Report of the George River Water Quality Panel

June 2010

An investigation into the Australian Story report: 'What's in the Water?'



George River Water Quality Panel Members

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www.georgeriverwater.org.au

Executive Summary

The George River Water Quality Panel was convened at the direction of the Premier of Tasmania in March 2010 to investigate information reported on Australian Story on February 15th and 22nd. In the program ecologist Dr Marcus Scammell and General Practitioner Dr Alison Bleaney asserted that toxicants derived from *Eucalyptus nitens* plantations in the George River catchment were having a deleterious effect on human health in the St Helens community, who rely on the George River for drinking water, and on the health of commercial oyster farms in Georges Bay.

The George River Water Quality Panel (GRWQP) was convened by the independent chair of the Environment Protection Authority (EPA) and includes nationally and internationally recognised experts in the area of human health epidemiology, ecotoxicology, water quality, oyster health, and eucalypt biochemistry. The Panel has reviewed all available information relating to the claims made on Australia Story with the aim of providing the Government and the community with an opinion as to the validity of the claims with respect to human, oyster and ecosystem health.

After initial reservations by Drs Scammell and Bleaney, the Panel received their full co-operation in making their research available. The Panel was also aware that another unknown party, a client of the law firm Slater and Gordon, had commissioned further relevant research by Dr Chris Hickey (NIWA, New Zealand) who also appeared on *Australian Story*. Despite a number of requests the information on this research has not been made available. This has perplexed the Panel given that one of the calls from the *Australian Story* was for the concerns raised to be further investigated.

The Panel has completed an in-depth review of the issues associated with human, oyster and ecosystem health and have found the following:

1. The Panel has reviewed all available human health data for the St Helens community, including investigations and reports completed in 2005 following Dr Scammell and Dr Bleaney's first report and subsequent investigations, which incorporate cancer rates through 1993 – 2008. The Panel did not receive any additional human health data during this review process from Dr Bleaney. Based on community health records for the period 1993 – 2008 provided by the Department of Health and Human Services (DHHS), a modest excess of colorectal cancer was identified for the larger Break O'Day area relative to the State, but this increase was not evident in the population residing in the St Helens water catchment, with cancer rates consistent with the demographics and socioeconomic profile of the community. The incidence and pattern of cancer within the region did not show any characteristics of a 'cluster'. These findings are supported by a number of other General Practitioners in the region who have not observed any unusual levels or clusters of disease.

2. The deflated foam samples used for the ecotoxicological investigations were highly concentrated by the 'skimmer box' apparatus used to collect the foam. The skimmer box effectively collected foam, but also effectively concentrated the surface microlayer of the river as it passed under the foam in the box. The ongoing collapse of the foam creates particulates composed of the organic material present in the surface layer of the river. The extreme concentration of the foam created by the skimmer box accounts for the observed experimental toxicity of the foam. A conservative estimate of the concentration factor of the samples from the South George River is ~1400-fold. All samples tested by Scammell (2010) were found to be non-toxic at concentrations of 25%-75%. These non-toxic concentrations are higher than the concentrations present in the natural environment by several hundred fold. A range of naturally occurring plant derivatives could be contributing to the observed experimental ecotoxicity in the highly concentrated foam, as it is well established that vegetation contains substances to repel potential grazers, and when concentrated, these substances may be toxic.

3. These highly concentrated, deflated foam samples pose no human health risk to the St Helens community because:
   - The sub-surface intake of the water treatment plant precludes the ingress of foam into the treatment system;
   - River water samples from the George River which do not contain concentrated foam have been found to be non-toxic to sensitive aquatic biota by both the scientists involved in the *Australian Story* and the Department

of Primary Industry, Parks, Water and Environment. (DPIPWE);

- Any toxicants that might be present at low concentrations in the water and its associated unconcentrated particulates will be effectively removed during treatment via settling and filtration;
- The aquatic toxicity of the foam is short-lived, lasting only 3 to 5 days. Treatment, storage and reticulation of water in St Helens generally exceeds 3 days except during the peak summer season;

4. There is no evidence that pesticides in the drinking water supply in St Helens pose health risk to the community as suggested by Dr Bleaney, because:
    - The water intake is at depth in the river thus eliminating the ingress of surface films or foams which might concentrate herbicides or insecticides;
    - Baseline water quality monitoring of the raw water supply has not detected any of a suite of 19 commonly-used herbicides and insecticides monitored at concentrations as low as 0.1 μg/L;
    - High flow water quality monitoring of the raw water supply has not detected any insecticides at concentrations down to 0.1 μg/L (1 μg/L = 0.000001 grams);
    - High flow water quality monitoring of the raw water supply has detected traces of herbicides on numerous occasions. For those herbicides for which Australian health guidelines exists, concentrations have been consistently below guideline levels. Concentrations of 2-methyl-4-chlorophenoxyacetic acid (MCPA), for which no Australian guideline presently exists, were below the WHO recommended level of 2 μg/L which incorporates a 300-fold human health safety factor.
    - The risk of herbicides entering the water supply during high flows is reduced by the management of the water treatment plant. If sufficient reservoir supply exists, water is not drawn from the George River during high flows as it is then more difficult to effectively and efficiently treat due to its rapidly changing characteristics;

5. The toxicity in the concentrated foam samples from the George River cannot be attributed to *Eucalyptus nitens* alone as postulated on *Australian Story* as toxicity has also been detected in concentrated river foam from Crystal Creek, a catchment devoid of *E. nitens* plantations. Ecological monitoring using AUSRIVAS, a standard technique for assessing river ecosystems, shows that the South George River and Ransom Rivers are in near pristine condition suggesting the plant-derived compounds in these catchments do not present a threat at naturally occurring concentrations.

6. Based on the information currently available, it is not possible to positively identify the source of the toxicity in the concentrated foam samples from George River;

7. River or bay foam and associated contaminants *may* be one of many stressors that in combination can affect the health of commercial oysters in Georges Bay;

8. The George River is a multi-use catchment with the water intake situated in the lower catchment. Continuous monitoring for all substances that could potentially enter the river is not possible nor is it an effective use of resources. The best way of ensuring good water quality for all 'users' (ecosystem, human health, oyster production) into the future, is to implement catchment management activities which maintain and enhance the present condition of the river, especially riparian buffer zones, such that the risk of contaminants entering the river are reduced. It is also recognised that in a multi-use catchment, there is need for better information collection and management associated with the chemicals used, and the community needs to be have access to that information;

9. Summary of Advice and Recommendations include:
    - **The Panel concludes that no additional investigations regarding the highly concentrated river foam are required to clarify the issues raised on *Australian Story*.** The extreme concentration of the foam samples more than accounts for the experimental toxicological response of the samples. Based on the natural concentrations of foams and their associated contaminants in the environment, no threat has been identified from them or from *E. nitens* to the ecosystem, Pacific oysters, or human health;
    - It is apparent that Pacific oysters growing in Georges Bay are subject to multiple stressors including temperature, grading, fresh water, toxic algae, turbidity, oyster stocking densities, TBT, other antifoulants agents and other catchment-derived contaminants. River or bay foam, and associated contaminants, may be an additional but minor stressor. **The Panel recommends that if further investigations into the cause of oyster mortalities are undertaken, they include a scientifically robust multi-stressor experiment which incorporates bay foam (and associated contaminants) as a potential stressor. If bay foam is found to exert a significant impact on oyster health, then additional monitoring of organic contaminants in the bay is warranted.**
    - To maintain public confidence in the quality of St Helens drinking water and Georges Bay waters, improved and co-ordinated catchment management and administration should be considered as a matter of priority. Information on the use of chemicals in catchments should be recorded by all users, and those records made available as required to assist with catchment monitoring and the security of water.

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Acronyms, abbreviations and glossary

TERM	DEFINITION
µg/L	0.000001 g/L (1 millionth of a gram per litre)
µm	0.000001 m (1 millionth of a meter)
96 hour LC_{50}	Concentration of a compound estimated to be lethal to 50% of the test organisms after an exposure period of 96-hours
ANZECC / ARMCANZ	Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand
APVMA	Australian Pesticides and Veterinary Medicines Authority: Australian government authority responsible for the assessment and registration of pesticides and veterinary medicines
ASCHEM	Agricultural, Silvicultural and Veterinary Chemicals (ASCHEM) Council
AUSRIVAS	Australian River Assessment System: a standardized method for the assessment of river health
C18 column	Reversed phase liquid chromatography column material used to isolate dissolved organic matter from water
CERF	Commonwealth Environment Research Facilities
Cladoceran	Freshwater flea commonly used in ecotoxicological testing. Common test species include *Ceriodaphnia dubia* and *Daphnia magna*
DFTD	Tasmanian Devil Facial Tumour Disease
DHHS	Department of Health and Human Services, Tasmania
DPIPWE, DPIW, DPIWE	Department of Primary Industries, Parks, Water and Environment. Previously vagency was also known as DPIW (Department of Primary Industries and Water) and DPIWE (Department of Primary Industries, Water and Environment)
DWQMP	Break O'Day Drinking Water Quality Management Plan
ecotoxicology	The study of the harmful effects of chemical compounds on species, population and the natural environment
ESA	Ecotox Services Australasia
Eucalyptus globulus (E. globules)	Native Tasmanian eucalypt tree
Eucalyptus nitens (E. nitens)	Eucalypt commonly grown in plantations, not native to Tasmania, but native to Victoria
FEA	Forest Enterprises Australia Limited
FPP	Forest Practices Plan

TERM	DEFINITION
FT	Forestry Tasmania
GCMS	Gas chromatography-mass spectrometry: an analytical technique used to identify organic compounds
HPLC	High performance liquid chromatography: an analytical technique used to identify organic compounds
IQ-Tox	Rapid ecotoxicity assessment technique based on feeding behavior of the cladoceran *Daphnia magna*
LCMS	Liquid chromatography-mass spectrometry: an analytical technique used to identify organic compounds
MCPA	An insecticide: 2-methyl-4-chlorophenoxyacetic acid
NH&MRC / NRMMC	National Health and Medical Research Council / Natural Resource Management Ministerial Council
NIWA	National Institute of Water and Atmospheric Research
NOEC	No Observable Effects Concentration: the highest concentration of a substance at which no effect is observed on the test organism
PAC	Powdered activated charcoal
PBO	Piperonyl butoxide: a compound that enhances the toxicity of pyrethroid insecticides and decreases the toxicity of organophosphates.
PFT	Private Forests Tasmania
QA/QC	Quality Assurance / Quality Control: laboratory management procedures used to ensure quality of results
TBT	Tributyltin $(C_4H_9)_3Sn$: toxic compound containing tin used as a biocide in marine antifouling paints

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1. Introduction

1.1 Why the George River Water Quality Panel?

On February 15 and 22, 2010, ABC Television broadcast two episodes of *Australian Story* entitled *'Something in the water'* in which allegations were made that an unidentified toxicant was having a deleterious impact on the health of the community commercial oyster production in Georges Bay and the George River and Georges Bay ecosystem (region shown in . The program followed St Helens GP Dr Alison Bleaney and Sydney-based ecologist Dr Marcus Scammell on their journey to identify the mystery chemical. Their work focussed on the collection and analysis of river foam from the George River in which the toxicant was believed to be concentrated. Investigations included ecotoxicity testing and the application of toxicity identification and evaluation (TIE) procedures conducted by well qualified and respected scientists from numerous universities and research institutes. The findings of the investigations ruled out man-made chemicals as the toxicant, and pointed to a substance derived from *Eucalyptus nitens* trees in forestry plantations in the George River catchment as responsible for the observed human and oyster health issues. The program also highlighted that in 2004, similar issues were raised by Scammell and Bleaney with respect to pesticide usage in the catchment, but the lack of man-made substances in the toxic river foam ruled out pesticides as the suspected toxin.

The ABC program created a high level of alarm in the Tasmanian community in general, and in St Helens in particular. In response to the allegations contained in *Australian Story* and the community concern, the Director of Public Health recommended to Government that a process be established to address the scientific research issues raised in the *Australian Story* program. The Premier of Tasmania invited the independent Chair of the Environmental Protection Agency, John Ramsay, to oversee the gathering of evidence and its assessment by relevant experts. The letter outlining this request is contained in Appendix 1 of this report. On May 28, 2010, the Premier granted the Panel an extension of time until June 29, 2010 to submit its Interim Report.

John Ramsay assembled a Panel, comprising experts in human health epidemiology, water quality, ecotoxicology, eucalypt biochemistry and Pacific oyster health, to review and report on all available information associated with the *Australian Story* allegations. Members of the Panel include: Dr Graeme Batley (ecotoxicology, water quality), Dr Christine Crawford (oyster health), Prof Michael Moore (ecotoxicology, water quality, Prof John McNeil (epidemiology), Prof Jim Reid (eucalypt biochemistry). The Panel was assisted by Coordinating Scientist Dr Lois Koehnken. The CVs of the Panel are contained in Appendix 2.

