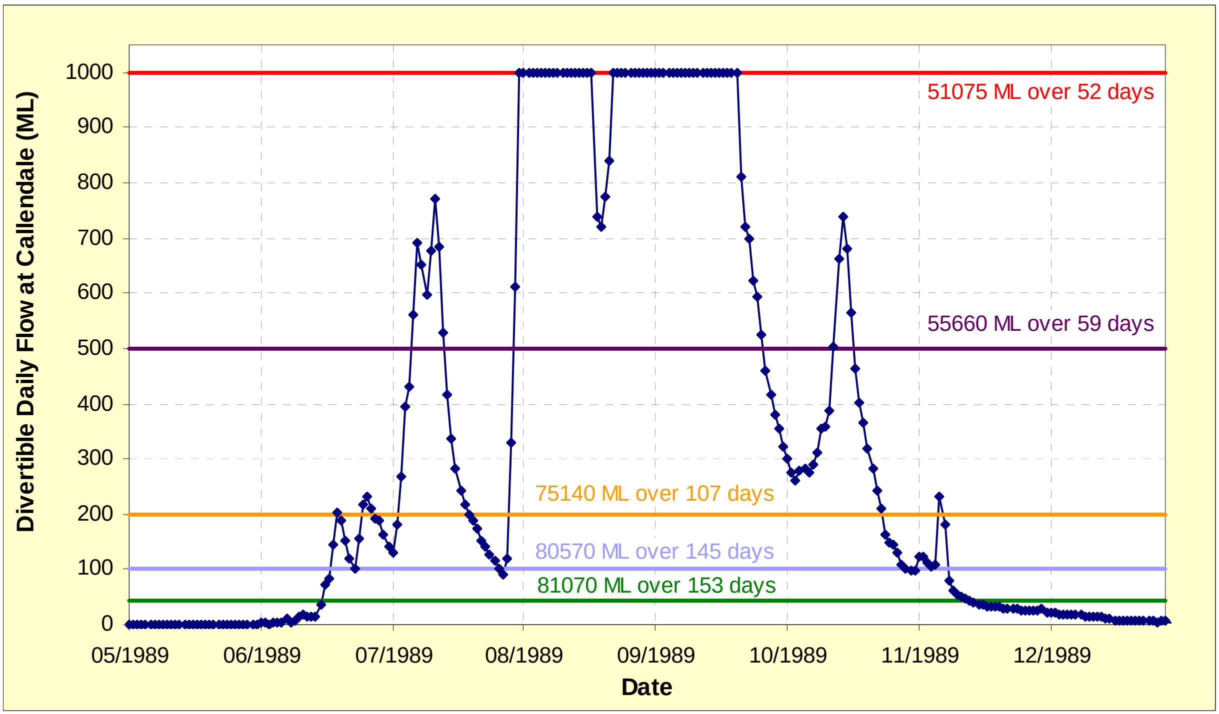


Figure A.14 Hydrograph Showing 1989 Potential Diversions at Callendale.

