Derwent Catchment Review

PART 3 Discussion and Recommendations

Prepared for Derwent Catchment Review Steering Committee June, 2011

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1 Introduction

The water quality analysis (based on data available to this project) has identified point-source and diffuse inputs, and flow-regulation as principle factors affecting water quality in the Derwent catchment. These are discussed in the following sections.

2 Point source inputs

Point source impacts identified in the Derwent include waste water treatment plants and aquaculture hatcheries. Large waste water treatment plants with a design capacity of at least 100 kL (average dry-weather flow) per day are Level 2 activities, with water quality monitoring results reported to the EPA, and made available for this investigation. Smaller treatment plants (Table 28 PART 1) are Level 1 activities, and information is held by Councils and/or Southern Water; comprehensive datasets were unable to be accessed within the time-frame of the project.

In the case of aquaculture, hatchery operators were reluctant to provide information for the project. Information about the impact of hatcheries is available for the period of the Upper Derwent Nutrient Study (1996-1998), and in the absence of more contemporary data and information on upgraded treatment capacity or infrastructure, impacts are assumed to persist. Aquaculture facilities are regulated as a Level 1 activity, although applications for new premises may be referred to IFS and EPA for comment.

1.1 Waste Water

Waste Water Treatment Plants can also have significant impact on receiving waters, with the level of treatment required partially dictated by the nature of the receiving environment, with tertiary treatment becoming the standard for effluent discharged to inland watercourses (OTTER, 2011). Three Level 2 WWTPs are located within the study area; Bothwell and New Norfolk, operated by Southern Water, and the Lake St Clair WWTP operated by Parks and Wildlife. Effluent from New Norfolk is discharged into the estuarine section of the Derwent, but is included in this study as it represents the largest urban WWTP at the base of the study area. Only a limited number of parameters were recorded in the EPA database (BOD, TSS, pH, thermotolerant coliforms), while a subset of nutrients recorded in 2002 were reported in the State of the Derwent Estuary Report (2009). The 2002 data showed that significant quantities of ammonia, nitrate + nitrite, TSS and TP were discharged from the plant. New Norfolk WWTP is scheduled for an upgrade, with investigations into the feasibility of effluent re-use planned, commencing in 2010-2012 (OTTER, 2011). Upgrades on the Gretna and Maydena Level 1WWTPs are also scheduled, however it is unlikely that any additional Level 1 WWTP re-use schemes will eventuate in the study area, due to the small size of the plants and low flows involved (*Sarah Jones, pers. comm*).

Monitoring from above and below the Bothwell WWTP in 1996-1997 showed an increase in ammonia and dissolved phosphate, and decreased pH downstream of the plant accompanied by a reduction in dissolved oxygen levels in summer. TN, TP and TSS were unchanged. Following an upgrade in 2005, monitoring data for the Bothwell outfall (i.e. the discharge point, not the receiving environment) shows a significant reduction in ammonia. The seasonal signal of high ammonia in winter persists in most years (Figure 1). Similar trends are recorded for TN and TP. This cycling is associated with higher winter rains reducing residence time and storage capacity within the lagoons.

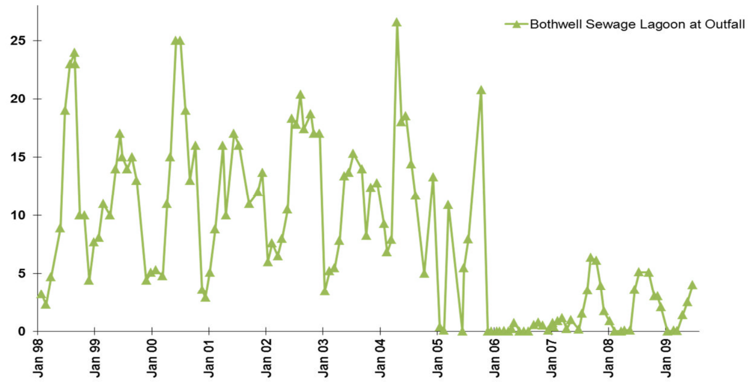


Figure 1 Ammonia (mg/L) data from the Bothwell WWTP outfall, 1998- Jun 2009. (Data Southern Water, EPA).

The timing is generally co-incident with reduced demand for irrigation, and under those conditions the lagoons are permitted to have emergency discharge to the Clyde (*Sarah Jones, pers. comm*). Bothwell WWTP has been on a waste water re-use scheme since 2005, with water used on one property for poppies and pasture, typically irrigated following mixing with Clyde River water.

Discharge from the Lake St Clair WWTP showed increased levels of ammonia, and total Phosphorous, with the TP signal possibly detected downstream in Lake King William. Occasional spikes in Total Kjehldahl Nitrogen and thermotolerant coliforms were observed. There are a number of accommodation based development projects proposed around Lake St Clair, which would require connection to the WWTP. Upper-end accommodation often has high-water demand, and the capacity of the plant to cope with additional demand will be part of the assessment process (*Barry Batchelor, pers. comm*).

On a general note, sewage lagoons provide ideal conditions for the establishment of cyanobacteria (blue-green algae) due to the warm, quiescent and nutrient rich conditions present. Favourable conditions may lead to “over-wintering” of cyanobacterial species as akinetes or vegetative colonies, and lagoons potentially form a year-round supply source to the receiving environment (EPA, 2011). Whilst no data from lagoon systems was available for this report, it is assumed that cyanobacteria are present in most Tasmania sewage treatment lagoons (EPA, 2011). Recently guidelines for the management of cyanobacterial blooms in Tasmanian sewage lagoons have been released, that emphasize the need for contingency management plans that minimize release to the aquatic environment for human, animal and aquatic health reasons.

The impact of septic systems in areas that are not sewered is largely unknown.

1.2Aquaculture

Salmon aquaculture has undergone significant growth in Tasmania in the past 15 years, with expansion of marine farm areas in southern Tasmania and the west coast. Smolt for marine grow-out facilities is sourced from a number of hatcheries in Tasmania, and increased production at the farm level requires increased production at the hatchery level, with hatchery expansion scheduled for the Derwent catchment. There are 5 hatcheries in the Derwent catchment (salmon and trout), a "dormant" license for the Broad River, with a further 2 licences granted in 2010 in the Derwent below Meadowbank Dam (205 and 205.2 ML/day each). It is not known if these licences relate to flow-through hatcheries, or facilities with water treatment for recirculation, although construction has begun on one facility.

Water quality issues associated with the presence of flow-through aquaculture facilities include increased ammonia and ammonium, dissolved phosphate, TN, TP, TSS and conductivity. These impacts are apparent in the water quality results for the Florentine upstream and downstream of a hatchery, and in the Tyenna. Flux calculations show the source of ammonia in the lower Florentine can comprise a significant portion of the total flux, under drought conditions. The level of treatment that water receives before it re-enters the river is unknown, but may include settlement ponds (based on Google Earth imagery). Anecdotal reports of slimes and increased attached algae downstream of nutrient point sources such as hatcheries (and STPs) have been recorded in the Tyenna and Florentine, but the length of river affected by nutrient-enriched discharge is unknown. Concerns have been raised about pathogens/faecal contamination, organic carbon loads and therapeutic drug use from flow-through facilities (*Greg Dowson, pers . comm*). Water quality from facilities using re-circulation and water treatment (e.g. IFS New Norfolk) is assumed to significantly reduce loads, but no monitoring data was assessed for this project. A review of the impact of aquaculture operations is seen as a priority, and a key knowledge gap.