1.2 Background to issues raised in Australian Story

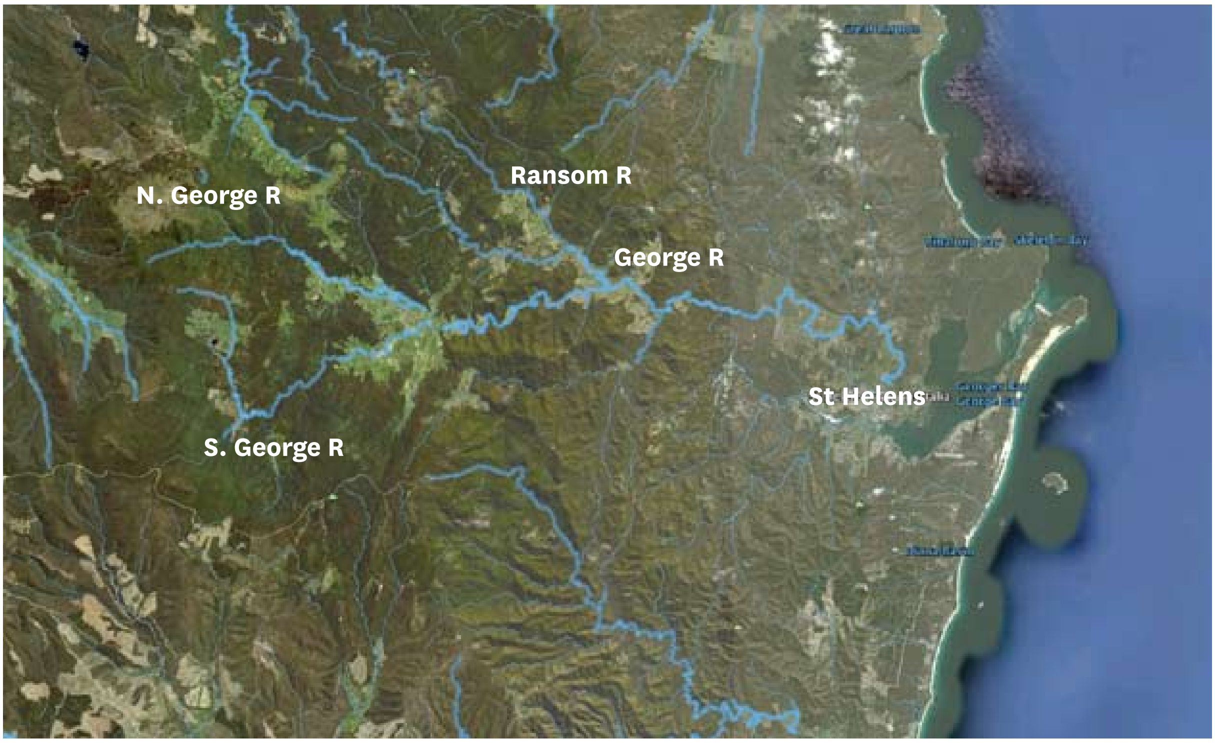
A very brief summary of the history of issues raised in the *Australian Story* is outlined below. Additional information about past investigations and findings is contained in Section 3:

- Late 1990s: Oyster farmers in Georges Bay began recording poor oyster growth rates and elevated mortalites;
- 2002: Dr Scammell investigated tributyltin (TBT) in Georges Bay and concluded that observed shell deformities were consistent with TBT, but concentrations in oyster tissue were well below those associated with shell deformity (Scammell, 2002). He suggested that there were other stressors in the environment which were making the oysters hypersensitive to TBT.
- 2003: Noller reviewed available information and concluded that TBT was unlikely to be the cause of the oyster health issues, and suggested other causes, such as algal toxins, seasonal freshwater, prolonged flooding, turbid waters or agricultural and industrial pollutants, were affecting the oysters;
- Jan – Feb 2004. A one in fifty-year flood event occurred in George River catchment. Following the flood, there was widespread mortality of Pacific oysters at intertidal oyster leases in Moulting Bay. Mortalities were much lower at intertidal oyster leases near the mouth of Georges Bay. Pacific oyster mortalities were also recorded at other oyster leases in the flood effected region (Oyster Bay);
- 2004: Following the flood, Dr Scammell released a report which summarised the oyster issues in the catchment and suggested that the decline in oyster health coincided with an increase in the establishment of plantations in the George River catchment. He suggested that the herbicides, insecticides and fungicides used in the management of plantations were contributing to poor oyster health. He also noted a correlation between the increase in forestry plantations in the northeast of the State and the rise and spread of facial tumour disease in Tasmanian Devils. His conclusions included a recommendation that the *'practice of aerial spraying of biocides on Tasmanian plantations cease immediately until such practices can be shown to be safe'* (Scammell, 2004).
- 2004: Dr Bleaney submitted a letter to the Department of Health and Human Services outlining concerns about human health issues in the community, including an increase in disease rates.
- 2004 – 2008: Various human health, oyster health and environmental investigations were undertaken by Government and reviewed by external experts. Conclusions included:
  - There was no identifiable increase in cancer or other diseases in St Helens, with the rates of disease consistent with the demographics of the community which were rapidly changing between 2000 – 2004 (DHHS, 2004; Sims, undated);
  - No identifiable link between environmental factors and Tasmanian Devil Facial Tumour Disease were identified (Moore, 2008, Ross, 2008);
  - The risk of TBT causing a significant hazard to oysters at the Georges Bay leases was minimal based on the available information (Noller and Ricci, 2006);
  - The impact of pesticides lacked proof of causation because of incomplete information (Noller and Ricci, 2006);
  - There was demonstrated toxicity of naturally occurring toxins (Noller and Ricci, 2006; DPIWE, 2005);
  - Pathological analyses of the oysters following the 2004 flood found a generalised 'metabolic insult' with no single underlying cause identified. Known stressors included prolonged flooding and recent spawning (DPIWE, 2004);
  - No apparent single cause was identified for oyster health problems observed since 1997, and the underlying ill-thrift (failure to thrive)

rendered the oysters vulnerable to additional stressors (DPIWE, undated). Known stressors were identified as grading, flooding and spawning with potential stressors including poor oyster nutrition, toxic phytoplankton, temperature and contaminated water and contaminated sewage (Percival, 2004).

- 2005 – present: Ongoing quarterly and high flow monitoring for 19 herbicides and insecticides has been completed in the Georges River at the Water Intake location;
- 2009: Dr C. Hickey (NIWA) presents a paper at the Australasian Society of Ecotoxicology in Adelaide in September suggesting compounds derived from the leaves in *E. nitens* plantations in the George River catchment are linked to oyster deaths in Georges Bay;
- 2010: Implementation of powdered activated charcoal pre-treatment commenced at the water intake of the St Helens treatment plant, in response to community concern related to *Australian Story*;

Figure 1. (Below) Google Earth image of the George River catchment in northeast Tasmania



1.3 Approach of review

The Panel has adopted the following tiered approach to the information provided by Drs Scammell and Bleaney:

1. Understand the experimental design and approach of the study, e.g. what question(s) were being investigated;
2. Evaluate the experimental and analytical techniques adopted, e.g. were the techniques used appropriate to the question(s) being investigated, and were experiments and analyses completed using appropriate techniques and procedures;
3. Integrate the findings with other available information, and interpret the results with respect to human health, ecosystem health and commercial Pacific oyster production issues, including the identification of any potential hazards and exposure pathways;
4. Identify gaps or additional information needs to fulfil the requirements of the brief;
5. Make recommendations as to further actions or investigations required in light of the findings.

To complete the review, the Panel sought relevant information from the Department of Health and Human Services, the Department of Primary Industry, Parks, Water and Environment (DPIPWE). The Panel also reviewed information about the George River catchment and Georges Bay, forestry operations, and chemical usage in the region.

The Panel met with Drs Scammell and Bleaney, and several of the ecotoxicologists involved in the investigations (R. Krassoi, Ecotox Services Australasia, C. Khalil, University of New South Wales). Valuable input was also provided by individuals involved in the collection of samples (J. Marshall, I. Coatsworth).

The Panel visited the catchment, and met with oyster farmers, Break O'Day Council members, the Chamber of Commerce, Ben Lomond Water representatives and the local NRM coordinator. The catchment visit included the South and North George Rivers, the Water Intake site and Georges Bay.

Human health issues were discussed with the Director of Public Health and Director Population Health, Dr. Roscoe Taylor, and other General Practitioners practicing in the region.

The Panel consulted an international expert, Dr Paul Stevenson of the Department of Chemical and Materials Engineering, University of Auckland, on the nature and behaviour of foams. Drinking water quality, monitoring issues and risk management trends were discussed with Dr Martha Sinclair, Department of Epidemiology and Preventive Medicine, Monash University, who is involved in the recent revision of the NH&MRC drinking water guidelines. Expert opinion on the composition of amino acids in vegetation was provided by Professor Adrian West of the School of Medicine at the University of Tasmania

The structure of the report is as follows: Section 2 contains a summary of the Scammell and Bleaney findings, Section 3 summarises additional information considered by the Panel to be of relevance to the review, with all information synthesised in Sections 4 which constitutes the findings of the Panel's Review. A summary of identified knowledge gaps and recommendations are contained in Section 5.

2. Summary of Scammell and Bleaney Findings

2.1 Health issues raised by Alison Bleaney

In the *Australian Story* program, Dr Bleaney stated that starting around 2000 she observed an 'increase in all sorts of diseases' that was 'quite unexpected and unexplainable'. Illnesses stated to have increased include a wide range of cancers (gut, oesophageal, gastric, bowel, gall bladder, head, and neck), rheumatoid arthritis, scleroderma and lupus *(Australia Story)*. These concerns are similar to those initially expressed in a letter to the DHHS in 2004 as outlined in Section 1.2.

In a meeting with the Panel in St Helens on 20 April 2010, and in a subsequent email (partially reproduced here), Dr Bleaney reiterated these concerns:

> *'The types of illnesses have continued in the last 5 years; especially noticeable has been the auto-immune diseases (e.g. polymyalgia rheumatica) and the cancers. I did notify him (Dr Roscoe Taylor, Director of Public Health) of the GISTs (gastrointestinal stromal tumours) in the NE.*
>
> *The increase in Parkinson's Disease and allergy and diabetes has been especially noticeable over the last 5 years or so but these and the other issues such as increased depression rates etc., have been known to the Health Department for some time, and are also known also (sic) to have increased in Tasmania. Cancer continues to take its toll in the area.'*

In the meeting with the Panel in April 2010, Dr Bleaney also raised concerns that herbicides and insecticides associated with aerial spraying in the catchment could be a contributing factor in her observed increase in diseases. In support of this view, she cited the detection of herbicides (MCPA, 2,4-D and metsulfuron-methyl) in the George River by DPIPWE during monitoring of flood events, the helicopter crash in 2003 in which a range of pesticides were detected at the crash site, and over-spray incidents that have occurred in the catchment.

2.2 Summary of toxicity testing completed by Scammell and Bleaney

Since the 2004 letter, Dr Bleaney has not presented additional human health related data to Government or the Panel. She has indicated that there are difficulties associated with accessing patient records due to changes in filing systems and ownership of the medical practice in St Helens.

The results from Dr Scammell's investigations, completed in 2005 to 2008, were presented to the Panel during a meeting in Sydney and are available on the GRWQ Panel website (Scammell 2010). The findings relevant to the Panel's deliberations are summarised in the following dot-points. The complete report should be consulted for sampling and testing details, and the complete description of results.

1. Water and concentrated foam samples, were collected from various locations in the George River catchment and were used to run a range of toxicological tests. On one occasion surface water from Moulting Bay was also collected and tested;

2. The results of toxicity tests using 'grab' water samples which did not include foam are shown in Table 1.

3. The remainder of the toxicity investigations were completed using concentrated river foam which had been collected using a 'skimmer box' over a 24-hour period. The skimmer box was designed to concentrate and collect contaminants present in the surface microlayer or film of a river. Scammell (2010) employed the skimmer box to collect a concentrated sample to make identification of the toxins easier. He stated that if lipid-soluble (foam-soluble) toxins are present, it does not necessarily mean that they are at sufficient concentrations in the water column to be of concern. Most of the investigations were completed using deflated-foam samples from the South George River upstream of Pyengana. Other sampling sites included the North George River, George River at Pyengana and the water intake for St Helens in the lower catchment;

4. Large volumes of foam were collected and 'deflated'. These concentrated samples were treated in various ways to investigate the source and nature of the toxicity. Their findings include (refer to Scammell (2010) for full description of findings):

a. Filtered deflated-foam samples were found to be non-toxic to the cladoceran (water flea) *Ceriodaphnia dubia*, indicating that the toxicity is associated with particulates present in the foam;

b. The toxicity of the samples to cladocerans decreased over time, with toxicity disappearing within 3 to 6 days of sample collection;

c. Toxicity of the deflated foam samples to cladocerans decreased with dilution. Toxicity disappeared in samples once the concentration of deflated-foam decreased to between 25% and 75% of the sample, depending on the sample;

d. On two sampling dates (March 3 and 24, 2005), toxicity in the samples increased with the addition of piperonyl butoxide (PBO). PBO is a synergist that has been used in toxicity identification evaluations (TIEs) of water and sediment samples to indicate pyrethroid-related toxicity (Amweg and Weston, 2007). It enhances the toxicity of pyrethroids, but will decrease the toxicity of organophosphates. The increase in toxicity associated with PBO addition in the South George samples is consistent with the presence of pyrethroid-like pesticides. The sample collected on March 3 was not analysed for pesticides. The sample collected on March 24 was analysed but no pesticides were found in the sample at an analytical limit of 1 μg/L. It was suggested this analytical limit was too high for the application. Subsequent samples did not show evidence of pyrethroid-like pesticides at the 0.1 μg/L level;

e. Foam samples collected over a rainfall event showed reduced toxicity to cladocerans as inflows to the river increased;

f. Several samples were analysed for a wide range of metals, pesticides and man-made compounds, but none were found in the samples at the detection limits of the analytical methods. It was estimated that 400 naturally occurring substances were detected by the analyses, although none of these were identified;

g. No evidence of cyanobacteria toxins were found in the deflated foam samples;

h. The organic component of the foam and associated particulates was isolated using a C18 column and extracted using various concentrations of methanol. Several of the extracts produced significant toxicity in the cladoceran test, suggesting a range of organic compounds may be contributing to toxicity in the samples;

i. Similar peaks were identified in chromatograms obtained using liquid chromatography-mass spectrometry (LCMS), from the deflated foam and extracts from E. nitens trees present in plantations in the catchment, but no identification was made of the compounds present;

j. Foam collected from a small catchment in St Mary's which does not contain plantations did not result in significant toxicity to the cladoceran test organism;

5. Soils tested from the catchment were not toxic to the test cladocerans. Simazine, metabolites (breakdown products) of simazine, and atrazine were detected in the soil samples.

Table 1. Summary of toxicity testing using 'grab' water samples

Site	Date	Cladoceran Test	Oyster Survival Test	Oyster Larvae Test	Sea Urchin Test
North George R Dry weather	17/01/05		Not Toxic	Not Toxic	Sig. Toxicity*
Pyengana** Dry weather	17/01/05		Sig. Toxicity		Sig. Toxicity
South George Rain event	2/02/05	Not Toxic			
Moulting Bay Rain event***	3/02/05	Sig. Toxicity			

Blank boxes indicate sample was not tested.

Sig Toxicity = Response of the test organism to the test water was significantly different from the control samples.

Not Toxic = Response of the test organism to the test water was not significantly different from the control samples.

*Statistically significant but low toxicity. Survival of controls = 90.8+/- 3.1; survival of test organism = 80.5 +/- 2.7
**Sample collected from George River downstream of confluence of North and South George Rivers and a dairy farm during a dry summer period.
***This sample is reported by Scammell as a 'grab' sample however the field notes and laboratory sample log report record this as a beach froth sample, indicating it was not a 'grab' as reported.

3. Additional information considered by the Panel

A wide range of documents were received and reviewed by the Panel. These are listed in Appendix 3 and the documents are available on the George River Water Quality Panel website **(http://www.georgeriverwater.org.au/)**. Additional documents used by the Panel in their investigations are included in the reference list of this report.