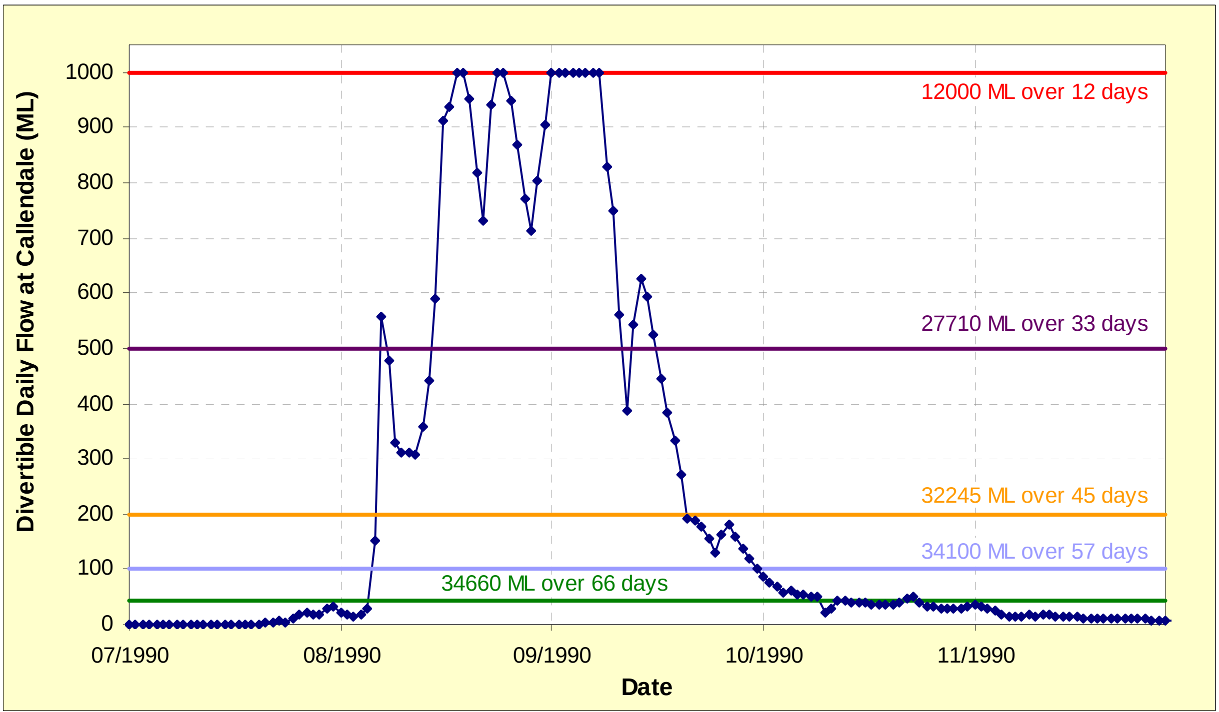


Figure A.15 Hydrograph Showing 1990 Potential Diversions at Callendale.

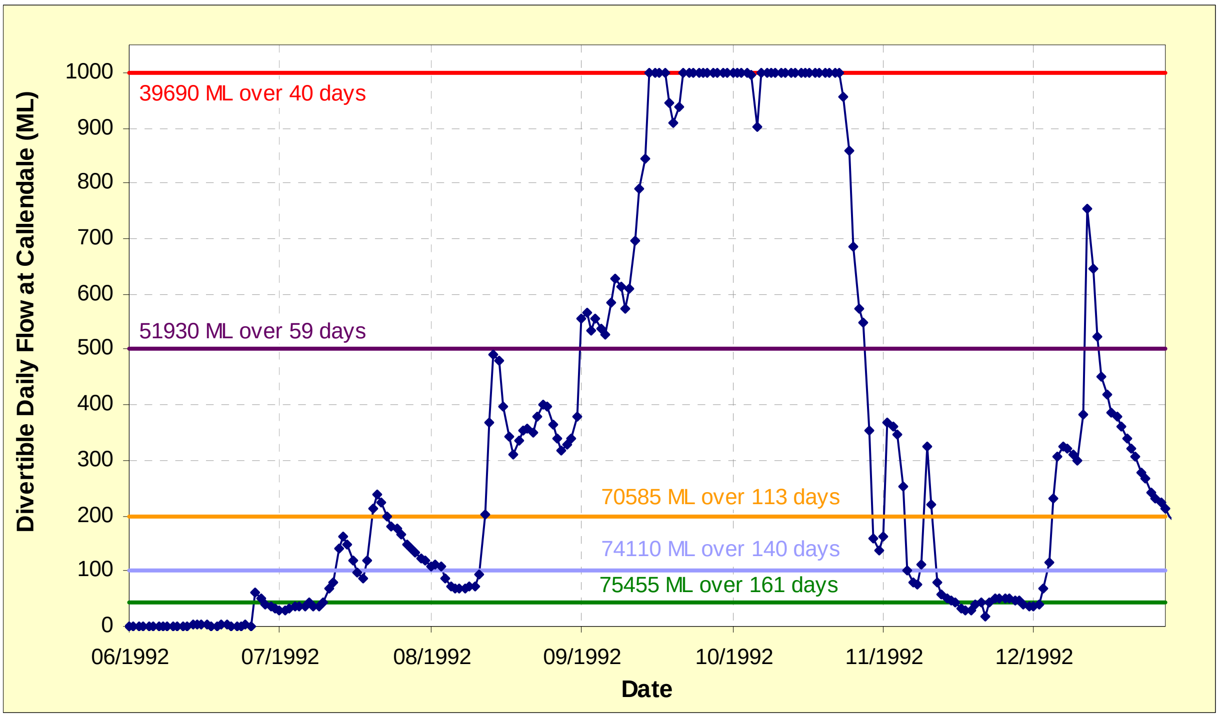


Figure A.16 Hydrograph Showing 1992 Potential Diversions at Callendale.

