

# South Esk – Great Lake Water Management Review

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## **Scientific Report on Tamar Siltation**

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Prepared by  
Hydro Tasmania

### **Table of Contents**

1. Assessment of Issues and Status .....	1
2. Formulation of Study Objectives .....	10
3. Data Collection and Analysis .....	11
4. Management Options for Tamar Siltation Issue .....	12

## TAMAR SILTATION

### 1. ASSESSMENT OF ISSUES AND STATUS

#### **Siltation in the Upper Tamar River**

Following the public consultation phase of the South Esk – Great Lake Water Management Review, comment was received that sedimentation in the Upper Tamar Estuary was an issue that should be considered during the Technical Studies stage of the Water Management Review, and that operation of the Trevallyn Power Station should be examined as a possible method of reducing dredging activities in the area.

This issue was canvassed in the mid-1980s during a comprehensive scientific study of sedimentation in the Tamar River (WRL, 1986a&b). Siltation of the upper Tamar River has long been an issue for use of this waterway, and dredging activities have been undertaken there since as early as 1859. The Upper Tamar River Improvement Authority, a body that comprises members of Launceston City Council, West Tamar Council, the Port of Launceston, the Tasmanian State Government and a number of other community members, currently supervises dredging. The principal objective of Upper Tamar River Improvement Authority is to provide river dredging for flood protection, recreational amenity, commercial activities and general navigation in the upper reaches of the Tamar River from the northern point of Tamar Island to the Yacht Basin and the North Esk River from its junction with the Tamar River to Black Bridge. Although the port is no longer used for major shipping activities, there are some industries that rely on use of the port facilities and there are a variety of recreational and amenity uses.

Since commissioning in 1955, Trevallyn Dam has diverted a significant proportion of the water from the South Esk River in Cataract Gorge through to the Trevallyn Power Station, located near the bottom end of Home Reach.

#### **Tidal Processes and Siltation in Estuaries**

Tidal fluctuations in the confined waters of estuaries are quite different to those that occur in oceanic waters. In deep waters, tides vary in a reasonably symmetrical, sinusoidal fashion. However upon entry to an estuary, the amplitude of the tide and the magnitude of the tidal currents diminish towards the head of the estuary (Dyer, 1973). As a tidal wave progresses up the estuary and the water depth decreases, the wave crest travels faster than the trough, resulting in an asymmetric pattern of tidal change. The overall effect of this is to reduce the time of rise from low to high water and increase the time of fall from high back to low water again.

Another significant effect of this non-linear change in tidal cycling is an increase in water velocity during the flood tide and a reduction in velocity of the ebb tide, which results in a greater capacity for tidal water to carry suspended material up the estuary. The density difference (due to differences in salinity) between the water at the seaward end of the estuary and water entering from rivers causes a nett landward movement of water near the estuary bed. This causes fine sediments to be carried landward in suspension to a point of zero nett movement (McDowell and O'Connor, 1977). When river flow is high, the position of zero nett movement is located closer the sea, and when river flow is low it is located nearer to the head of the estuary.

Hence the flow of fresh water has a major effect on the location of the saline density gradient, and therefore also on the location of sediment deposition in an estuary. At the headwaters of an estuary, where water is always fresh, sediment movement is always towards the sea. Just down from this, in an ever-increasing gradient towards the sea, the situation changes, and there is likely to be a nett landward movement of both water and solids close to the bed. Although strong freshwater flows may bring sediment into an estuary from the land surface, the main effect of river flows is to move the site of deposition to areas lower in the estuary. High flows also create scour, which actively moves sediment from the upper estuary further towards the sea.

These basic hydraulic processes are critical to understanding the problem of siltation in the upper Tamar River, how hydro-electric power schemes have altered the pattern and volume of silt being deposited there and how operation of the Trevallyn Power Station has the capacity to influence the pattern of siltation in the estuary.

### **Dredging Activities in the Tamar**

Some form of dredging has long been practiced in the upper Tamar estuary. In a report to the Marine Board of Launceston in November 1899, Mr C. Napier Bell noted that between Launceston and Rosevears, dredging efforts had maintained reasonable depths for navigation (10 feet). He mentioned that most of the trouble and expense incurred by the Board had been to improve and maintain adequate depth in the harbour, where any gains made tended to be lost in a very short time.