1.3 Other activities

None of the other major activities (Level 2) in the catchment were captured in this study (Table 29 PART1). Known activities in the catchment which have the potential to impact water quality include refuse disposal sites, a colliery, a peat mine, a compost facility and a biodiesel plant. The range of potential contaminants from these activities is large, although appropriate management practices would reduce water quality risks associated with these operations significantly. Quarries, crushers and gravel pits which make up the bulk of Level 2 premises in the study area, and have the potential to impact water quality through the generation of dust and movement of solids, particularly with rain events. However the footprint of these activities is often small, and appropriate sediment and erosion control strategies are relatively straight forward and effective when properly maintained and managed.

Leachates and run–off associated with tips and landfills (both current and historical) may potentially affect both ground and surface waters, and there appears to be limited available information on the impact of historical facilities on water quality within the study area, with no data available for this study. Under EMPCA, active sites are regulated as Level 2 premises. Specific licence conditions typically require leachate management, and monitoring of leachate, ground-water and nearby waterways (Green and Coughanowr, 2003). Parameters which are commonly monitored include nitrate, ammonia, phosphate, pH, BOD, COD, total coliforms, faecal coliforms, metals and organic contaminants. Variation in leachate quality between sites can depend on the site design, refuse composition, water content, stage of decomposition, temperature, and oxygen availability. Some contaminants which may be present in leachate are hazardous even in very low concentrations, including chlorinated hydrocarbons, aromatic solvents, phenolic compounds, pesticides and herbicides and metals such as cadmium, mercury and lead (Green and Coughanowr, 2003).

Considerable rationalisation in the number of tips in Tasmania has occurred since the early 1990s, with a transition to a smaller number of larger regional landfills, operating at a higher standard. Storm water management at tips during heavy rain events, windblown litter, potential or actual discharge of leachate to the environment, and intermittent direct discharge to the environment were identified as issues in a review of infrastructure needs for waste management in Tasmania (RPDC, 2003). Post closure monitoring of surface and groundwater at landfills to determine the scope and degree of contamination and potential risk to groundwater was identified as a knowledge gap in the State of the Environment Report (RPDC, 2003). The majority of active landfills in Tasmania have some kind of liner, with leachate collection systems, stormwater management, and control of air emissions (dust, litter, odour) reported to be high (Wright Corporate Strategy, 2010). No site specific information on tip sites within the Derwent catchment was available for this study, so assessing the importance of these sources on a catchment basis is difficult.

3 Diffuse inputs

Diffuse inputs are harder to assess than point source inputs, as by their nature can occur over wide areas often from multiple sources. Monitoring for diffuse inputs is difficult at a catchment scale where multiple land-uses and practices exist. Water quality results suggest that diffuse inputs to the Derwent are generally associated with runoff during storm events from cleared land used for grazing or agriculture. There were insufficient water quality results to evaluate the impact of other land uses, such as forestry on diffuse inputs to waterways and forestry.

Diffuse inputs are most pronounced in the eastern tributaries (Dee, Ouse, Clyde) in which the hydrology has been altered, and land has been cleared, including significant disturbance to riparian zones. Turbidity and total nutrients are the main parameters which increase as surface flow to the catchment increases. Overlain on these seasonal patterns, are site-specific issues such as local erosion which may result in pulses of sediment, turbidity and nutrients , particularly during summer storms when soil dryness is high and ground cover may be sparse. This is evident in the turbidity record at Bryn Estyn which shows increases in turbidity associated with most high flow events, which is believed to be associated with local erosion in small, often ephemeral creeks upstream of the Bryn Estyn intake. (*A. Crawford, pers. comm*).

Diffuse inputs associated with groundwater, primarily salinity, increase during dry periods when groundwater inputs provide the majority of inflows to the catchment. EC values of up to 2000 µS/cm have been measured in a tributary of the Clyde River, and parts of the Dee, Ouse and Clyde catchments have been identified as having salinity issues in 5-25% of land systems. Accumulation of saline groundwater in pools during periods of low flow may cause localised anoxia and decline in water quality until pools can be flushed in higher flows. Mapped areas of dryland salinity in South-East Tasmania are shown in Figure 2.

and show that salinity is potentially a major issue on a regional scale in the eastern catchments, and should be considered in future water quality monitoring and / or management.

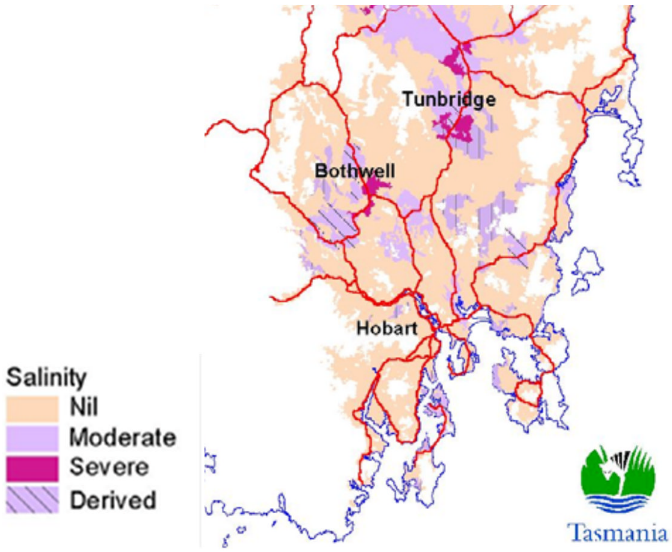


Figure 2 Map of South-East Tasmania showing areas of dryland salinity (DPIPWE, 2007).

2.1 Stormwater

On the scale of the Derwent catchment, stormwater may almost be considered a point source as contaminant-bearing stormwater is almost exclusively derived from surface runoff associated with developed areas such as small towns, and the peri-urban fringes of greater Hobart. Stormwater in these circumstances is often channeled, piped or drained to waterways through a stormwater system, and is characterized by a broad range of pollutants including oil and grease, pathogens, litter, nutrients, metals and sediments (DEP, 2002). Infiltration of stormwater into sewerage systems may cause treatment and/or overflow problems and is an almost universal issue in regional areas (Green, 2001).

Stormwater monitoring throughout the towns in the catchment is limited, although Lachlan River south of New Norfolk was monitored as part of the DEP Rivulet and Stormwater Monitoring Program. Under dry weather flow conditions, water quality in the upper Lachlan was good, with a slight increase in faecal contamination at the lower monitoring site (DEP, 2004). Installation of litter traps and sediment traps have reduced the amount of gross solids entering the Derwent (*S. Joyce, pers. comm*). No further stormwater monitoring data was available for this study. Stormwater may present a risk to drinking water quality in the lower catchment in particular.

2.2 Agriculture and forestry

Impacts from major land-use groups such as agriculture and forestry could not be clearly defined with the data available. Potential impacts are mostly associated with water extraction, exposure of soil over large areas through clearing, cropping, and harvesting cycles, management of high organic/nutrient wastes, storm water runoff, and the application of chemicals such as fertilisers and pesticides.