3.1 Additional health related information

The Panel has reviewed the existing statistical analyses and investigations of health-related issues in the Break O'Day municipality, many of which were completed following the initial concerns raised by Dr Bleaney in 2005. These reports and a summary of the findings were:

- DHHS, 2000. *Demographic and health analysis of the Northern Region*. This report summarised the socio-economic condition and health-related issues of Local Government Councils in northern Tasmania. It found that Break O'Day council had an older population and was substantially disadvantaged compared to other local government areas. The results from this report were used in subsequent health analyses.
- Sims, M. (undated) *Review of neurological cases, St Helens.* Dr Sims, of the Unit Occupational and Environmental Health, Department of Epidemiology and Preventative Medicine, Monash University, reviewed 8 neurological cases identified by Dr Bleaney to the DHHS in the St Helens area. He found that there was no identifiable common underlying cause to the cases, and there was no evidence of an underlying toxicant being responsible for the neurological conditions. Dr Sims
- also suggested that, although not applicable to the cases under consideration, the available data do not suggest that chronic exposure to pesticides such as those used locally in the St Helens area are linked to the development of neurological conditions;
- DHHS, 2004a. Investigation of disease cluster in St Helens. The DHHS investigated 8 neurological cases identified by Dr Bleaney as being abnormal. The investigating officers discussed the cases with Dr Bleaney, examined the medical notes associated with each case and obtained specialist advice regarding the cases. It was found that there were no similarities between diagnoses or case histories of the individuals, and no environmental exposure link was identified. Plausible explanations for the symptoms of each case were identified and the characteristics of the cases were not consistent with a 'cluster'.
- DHHS (undated). *Review of thyroid cancer.* Thyroid cancer rates have increased in Tasmania between 1978 and 1998. Part of the increase can be accounted for by better screening and detection, and part may be attributable to changes in iodine intake associated with the discontinuation of universal iodine prophylaxis in Tasmania in the 1980s (Burgess, *et al.,* 2000). Experts consulted during the review knew of no evidence supporting a link between thyroid cancer and usage of chemicals such as atrazine.
- DHHS, 2004b, *Draft interim report St Helens connective tissue disease and haematopoietic malignancy incidence. This investigation compared the actual rates* of various diseases with the expected rates based on the demographics of the community. For diseases for which information was available, no increased incidence of disease was identified.

More recent health analyses of health in the St Helens area reviewed by the Panel include:

- Tasmanian Cancer Registry, 2010. *Cancer in the St Helens area 1997-2007.* Based on information from the Cancer Registry, between 1997 and 2007 there was variability in the number of cancer cases diagnosed and the number of total cancer cases recorded each year, but there was no pattern showing an increase over the ten year period. The report noted that it is difficult to examine results for groups smaller than a Local Government Area because random variation in incidence rates is common in small populations and trends over time are more difficult to interpret;

- DHHS, (2010). *Summary of the St Helens Water District Cancer Investigation for the George River Quality Panel, June 2010.* The DHHS has found that based on statistical analysis of the cancer incidence data for 1993 – 2007, as well as trend data for the period 1994 – 2005, there does not appear to be any evidence of a cancer cluster or abnormal trend in cancer incidence in either the Break O'Day LGA or the St Helens water supply district. Individual cancer types show variability, with some above and below predicted incidence rates, and these are discussed more fully in Section 4.6.4.

The Panel also referred to the recently released report from the US President's Panel on Cancer (President's Cancer Panel, 2010) which suggests that cancers from environmental factors are underestimated, and highlights the range of exposure pathways through which environmental exposure occurs, including drinking water, environment (radon, smoke, car exhaust), and food (pesticides on fruits and vegetables, medications in meat, plastics from the storage and cooking of food in plastics). The Panel has also considered The American Cancer Society's response to the report stating that cancers derived from environmental factors remain comparatively low compared to cancers known to be associated with lifestyle choices (smoking, alcohol).

3.2 George River water quality and toxicity testing results

The Panel reviewed water quality results for the George River associated with the following monitoring programs:

- On-going baseline monitoring of water quality in George River at Water Intake;
- On-going baseline monitoring of pesticides in George River at Water Intake;
- High flow water quality monitoring in George River at Water Intake

Modelled and actual flow data for the George River and its tributaries was provided to the Panel by DPIPWE. Modelled flow results were provided for the South George, North George and Pyengana sub-catchments as well as the Water Intake site in the lower catchment.

The ecotoxicological investigations completed by DPIPWE in 2005 were also considered by the Panel. The DPIPWE investigations found no toxicity in water samples collected from the George River catchment. Foam samples collected with the skimmer box from the George River were found to be toxic using the IQ-Tox test, as was a foam sample collected from Crystal Creek, a catchment that does not contain any *E. nitens* plantations. DPIPWE concluded that 1,8-cineole and β-pinene were likely to be responsible for the observed toxicity, but the concentrations estimated to be present in the samples were well below those known to result in toxicity. The foam samples did contain concentrations of aluminium and iron above those recommended for use with the IQ-Tox test which might have affected the results of the tests (Battelle, 2003).

Dr Rick Krassoi of Ecotox Services Australasia made available to the Panel range-finding test results using 1,8-cineole and β-pinene which showed that the concentrations required to account for the ecotoxicological response observed in the foams was well in excess of those present in the samples.

3.3 Land use in George River catchment

Land use in the George River catchment has recently been investigated as part of the CERF Landscape Logic Project (Kragt and Newham, 2009). The results were made available to the panel and are shown in Figure 1. Based on the recent analysis, approximately 38% of the catchment is categorised as conservation or natural, with 44% classed as production native forests. Agriculture is the next most common land classification, occurring in about 11% of the catchment (dryland farming = 9%). Most of the agricultural activity is located in the central catchment, bordering the George River. Forestry plantations occupy about 6% of the catchment and are located predominantly in the headwaters of the North and South George River, and Powers Rivulet. Urban areas are limited to the lower catchment near Georges Bay and the coast and comprise ~1% of the total catchment area.

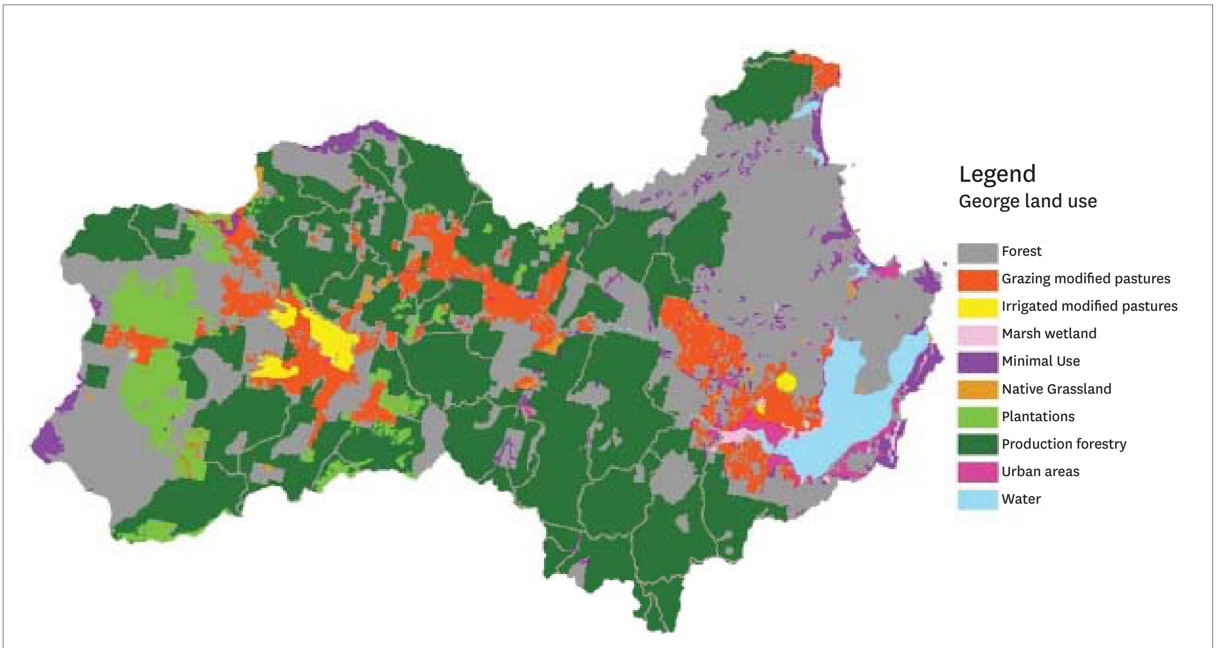


Figure 2. Land use in George River from Kragt and Newham (2009)

3.4 History and distribution of plantations in catchment

The Panel has reviewed the establishment history of *E. nitens* plantations in the George River catchment using information provided by the private companies operating in the catchment, Forestry Tasmania (FT) Private Forests Tasmania (PFT), and the Forest Practices Authority (FPA).

Forestry information is grouped by the sub-catchments shown in Figure 2 (CFEV 2005). Most plantations in the George River catchment are located in the South George, North George and Powers Rivulet sub-catchments. The area of plantations established in each of these three sub-catchments is shown in Figure 3, with information about the remaining sub-catchment summarised in Table 2. The cumulative area associated with plantations in each sub-catchment is also shown for the three sub-catchments.

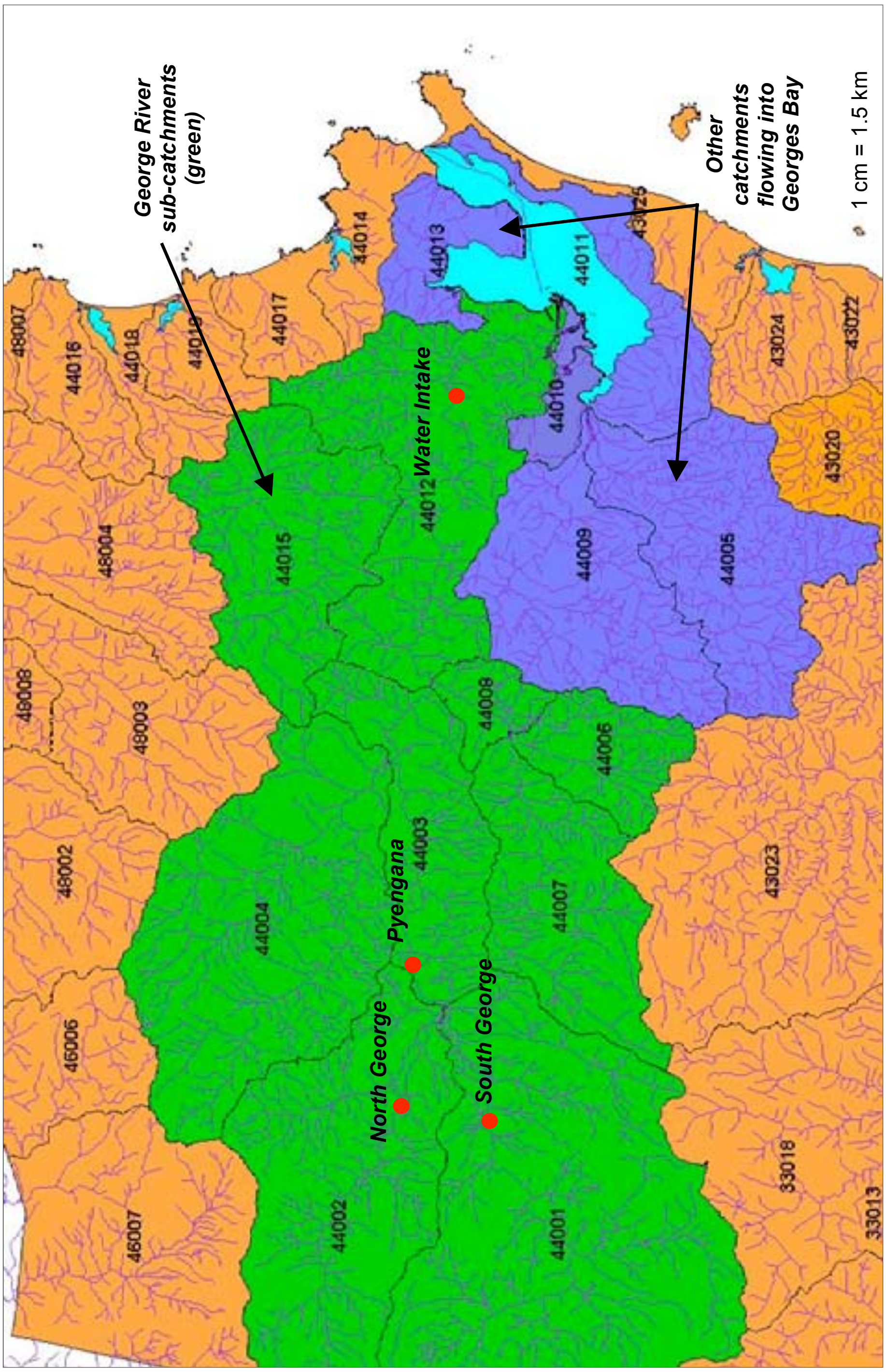


Figure 3. Map of George River catchment from CFEV data base showing sub-catchments. Red dots show sample collection locations of Scammell (2010)

The sub-catchment summaries show that the South George contains the largest area of plantations (1483 ha) with the North George having about half that area (749 ha) and Powers Rivulet about 500 ha. The areas occupied by the plantations range between 9 – 13% in each of the sub-catchments.

The pattern of plantation establishment varied through the catchment. Plantations have been established in the North and South George sub-catchments throughout the 1990s and 2000s and in Powers Rivulet during the 2000s only. In the South George, there was a large phase of plantation establishment between 1992 and 1996, and then smaller phases between 2000 and 2002 and 2006 and 2009. Based on the forestry records the total area occupied by *E. nitens* plantations is approximately 3,000 ha, which is ~7% of the George River catchment, or ~5% of the Georges Bay catchment, which is in good agreement with the CERF Landscape Logic land use analysis.

A comparison between plantation activity in the George River catchment and all FPP aprovals is shown in Figure 4 which compares Forest Practice Plan certifications for plantations with certifications for all forestry activities. Forest Practice Plans only extend back to 1996, so plantations and forestry activity prior to this date are not included, although forestry activities extend back over 100 years in the catchment. 'Other' forestry activity includes the partial harvesting of native forests, and any land clearing which requires a Forest Practices Plan. The graph shows that about half of the certified forestry activities within the catchment over the time period have been associated with plantations.