Between 1947 and 1966 approximately 5.25 million barge yards of silt was removed from the area between the top end of Home Reach and Stephenson's Bend through dredging activities. This amounts to about 255,000 tonnes of silt removed annually, or approximately 360 tonnes per tidal cycle removed by way of dredging to maintain depth of the river channel. These estimates cover a range of environmental conditions, including the commencement of operation of Trevallyn Power Station in 1955, the riparian release of 0.42 cumecs from Trevallyn Dam and the occurrence of spates and floods which would have induced scour of the Tamar River channel. These figures were taken from a report on the history of dredging in the Tamar undertaken as part of the Tamar River Siltation Study (WRL, 1985). While they are very approximate, these figures can be considered as indicative of the general level of silt that must be removed to maintain adequate depth in the river channel.

Since the mid-1960s, when a major deep-water port was established at Bell Bay, dredging activities in the wider river have been more intermittent, with most effort concentrating on maintaining water depths alongside Kings Wharf at Inveresk. Typical figures quoted for 1984 and 1985 are 14,150 and 17,800 yards respectively (WRL, 1985). Information from a relatively recent Operations Report (UTRIA, 1995-'98) indicates that during the period July 1995 to June 1998, total funds spent on dredging was about \$1,085,000. This resulted in the removal of about 214,814 m<sup>3</sup> of material from the Tamar River. Dredging for 2001/02 is about to enter a new phase, with the development of a 5-year plan that will see the removal of a further 180,000m<sup>3</sup> of material.

### **Investigations in the Tamar**

There have been a number of studies and reports on siltation in the Tamar River in the area between Stephenson's Bend (Invermay) and the junction of the North Esk and South Esk rivers near the centre of Launceston. The majority of these have been concerned with navigation and dredging works and lacked the survey and tidal

data required to fully understand the factors influencing siltation in the upper estuary. Most of these historical reports and the data they contain were reviewed during a comprehensive technical study undertaken by Professor Doug Foster of the Water Research Laboratories, University of New South Wales in 1986. In his report, Prof. Foster concluded that while many of the historical reports did provide valuable information on the nature of the bed material and the response of the river to man-made changes, all previous reports were limited by a lack of specific and accurate data on the extent of silt in the estuary.

The best and most reliable body of information that is available is the information that was collected during the Tamar Siltation Study (completed in 1986), a study conducted by the Water Research Laboratories and coordinated by Prof. Foster. The technical projects that were undertaken for that study included; survey work to define the form and nature of the channel in the upper estuary; tide gaugings to examine the flow characteristics; an investigation of the nature and physical properties of the bed and bank sediments; an estimation of sediment inputs to the estuary and a review of possible remedial measures.

The Tamar Siltation Study (WRL, 1986a) found that the build-up of sediment in the upper Tamar River was controlled by two major factors. The first was the supply of fresh sediment to the estuary through river inflows from the South Esk and North Esk catchments. The second was the movement of the stored sediment in the estuary by river flows and the tides. Essentially, major flood flows from the two rivers flush the sediments from the upper Tamar (through scouring) down into the lower reaches of the estuary, while the tidal mechanism acts to return this sediment during periods of low river flows.

One of the findings of the report was that the development of the Trevallyn/Poatina Power Scheme had been beneficial in reducing the incidence of low flows down the South Esk River, thereby reducing to some degree the movement of silt into Home Reach from the lower estuary. Since commissioning in 1955, Trevallyn Dam has diverted a significant proportion of the water from the South Esk River away from Cataract Gorge and through the Trevallyn Power Station, located near the bottom end of Home Reach. It was estimated that the overall effect of the scheme has been to reduce sedimentation in Home Reach from about 100,000 m<sup>3</sup> per year to around 30,000 m<sup>3</sup> per year. These estimates were made following reasonably detailed tidal gaugings and cross-sectional surveys carried out over a number of different power station discharge regimes during 1985. At the time of the study, it was thought that maintenance dredging of about 20,000 - 30,000 m<sup>3</sup> per year would be required to keep the channel open and navigable.

The study from the 1980s concluded with an examination of various options for managing silt in the estuary. It identified three potential options that could be employed to reduce the amount of maintenance dredging required in Home Reach. These were:

- The operation of Trevallyn Power Station in phase with the tides
- The use of silt trap methods
- The encouragement of vegetation to trap silt on the mud banks.