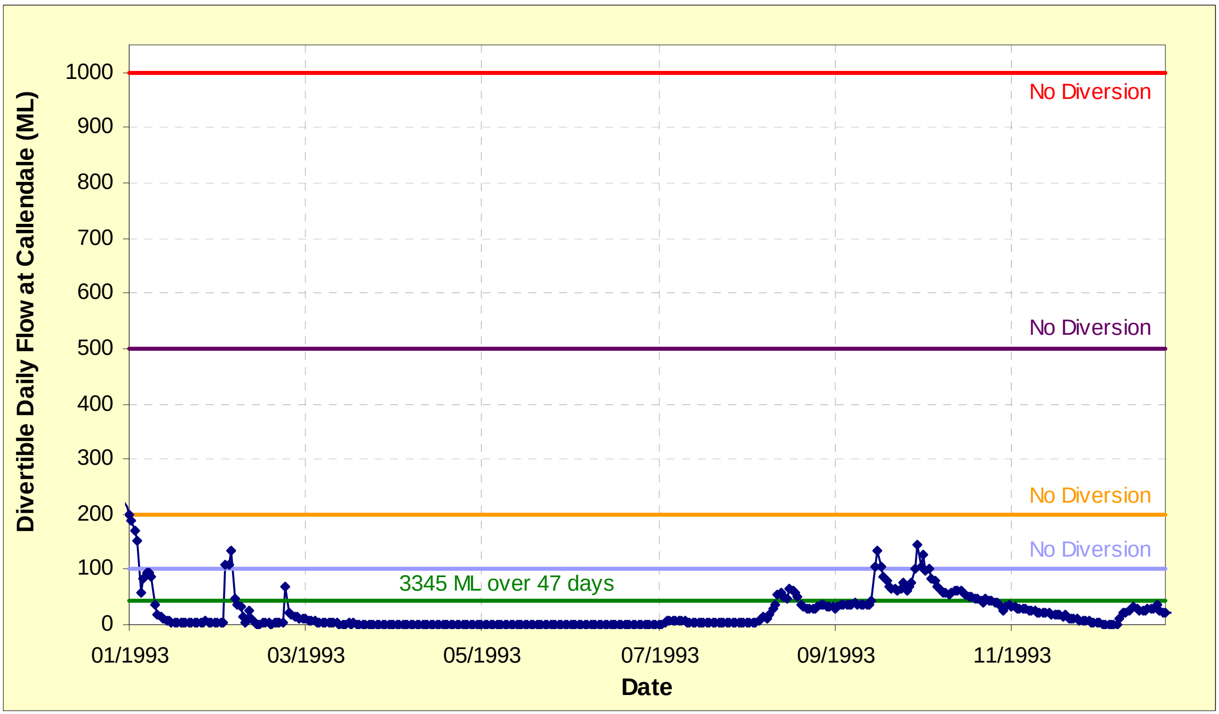


Figure A.17 Hydrograph Showing 1993 Potential Diversions at Callendale.