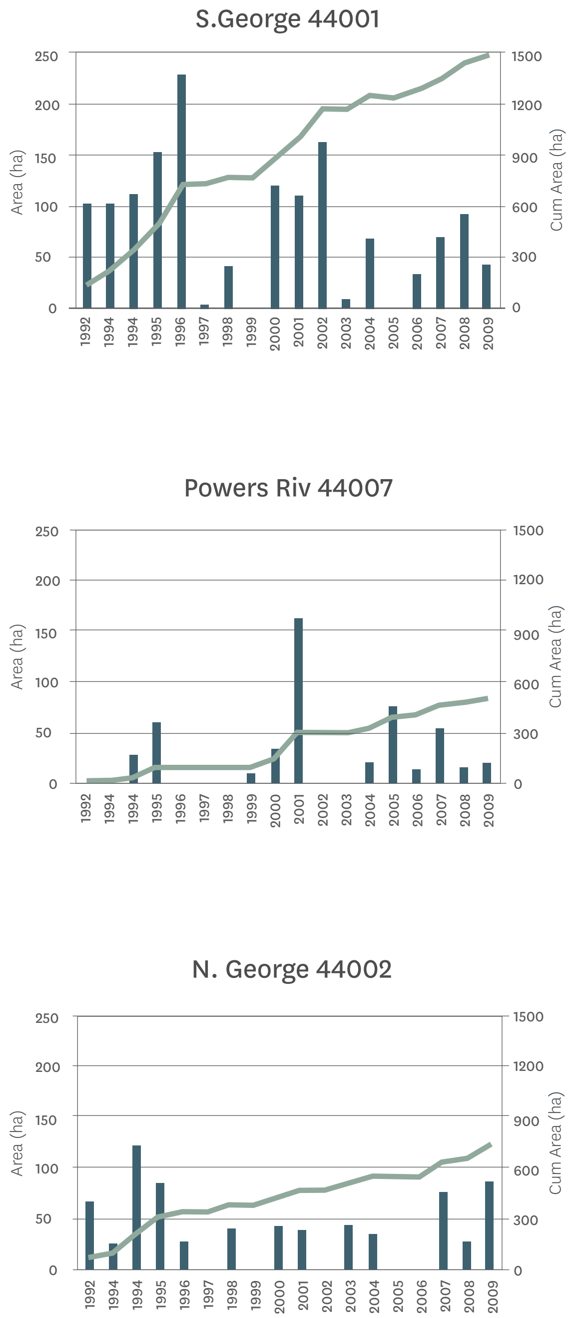


Figure 4. E. nitens plantations in the George River by sub-catchment based on Private Forests Tasmania records. Cumulative total area in each sub-catchment occupied by E. nitens plantations is shown by line graph. Cumulative area shown for 1992 includes area of plantations in catchments existing prior to 1992.

Table 2. Summary of plantations in the George River catchment and in the Georges Bay catchment [a]

George River Catchment	Area (ha)	Area of Plantations (ha)	% Plantations Sub-catchment	% Plantations George R Catchment	% Plantations Total George Bay Catchment
sub catchment 44001	10851	1483	13.7	3.5	2.6
sub catchment 44002	6486	749	11.5	1.8	1.3
sub catchment 44003	3072	75	2.4	0.2	0.1
sub catchment 44004	7202	69	1.0	0.2	0.1
sub catchment 44006	1498	0	0.0	0.0	0.0
sub catchment 44007	3404	499	14.7	1.2	0.9
sub catchment 44008	704	0	0.0	0.0	0.0
sub catchment 44012	5511	0	0.0	0.0	0.0
sub catchment 44015	4014	48	1.2	0.1	0.1
George River Total	42742	2923		6.8	5.2
Other catchments entering Georges Bay	13863	0	0	0	0

a. Area of George Bay catchment is 56605 ha. Plantation data provided by FPA and FT, catchment areas from CFEV

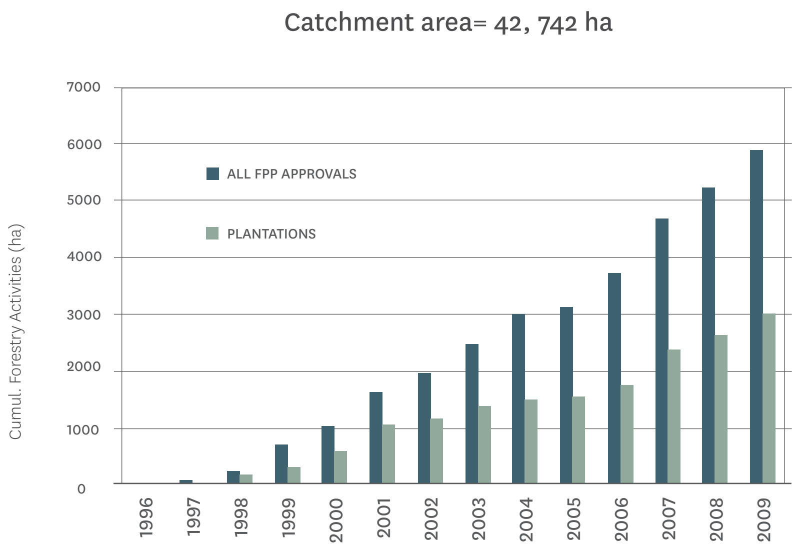


Figure 5. (Opposite) Summary of forestry activities based on certified Forest Practice Plans (FPP) in the George River catchment. FPP approvals includes all activities for which an FPP is required, including partial harvesting of native forests and land clearing not associated with plantation establishment or management. 'Plantations' includes activities directly associated with hardwood plantations. Actual date of plantation activity may differ from approval date. Data provided by Forest Practices Authority. Note Forest Practice Plans only extend back to 1996. Plantation establishment and forestry activities prior to this date are not reflected in the graph.

3.5 Characteristics of *E. nitens* with respect to potential toxicity

3.5.1 Composition of *E. nitens*

The Panel reviewed information about potentially toxic compounds derived from eucalypts in general and comparisons of composition of *E. nitens t*o other Tasmanian native eucalypt species. The Panel's main line of inquiry related to the toxicity and composition of oils contained in eucalypt species as this is one of the natural defences the species have developed against insects and herbivores (Batish *et al.*, 2008, Canhoto and Craca, 1999) and some of these compounds were identified by DPIWE.

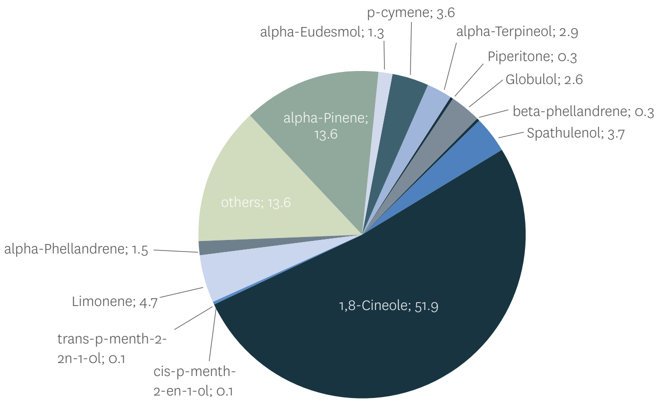
The following information is summarised from Potts *et al.* (2010) which draws heavily on a PhD study completed in 1993.

1. There are two sub-genera of *Eucalyptus* in Tasmania, *Symphyomyrtus* and *Eucalyptus;*
2. Many factors can affect the composition of volatile oils in eucalypts, including species, provenance, environment, season, and the age and stage (seedling, juvenile, adult) of the leaves;
3. The types of oils present in these two sub-genera are broadly similar, but the two groups vary in the relative proportions of the oils present, as shown in the pie diagrams in Figure 5, which show the distribution of oils in adult leaves. The major oil composition of individual species within each sub-genus is contained in Potts *et al.* (2010);
4. *E. nitens* belongs to the Symphyomyrtus sub-genus and adult and juvenile leaves have similar oil compositions to the Tasmanian *Symphyomytus* species (see figures in Potts, *et al.*, 2010);
5. The variability of oil composition within *E. nitens* is influenced by environmental factors as demonstrated where trees from the same seed source were grown at different altitudes;
6. The oil yield (g oil / g dried leaves) from *E. nitens* leaves is low compared to Tasmanian native species, and the lowest of all species in the analysis of adult leaves (Figure 6).

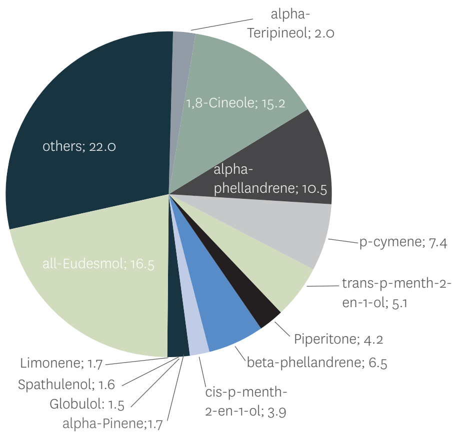
Other natural leaf components known to discourage grazing and insects are cyanogenic glycosides and formylated phloroglucinol compounds (FPCs). Cyanogenic glycoside has been reported to be present in the Tasmanian species *E. viminalis* and *E. ovata*, but has not been reported in *E. nitens* (Gleadow *et al.*, 2008). FPCs are present in a wide range of eucalypt species, including native Tasmanian eucalypts and *E nitens*. Those present in *E. nitens* are also present in other Tasmanian *Symphyomyrtus* species (Eschler *et al.*, 2000).

Experiments have been conducted which indirectly assess the toxicity of leachate from *E. nitens* and *E. globulus* by comparing the ability of linseed, *E. niten* and *E. globulus* seeds to germinate when planted under *E. nitens* and *E. globulus* trees. No significant differences were detected between filtrates from soils beneath *E. nitens* and *E. globulus* for pH, proportion of seeds germinated, and root length (Potts and Brooker, 2010).

All Tasmanian Subgenus *Symphyomyrtus* spp. Adult



All Tasmanian Subgenus *Eucalyptus* spp. Adult



E.nitens Adult

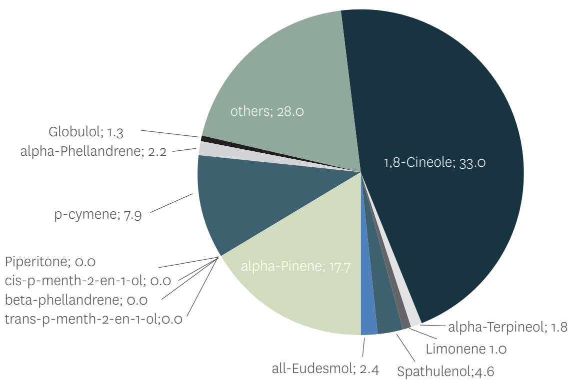


Figure 6. The percentage composition of major oil components of adult leaves averaged across all samples of all Tasmanian species of the subgenus Symphyomyrtus (17 species, 67 populations) and subgenus Eucalyptus (12 species, 71 populations) compared with the average of E. nitens sampled from field trials at seven sites in Tasmania. The 'others' category includes both oils with minor percentages and some unquantified components. From Potts et al. (2010).

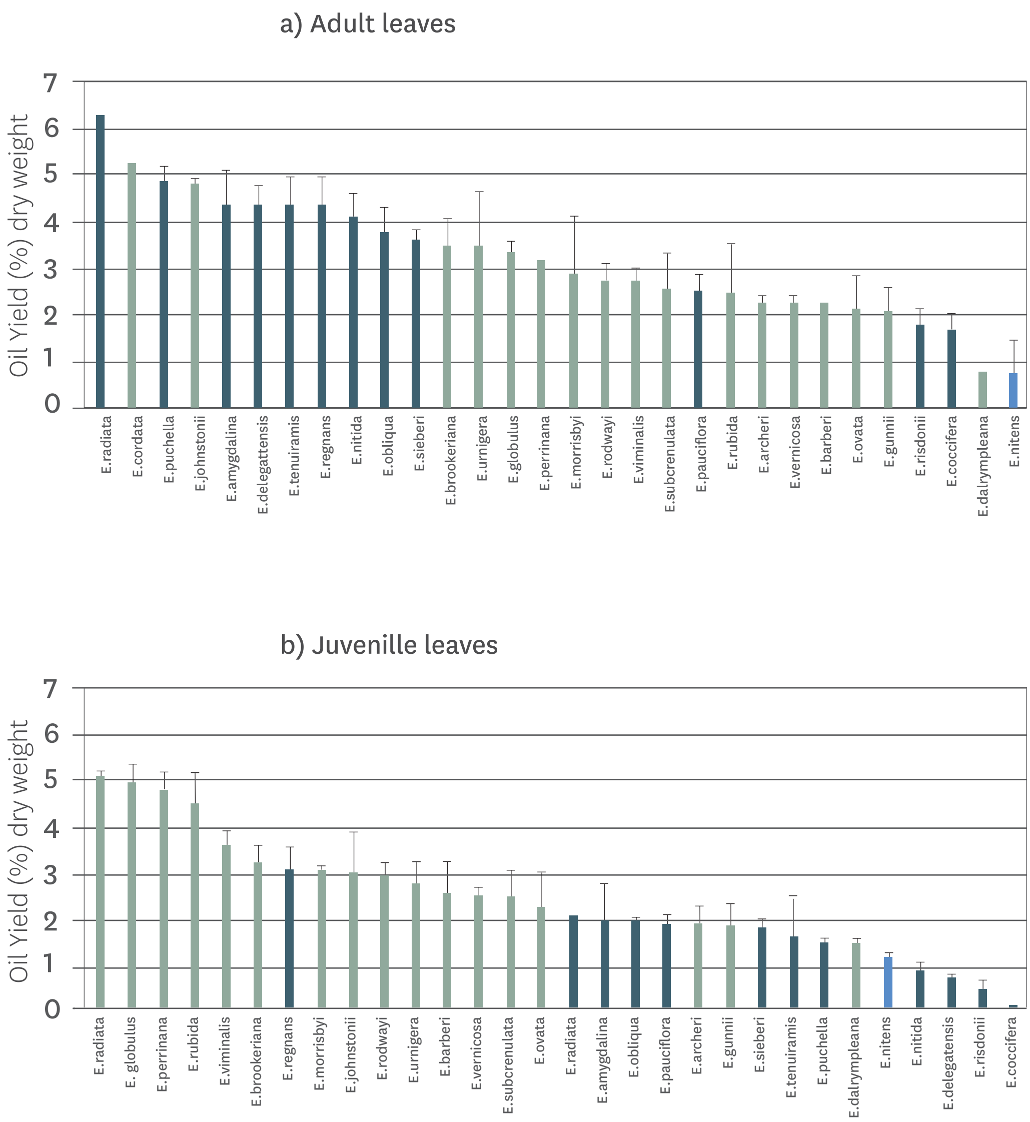


Figure 7. Variations in the mean oil yield (+ 1 standard error) from (a) adult and (b) juvenile leaves expressed on a leaf dry weight basis (g/g) for the Tasmanian native species from subgenera *Symphyomyrtus* (grey) *Eucalyptus* (black) in the wild and *E. nitens* (blue) grown in field trials in Tasmania from Li 1993 and resulting publications). The means are derived from an average of 5 populations per native species and for *E. nitens* adult foliage was sampled from seven sites and juvenile foliage samples from one site. Only one sample was obtained from the rare taxa *E. perriniana* and *E. radiata* and no standard errors are shown. From Potts *et al*. (2010).

3.5.2 Provenance of *E. nitens* seeds

The private forest companies and Forestry Tasmania provided information about the provenance of the *E. nitens* growing in the George River catchment. The *E. nitens* in the George River catchment are sourced predominantly from second-generation seed orchards in Tasmania. The seed orchards were originally established with native forest seed primarily from the Victorian areas of Toorango, Rubicon and Macalister. Some orchards also incorporated seed from Northern and Southern NSW provenances.