A number of on-ground and research programs have targeted diffuse inputs from agriculture in the catchment in recent years. Examples include effluent management, riparian condition and pesticide use. NRMs and peak bodies in the dairy sector have partnered statewide in reducing environmental impacts, particularly on water quality, by introduction of an industry code of practice for managing dairy farm effluents, with all farms required to develop effluent management plans to reduce nutrient and solids loadings to local waterways. The implementation of effluent management practices, combined with improved irrigation practice have significantly reduced the impact of dairies in the lower Derwent catchment (*G. Rogers, pers. comm*). TP and turbidity levels in upper Meadowbank Lake have occasionally been slightly higher compared to other sites in the lake, but this is not a strong signal, which may be linked to the shallow nature of the lake in this area, rather than inputs from local land-use. Faecal contamination from dairies may also be effectively managed through appropriate effluent management strategies, with Southern Water actively working with properties identified as affecting water quality at the Bryn Estyn intake (see PART 2). Rivercare and Landcare projects have focused on preventing stock access to water and riparian zones through strategic fencing and off-stream watering points, with the aim to protect water quality and native riparian vegetation (Greening Australia, 2009a, b).

In 2008, DPIW summarised the nature and extent of pesticide use in Tasmania as part of the Tasmanian River Catchment Water Quality Initiative (Bendor et al, 2008). Data on pesticide use, land use, crop type and application rates were collated for the upper and lower Derwent catchments; however limited pesticide usage data was collected for the Ouse and Clyde catchments due to poor survey response. Pesticide monitoring is generally conducted to determine if pesticide usage has resulted in movement into waterways, via spray drift, accidental spillage, agricultural runoff after rain or via atmospheric deposition. In a broader context, pesticide monitoring also gives information on industry and agronomic trends, including over-use and the development of pesticide resistance in target species, and the assessment of the effectiveness of integrated pest management strategies designed to reduce pesticide use (Bendor et al, 2008). Within the greater Derwent catchment, only three sites appear to have been routinely sampled for the presence of pesticides. These are in the lower Derwent catchment at the Tyenna River at Newbury, in the headwaters of the Clyde River, downstream of Lake Crescent, and at the intake to Bryn Estyn. The quarterly DPIPWE monitoring in the Tyenna River did not detect the presence of any of the 19 target pesticides, however, no sampling of high-flow events was completed in this, or any other sub-catchment of the Derwent. Whilst it is encouraging that under 'normal' flow conditions no pesticides have been detected, the lack of high flow monitoring is considered a significant knowledge gap in the Derwent. Monitoring at the DPIPWE sites ceased in late 2010 due to rationalisation of the sampling program. Information on pesticide use in the Ouse and lower Clyde is lacking.

Pesticides are used in forestry plantations to reduce weed and pest infestations, enhancing growth rates and survival of plantation species (Roberts, 2010). Herbicides are used to remove weeds that compete for light, moisture, space and nutrients, both before and after seedlings are planted. Where soil nutrient levels are low, fertilisers may also be applied (Roberts, 2010). Except in rare circumstances, chemical treatments are not used in native forests. Extensive monitoring of pesticide usage, and the development of the

Pesticide Impact Rating Index (PIRI) risk assessment tool has resulted in a review of both the type of pesticides used in forestry operations, and the way water quality monitoring is undertaken (*S. Roberts, pers. comm*.). Forestry Tasmania monitors on an operation basis in accordance with protocols outlined in the Forest Practices Code (Elliot and Hodgson, 2004), & typically do not maintain long-term sites for assessing contaminants.)

As a result of program rationalisation, there is currently no long-term active monitoring of pesticide use anywhere within the Derwent catchment, aside from Bryn Estyn. Southern Water has monitored pesticides with varying intensity, and are currently investigating methods for the on-line detection of 2 target pesticides, hexazinone and atrazine. This is intended to allow real-time detection of these chemicals and significantly increase understanding of the use of pesticides in the catchment, as well as conditions resulting in an increase risk to drinking water quality.

Water flow may also be affected by the harvest cycle of forestry operations, with an increase immediately after harvesting, and a decrease when a new forest is establishing (Green, 2001). Similarly, agricultural activities and irrigation will affect water flow in rivers.

4 Flow regulation

3.1 Hydro

Flow regulation is a major feature of the Derwent catchment, with a complex series of dams, diversions, storages and inter-basin transfers. There is no known historical data that describes water quality conditions prior to the development of power schemes (Hydro Tasmania, 2001). Dams can impact water quality through changing the residence time of water, the pattern of flows and associated changes in sediment transport. From an aquatic habitat perspective, dams significant alter habitat type and conditions such as water depth, light penetration, temperature and oxygen conditions as well as changes in channel geomorphology affecting the formation, distribution and exposure of riffles, gravel bars, and movement of large woody debris. Water level manipulation in artificial storages can impose cycles of inundation and exposure not normally experienced in natural systems.

Regulated waterways have highly modified daily, seasonal and annual flow patterns. Power station operation can be dictated by peak demand periods (morning, evening), as well as seasonal demand (winter vs summer), annual variability related to inter-basin storage levels, or natural variability (drought vs normal or flood conditions). Flows through power station can also be a reflection of operation cycles, with pulses in downstream discharge from the start and cessation of power production on a daily basis (Hydro Tasmania, 2001). In the Upper Ouse and Dee catchments, flow diversion has affected water quality through reducing water flows, thus increasing the impact of ground water inflows or turbid surface inflows on water quality in the river.

Dams and storages tend to have a shorter water residence time than natural lakes, and this can influence the cycling of nutrients, with lakes typically having longer nutrient cycles than storages. Storages may develop gradients from end to end associated with flow conditions (high at the upper end, more quiescent at the lower end), with concomitant gradients in turbidity and suspended solids, and oxygen levels. Stratification may also develop with depth, significantly altering surface and bottom water quality. Longitudinal gradients are not clearly evident in the data from storages presented here, with the possible exception of chlorophyll-*a* and blue-green algae, however the datasets are limited. Thermal stratification with depth occurs in a number of reservoirs and lakes, with summer waters considerably warmer than those at depth.

The depth of water intakes associated with power stations or tunnels can affect water quality by creating preferential flow paths within impoundments, leading to different residence times for surface and bottom waters. This process can contribute to thermal stratification effects in summer months, promoting the movement of warm surface waters and resulting in the prolonged isolation of bottom waters. Low dissolved oxygen concentrations near the Catagunya and Meadowbank dams likely reflect these processes.

Low lake levels can have a substantial effect on water chemistry through increased turbidity associated with wave action, higher water temperatures and greater light penetration, with resultant changes in biological communities. Increases in phytoplankton numbers have been observed in a number of storages, attributed to increases in nutrients during drought periods. The presence of cyanobacterial species in phytoplankton blooms is a concern for human health, and more detailed investigations have shown that the biovolume[1] periodically exceed guidelines derived by NHMRC. Once established, blooms may persist through winter months, although this is less common in “natural” water bodies.

Under favorable conditions, the numerous hydro and irrigation impoundments may act as sediment traps, through settling of material in lakes; however during periods of low lake levels, wind driven waves and resuspension may increase turbidity levels in the lake and in downstream water ways if the water is released.

Lake level has a significant impact on nutrient and turbidity levels in Lake Crescent, with resultant impacts on the water quality released into the Clyde through the outlet gate. Water Management Plans have been prepared for both Lakes Sorell and Crescent (DPIWE, 2005) and for the Clyde (DPIWE, 2005) to provide a framework for managing the catchments water resources in accordance with the objectives of the *Water Management Act 1997* and the *State Policy on Water Quality Management 1997*. The WMP for the Clyde include rules on cease-to-take provisions to protect base flows, and allocation limits determine annual maximum volume available for extraction, with consideration to higher flows components for environmental outcomes. The WMP for the lakes specify operating guidelines associated with lake level and draw down to maintain wetlands and the Golden galaxid. No other WMPs are scheduled for the Derwent catchment.