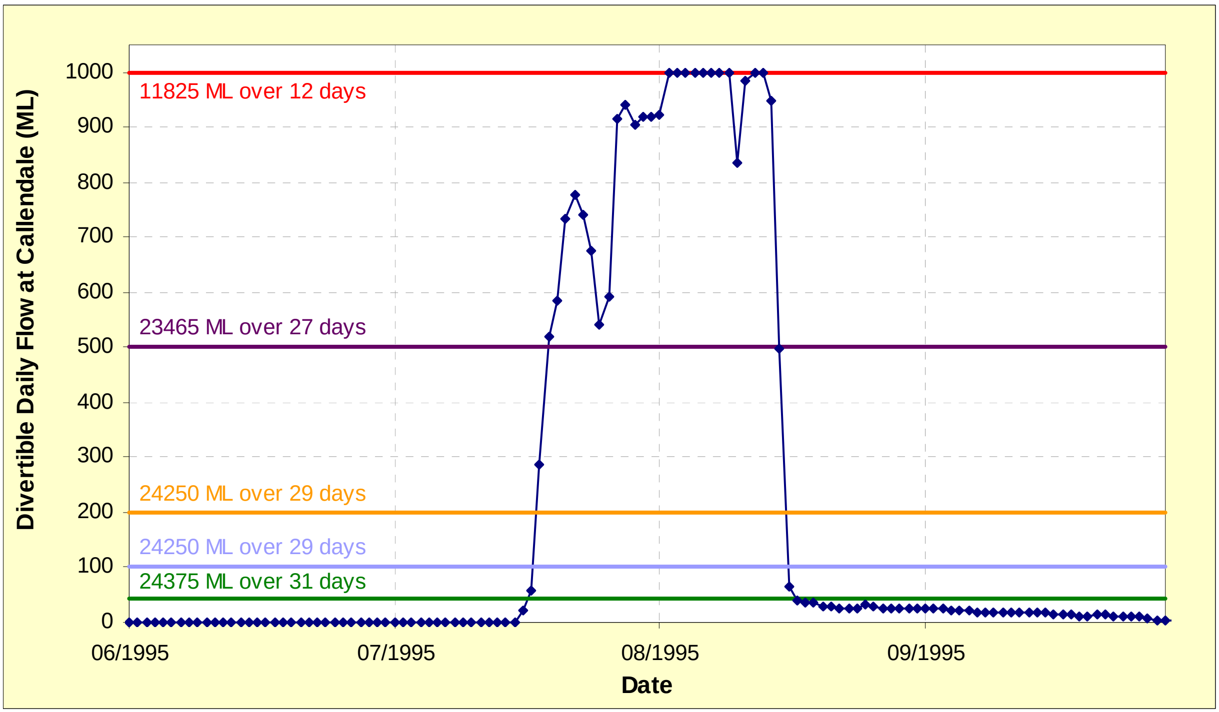


Figure A.18 Hydrograph Showing 1995 Potential Diversions at Callendale.

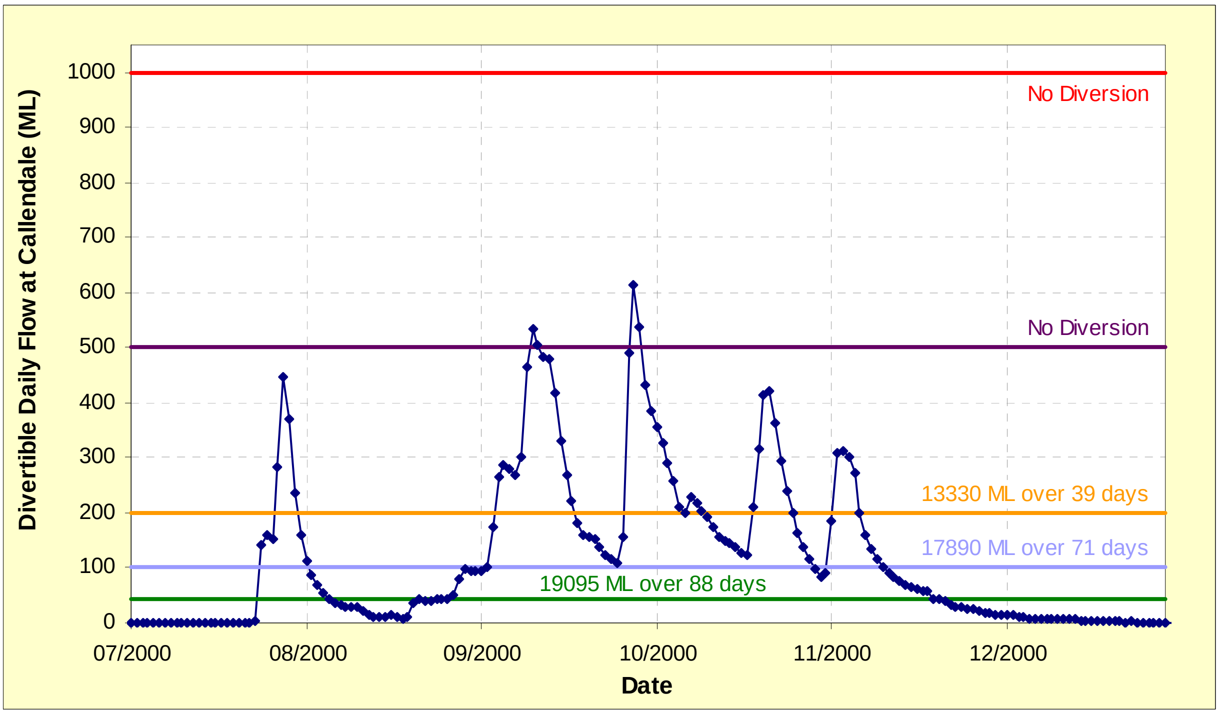


Figure A.19 Hydrograph Showing 2000 Potential Diversions at Callendale.