As mentioned above, tide gaugings and channel cross-sectional surveys were conducted to ascertain the effect of discharge from Trevallyn Power Station on deposition in the middle reaches of the estuary (WRL 1986b). The study found that discharge from the power station of 60 m<sup>3</sup>s<sup>-1</sup> (3 units operating) during the flood tide caused a net export of sediment from the area of Ti-Tree Bend (lower Home Reach) and deposition lower down the estuary as far as Freshwater Point. During zero

discharge from Trevallyn Power Station, deposition was restricted only to the area upstream of Stephenson's Bend (diagrammatically presented in Figure 1).

This result clearly showed that with the power station operating three turbines, peak flood-tide velocities were reduced, while peak ebb-tide velocities were maintained for longer. As a result of this finding, it was recommended that consideration be given to increasing power station discharge during the flood tide to reduce the transport of sediment upriver from lower in the estuary. In its final report to Tamar River Improvement Committee (TRIC), the WRL study concluded that the rate of dredging in the upper Tamar River could be further reduced by approximately 10,000 cubic metres per year by modification of 1-unit to 2-unit operation of Trevallyn Power Station in phase with the tides. This was estimated to result in a saving in dredging costs (at that time) of up to \$60,000 per annum. It did recognise that there might be a resultant loss in energy production from the power station if this operating system were to be implemented.

Following this investigation a desktop review was conducted by the Power Branch of the HEC, and this indicated that ignoring the possible network and daily load cycle constraints, it was possible to achieve the modified operating mode, provided inflow was less than  $8.5\text{m}^3\text{s}^{-1}$  or greater than  $42.5\text{m}^3\text{s}^{-1}$ . It was stipulated that within that range, changes to operating policy would be required, resulting in lower conversion efficiencies and reduced power output from the power station. Flow duration analysis indicated that inflow within the  $8.5 - 42.5\text{m}^3\text{s}^{-1}$  range occurs for 23% of the time, resulting in an average annual energy loss of about 588 MW hours. Based on 1987-'88 generation costs, it was estimated that the cost of this adjustment would be of the order of \$15,000 per annum.

As a result of this, a trial was conducted by the HEC between May 1990 and April 1991 to determine more precisely the costs of implementing such an operating regime for Trevallyn Power Station. During this trial, modified output from the power station occurred on 56 days. In a letter to the TRIC dated 20<sup>th</sup> September 1991, the HEC indicated that this resulted in a power loss of 827 MW hours (at a cost of \$40,523) rather than the initial estimated 588 MW hours. The costs of this power loss were paid for by the Tamar River Improvement Committee. Other costs that the HEC incurred due to this trial related to increased engineering time in the management of Trevallyn Power Station, increased network losses due to importing power to Trevallyn and modifications to system generation to take into account the trial. It was estimated that with these added costs, the total cost of implementing this operational regime amounted to about \$80,000.

During the trial, measurements carried out by Prof. Foster for the Tamar River Improvement Committee concluded that there was a reduction in siltation of about 8,080  $\text{m}^3$  in the area of Home Reach. Using the cost estimate of \$40,523 provided by the HEC, Prof. Foster found the cost of the reduced siltation to be about \$5 per cubic metre, which was roughly equivalent to the cost of dredging at that time.