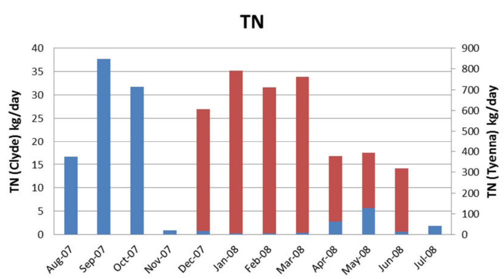
3.2 Irrigation

Major storages associated with irrigation have impacts on aquatic ecology in the inundation area, in addition to the area downstream of the storage (Graham et al, 2009).

[1] cell volume determination (mm^3) used to estimate biomass or quantity of biological material per unit volume of sample. Calculation of biovolume is based on the nearest geometric shape, or combination of shapes ie sphere, cone, cylinder

Most streams in the State have had their irrigation extraction capped over the critical period between December and April, pending implementation of environment water provisions (Australian Natural Resources Atlas). Water harvesting for storage in farms dams is typically managed by allowing winter extractions for storage, and later use in drier summer months. In the Derwent (Clyde catchment), the harvest cycle alters the seasonality of flow by storing winter inflows and releasing them in summer. This flow pattern is the reverse of unregulated river flows in Tasmania where peak flows tend to occur in winter and spring, with low or base flows in summer. A similar reversed seasonality occurs downstream of large Hydro storages which are used for power production during summer.

In unregulated rivers, nutrient transport tends to be lower in dry periods, with greatest loads of TN, TP, and solids typically being transported during peak winter/spring flows. Rivers with seasonal flow dictated by irrigation demand may have this pattern completely reversed, as shown in Figure 3, for the Clyde downstream of Lake Crescent and the Tyenna at Newbury Rd sites. A similar pattern was evident for dissolved nutrients and turbidity (Figure 4). It should be noted for the example below that although concentrations of nutrients measured in the Clyde River are orders of magnitude higher than the Tyenna, the comparatively low flows in the Clyde result in much smaller fluxes. Additionally, the Clyde monitoring location is the headwaters, while the Tyenna location is mid-catchment. As with previous discussions on fluxes, the numbers presented here are crude estimates based on monthly grab samples. Flow monitoring and a sampling intensity (and locations) that will detect changes in mass loads are critical to understanding the way nutrients and contaminants move through the catchment.



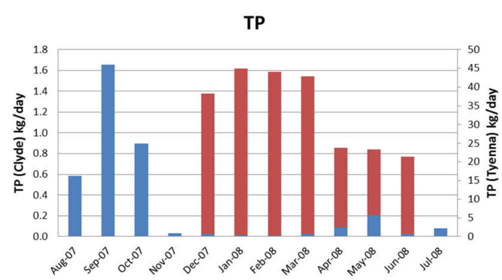


Figure 3 Seasonal fluxes of TN (left) and TP (right) for an unregulated river (Tyenna, blue, right axis) and a regulated river (Clyde, red, left axis) for the period 2007-2008. (Data from DPIPWE).

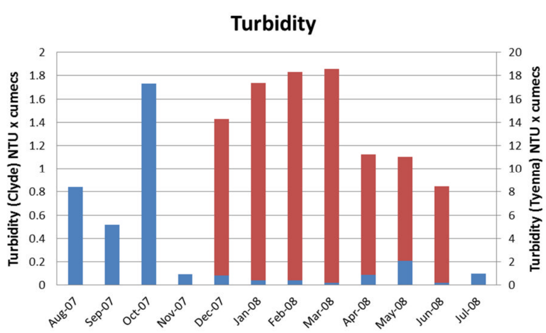


Figure 4 Seasonal "fluxes" of turbidity for an unregulated river (Tyenna, blue, right axis) and a regulated river (Clyde, red, left axis) for the period 2007-2008. (Data from DPIPWE).

Demand for irrigation is predicted to increase as properties diversify activities and broaden crop types or area under culture (CSIRO, 2009). Other identified risks associated with irrigation include salinity, acid sulphate soils, and impacts to on-farm biodiversity (TIDB, 2010). Farmers are required to complete Water Access Plans addressing sustainable water use, soil type and biodiversity issues on land directly affected by the scheme before water from Tasmanian Irrigation Development Board schemes can be applied.

3.3 Water allocations and extractions

Extractions, and over allocations can have impacts similar to drought periods where low lake levels and reduced river flow can result in a disconnect between aquatic systems (Walker in NWC, 2010). Over allocation has occurred in some tributaries (these include the Plenty, Styx, Jones, Lachlan and Tyenna rivers) of the Derwent catchment where irrigation direct takes are present. In recent years, this has led to water restrictions being placed on these rivers in most average to dry summer periods to ensure adequate flows for stock and domestic, and environmental purposes are met (see Table 11 PART 1). Severe restrictions have also been placed on the direct irrigation from the Clyde River over several seasons due to low lake levels in Crescent and Sorell.

Actual water use within the catchment is unknown as allocations are not necessarily an accurate indicator of water consumption. Not all dams are registered, as dams less than 1 ML (that do not lie on a watercourse) do not require a license, and there a number of illegal dams up to 20ML in size reported to exist. Whitehead et al (2010) reported the estimated total volume of unlicensed dams in the Derwent Catchment to be 712.6 ML, based on Hydro Tasmania modeling. Water metering is required to provide a more accurate picture of water use within the catchment, and ensure compliance with water licenses

5 Water quality stressors and risks

4.1 Climate change

Stressors and risks identified in the Derwent catchment, based upon available information include climate change related variations in temperature, rainfall, and evaporation. The seasonality and intensity of rainfall is predicted to have a greater impact on water quality than climate-change induced increases in temperature rise or evaporation, due to the strong linkage between nutrient transport and river flow. On a local scale, temperature rise and increased evaporation may result in increased stress to aquatic fauna, and/or shifts in community composition in the longer term. Stress to ecological communities from climate change related changes in water quality are not well understood on a catchment level.

4.2 Blue-green algae

Algae and cyanobacteria are associated with still or slow-flowing environments with adequate available nutrients and light. Low flows or lake levels, and warmer temperatures in summer and autumn can provide ideal conditions for blooms. Both the frequency and extent of blooms in aquatic systems is predicted to increase with climate change (Walker, 2010) with implications for water supply, drinking water quality and environmental impacts expected. Blooms of cyanobacterial species occur in the headwater storages of the

Derwent, as well as the Lakes in the Lower Derwent Power Scheme and it is believed that blue-green algae are resident in most Tasmanian sewage lagoons, and as such present a source of algae to the receiving environment under bloom situations where discharge cannot be restricted. Due to a lack of historical monitoring results, it is unknown if the levels of blue green algae measured by Hydro Tasmania throughout the Derwent Lakes during the recent drought represent 'typical' conditions, or an increase in response to the drought.

The presence and down-stream transport of blue-green algae capable of producing toxins poses a threat to the drinking water supply intake at Bryn Estyn, and a better understanding of the levels, movement and cycling of algae is warranted in the catchment.