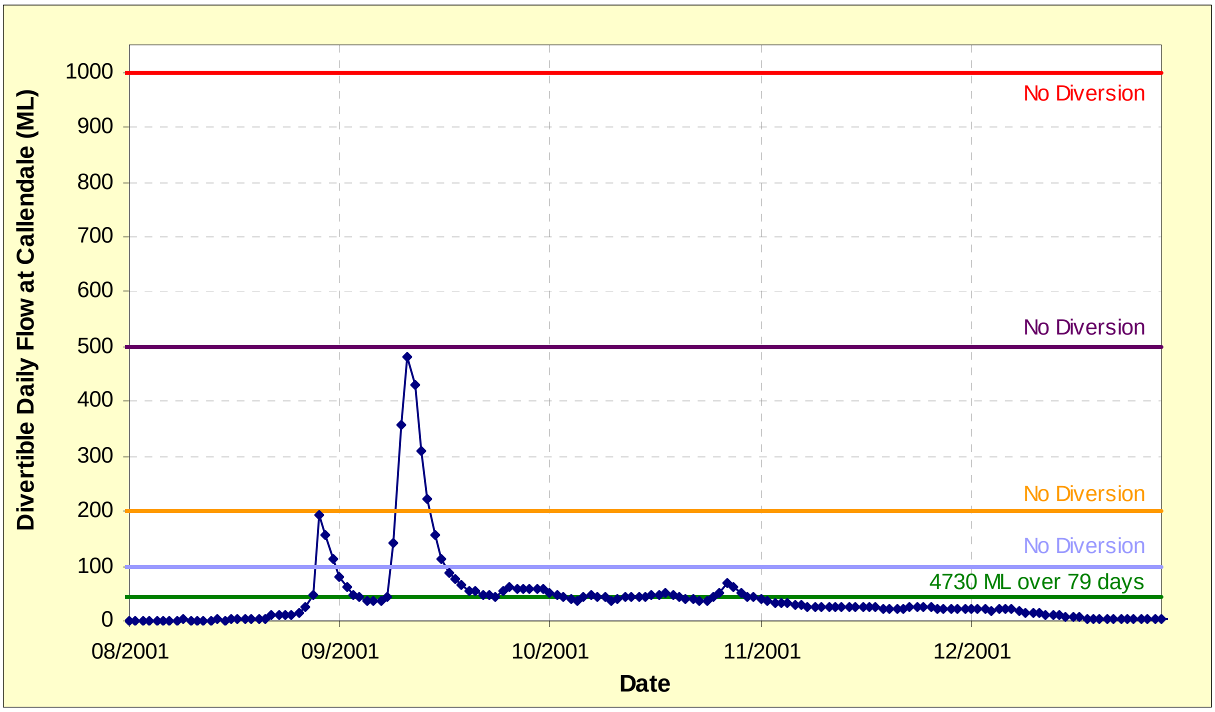


Figure A.20 Hydrograph Showing 2001 Potential Diversions at Callendale.