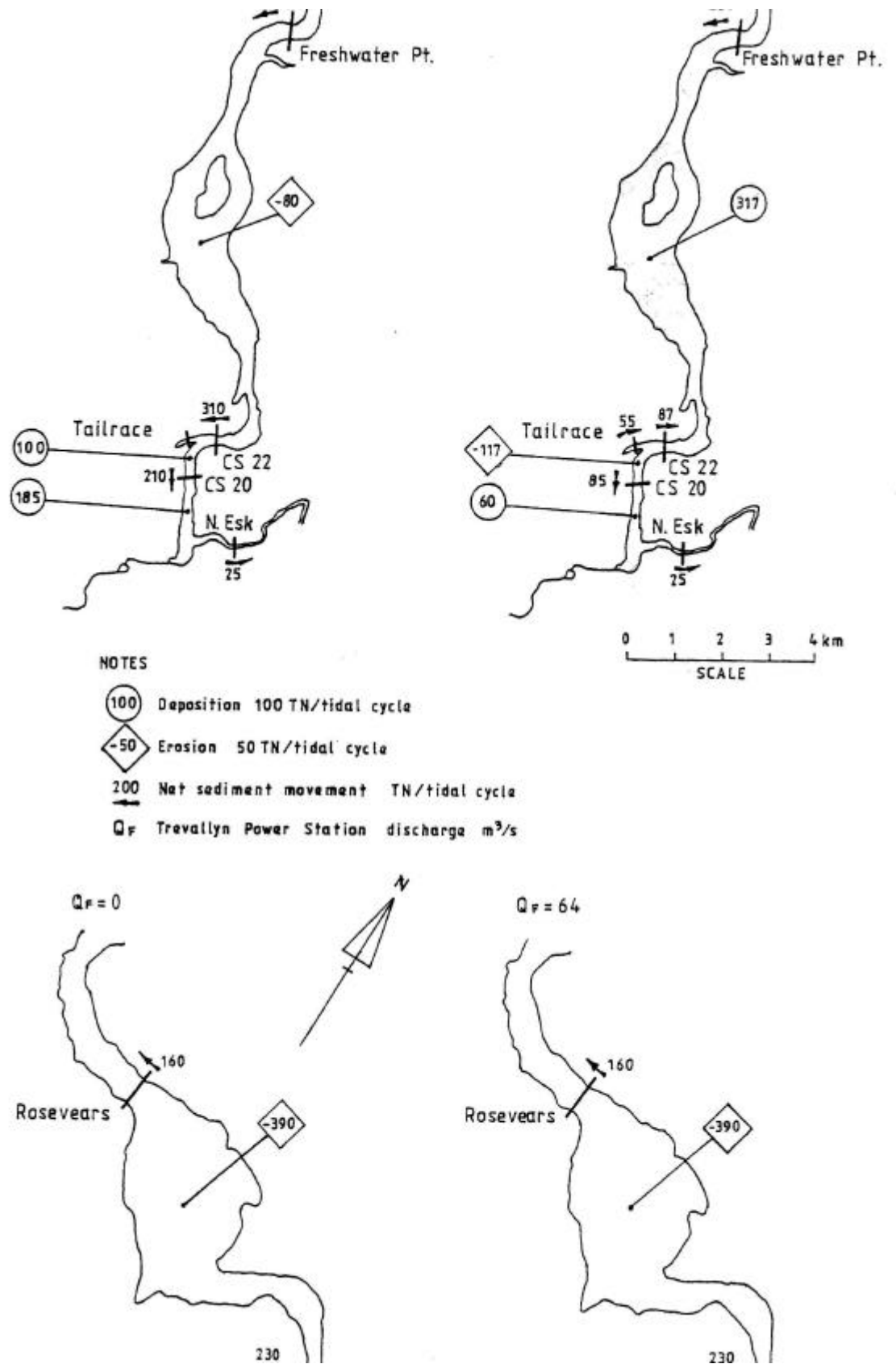


Figure 1: Illustration of results from silt movement surveys conducted during two phases of power station discharge (taken from - Interim Report No. 85/07/IR-6 April, 1986. WRL).

## Current Operation of the Trevallyn Power Station

Lake Trevallyn is a typical 'run-of-the-river' storage and is generally operated in step mode to provide power over and above that already provided by other stations in the system. Trevallyn Power Station has four turbines that presently have a capacity to discharge a maximum of about  $85 \text{ m}^3\text{s}^{-1}$ . The power station generally only operates at full gate capacity to minimise energy losses due to spill over the dam during periods of flooding.

The trace of discharge from a "typical" year for Trevallyn power station (see Figure 2) shows that there are several distinct levels of discharge that reflect the cumulative use of turbines. At lower discharges, these steps occur at approximately  $20\text{m}^3\text{s}^{-1}$  intervals, which tend to mirror the use of each machine within the power station. This is confounded to some degree by the difference between full load discharge and efficient load discharge for each turbine, so that when three machines are operating (for instance) their sum total discharge may be less than  $60 \text{ m}^3\text{s}^{-1}$ . There are reasonably extended periods of discharge at about  $85 \text{ m}^3\text{s}^{-1}$  between July and October, when inflows are high and all turbines tend to be used to maximise power output. Examination of a shorter time-series (see Figure 3) shows more clearly that although discharge frequently stops, these shutdowns are normally no longer than 12 hours.