One company describes the management of the seed orchards as follows:

> *The genetic variation within these orchards has been refined over time as lower ranked individuals have been culled. Ranking was based primarily on superior growth rates and wood properties such as pulp yield.*

A discussion of genetic improvement in *E. nitens* in Australia is provided in Hamilton *et al.* (2008). They report:

> *Advances in the understanding of E. nitens genetic architecture and reproductive biology have been integrated into operation breeding and deployment programs. Despite extensive research into alternative deployment strategies, improved E. nitens genotypes are almost universally deployed as seedlings derived from open-pollinated seed-orchards.*

3.5.3 Ecotoxicity of essential oils and other components

Ecotoxicological information does not exist for each of the individual oils present in *E nitens* or the Tasmanian eucalypts. Limited invertebrate toxicity information is available for 1,8 cineole, which has a 96-hour LC_{50} of 10 mg/L (concentration estimated to be lethal to 50% of the organisms after an exposure period of 96 hours). This concentration is high, indicating relatively low toxicity compared to many man-made compounds. This concentration is highly unlikely to occur in the natural environment, or in rivers in which plantations are present.

Several investigations have examined the impact on river fish and invertebrates when exposed to highly concentrated eucalypt leachate. McMaster and Bond (2008) found that 'blackwater events' caused by leachate from Red Gums *(E. camaldulensis)* entering isolated pools during dry summers had no impact on fish even when dissolved organic carbon (DOC) concentrations were ~50 mg/L (typical concentrations of DOC are <10 mg/L). In laboratory experiments, fish were affected at DOC concentrations in excess of ~100 mg/L. The authors identified a wide range of polyphenols and volatile and semivolatile oils and waxes in the leachate. Canhoto and Laranjeira (2007) found that high concentrations of leachate derived from *E. globulus* had detrimental impacts on leaf shredding invertebrates in Portuguese streams.

The investigators found that in addition to the presence of phenolic compounds, the formation and precipitation of phytomelanin polycondensates may have contributed to toxicity through the continued deoxygenation of the water and direct toxicity.

The Panel directly contacted Dr Canohoto to discuss the leachate research. She has observed that a lot of foam is generated during the production of leachates from *E. globulus* leaves, but has not directly investigated foams associated with leaching of the leaves, and suggested that the effective toxic compounds present in the leachate (volatiles and derivatives) may be trapped in the foam. Her recent work has investigated the toxicity of *E. globulus* leachate on a range of organisms, including blackflies, midges and freshwater shrimp and found that aeration has a notable impact on toxicological response. She suggests that oils and derivatives, and phenolics in the pure leachates have the potential to affect the digestive capacity of invertebrates in non-native ecosystems.

A copy was obtained of a presentation made by Dr Hickey to the SETAC-Europe Conference in Seville, Spain in May 2010 (Hickey and Stewart, 2010), in which he reported a comparison of mass spectrometric analyses of the toxic and non-toxic crude ethanol extracts of leaves of both Tasmanian and Victorian

E. nitens samples for comparison with analyses of the toxic foam fractions. The leaf fractions contained a range of foam producing compounds including jensenone and grandinol/homograndinol, together with monoterpene eugenols, macrocarpals and sideroxylonals, none of which could be detected in the foam samples. This finding appears to be similar to the results reported on leaf extracts in the Scammell (2010) report. Hickey also reported a marked difference in the foam characteristics, with the decay half-lives for ethanol extracts of foam (2.8 hours) being markedly different from that of the Tasmanian *E. nitens* leaves (12 hours).

3.6 Herbicide / pesticide spraying information

3.6.1 Overview of available information

The Panel sought information about the use of herbicides and pesticides in the George River catchment from the forestry industry, the State Government, agricultural suppliers, the APVMA database and the Break O'Day Council. The Panel recognised that previous investigations had attempted to review chemical usage in the catchment without success due a lack of availability of information. In discussions with various stakeholders, the Panel also found a widespread belief that large amounts of chemicals are used in the catchment, often in a manner that some considered inappropriate.

The Tasmanian Code of Practice for Aerial Spraying (ASCHEM, 2000) calls for operators to record the date, location, chemical used and rate of application and maintain the records for a two-year period. In the case of land being leased, the operator must maintain records, but there is no obligation for the owner of the land to hold spraying records. There is also no requirement in the Code of Practice for spraying records to be transferred to a new owner if the land is sold.

The forestry industry (Forestry Tasmania, FEA, and Gunns) provided detailed records of aerial and ground based spraying dating back to 2006. The information provided by the companies included the name of the herbicide or pesticide, the application rate, the area treated and the application method. Detailed spraying information for dates prior to 2006 were provided by one operator and the 2005 data is included in the summary presented in Figure 8. Historical notes pertaining to spraying operations in the South George catchment on the large Sea View property, prior to the helicopter crash in December 2003, were provided by Private Forests Tasmania.

The Break O'Day Council was able to provide spraying records dating back to September 2008. The records relate to ground-based spraying using herbicides and include the date, location, chemical used and application rate.

Obtaining information about the agricultural use of chemicals in the catchment was very difficult. The State Government does not maintain records of chemical usage, and the APVMA database does not include information by sub-region. Bendor *et al.* (2008) investigated the nature and extent of chemical usage in Tasmania using 'Grower's Surveys' to identify chemical usage patterns by region and crop. Unfortunately, no surveys were returned for the George River catchment. As no central database exists for agricultural chemical usage, the Panel approached suppliers of agricultural chemicals and obtained generalised information about what had been sold into the 7216 post-code area, which generally coincides with the George River catchment.

3.6.2 Forestry operation

The information received by the forestry industry provides the following overview of pesticide use in plantations:

- The use of herbicides, pesticides and fertilisers is standard plantation management, but the types, timing and quantities employed is site dependant;
- Herbicides are used prior to plantation establishment to prevent weeds from competing with the plantation seedlings. Herbicides with knockdown and residual characteristics were used as part of the establishment process prior to 1998 and included glyphosate, atrazine and simazine. Forestry Tasmania ceased using triazines in 1995 (atrazine) and in 1997 (simazine). There is one recorded use of simazine in the George River catchment in 2008 by another operator.
- The herbicides which are most typically used prior to planting include glyphosate and metsulfuron-methyl (and sometimes sulfometuron-methyl). Typically one or two applications of herbicides occur prior to plantation establishment using ground-based methods (tractor or backpack). Herbicides reported as used in the George River catchment and typical application rates are shown in Table 3 and the timing of herbicide application relative to the establishment of plantations is shown in Figure 7.
- Following plantation establishment, herbicides are rarely used due to the toxicity threat to the trees. Certain herbicides can be used post-establishment (clopyralid and haloxyfop-methyl), but there are no records of usage in the George catchment;

Table 3. Herbicides used by the forestry industry in the George River catchment.
Note that generally only 2 - 3 products are applied at any one time.

Product	Generic Name	Typical Application Rates
Roundup	glyphosate	2 – 3 L/ha
Brushoff	metasulfuron	30 – 50 g/ha
EucMix	terbacil & sulfometuron methyl	1 kg/ha
Clomac, Lontrol	clopyralid	0.35 - 0.4 – 1.0 kg/ha
Verdict	haloxyfop	350 ml/ha
Terbuthylazine	terbuthylazine	3 kg/ha
Oust	sulfometuron methyl	30 – 70 g/ha
Simazine	simazine	4 – 6 kg/ha
Nutrazine	atrazine	5 kg/ha

- Insecticides are used when required in young eucalypt plantations to control insect pests such as eucalypt leaf beetles (*Chrysophtharta bimaculata* and *C. agricola)*. The main insecticides are synthetic pyrethroids, however some biological insecticides can also be used. These products are applied by aerial application, generally during spring / summer.

Aerial spraying records obtained from the forestry companies have been combined to provide an overview of aerial spraying in the catchment. This analysis excludes the plantations on the large Sea View Property (~1,000 ha) and other plantations in the catchment which have changed ownership and for which no detailed records were available (only general information for 2003-2004 was provided in the historical notes from Sea View).

- The timing of insecticide application relative to plantation establishment in Figure 7 shows that there is typically a lag time of two or more years between establishment and insecticide application. The records show that no insecticides have been applied to date to plantations established since 2006.
- It is also evident that insecticides are applied to several plantations at the same time, presumably because if there is an insect infestation requiring intervention it is likely to occur across plantation boundaries. On at least one occasion (2005), spraying occurred in the Powers Rivulet, Groom River, North George and South George sub-catchments within a 3-day period.
- The cumulative area aerially sprayed with insecticides in each season is shown in Table 4. The area aerially sprayed in a given year is related to the level of insect activity and damaged being caused, which varies based on plantation age and climatic conditions. Even though the area of plantations increased between 1998 and 2007, the areas affected by spraying varied annually due to climatic conditions and pest populations.
- The insecticides reported as used in the George River catchment include alpha-cypermethrin (synthetic pyrethrin,), chlorpyrifos (organophosphate) and spinosad (biological pest control derived from naturally occurring bacteria).
- The helicopter crash in December 2003 occurred while spraying a 1,000 ha area in the South George catchment. Approximately two-thirds of the area had been sprayed using α-cypermethrin when the crash occurred. About 60 L of mixed insecticide was on board at the time of the crash, and 40 L was recovered. Subsequent soil samples collected and analysed by DPIPWE found α-cypermethrin and simazine. There was no recorded previous usage of simazine on the property.
- Approximately 10 days after the spraying and helicopter crash in 2003, there was a summer high flow event in the George River. Hydro Tasmania Consulting (2008) flow modelling indicates that the daily flow in the South George was about 4 m3/s, and at the Water Intake in the lower catchment, daily flows were 17 m3/s. This flow event is significant as it was the first high flow following the crash and spraying in the catchment, and was likely to be large enough to induce surface runoff into the river, however no impact on oysters (or other biota) was observed during or after this event. The 1 in 50 year flood event in January/ February 2004 occurred over one-month after this high-flow event.
- The sprayed area drained into a 200 ML dam that breached on January 30, 2004 following 250 mm of rain. The dam had been stocked with trout and there were no reports of fish kills in the dam following the high flow event 10-days after the spraying occurred, or during the large flood event prior to the dam failure.

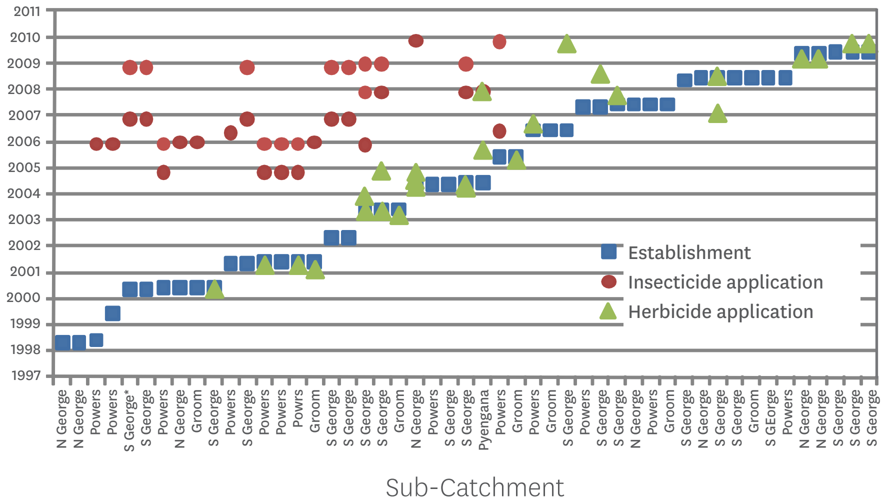


Figure 8. Establishment dates and herbicide and insecticide application history for plantations in sub-catchments of the George River 2005 to present. 2005 results available for one company only, and records were not available for all plantations. Data provided by private forestry companies and Forestry Tasmania. (S. George* is an *E. globulus* plantation).

Table 4. Area (ha) of forestry plantations aerially sprayed with insecticides each season. Data from FEA, Forestry Tasmania and Gunns.

Season	Area treated with insecticides (ha)	Sub-catchments
Summer 03/04*	~1,000	S. George
Summer 04/05**	146	Powers Rivulet
Summer 05/06	319	Powers, N George, S George, Groom
Summer 06/07	387	S. George
Summer 07/08	100	S George, Pyengana
Summer 08/09	524	S George
Summer 09/10	38	Powers Rivulet

*Based on notes provided about management of Seaview property. Area aerially sprayed in December 2003. No records available from other operators or about other properties.

**records for 04/05 only available from one operator

3.6.3 Council chemical usage

Break O'Day Council records chemical usage with records dating back to September 2008. Chemical use by the Council is limited to herbicides, which are applied by ground spraying, and multiple herbicides are usually applied simultaneously. Records include the names of the herbicides used, the weed species being targeted, the total volumes of herbicide and water, and the location of spraying.

Target weed species include grasses, thistles, blackberries, ragwort, Spanish heath, couch, gorse and other broadleaf weeds. Common areas of application include streets, footpaths and tip-sites. Areas bordering Georges Bay are also periodically spayed, including the foreshore footpath and parks, Medeas Cove Rd and the Binalong Bay causeway.

The most common herbicides used include Roundup, Pulse and Grazon, at dilutions of 1:100, 1:1000 and 1:300, respectively. Less frequently, Agritone 750 and Lontrel are used. The Council sprayed approximately 5,600 L of water mixed with herbicides in 2009. Over half, approximately 3,750 L, was applied during spring when weed growth is greatest.

3.6.4 Other chemical usage in the catchment

No aerial or ground spraying records associated with agricultural or domestic activities in the catchment were available for review by the Panel. As a surrogate for what *may* have been used in the catchment, the Panel contacted a major distributor of agricultural chemicals and was provided with a list of chemicals sold into the George River catchment area (post code 7216) between 2005 and 2009 (Table 9). The list provided an indication of what was sold into the area, but provides no information as to the intended use, location or concentration of the chemical, or the date of usage. It is also unknown if this information includes some of the chemicals reported by the forestry industry or Break O'Day Council. The range of chemicals sold into the area did not increase between 2005 and 2009, although the number of commercial brands did. The summary shows that there were a wide variety of chemicals used, and quantities sold between these years.

3.6.5 Estimates of chemical usage in George River catchment

The lack of available information associated with chemical usage in agricultural and domestic activities makes it difficult to provide an overview catchment usage. Other factors which hinder the understanding of chemical usage in the catchment are the short time periods for which records are required to be kept, and the lack of a requirement for records to be transferred with land ownership under the Tasmanian Codes of Practice for aerial or ground spraying.

Recognising these short-comings, the Panel examined the usage of a common herbicide (glyphosate) and insecticide (∝-cypermethrin) across the agricultural, forestry and municipal sectors for 2008 and 2009. The best estimates of usage are summarised in Table 6. The rough estimates show there is high variability between years, presumably associated with climatic and other factors, which control weed and insect levels. It is not possible to determine whether the rates of chemical usage in the George River catchment are high, low or typical, as there is no Tasmania wide information available for comparison.