4.3 Contaminants

Information on heavy metals, organic contaminants and other chemicals associated with industry and/or trade waste were not easily accessible for this study, and based on the limited monitoring available, appear to be poorly defined within the catchment. The level of risk associated with these contaminants not well understood.

4.4 Land use change

Updated land use data in the Derwent catchment from the Rapid Eye project was not available for use within the time-frame of this study. One of the identified future benefits of contemporary land-use data is that impacts (changes in cropping type, water use/storage and demand for example) from proposed irrigation schemes in South-East Tasmania can be more accurately assessed. Once available for public use, the updated land-use data would be useful for considering the location of water quality and quantity monitoring sites, for a range of land-use categories, and for best assessing the long-term impacts of future irrigation development. It may also be useful for determining what kinds of water quality parameters are best suited to assessing water quality (by examining chemical use associated with various crop or plantation types) and where contaminant monitoring should be undertaken in addition to basic WQ parameters.

4.5 Changes to flow through future energy demand and production

Whilst hydro power generation is a renewable energy source, it is climate dependent and not immune to changes in rainfall patterns and water inflows. Changes to the demand for energy through population or industry growth may also potentially affect flows in the Derwent through altered energy demand. Lake level management is demonstrated to have impacts on water quality within the catchment, and management of storages for long-term yields is a critical factor in water quality in the upper catchment in particular.

4.6 Aquaculture expansion

Allocations for aquaculture represents the largest single use for many rivers in the catchment. Despite being a "non-abstractive" use, the impact of aquaculture operations on local water quality is believed to be significant, based on the Upper Derwent Nutrient Study, however there is no contemporary data available for this project to re-assess the current situation. Given the trend for an increase in marine aquaculture in Tasmania, demand and dependency upon good water quality by hatcheries will also increase. A re-evaluation of the regulatory framework for freshwater aquaculture has previously been proposed (*K. Allen, pers. comm*).

4.7 Recreational pressure

Increased visitors to National Parks and reserves put pressure on water resources. Water quality in areas of wilderness may not meet drinking water standards due to the presence of faecal contamination (human and/or wildlife), and waste treated at WWTPs may

still impact downstream water quality. Increased demand for accommodation and the 'wilderness experience' requires careful management of associated infrastructure (roads, water supply etc). Increased recreational use and popularity of the lakes in the lower catchment for shack accommodation has been raised as a concern, particularly for drinking water quality downstream of areas where multiple waterfront dwellings have appeared which rely on septic systems.

4.8 Aesthetic aspects of water management

Whilst not addressed in any detail in PART 2 of this study, it is recognized that aesthetic water quality is an important component of community perception of water quality and environmental health. Water level management in storages and lakes has demonstrated effects on water quality through nutrient cycling and turbidity, and in some instances the occurrence of blue-green algal blooms. Low lake levels, particularly in artificial water bodies where vegetation has been "drowned" or where fluctuating water levels has left shoreline scars have low aesthetic appeal. Restricted access due to receding water levels, poor recreational water quality ratings and impacts on recreational fisheries are also among community concern about waterway health.

6 Summary of catchment processes & condition

A summary of catchment and water quality condition can be gained by combining information available from CFEV database with the water quality information integrated for this report. The CFEV naturalness score combines a range of ecosystem condition scores using expert rule systems (DPIW, 2008b). Geomorphic condition, biological condition, hydrology, fish, native riparian vegetation, artificiality, sediment input, catchment disturbance, water quality, physical sensitivity and catchment size are used as inputs to describe naturalness in rivers, water bodies, wetlands and karst systems, with naturalness defined as pre-European settlement conditions. Figure 5 shows the naturalness categories for river sections (>2 order) for the Derwent catchment. Scores broadly parallel the findings of the water quality assessment on a catchment scale, with headwaters of the upper Derwent and western inflows in a state of high naturalness, with eastern inflows and parts of the main stem of the Derwent River classified as having low naturalness.

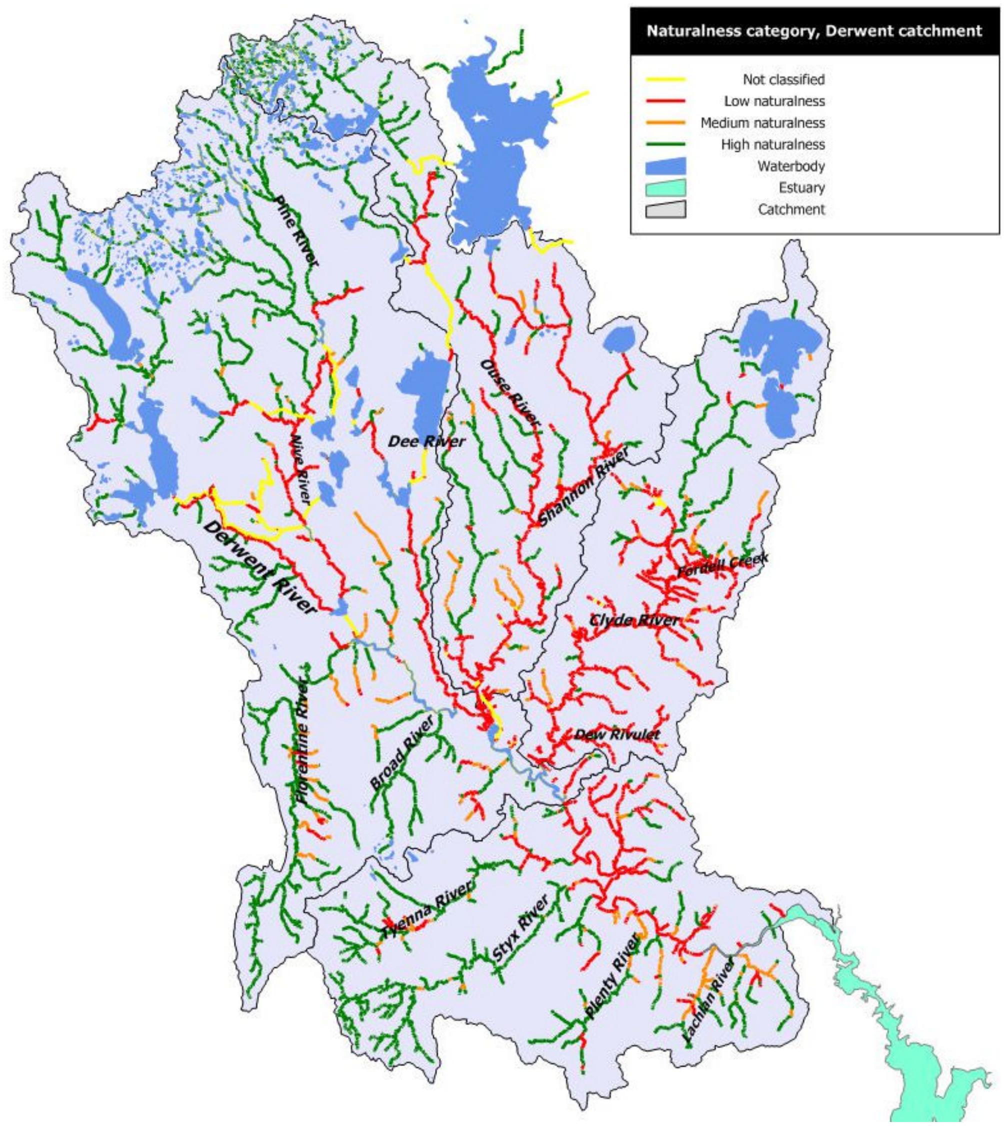


Figure 5 Naturalness ranking for rivers in the Derwent catchment. (Base layer by CFEV, the LIST © State of Tasmania).