Several constraints on power station operation arise from rules regulating how water levels in Lake Trevallyn are managed and rules which minimise the risk of loss of generating capacity during periods of high flows. Although the lake can be drawn down for maintenance purposes or to create greater storage capacity prior to the arrival of a flood, the lake is a designated recreational area for the City of Launceston, and under an agreement between Hydro Tasmania and the Launceston City Council the lake is normally maintained at a minimum level of 124.97 m above sea level. The spill level for Lake Trevallyn is 126.49 m above sea level, which leaves only about 1.5 m for normal operating fluctuation. As the lake is a 'run-of-the-river' storage, the power station is broadly bound to use water as it flows into the lake, and the trace in Figure 3 illustrates that discharge from the power station is shut down for only a small percentage of the time. Duration analysis of all the data available for water discharge from power station (see Table 1) shows that discharge stops for only 4 % of the time, while discharge is greater than  $40 \text{ m}^3\text{s}^{-1}$  for more than 66 % of the time.

1053.1/156.00/1: TREVALLYN PWR STN [POWER STATION] (PTo(140.00,0)) - Flow (Cumecs)

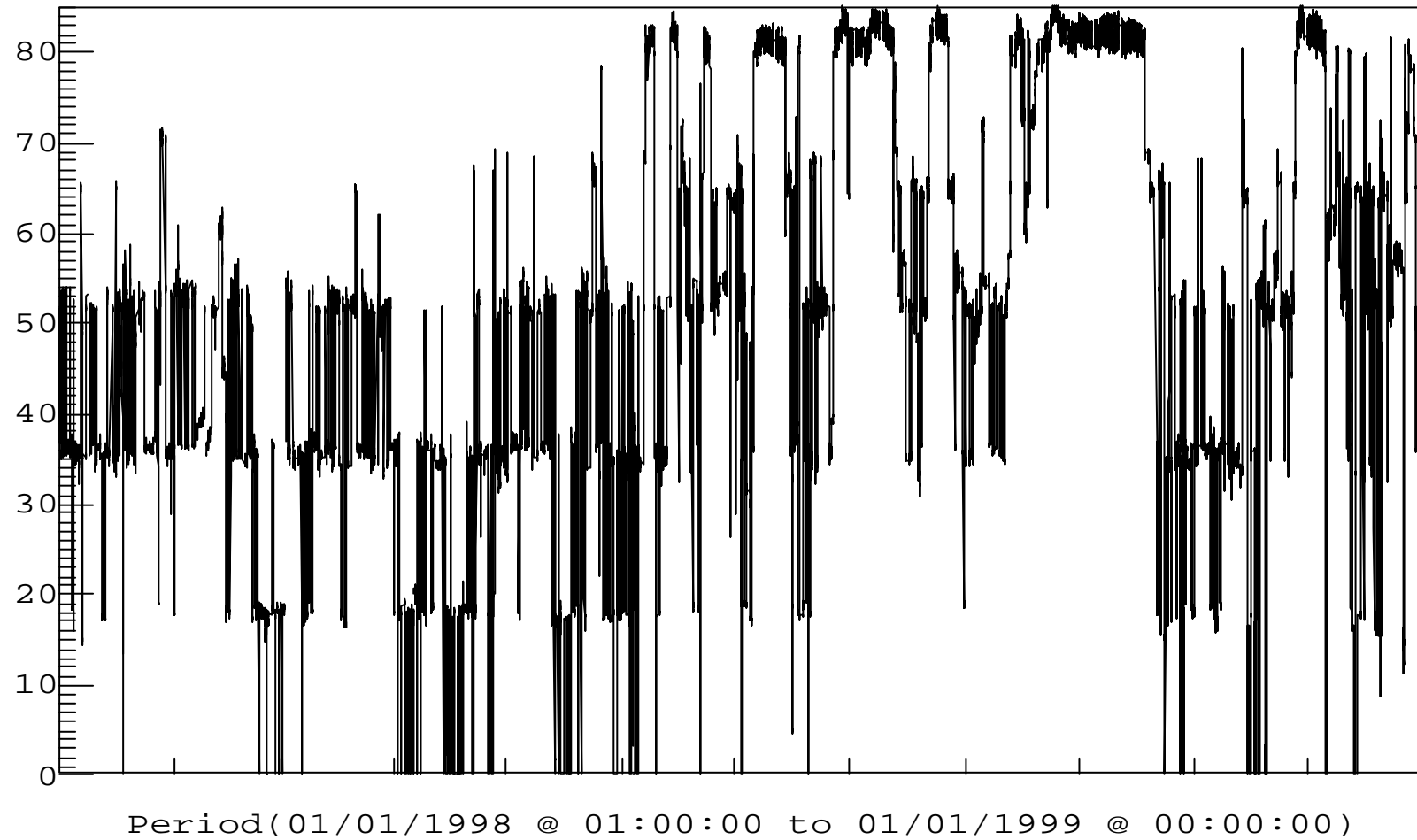
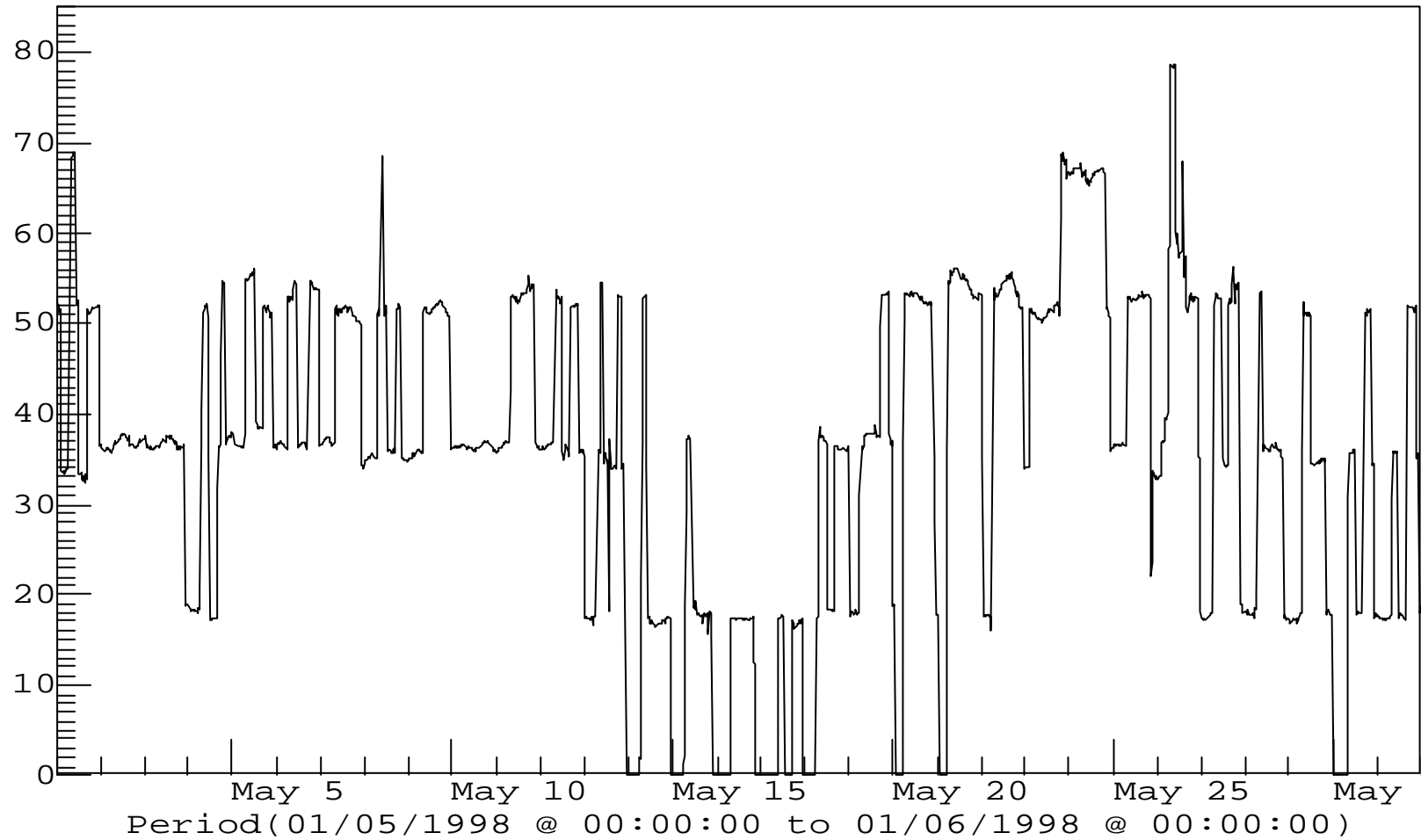