It is important to emphasise that it is the management of chemicals within the catchment rather than the total volumes used which determines the environmental impact resulting from chemical use. These estimates provide an order-of-magnitude estimate of chemical usage in the catchment enabling debate about chemical reporting and catchment management rather than an indictment of chemical users within the catchment.

Table 5. Summary of chemicals sold into George River catchment area from 2006 – 2009.

Chemical	2006	2007	2008	2009
2,4-D (H)	60 L	260 L	100 L	60 L
Alpha-cypermethrin (I)	5 L	65L		
Chlorothalonil (F)		20 L	20 L	50 L
Chlorpyrifos (I)				20 L
Chlopyralid (H)	5 L	10 L	6 L	10 L
Diquat (H)				20 L
Fenitrothion (I)	22 L	0.5 L		
Glyphosate (H)	329 L	345 L	202 L	395 L
MCPA (H)	101 L	4 L	113 L	105 L
Paraquat (H)	20 L	20 L	20 L	40 L
Picloram + 2,4-D (H)		60 kg	35 kg	20 kg
Triclopyr, picloram, aminopyralid (H)	11 L	19 L	41 L	88 L

Different brands and strengths of the same chemical are grouped together (e.g. all glyphosate products grouped together). Chemicals not necessarily applied in year purchased or in George River catchment. Volumes (or mass) refers to unmixed chemical. (I)=insecticide, (H)=herbicide, (F)=fungicide

Table 6. Estimates of chemical usage in George River catchment for 2008 - 2009.

Sector	Estimated glyphosate usage (L of undiluted product)	Comments
Agriculture + Domestic	2008: 200 L 2009: 400 L	Assumes all glyphosate sold into catchment was used
Forestry	2008: 600 – 1200 L 2009: 450 – 900 L	Depends on area of new plantations and number of herbicide applications. Estimates assume all new plantations are treated. Range of estimates is for 1 and 2 applications a year
Council	2009: 50 L	Records not available for all of 2008
Sector	**Estimated ∝-cypermethrin usage** **(L of undiluted product)**	**Comments**
Agriculture + Domestic	2008 and 2009: 0 L	Up to 65 L sold into area in previous years
Forestry	2008: 131 L 2009: 9.5 L	Highly variable between years, based on application rate of 0.25 L/Ha
Council	0 L	No reported usage of insecticides

3.7 Pacific oyster health

The condition of introduced Pacific oysters (*Crassostrea gigas*) in Georges Bay has been a concern to oyster growers since the late 1990s. The oysters, especially in the intertidal farming leases, have shown poor condition, feathering and / or thickening of shells, and internal weaknesses and abnormalities. As discussed in Section 1.2, it was initially suspected that TBT, a biocide in antifouling paints was the cause of the abnormalities and ill-thrift, largely because of the similarity of the shell deformities to those caused by TBT. Concentrations of TBT found in the oysters were too low to account for these effects, and not unexpected as Tasmania banned the use of TBT on boats under 25 m in 1987. Replacement antifouling agenets may however be potential stressors.

The Fish Health Unit of DPIPWE in 2002 concluded that the causes underlying the poor condition of the oysters were multi-factorial and environmentally induced. The same report also stated that the farmers were experiencing poor growth in the winter months, and higher mortalities in the summer months, and after high rainfall events.

The Panel has reviewed information associated with the largest Pacific oyster mortality event in Georges Bay, which followed a 1 in 50-year rainfall flood in February 2004, and subsequent reports pertaining to oyster health. The peak discharge during the flood event of 675 m^3/s, was the highest recorded in the 42-year history of the site (DPIWE, 2004). Oyster mortality occurred nine days after rainfall commenced. Mortalities were localised to intertidal oyster leases closest to the mouth of the George River, and ranged from 57% to 95%. No significant mortalities occurred in sub-tidal leases or intertidal leases near the mouth of Georges Bay. These events led to numerous investigations and reviews.

Percival (2004) found that oyster mortalities have been on the increase in Georges Bay since 1997 and that ill-thrift in farmed Pacific oysters has also been observed on other oyster farms around Tasmania, most notably in the Duck River in north-western Tasmania. However, there are differences of opinion amongst oyster farmers on the increased rates of mortality observed on their farms (pers. comm. Tasmanian oyster growers). Percival (2004) concluded that no single stressor could be linked to the oyster mortalities, and identified known stressors (low salinity, handling, spawning) and potential stressors (poor nutrition, toxic phytoplankton, contamination of water from chemicals or sewage) for future investigation.

In recent presentations by Poke (2009a, 2009b) that were made available to the Panel, it was noted that similar oyster ill-thrift and mortalities had been recorded in oyster leases near Smithton, and harvesting was limited for long periods due to elevated levels of thermo-tolerant coliforms. Testing for metals and pesticides found low concentrations, and no underlying cause for the poor oyster health was identified.

3.7.1 Pacific oyster production in Georges Bay

Figure 8 shows that Pacific oyster production in GeorgesBay increased consistently between 1987 and 1997. During 1998 and 1999, there was a decrease in production, but this was followed by a large increase in production between 2000 and 2003. Production again decreased between 2003 and 2007, but has since increased, with 2009 production levels the highest recorded. Pacific oyster production in Moulting Bay remained relatively constant between 2000 and 2009 with the exception of 2003 (high production) and 2007 (low production). In 2009, the Bay was producing about three-times as many Pacific oysters compared to 1997 when concerns about Pacific oyster health began. Production levels in 2004, the year of the flood, were lower than in 2003, but similar to other years between 2001 and 2006.

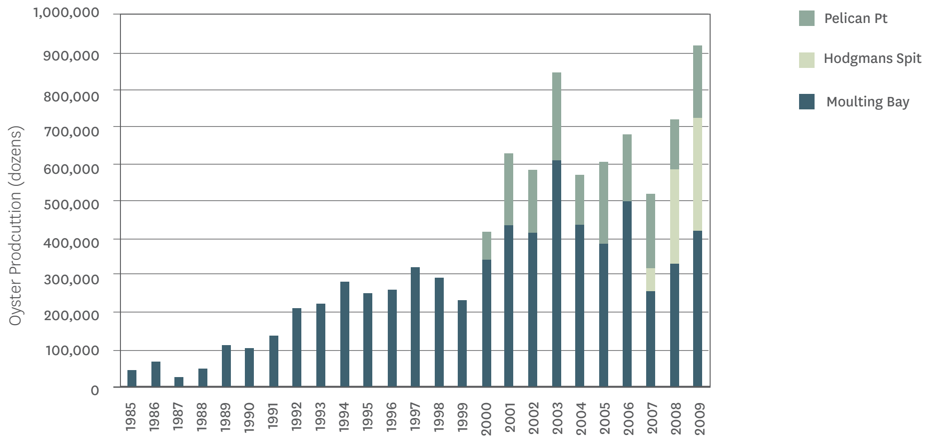


Figure 9. Annual Pacific oyster production in Georges Bay(dozens). Data from Marine Farming Branch, DPIPWE.

3.7.2 Water quality in Georges Bay

Water quality monitoring in Georges Bay has been limited, but Crawford and White (2005) and Crawford and Cahill (2008) found that, based on available water quality information, the bay was in reasonable health, although most sampling had been completed under 'normal' conditions. Nutrient concentrations were generally low and no herbicides or insecticides were found in the water or oyster flesh. The limited data collected during flood events indicated a significant deterioration in water quality. Water quality impacts were also linked to periodic poor functioning of the municipal sewage treatment lagoon system, which has since been upgraded.

On-going annual monitoring of oysters in Georges Bay under the TASQAP program finds low concentrations of metals and undetectable levels of herbicides and insecticides in oysters in Moulting Bay (DHHS, 2008).

All metal concentrations are low, but the concentration in oysters closer to the mouth of the George River are relatively higher and are probably indicative of higher concentrations of these compounds in the river. Similar to trends reported by Poke (2009a), closure of oyster harvesting is occurring at lower salinities in Moulting Bay due to levels of thermotolerant coliforms. Harvesting is now linked to rainfall in Pyengana over the previous 7-days as this is a good indicator of thermotolerant coliform levels in the bay (the higher the rainfall, the higher the coliform counts). It is unknown if the higher concentrations of thermotolerant coliforms detected in the bay are due to altered freshwater inputs or increased thermotolerant coliform input.

3.7.3 Changes in Georges Bay

The multi-stressor hypothesis consistently identified in the investigations along with similar suggestions from the oyster farmers has lead the Panel to consider what changes have occurred within the George River over the past decade. Changes which could potentially affect the physical and chemical environment of Georges Bay include:

a. the establishment of plantations and other land use change in the catchment (discussed in Section 3.4);

b. possible changes in the flushing and circulation of Georges Bay due to changes at the bar at the mouth of the river over time (Coastal Engineering Solutions, 2007);

c. altered freshwater inflows due to extractions or drought;

d. changes to the bay due to the presence of toxic algae (Pearce *et al.,* 2005);

e. increased oyster production (Figure 8); and

f. changes to the bay due to warming ocean temperatures (Thompson *et al.,* 2009), which could also be linked to the incidence of algae.

The region also experienced a 1 in 50 year flood event, which delivered a large load of sediment to the bay leading to the smothering of clam beds and establishment of sea grass beds. More recent changes include a large reduction in the concentrations of nutrients in sewage treatment plant discharge waters near the mouth of the George River following the plant upgrade (DPIPWE, 2010a).

3.8 Ecosystem health information

Ecosystem health in a water body can be assessed in several ways. In rivers and streams a rapid biological assessment approach is commonly practiced where the presence of macroinvertebrate taxa are assessed and compared to what would be expected to be present in the absence of environmental stress. In Australia, the recommended rapid assessment approach uses the AUSRIVAS (Australian River Assessment System) model (ANZECC/ARMCANZ, 2000). This targets macroinvertebrates in the rivers because they are 'natural' indicators which are very sensitive to change. Changes to river systems which can be detected using this assessment technique include chemical contamination, temperature changes, or alterations to the flow of the river.

This approach is widely used in Tasmania by DPIPWE, and historical river health data are available for the George River catchment from 1994 to the present. The output is typically a measure of Observed/Expected taxa for both riffle and edgewater samples collected in both autumn and spring samplings by disturbing 10 m of the substrate to dislodge animals that are swept by the current into a net. The closer the measured ratio is to 1, the better the condition of the river (a value of 1 indicates that the condition is the same as in an undisturbed catchment).

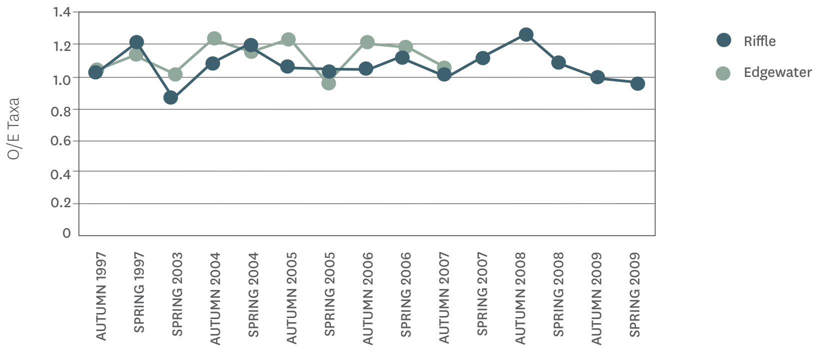
Seasonal results for two sites monitored in the George River are shown in Figure 9. For the period 1997-2009, the O/E measurements showed only minor differences from the preferred ratio of one for most samplings. A notable exception occurred in spring 2003 in the Ransom River when the edgewater 'score' was 0.64. No reason for this was identified, and the condition of the river returned to a ratio near 1 in subsequent samples.

DPIPWE also uses a second AUSRIVAS model which combines seasonal monitoring results to provide an annual assessment (DPIW, 2009). Using this model the O/E results for the South George site were slightly lower for the spring 05/autumn 06 and spring 06/autumn 07 (0.85 and 0.84, respectively) but increased to 1 or greater in subsequent samplings. Using the annual model, results for the Ransom River site were 0.95 or greater for all periods.

For both sites, the results suggest that the river is in very good ecological health with the macroinvertebrate communities present in the rivers similar to those known to occur in undisturbed reference rivers.

A more detailed assessment of ecosystem health measures both abundance and diversity of a full range of taxa sampled by nets and counted and identified by optical microscopy. This can be done both in sediments and in the water column and is a lengthy, tedious and costly process. To the Panel's knowledge, such assessments were not undertaken in the George River.

Other indicators of ecosystem health in relation to water toxicity might be the presence of dead fish or other aquatic species. No statistically robust data relating to recreational fishing in the George River were available. Anecdotal comments related to fish in the river ranged from 'fishing had never been better' to 'there are no fish in the river'.



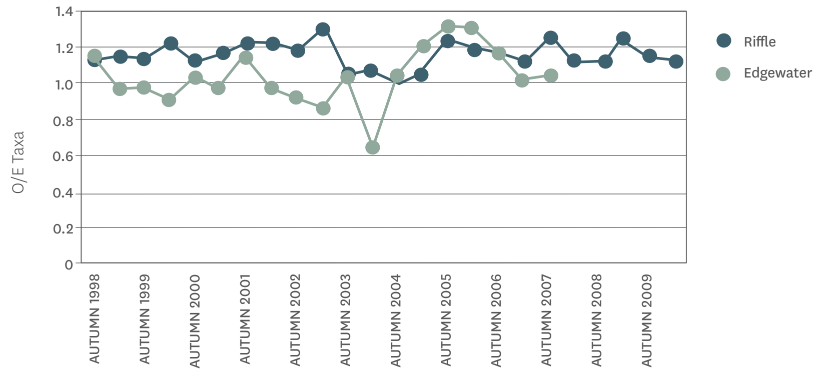


Figure 10. AUSRIVAS monitoring results for the George River near Columba Falls (top) and in the Ransom River at Murdochs Road, 1997 - 2009. Results show ratio of taxa present to taxa expected to be there based on undisturbed reference streams. O/E value of 1 is equivalent to the reference condition.

3.8.1 Tasmanian devil facial tumor disease

The Panel reviewed recent papers on the potential link between Tasmanian Devil Facial Tumour Disease (TDFT) and chemical exposure. TDFT is an infectious cancer which likely arose as a single incident in the extreme northeast of Tasmania, in the Mt King William National Park, to the north of the George River catchment (McCullum *et al.*, 2007)

Ross (2008) examined the distribution and concentrations of persistent chemical in Tasmanian Devils and found no difference between positive and negative TDFT individuals. The review examined results from 32 devils with and without the disease and found that detectable residues of dioxins, dibenzofurans, PCBs, poly-brominated diphenyl ethers, arsenic, cadmium and lead were present in the fat or liver of the devils, but no detectable residues were found for 1080, or 27 other herbicides and pesticides. One devil had detectable mercury levels and two had measurable DDE. The review found no significant difference between chemicals in the TDFT positive and negative individuals. It was also concluded that the concentrations were consistent with other top of food chain species.