The naturalness scores for water bodies in the Derwent are presented in Figure 6, and differ considerably from the water quality findings due to the artificial and managed nature of most water bodies in the catchment which lowers their naturalness rating. Lakes affected by hydro power production and/or irrigation are typically classified as having low or medium naturalness, with only a portion of the lakes of the central plateau having a high N-score. This lower rating does not necessarily indicate poor water quality, but rather a deviation of the lake from natural conditions, as evidenced by Lake Fenton which has a low naturalness score, despite providing water of very high quality to Hobart.

To summarise the information gathered during the study, a description of the flow regime, important water quality processes and risks or threats was prepared to assist in the development of conceptual models for key aspects of water quality and quantity in the Derwent catchment. Details are included in Table 1 and Table 2.

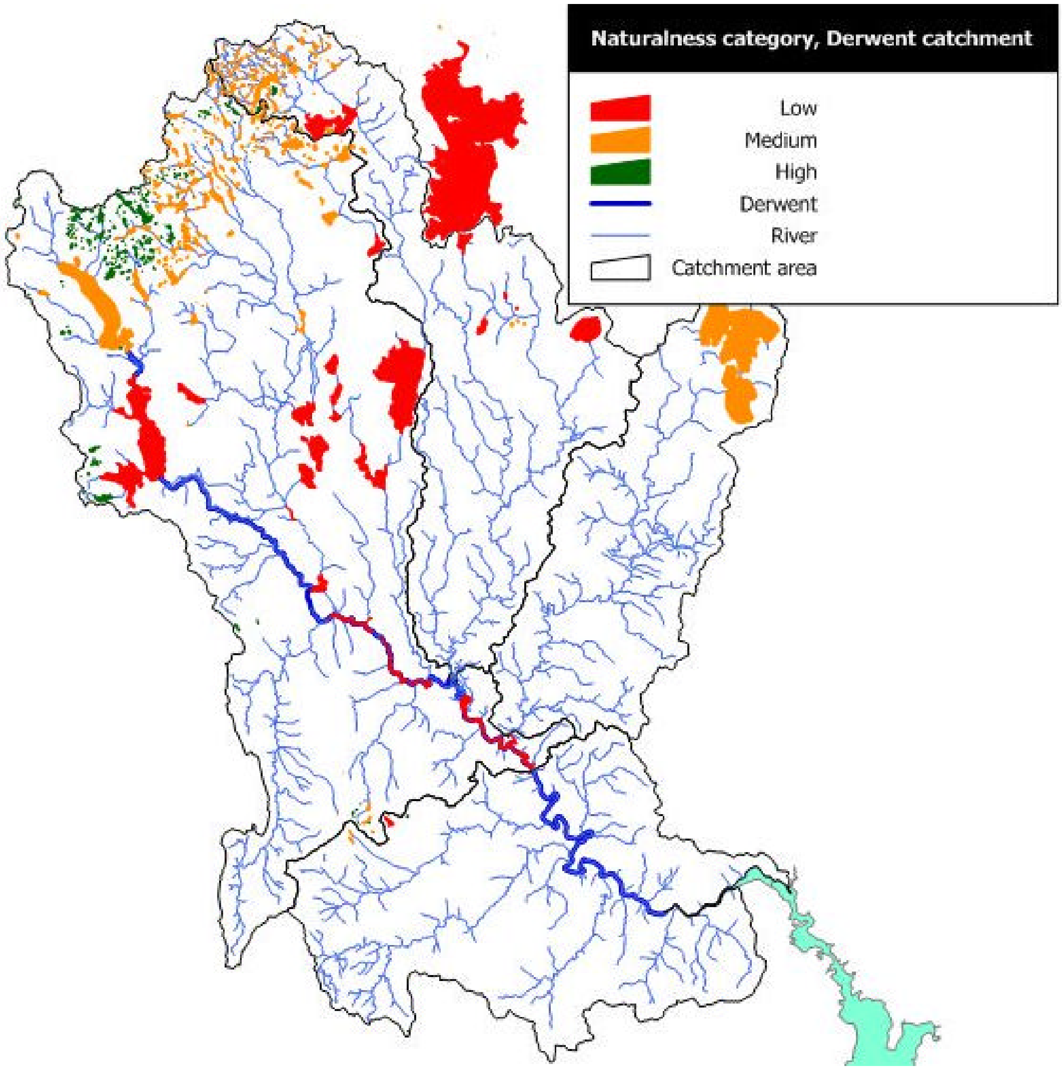


Figure 6 Naturalness ranking for water bodies in the Derwent catchment. (Base layer by CFEV, the LIST © State of Tasmania).

Table 1 Summary of flow regime, water quality processes and inputs, risks or threats to regions within the Derwent catchment.

Region	Flow regime(s)	WQ Processes	WQ Inputs/Risks/threats	Other comments
Upper Derwent	-Year round rainfall but higher in winter; -Few unregulated waterways apart from Upper Nive and from catchment area downstream of diversions; -Flow variables in most waterways highly modified due to numerous diversions and storages in catchment; -Approximately 30% of flows from Upper Derwent are diverted out of catchment via Great Lake; -Most water directed to lower Derwent via 2 power stations; -Managed to provide relatively uniform flows year round; -High flow events result in 'spills' into Lower Derwent system.	-Water is highly dilute, with EC generally 10 - 30 µS/cm in unregulated rivers and <20 µS/cm in lakes; -Tributaries below diversion points are characterised by larger temperature and turbidity fluctuations associated with reduced flow volumes; -Atmospheric and ground water inputs predominate; -Water temperatures in unregulated tribs range from ~4°C in winter to 20°C in summer; -Thermal stratification of lakes in summer is common, with vertical mixing producing uniform profiles over winter. -Temperatures in lakes range from ~4°C in winter to ~15°C in surface waters in summer; -DO decreases with depth in lakes in winter but no evidence of hypoxia; -Waters well mixed before entering lower Derwent due to passage through power stations.	-Available results suggest water quality is very good. -Chlorophyll-a higher in summer in lakes; -Higher nutrient levels associated with low lake levels, as is higher turbidity; -Point source inputs associated with recreation and parks infrastructure; -Outside of National Parks and reserves inputs from land use practices (grazing, forestry, unsealed road runoff) major risk; -Lakes generally provide 'buffers' for water quality and prevent rapid changes over short time periods; -Lakes can also promote algal growth under right conditions; -Climate change could affect flow regimes and lake levels	-Limited water quality data, but what is available suggests water is in excellent condition. -Hydro Tasmania monitors and manages lake level associated water quality issues during droughts