Figure 2. Time series trace showing variation in discharge of water from the Trevallyn Power Station between 1/1/1998 and 1/1/1999. Discharge (Y-axis) expressed in terms of flow ( $m^3 s^{-1}$ ).

1053.1/156.00/1: TREVALLYN PWR STN [POWER STATION] (PTo(140.00,0)) - Flow (Cumecs)

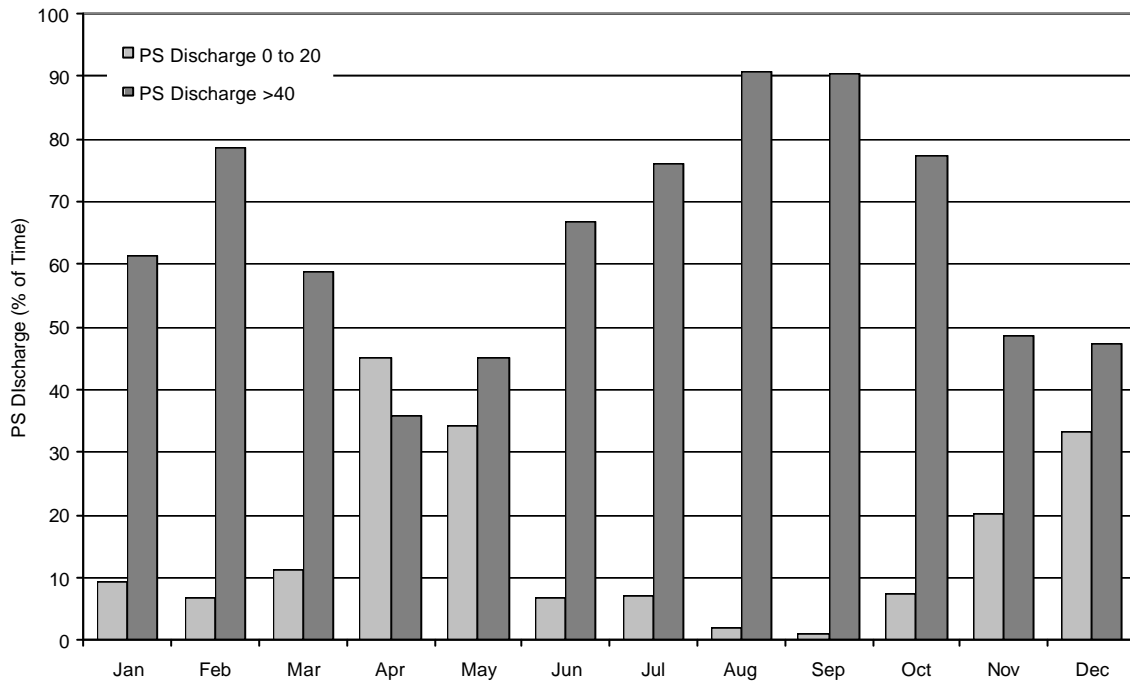


**Figure 3. Pattern of water discharged from the Trevallyn Power Station between 1/5/1998 and 1/6/1998. Discharge (Y-axis) expressed in terms of flow ( $m^3s^{-1}$ ).**

Discharge Range	% Time within Range	% Time $\geq$ Lower Bounds
0 to 1 m <sup>3</sup> s <sup>-1</sup>	4.37	100
1 to 20 m <sup>3</sup> s <sup>-1</sup>	9.64	95.63
20 to 40 m <sup>3</sup> s <sup>-1</sup>	19.19	85.97
40 to 60 m <sup>3</sup> s <sup>-1</sup>	27.06	66.78
$\geq$ 60 m <sup>3</sup> s <sup>-1</sup>	39.72	39.72

**Table 1. Duration analysis of discharge from Trevallyn Power Station into the Tamar River. (Period of record 1996 to present).**

Analysis of the duration data from another perspective shows how power station discharge is distributed on a seasonal basis (see Figure 4). It is clear from this that during the winter (July to October) discharge from the power station is generally very high to take advantage of high inflows to the lake. Power station stoppages are greatest during April, May and December.