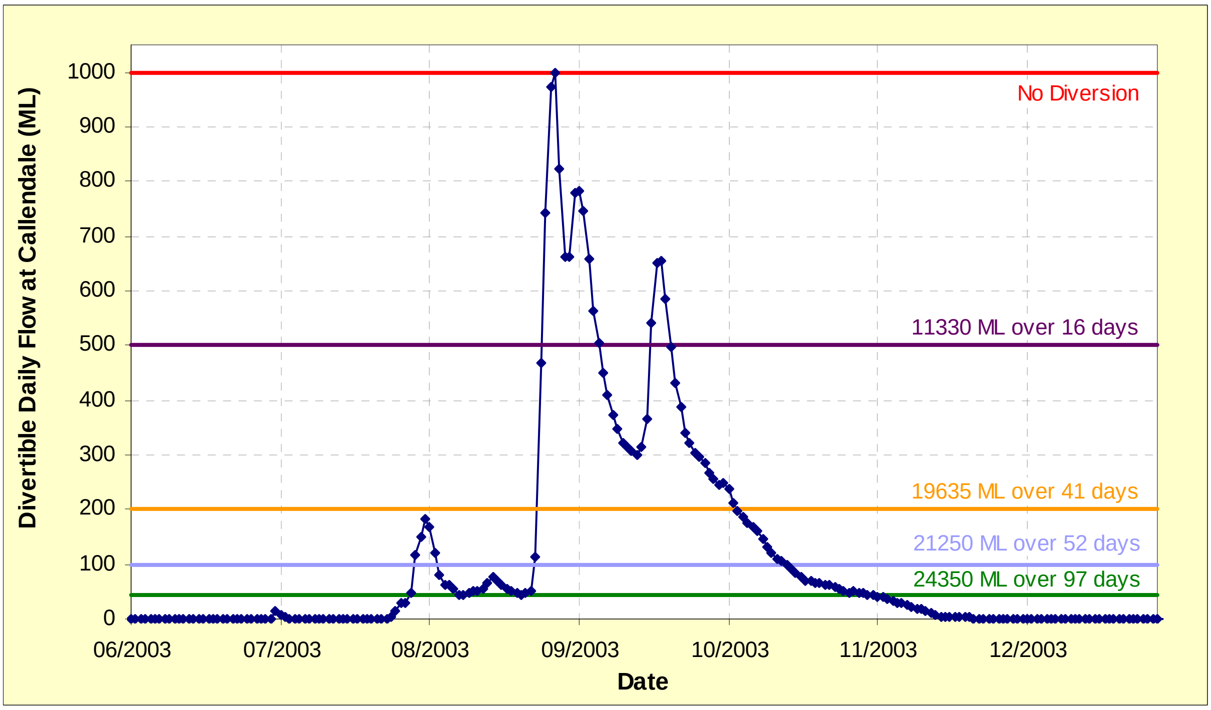


Figure A.21 Hydrograph Showing 2003 Potential Diversions at Callendale.

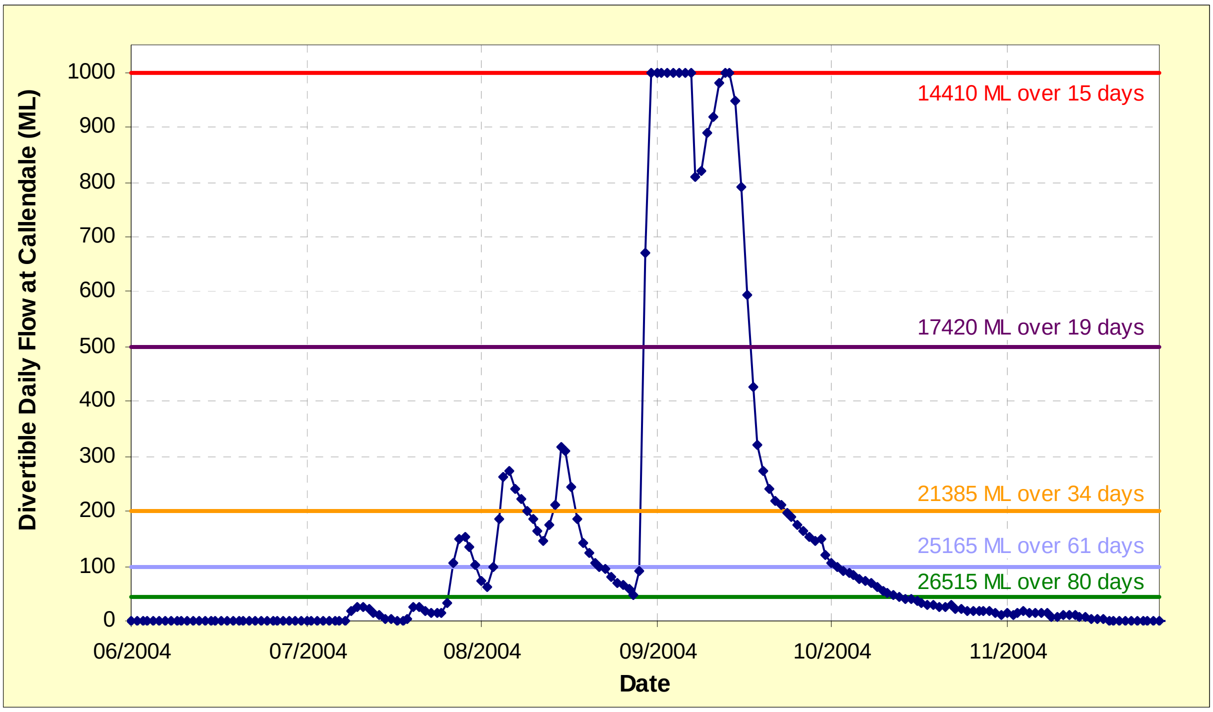


Figure A.22 Hydrograph Showing 2004 Potential Diversions at Callendale.

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