Moore (2008) completed a review of the aetiology (causation) of TDFT and considered metals, pesticides and toxic organic compounds. It was found that within the limits of the available information and the length of time since initiation of the disease, it was highly unlikely that any primary event could be identified. However, the lack of measurable fluoro-acetate pesticides at present suggests there has not been over-exposure to chemicals in agriculture or forestry.

The review also noted that the initial development of the disease could possibly have been associated with a chemical or radiochemical exposure, but there is no evidence to support this. Tasmanian devils are known to be prone to the development of various cancers.

3.9 St Helens water treatment system and monitoring

The Panel visited the St Helens water treatment plant and discussed water treatment with representatives of the Ben Lomond Water Corporation. The 2006 *Drinking Water Quality Management Plan for the St Helens Drinking Water Supply System* (DWQMP), which contains a risk analysis for the drinking water supply, was also reviewed.

Multi-stage water treatment is used at the St Helens plant. The system currently treats approximately 400 ML/year, but could treat up to 1800 ML/year. Treatment includes the removal of solids (coagulation, flocculation, dissolved air flotation and high rate media filtration) and the removal of pathogens (chlorination). The summary of monitoring results in the DWQMP shows that the plant consistently produces high quality drinking water in line with Australian Drinking Water Guidelines (NHMRC/NRMMC, 2004)

The risk assessment in the DWQMP identified the lack of existing barriers to the prevention of contamination of source water, and included chemical usage in the agricultural and forestry industries as a potential threat. The risk assessment also identified the means through which contaminants are removed (Table 6). Of relevance to the Panel's investigations is a proposed preventative measure identified in the DWQMP for the '*continued lobbying for accountability in chemical use for forestry and agricultural practices within the catchment and (the need to) seek regular audits of land areas subject to chemical application and strength and frequency of application not within Council's jurisdiction*.'

The issue of monitoring the raw drinking water supply was discussed with Dr M. Sinclair at the Department of Epidemiology and Preventative Medicine, Monash University, who is an expert in drinking water quality and human health. Her experience is that most water supply organisations only monitor infrequently for parameters such as metals or pesticides due to the high cost of analyses and the time lag associated with obtaining the results. Parameters that guide the operational control of the treatment plant, such as turbidity or pH are generally continuously managed. She indicated that there is a move towards a preventative risk management approach rather than a reactive approach based on testing of drinking water supply. Where possible, this includes the water supply catchment being protected from development which might compromise water quality. Where this is not possible, a multifaceted approach to water quality management is suggested, including risk assessment, best practice catchment management, water quality and human health studies, toxicological studies and use of water quality guidelines.

Table 7. Summary of 'Barriers to contamination' as identified in the *Drinking Water Quality Management Plan for the St Helens Drinking Water Supply System (2006)*

Requirement	Existing Barriers
Prevention of contamination of source water	Nil
Removal of particles from water	Coagulation, flocculation, dissolved air flotation and filtration treatment.
Elimination of pathogens	Chlorination
Prevention of recontamination of treated water in the reticulation system	Residual Chlorine
Assessment of ability of system to prevent/ eliminate pathogen contamination	Adequate

3.10 Chemical and physical characteristics of foam

The Panel invested considerable time and resources into understanding the chemical and physical characteristics of foam, and how foam was collected and altered in the skimmer box deployed by Scammell (2010). Foam is not a commonly sampled material in the natural environment, and understanding its origin, characteristics and behaviour is fundamental to the interpretation of the ecotoxicological results presented by Scammell (2010).

Surface films (the surface microlayer) are present at the air-water interface of most natural waterways. These films range from only a few molecular layers thick up to 300 µm and contain enriched concentrations of hydrophobic compounds, both natural and man-made relative to the water column as a whole (Sodergren *et al.*, 1993). Enrichment factors in this surface layer have been found to vary from 10 to 1,000 (Liu and Dickhut, 1997). The surface film formation process is complex and is thought to involve surface-active compounds carrying less soluble chemicals to the surface via rising bubbles, convection currents and diffusion (Duce et al., 1972; Wheeler, 1975). Although the microlayer contains elevated concentrations of compounds, they generally present little risk to the environment due to the very small volume of this material relative to that of the underlying water column.

Surface foams are created when surfactants (natural or man-made) are present in the surface layer and aeration occurs which promotes bubble formation, allowing this surface layer to persist as foam on the surface of waterways. These foams are known to contain higher concentrations of organic compounds derived from higher plants, bacteria, algae, fungi and diatoms (Mills *et al.*, 1996). As surface films or surface foams collapse, interactions occur which lead to dissolved compounds present in the surface layer flocculating to create fine organic-rich particulate matter (Wheeler, 1975, Johnson and Cooke, 1980). The transformation of dissolved matter to particulate matter has large implications for the execution and interpretation of ecotoxicological investigations.

In one of the few reported studies of natural aquatic foams, Mills et al. (1996) showed that for a range of US sites, foams typically had 10-20 times the dissolved organic carbon of the bulk water, and were made up of 90% humic substances, but contained organic aggregates with varying degrees of chemical complexity. This chemical complexity made it difficult to identify all but major components, however, more detailed analysis for specific biomarker compounds showed differences characteristic of the different flora around the streams. For example, lignins characteristic of flowering and non-flowering plants were detected. In their investigation, the foam collapsed to about 25% of its original volume.

Figure 11. Photo showing the latest skimmer box construction

Figure 12. Natural foam in S. George River prior to collection. Opening of skimmer box is approximately 1.25 m.

3.10.1 Review of the skimmer box sampling procedure

Surface films are typically sampled using a framed nylon screen that is immersed vertically and withdrawn horizontally through the plane of the water surface trapping the film in the netting holes (typically 1.2 mm). The film is collected by draining the screen, when held vertically, into a bottle. Because the mesh is relatively large this collects more than the depth of the actual microlayer. The other common collection method uses a rotating drum sampler in a floating rig. The surface film adheres to the outside of the mechanically rotated drum and is scraped off by a plastic blade, and collected in an attached bottle. These techniques sample to a depth of around 100 µm, so entrain water with the very thin microlayer, which is about 3 µm thick. The skimmer box method is a unique approach developed by Dr Scammell to specifically collect foam.

Using our understanding of foam characteristics, the Panel reviewed the skimmer box foam collection method as described by Scammell (2010). The skimmer box is designed to collect surface foam from the river by trapping the foam within two baffles and then delivering it to a collector box, while allowing the underlying water to continue to flow downstream. The design of the box which was demonstrated to the Panel appeared to have evolved over time. This current version was described as more efficient at collecting foam than the original model (Figure 10). A significant modification was the addition of the curved baffle at the front of the box which promoted the retention of foam and the smooth flow of water under the foam and out of the box. Prior to this improvement, foam was frequently 'sucked through' and lost with the river water.

The Panel investigated operation of the box via videos of the skimmer box while it was deployed in the South George River. The skimmer box was deployed in an area of the river with a relatively strong current and videos were recorded of foam entering the box, and the transformations, which occurred within the box.

The river itself had a very low visible foam concentration (around 5-10 surface bubbles/m^{2}) (Figure 11). This natural surface concentration may vary slightly depending on flow conditions and turbulence. The foam bubbles begin to collect as they are constrained by the arms of the skimmer box. After a brief period the accumulated foam begins to fill the surface of the collection bucket and then gradually extends further into the box. Visible physical changes to the foam occur soon after entering the box. As foam collects in the apex of the box, it develops brown streaks, darkens in colour and surface bubble increase in size (Figure 12 a, b). Based on discussions with Dr Paul Stevenson, an expert in foam mechanics and chemistry, these changes are associated with the skimmer box collection method which allows the base of the foam layer to continue to interact with and 'skim' compounds from the surface layer of the river, which is flowing beneath the box. As the foam collects and is concentrated, the foam undergoes Ostwald ripening, leading to smaller bubbles at the base of the foam collapsing into larger bubbles at the surface. This process is accompanied by a loss of surface area and precipitation and flocculation of previously dissolved compounds on the surface of the remaining foam. This process of collection and collapse of the foam effectively 'pumps' compounds from the surface microlayer of the river into the foam, where precipitation and flocculation occurs leading to the creation of particulates on the surface of the foam. This accounts for the appearance of brown material on the surface of the foam. The surface nature of this material is demonstrated in Figure 12c in which the brown material has been removed, revealing the underlying 'clean' white foam underneath. The collapse of foam is enhanced by the ongoing pressure exerted by new foam entering the back of the box, and the river flowing below the surface of the foam.

This extreme concentration and precipitation of material is an artefact of the sampling methodology and accounts for the elevated concentration of particulates in the deflated foam samples investigated by Scammell (2010). A discussion of concentration factors associated with this sampling technique is contained in Section 4.3.1.

The foam in the skimmer box was also found to increase in density and became quite 'stable' compared to the foam floating down the river (Figure 12d). This is attributable to the continued adsorption of hydrophobic surface film components to the foam constrained by the skimmer the river continues to flow underneath.

Following discussions with Dr Stevenson it became evident that this extreme concentration of material in the skimmer box could be demonstrated by collecting

Figure 13. (a) Leading edge of foam in skimmer box showing initial development of brown material on surface; (b) more compressed foam showing larger surface bubbles, and thicker layers of brown flocculated material; (c) white foam exposed when overlying brown material is removed (note bubble size is much smaller in underlying foam); (d) 'coherent' foam created by collection and concentration in skimmer box.

river foam from the same location using a 'free-draining' container, in which water did not continue to flow under the foam. This experiment was completed by the Panel, and a photo of river foam from the same location in the South George is shown in Figure 13. Although the foam was collected for over 10-minutes, brown lines did not form on surface because the flow dynamics of the container were different and did not lead to the collection and concentration of the micro-surface layer. The foam was less coherent (collapsed more rapidly) compared to the skimmer box foam because it had not adsorbed high concentrations of surfactants and when collapsed, no precipitates were formed. This is in stark contrast to the highly concentrated foam created by the skimmer box (Figure 14).

These experiments show that the skimmer box sampling method dramatically alters the nature and chemical characteristics of naturally occurring river foam through the continuous adsorption and concentration of the compounds from the surface micro layer of the river into the foam trapped in the skimmer box. The extreme concentration of foam achieved by the skimmer box is apparent in Figure 15 in which after a long period of deployment, the foam in the box is uniformly brown, with only the newest foam entering the back of the box showing the white colour as naturally occurs on the rivers. Calculations indicate that the concentration factor achieved by the skimmer box may be in the order of 1400 *per hour of deployment,* and are discussed in more detail in Section 4.3.1.

Of note is that over the history of the Scammell (2010) investigations, the proportion of foam samples which were found to be toxic increased. Between 17 January 2005 and 3 February 2005 more foam samples were non-toxic than toxic, including several from the South George River. From March 2005 onwards, all foam samples collected in the George River were toxic. We speculate, consistent with the evidence and understanding of the physics of foam, and with comments provided by those involved in the investigation, that this increase in the proportion of toxic samples coincides with improvements in the skimmer box which increased foam concentration by holding the foam and allowing it to continually 'skim' the surface layer of the river.

Figure 14. River foam collected from the South George River using a free draining technique which does not lead to the ongoing concentration of the surface microlayer by the foam.

Figure 15. Collapsed foam collected using a free-draining method (left) and the skimmer box (right). Foams were collected over approximately the same length of time.

Figure 16. Foam collection from the skimmer box. Photo from *Australian Story* website.

4. Synthesis of findings and discussion

Based on an analysis of the findings of the Scammell (2010) and the additional information presented in this report, the Panel provides its synthesis of findings in this section. As the issues raised in the *Australian Story* programs cover a wide range of topics, the Panel has structured its analysis to address the following questions:

- What is in the water of the George River?
- What is in the foam of the George River?
- What is the environmental impact of the water and foam on the ecosystem?
- What is the impact of the water and foam on the production of Pacific oysters in Georges Bay?
- What are the human health implications of the water and foam on the St Helens community?

Because the findings of Scammell (2010) are based on ecotoxicological results, the Panel's general comments about the methodology used are presented before addressing the questions.

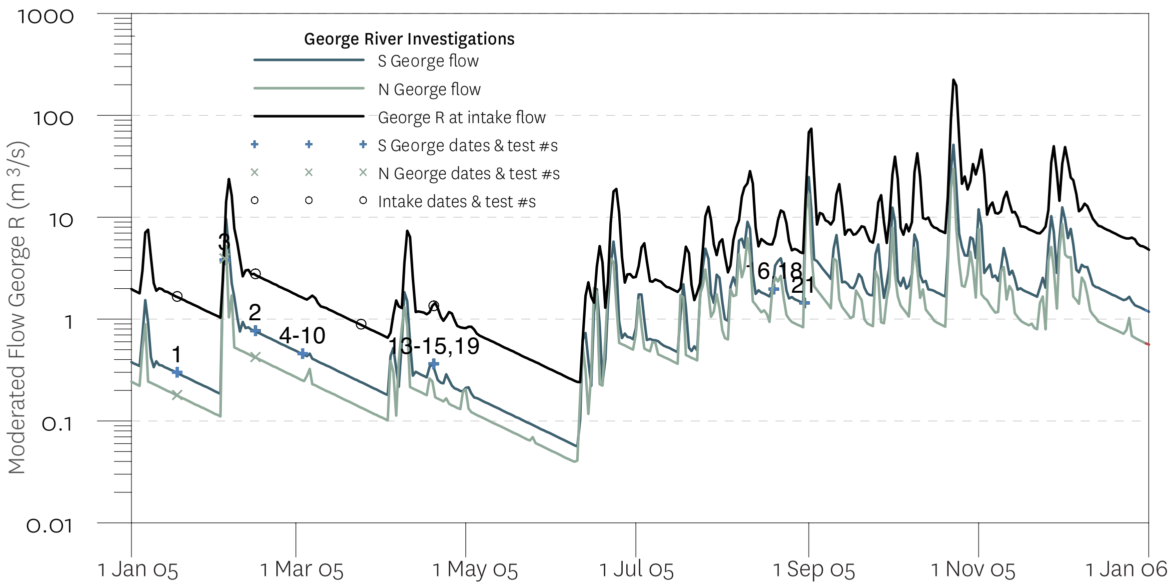


Figure 17. Modelled flow in George River catchment for South George, North George and George River at St Helens Water Intake. Symbols show dates each river was sampled by Scammell (2010) for toxicity investigations, numbers indicate which tests were completed using the sample. Flow data from model developed by Hydro Tasmania for DPIW.