Region	Flow regime(s)	WQ Processes	WQ Inputs/Risks/threats	Other comments
Western inflows (Tyenna, Florentine and Broad Rivers)	-Year round rainfall but higher in winter, low summer flows; -East/West gradient in rainfall with eastern side of catchment drier; -Water quality in Broad, upper Florentine very good. -Smaller rivers with no regulated waterways in catchment, contribute natural flow patterns to the lower Derwent but do not override regulated "signal" from Upper Derwent; -Flows dictated by seasonal rainfall patterns; -Most dams and off-takes located around Tyenna, Plenty, Lachlan Rivers and Sorrell Ck to west and Allenvale Rivulet, Back River to east; -Some weirs/diversions in the lower Plenty; -Flow regime and sediment transport affected in some tribs due to willow infestations; -Flow in lower Derwent River dictated by releases from Meadowbank; -Position of salt-wedge "managed" by flow to maintain position below Bryn Estyn and Lawitta.	-WQ in western upper catchment generally good, low turbidity < 5 NTU and nutrients; EC~100-200 µS/cm; -Mix of forestry and conservation in headwaters; -Deterioration in WQ downstream towards low lying areas used for intensive agricultural production and population centres, with increase in nutrients and EC; -Significant geo-conservation areas (Karst) in upper Tyenna, carbonate geology influence water quality through higher pH; -Seasonally high inputs of TN and TP in some rivers; -Floodplains around the Plenty and Styx have been developed for agriculture; -Turbidity increases with floods and storm events; -Small ephemeral streams can influence WQ at BE intake; -Water temperatures in unregulated tribs range from ~5°C in winter to ~20°C in summer; -EC affected by seasonal flows, ranges between 60 and 300 µS/cm.	-Nutrient point source (ammonia, phosphate) associated with fish farms on Tyenna, Wayatinah and Florentine River STP's; -Karst systems vulnerable to land use practices; -Riparian vegetation highly disturbed in lower reaches of rivers, extensive weed encroachment and slumping of riverbank in some locations; -Pesticide use in agricultural areas, forestry inputs; - Stock access, roading, gravel extraction and de-snagging identified as threats; -Stream diversion/weirs alter channel character and fluvial processes, limit sediment transfer and replenishment of bars and floodplains during flood events; -Major intake for Hobart's drinking water supply vulnerable to catchment practices, but Meadowbank and upstream lakes provide some buffer although may become problematic in the event of blue-green algal blooms; -BE intake WQ vulnerable to river flow/climate change conditions; -Potential over allocation of water in some tributaries of Lower Derwent.	-DPIPWE have developed site specific water quality triggers for the Tyenna at Newbury Rd;

Region	Flow regime(s)	WQ Processes	WQ Inputs/Risks/threats	Other comments
Lower Derwent Lakes	-Highly regulated by managed flows from Upper Derwent and at Power Stations; -Seasonal inflows from unregulated tributaries in lower Derwent tributaries during winter; -Outflow from Lake Meadowbank is primary freshwater source to Derwent Estuary and main supply of water to Hobart Water.	-Seasonal thermal stratification; -Increase in EC from ~20 at Liapootah to >50 µS/cm at Meadowbank; -Increase in nutrients through lakes; -Inc. in water quality parameters related to episodic inflows from tributaries; -Increase in algal growth d/stream	-Inputs from land use practices (agriculture, grazing) are a risk as riparian zones in poor conditions in many areas; -Inputs from recreational activities, including 'shacks'; -Increased nutrient levels can promote increased algal growth.	-Hydro Tasmania monitors and manages lake level associated water quality issues during droughts; -Dominant source of water to Hobart especially in Summer months; -Blue green algae are a potential risk.
Eastern inflows -Ouse	-Seasonally variable rainfall with higher winter rainfall, lower rainfall overall than upper/western catchment; -Both the Ouse and its major tributary the Shannon regulated by Hydro power development (Waddamana closed 1994); -Dams on the upper Ouse and upper Shannon divert water to South Esk basin; -Reduced flows in lower Ouse as result; -Releases from Shannon Lagoon and Lagoon of Islands provide water for stock, irrigation, to lower catchment; -Flow regime and sediment transport affected downstream of Waddamana (and tribs) due to willow infestations and cumbungi in lower reaches; -Density of dams and offtakes concentrated in lower third of the catchment; -Number of weirs located in the lower sections of the Ouse; -No environmental flow established for Ouse.	-Upper catchments assessed as generally healthy, but not pristine; -Mid-section of river in moderate condition; -Significant degradation of water quality in lower Ouse, with occasional high conductivity in lower reaches (200 – 550 µS/cm), and periodic low DO.	-Nutrient/algae/turbidity issues with Lagoon of Islands, Boggy Marsh Rivulet; -Poor in-stream & riparian habitat, impacted by land-use (intensive grazing, dairy farming, cropping); -Low flows in middle & lower catchment affect oxygen, temp, pH -Riparian vegetation highly disturbed in lower reaches of rivers, extensive weed encroachment and willow; -Ouse STP may impact (no data but known poor design). Reuse should be considered; -Fertiliser application/runoff in areas of intense grazing & cropping; -Stock access leads to localised stream bank instability, faecal contamination; -stream diversions in lower reaches of Ouse near confluence.	-Most impacts associated with agricultural land-use and controlled river flows, impacts greatest in lower reaches of river; - Restoration of instream and riparian habitat key to improvement in macrofauna communities, bigger driver than water quality.

Region	Flow regime(s)	WQ Processes	WQ Inputs/Risks/threats	Other comments
Eastern inflows - Clyde	-Catchment rainfall low compared to rest of Derwent catchment; -2 major lakes at headwaters of river, water level in both lakes regulated; -Flows in river controlled by releases from Lake Crescent and Sorell; -Flows further down the catchment supplemented by pick-up downriver; -Most of the entire length of the river classes as moderate or poor condition; -Management of carp affects lake level management; -No natural seasonality in flows, low in winter (storages filled), highest flows in summer -Flow regime prescribed in Clyde WMP.	-Moderate to severe erosion in the central plateau contributes to water quality issues. -25% of catchment around Bothwell and Hamilton moderately affected by salinity with 7% severely affected -Bothwell STP on 100% effluent re-use. -Lake Crescent/Sorell source of high nutrient concentrations, frequently turbid. -Low flows result in low DO, turbidity, taste and smell issues -Low flows and poor water quality resulting from low lake levels in Sorell/Crescent triggered Hamilton drawing town water supply from Meadowbank -riparian veg fragmented and isolated -AUSRIVAS assessment shows lower reaches significantly disturbed - Poor WQ in tribs (Dew Ck, Fordell Ck) also contribute to high nutrients, conductivity, turbidity and low DO.	-Water quality issues associated with larger residential centres (sewage treatment, refuse disposal, drinking water supply) are high priority; -High nutrients from Crescent affect WQ in entire river length; -Natural seasonal flow overridden in upper Clyde by controlled releases for irrigation; -Intense land-use (grazing, irrigation, agriculture). -Reports of nutrient enrichment, siltation below Hamilton STP.	-DPIPWE have developed site specific water quality trigger for the Clyde d/s of Crescent; -WMP for Lakes Crescent and Sorell.