**Figure 4. Seasonal distribution of two major discharge categories (<20m<sup>3</sup>s<sup>-1</sup> and >40m<sup>3</sup>s<sup>-1</sup>) from Trevallyn Power Station (Period of record 1996 to present).**

## 2. FORMULATION OF STUDY OBJECTIVES

The review of information regarding siltation in the upper Tamar Estuary, and following discussions with the major stakeholder group (the Upper Tamar River Improvement Authority - UTRIA), clearly shows that there is some evidence that discharge of freshwater from Trevallyn Power Station has the capacity to reduce the local build-up of silt in the area of Home Reach just below the tailrace. The extensive studies carried out in the mid-1980s have presented evidence that while the power station already significantly reduces siltation in the area, further reductions in silt deposition might be achieved if Trevallyn Power Station operation can be more closely aligned with the tidal cycle.

As mentioned earlier, pilot studies conducted by the TRIC and the HEC between 1990 - 91 suggested that siltation could be further reduced by about 8,000 m<sup>3</sup> in the area of Home Reach, at a cost of between \$40,000 - \$80,000 per annum. UTRIA has always questioned this cost estimate.

The objective for this study was therefore to conduct modelling using the power generation system modelling program (SYSOP) to re-examine the potential cost (in terms of lost generation) associated with modifying the operational scheme for Trevallyn Power Station to further reduce siltation in the upper Tamar River.

### 3. DATA COLLECTION AND ANALYSIS

A brief modelling study was undertaken to re-evaluate the costs associated with modifying the operation of Trevallyn Power Station as suggested by the Tamar Siltation Study (1986) and Upper Tamar River Improvement Authority. The Hydro Tasmania power generation system modelling program SYSOP was used to test the following operation scheme for Trevallyn Power Station:

“If there is operation outside the target time zone, then increase generation in the target time zone (flood tides), eg:

0 machines	→	1 machine
1 machine	→	2 machines
2 machines	→	3 machines
3 machines	→	4 machines

And decrease generation commensurately for other hours (ie during ebb tides)”.

The target zone was deemed to be the 4 hours leading to the peak of high tide. The rule is designed to maximise discharge from the power station during the flood tide, as suggested by the siltation studies, to reduce silt deposition in Home Reach.

The cost of this operational rule was evaluated as any of; increased shortfalls, increase thermal generation, and decreased energy in storage at the end of each test run. The tests were run over two planning horizons – multiple replicates over the short term (10 years), and a single replicate over the long term (1000 years). The tests were run using the present lake level restrictions (Hydro Tasmania has a lake level agreement with the Launceston City Council) and also relaxing this restriction to determine if this would increase flexibility in meeting the rule.

The results from this modelling analysis showed that there is likely to be an increase in average annual thermal generation costs within the range of costs associated with the trial in 1990 - 91. Costs that could not be determined using this model are those associated with network losses that are incurred to bring power into the Launceston area when generation at Trevallyn is deferred. It was therefore decided that the total costs that were estimated following the earlier trial were still relevant.

Lower Lake Trevallyn minimum operating levels were not found to be an effective off-setting approach for this cost. Although this strategy reduces spill it also appears to reduce Trevallyn’s average output by approximately 1%, and this loss is more significant than the one it is attempting to offset.

#### 4. MANAGEMENT OPTIONS FOR TAMAR SILTATION ISSUE

As a result of this review, it is evident that there are significant costs to Hydro Tasmania in altering the operational regime for Trevallyn Power Station to maximise discharge during flood tides. It highlighted that the issue of siltation in the Tamar is not one that arises as a result of Hydro Tasmania's operations, and that the construction of the power scheme already results in a reduction in siltation in the upper estuary.

The implications to the business of modifying its practices to further reduce siltation (and hence the cost of dredging), and the resulting loss in generation flexibility for Trevallyn Power Station, are still seen as significant issues. Hydro Tasmania has therefore concluded that any decision to alter the existing operational regime is an issue that would only be considered on a commercial basis.

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