Table 2. ISSUES COMMON TO ALL CATCHMENTS

Management issue or activity	Site	Issues	Water quality parameters affected (other measures)
Agricultural activities	Widespread impact on riparian zones, (loss of native habitat?)	Erosion, run-off from agricultural land and areas where stock have unrestricted access to waterways, (conversion of native vegetation to pasture?).	Damage/loss of riparian communities, loss of habitat for aquatic species, bacteria, pathogens, nutrients, BOD, TSS, (pesticides?).
Chemical use	Areas managed for cropping and forestry	Potential for contamination via spray drift/application entering waterways, drinking water, toxicity to non-target species.	Chemicals associated with land-use in catchment.
Storm water	Most significant around areas with large impervious areas (roads, roofs, paths, drains etc.)	Reduced groundwater recharge, increased run-off and mobilisation of sediment, contaminants and pathogens.	Pathogens, TSS, turbidity, heavy metals, oil and grease, nutrients (litter).
Septic tanks	Believed to be widespread	Poorly functioning or located systems result in seepage contaminating waterways.	Bacteria, pathogens, nutrients, BOD.
Waste disposal sites	Widespread	Leachates, groundwater/surface water contamination.	pH, conductivity, metals, organics, nutrients.
Climate variability/water sustainability	Whole catchment	Change in seasonality, intensity and quantity of rain, temperature/evaporation and run-off.	Streamflow, surface water extractions, impacts on high conservation assets.
Vegetation clearance	Widespread	Erosion, run-off, changes to sediment movement, link to dryland salinity	Nutrients, TSS, EC

Table 2 Summary of water quality related issues common to all catchments in the greater Derwent catchment.

7 Summary and Recommendations

6.1 Adequacy of existing monitoring

Present water quality monitoring in the Derwent catchment is generally limited to reactive monitoring in response to an incident or set of conditions, or the on-going monitoring of a routine set of parameters for a specific purpose (e.g. drinking water intake). Because the headwaters of the catchment are situated in a pristine area, and are managed to provide a year-round flow to the lower catchment, the 'base flow' of the Derwent is of very high quality. Historically this has lead the Derwent to be considered as a low water quality risk. Extensive development in the South of the State has occurred, with Hobart drawing 60% of its drinking water from the Derwent.

However, the analysis of water quality results has also shown that there are a range of actual and potential water quality issues in the catchment, with the understanding of the waterway limited due to a lack of information. Like many catchments in Tasmania, the Derwent is a multiple use catchment, with the drinking water intake situated at the most downstream site possible. This configuration has inherent risks as the water quality results from the catchment clearly shows that there are periods when water quality is compromised, usually due to large inflows associated with storm events (turbidity, nutrients), or no inflows associated with drought (salinity, blue-green algae).

In order to assess the state of the Derwent catchment, and support improvement and protection of water quality, a more integrated approach is required. Available water quality results suggest that whilst the water quality is generally good, in a number of regions there are issues which are increasing risks to water, and that the present approach is not adequate. Monitoring is spatially limited, with recent program rationalization resulting in the reduction of parameters at some longer-term sites.

Goals of existing monitoring programs across organisations are not universal, and necessarily reflect the management responsibilities, budget, and interests of each organization. This leads to disparity between data sets, which limits the ability to integrate information between monitoring programs. The variation in spatial and temporal monitoring, along with variation in parameters, makes catchment scale comparison extremely difficult and of limited value.

A template for a long-term broad-scale monitoring program involving multiple organisations, and agencies already exists with the ambient, stormwater and recreational water quality monitoring programs managed by the Derwent Estuary Program. This multi-stakeholder approach to water quality provides a model for coordinated monitoring, data management, sharing, and review, with demonstrated benefits to participants, improved understanding of the estuarine system and targeted management actions.

A collaborative approach to monitoring and reporting will improve communication of existing and emerging issues between stakeholders, provide an opportunity for whole of catchment reporting, and improve opportunities for management of often complex or widespread natural resource issues.

6.2 Knowledge and data gaps

- There is no comprehensive catchment water monitoring program that addresses the range of water quality issues and emerging threats in the catchment;
- There is no comprehensive data set which provides a contemporary overview of water quality throughout the catchment. Different regions of the catchment are monitored for different parameters and at different frequencies, and these are difficult to integrate.
- There is a lack of information about actual water use in the Derwent catchment, (allocation does not necessarily equal use); All water allocations should be metered to ensure compliance with licences by water management regulators;
- Impacts of Level 2 facilities other than WWTP are unknown. Data availability was limited for this study, and a more detailed assessment of other activities would require the participation of both the operators and the EPA.
- Fish hatcheries are an un-quantified source of nutrients to several tributaries and lakes in the Derwent. As this industry has expanded, and continues to expand in the State, a better understanding of the impact from these facilities is warranted;
- Level 1 STP and receiving environment data is difficult to obtain, but potentially important on a local scale. The central collation and analysis of this information would fill a major information gap;
- To provide a more thorough indication of the impact from waste water treatment plans, the monitoring of level 1 and level 2 STP effluent sites should encompass a wider range of parameters, based on risk assessment of STP influents, and the sensitivity of the receiving environment;
- Impact of septics in non-sewered areas on local water quality not known;
- Drinking water quality data for rural towns (other than microbial summaries prepared as part of the State of the Industry reports) are not easily available. This data would provide an additional level of detail on local catchment water quality.
- Similarly, stormwater quality for rural towns associated with light industry and commercial activities information either does not exist, or is not easily available;
- There is a lack of information about the sediments residing in the lakes and impoundments. Sediments can influence water quality under low lake level scenarios, and are important for nutrient and blue-green algae processes and cycling;
- No information was available regarding the ongoing water quality impact of historical tips and landfills. An audit of these sites, which includes flow monitoring to allow the calculation of fluxes would fill this information gap.
- Insufficient information is available on contaminants such as pesticides, particularly in the Ouse and Clyde catchments;
- There is a general lack of event-based monitoring in the catchment, making flux estimates inaccurate and understanding of important processes difficult ;

- Little is known about tributaries other than the major rivers; ephemeral systems and smaller rivers are largely unmonitored. These waterways have been identified as an important knowledge gap in the lower Derwent CAP process, and by Southern Water; and,

6.3 Priorities for collaborative monitoring program

It is strongly recommended that a whole of catchment water quality monitoring program be initiated which replicates the style of the Upper Derwent Nutrient Study (ie. spatial and temporal monitoring, combined with high frequency or event based studies of key parameters). The scope should include at minimum nutrients, chlorophyll-*a,* phytoplankton composition, flow, basic physico-chemical parameters (pH, EC, temperature, turbidity, dissolved oxygen, total suspended solids) and pesticides, over a range of flow conditions. These concentrations and fluxes would provide a baseline of present conditions in the catchment and be able to be compared to the early study to provide an indication of any significant change.

An initial approach would be a whole of catchment risk assessment to evaluate vulnerabilities, with involvement from all stakeholders to further identify knowledge gaps, and determine capacity and opportunities for collaborative monitoring program. A catchment management group would be required to co-ordinate activities, and develop a program to the benefit to all parties involved. Advantages of this approach include:

- Formalise some of the existing project-based collaborations between catchment managers;
- Provide a forum for on-going review of water quality issues by catchment managers;
- Enhanced communication between stakeholders about water quality issues and the downstream impact of management strategies (e.g advanced notification to downstream users of the development of blue-green algae blooms in the upper catchment);
- Liaison between group members as to issues and monitoring requirements for a co-ordinated program;
- Provide opportunities for cost sharing in broad-scale monitoring;
- Increase opportunities for collaborative partnerships in site-specific issues (e.g. value adding by including a water quality component to detailed geomorphological studies, riparian condition assessment, or before and after monitoring of rehabilitation works);
- Capacity for centralised data storage and/or formal data sharing arrangements to improve data sharing , review and reporting;
- Provide opportunities for co-investment in specialised monitoring equipment such as high-frequency samplers, data loggers or sensors;
- Provide a framework for developing resource condition reports, and provide an avenue to provide updates and information to key decision makers (NRM South, 2010).

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