4.1 General comments about ecotoxicological testing

The Panel is in agreement that ecotoxicological test work completed using both the grab samples and deflated foam was conducted by qualified and respected ecotoxicologists in accredited laboratories (Ecotox Services Australasia (ESA) and the National Institute of Water and Atmospheric Research, New Zealand (NIWA).

The toxicity testing carried out to date on the foam from the George River was largely undertaken using freshwater cladocerans, although a number of saltwater species such as oyster larvae or sea urchins (ESA) or blue mussel larvae (NIWA) were also used. It should be noted that in testing of freshwaters for toxicity, the use of brackish estuarine/marine species is not ecologically relevant, rather they are simply a sensitive indicator of toxicity. In assessing the significance of toxicity in a risk assessment where a safe dilution of the toxic water (or foam in this case) might be considered, the ANZECC/ARMCANZ (2000) water quality guidelines require toxicity testing of at least 5 species from at least 4 taxonomic groups. Ideally in a site-specific study such as this one, the use of local species is preferred. The Panel recognises that the high costs associated with completing the required range of test work are a factor in why a limited number of test organisms were included in the investigations, but this limitation of the results needs to be acknowledged.

The investigation used established toxicological testing methods with appropriate QA/QC procedures, however these test methods were developed and validated based on the exposure of organism(s) to dissolved toxicants, and how the organism(s) responds to particulate associated toxicants is unknown. The very high concentration factors of the samples and associated presence of a high number of particulates in the deflated foam samples raises some questions about the interpretation of these tests. The results of the tests could be affected by physical processes such as smothering or by toxicity through direct ingestion of the particles. Dr Krassoi commented that once the coarse material was removed from the deflated foam, the remaining solution contained fine particles in suspension and that these would settle overnight. At least with the cladoceran tests, which measure mobility, smothering of the organisms was not an issue, and he found no evidence of gill clogging in the cladocerans. Any toxicity was assumed to be the result of particle ingestion.

There is also a compounding factor in that the foams are created by the presence of surfactants (natural or man-made). These surfactants were found to be non-toxic when particulate material was removed, however, it is not known how they may affect test organisms especially in the presence of other compounds.

It should also be noted that the test organisms used in the investigations are very sensitive ecological indicators, and results from the tests are not directly applicable to drinking water. In fact, most of these organisms cannot be used to test drinking water quality as they would not survive in treated drinking water due to the presence of chlorine, alum or other treatment additives. This is evident in Table 7, which shows ecotoxicological results presented by Hickey (2009) in which the drinking water sample is presented as being toxic to the test organism due to the addition of alum (a flocculant) during water treatment. Aquatic organisms are more susceptible than humans to aluminium with water quality guideline for ecosystem protection for aluminium being 55 μg/L (ANZECC/ARCANZ, 2000), while there is no human health guideline for aluminium in drinking water, only an aesthetic guideline value of 200 μg/L (NHMRC / NRMMC, 2004).

The water (and foam) samples collected by Scammell and others for ecotoxicological testing were primarily sampled during periods of very low rainfall in the George River when groundwater inputs would have contributed the majority of flow in the river. One high flow event was sampled in February 2005 (Figure 16). The samples collected during the first few months of 2005 coincided with some of the lowest river flows recorded in the river.

The Scammell investigations include ecotoxicological test work using 'grab' samples collected from the George River and concentrated deflated foam samples collected from the surface of the river and Georges Bay. As discussed in Section 3.10, the foam is a highly concentrated substance which does not reflect the underlying water column. In contrast, 'grab' water samples directly reflect the water quality of the river (or bay) and provide the best 'snapshot' of what is happening in the river at the time of sampling. The 'grab' sample results provide the best answer to 'what is in the water' and are discussed in the next section.

4.2 What is in the water?

The Scammell and Bleaney investigations described three freshwater and one estuarine grab sample as indicated in Table 1, with two of the freshwater samples collected under dry conditions and one under wet (early rain) conditions. The Panel has examined the evidence associated with these tests and provides the following interpretation of the results:

- The North George River sample showed marginal toxicity to the most sensitive test organism. As previously discussed, the use of a marine species in the testing of freshwater has no ecological relevance;
- The sample labelled, ''Pyengana', was collected from the George River immediately downstream of a dairy farm during a very dry summer period (January 17, 2005) when flow in the river was extremely low (Figure 16). This sample is likely to reflect agricultural discharges and is not a good indicator of general catchment conditions;
- The estuarine sample listed by Scammell (2010) as a Moulting Bay 'grab' sample was described as 'beach froth' by the person collecting the sample, and in the sample receipt log of the laboratory. This sample is erroneously included as a grab sample.

In contrast to Scammell's results, river water grab samples from the North and South George River, George River at Pyengana, and in the George River at the Water Intake analysed by Hickey (2009) were found to be non-toxic, and he concluded that there were 'No detectable effects in river water' as shown in Table 7.

Hickey's findings are similar to those of a DPIPWE investigation conducted during February 2005 where twelve grab samples were collected from locations in the North and South George River, Crystal Creek, George River downstream of Pyengana and George River at the Water Intake and evaluated by DPIPWE using the IQ-Tox bioassay (Table 8). This is a short test that uses a measure of feeding activity in caldocerans (*Daphnia magna*) and is specifically designed to evaluate drinking water. No toxicity was found in any of the water samples, but it is recognised that the IQ-Tox test is slightly less sensitive than the *Daphnia magna* reproduction test.

To confirm the results, DPIPWE had ESA test samples from two of the sites (Water Intake and Crystal Creek) using the sensitive oyster larvae and sea urchin tests. No toxicity was found in either of the samples for either test.

Grab water samples were also collected from the South George River and the Water Intake site and tested by Makepeace *et al.* (undated) using T47D (cancer) cells. The test was conducted using filtered water, and no toxicity was present in the South George sample. The sample from the Water Intake did show a statistically significant response compared to the controls. This use of cancer cells for ecotoxicity testing is an emerging technique and how the results compare to established testing procedures, such as the cladoceran test, is unknown. The toxicity results were reviewed by the Health Protection Branch (Victory) for DHHS and it was suggested that aluminium or iron present in the water may have affected the toxicity results, and that the results do not indicate a clear human health effect as toxicity to a cell line is not transferrable to the whole human (Bowman, 2009).

It must be reiterated that while a lack of demonstrable toxicity using these tests indicates the water is not harmful to extremely sensitive test organisms and is presumably of very good quality, a positive result does not indicate the water is unsuitable for human consumption, as human health guidelines are typically orders of magnitude greater than ecosystem protection guidelines.

In summary, of the 26 grab samples from the George River for which toxicological test results are available (including 4 results from Hickey), 23 showed no toxicity. One showed low-level ecotoxicity to one of three saltwater organisms; and one collected downstream of a dairy showed high ecotoxicity in the saltwater tests. As previously noted, the use of salt water organisms to test freshwater is questionable. The only other sample to exhibit toxicity was collected at the Water Intake, and reflects the dissolved constituents in the water. It is noted that the Water Intake is located downstream of a large agricultural area, and the presence of contaminants from catchment runoff cannot be ruled out as evidenced by the occasional presence of herbicides at the Intake site during high flow events. The lack of toxicity in the South George sample collected at the same time does suggest that the ecotoxicity was not widespread and was not derived from the upper catchment.

When viewed collectively, the evidence supports the view that the bulk, untreated water in the George River is non-toxic to highly sensitive ecotoxicological test organisms. Exceptions may occur in agricultural areas of the catchment during limited periods, but it must be stressed that these tests are not indicators of drinking water quality. Scammell agreed with this conclusion during discussions with the Panel, as did the ecotoxicologists who performed the investigations. This finding is strongly supported by the evidence, and is in contrast to statements contained in the Executive Summary of Scammell (2010).

Table 8. Table summarising ecotoxicity tests using samples collected from the George River as presented by Hickey (2009) at the Australasian Society for Ecotoxicology in Adelaide in 2009.

Results: Water

		Cladoceran			Blue-mussels		
Site	Code	CL: Concentration (%)	CL: unfiltered	CL: filtered	BM: Concentration (%)	BM: unfiltered	BM: filtered
South George	SG	100	0	nt	61.1	0	0
North George	NG	100	0	nt	61.1	0	0
Pyengana	PY	100	0	nt	61.1	0	0
Water Intakes	WI	100	0	nt	61.1	0	0
Drinking Water	DW	100	0	nt	61.1	+++	+++
Treatment Filtrate	TF	100	++	nt	61.1	nt	nt
	TF	22	0	0			

Effect categories at specified dilution: nt, not tested; 0, no statistical effect; +, slight toxicity (10-30% effect); ++, moderate toxicity (30-75%); +++, high toxicity (>75%).

Toxicity associated with water treatment aluminium toxicity

→ No detectable effects in river waters

'o' indicates no statistical difference between the test water and the control water (not toxic). 'nt' indicates the sample was not tested.

Table 9. Summary of grab sample ecotoxicity test results from Scammell (2010) and DPIWE (2005).

TEST RESULTS REFERRED TO IN EXECUTIVE SUMMARY

Date	Location	Collected by	Toxic	Not Toxic	
Toxic	Comment	Oyster farmers	X		Low toxicity in sensitive sea water test (sea urchin) Not toxic in oyster survival or development test
17 Jan 05	Stream at Healey, Pyen-gana	Oyster farmers	X		Downstream of a dairy. Toxic in sea urchin and oyster survival and development test
2 or 3 Feb 2005	S. George River	J. Marshall, UTAS		X	During rain event
14,15 Feb 2005	Scammell states 5 grab samples collected from Water supply intake, North George, South George Crystal Ck and Groom River	DPIPWE		X	Scammell indicates that one of these samples grab samples was toxic, which is false. DPIWE (2005) shows that 12 samples were collected and none were toxic.

Table does not in clude samples collected and tested by Hickey as sampling dates are unknown.

Table 9. Summary of grab sample ecotoxicity test results from Scammell (2010) and DPIWE (2005).

SAMPLES COLLECTED BY DPIPWE

Date	Location	Collected by	Toxic	Not Toxic	
Toxic	Comment	DPIPWE		X	IQ-Tox test
14 Feb 2005	N. George sub-surface water	DPIPWE		X	IQ-Tox test
14 Feb 2005	S. George surface water	DPIPWE		X	IQ-Tox test
14 Feb 2005	S. George sub-surface water	DPIPWE		X	IQ-Tox test
14 Feb 2005	George d/s Pyengana surface	DPIPWE		X	IQ-Tox test
14 Feb 2005	George d/s Pyengana sub -surface	DPIPWE		X	IQ-Tox test
14 Feb 2005	George River at water intake- surface	DPIPWE		X	IQ-Tox test
14 Feb 2005	George River at water intake- sub-surface	DPIPWE		X	IQ-Tox test
15 Feb 2005	Crystal Creek surface	DPIPWE		X	IQ-Tox test
15 Feb 2005	Crystal Creek sub-surface	DPIPWE		X	IQ-Tox test
15 Feb 2005	Groom R surface	DPIPWE		X	IQ-Tox test
15 Feb 2005	Groom R sub-surface	DPIPWE		X	IQ-Tox test
15 Feb 2005	George River Water Intake	R. Krassoi (Ecotox)		X	Sea urchin larval development test
15 Feb 2005	George River Water Intake	R. Krassoi Ecotox		X	Oyster development test
15 Feb 2005	Crystal Creek	DPIWE		X	Sea urchin larval development test
15 Feb 2005	Crystal Creek	DPIWE		X	Oyster development test
Other samples					
May 2009	South George	Makepeace et al.		X	Human cancer cell test
May 2009	Water Intake	Makepeace et al.	X		Human cancer cell test

Table does not in clude samples collected and tested by Hickey as sampling dates are unknown.

4.3 What is in the foam?

The characteristics of foam and the alterations to river foam due to extreme concentration by the skimmer box during collection are discussed in Section 3.10. Before the results of the deflated foam samples presented by Scammell (2010) can be interpreted, it is necessary to examine the various concentrations factors the samples have been subjected to.

4.3.1 Concentration factors associated with foam collection

The collapsed foam samples have been subjected to a range of concentration processes. These include (i) concentration due to the collection of foam from a large area of the river into the skimmer box, (ii) the concentration of the contained compounds in the surface layer of the river due to the ongoing collapse of foam within the skimmer box and associated precipitation of compounds from the surface microlayer, and (iii) concentration associated with the deflation of the final foam sample.

The skimmer box corrals foam from an approximately 1.25 m wide area of the river into the apex of the box. The surface area of the river from which the foam is collected is dependent on the flow of the river, and length of time the skimmer box is deployed. This information was not recorded by Scammell (2010) except to state that the box was deployed for 24 hours.

In the video of the skimmer box in the South George River reviewed by the Panel, the skimmer box required approximately 1 minute to collect foam into the half-circle at the front end of the skimmer box. Using the area of the half-circle, the velocity of the river (estimated at 0.2 m/s), it is estimated that the area of foam on the river constitutes <0.1% of the surface area of the river. Filling the skimmer box with foam, without any additional concentration due to foam collapse represents a concentration factor of about 1400-fold. Given the variability of river flow and foam production in the river, this concentration factor probably varies between 500 and 2000-fold.

As the foam is stored in the box, it interacts with the surface microlayer of the river as it flows beneath the box. Using the estimated river velocity of 0.2 m/s, then over a period of 24 hours the skimmer box will effectively sample 21,600 m^2 of the river's surface. This 21,600 m^2 of the river's surface microlayer contains the highest concentrations of natural or man-made compounds of any water in the river. This layer accounts for <0.3% of the total volume of the river, so compounds are likely to be concentrated by a large factor even before they are adsorbed to the foam.

The final concentration of a sample will also depend on where and how the foam is collected from the box. The closer to the front of the box a sample is collected the more compressed the foam and associated material will be so the more concentrated the sample. Similarly, if only the surface of the foam is sampled, then the sample will contain a higher concentration of the colloidal material as compared to a sample, which collects the full depth of the accumulated foam.

In addition to these very high concentration factors, the final foam samples were deflated, leading to an additional concentration factor of between 3 and 10, depending on the sampling technique used (Scammell, Krassoi, pers. comm.). Table 9 summarises all of the potential concentration factors, and shows that the material being tested by Scammell (2010) was concentrated many thousands of times relative to the foam present on the surface of the river.

Interpretation of the skimmer box foam results is also complicated by the various skimmer box designs and sampling methods used, such that the sampling methodology and hence concentration factors changed over time. In early studies, as stated in the Scammell report (2010), the skimmer boxes were deployed for 24 hours. In later discussions with the Panel, Dr Scammell stated that although the boxes were deployed for these long periods, the actual foam sampled probably only represented a half hour of sampling, as the foam overflowed the container. This view was confirmed by I. Coatsworth who was directly involved in many of the sample collections.

Table 10. Summary of potential concentration factors of foam collected in skimmer box

Process	Estimated Range of Concentration Factors	Comments
Collection of foam in skimmer box without foam collapse	500 - 2000	Depends on river velocity and density of foam on river surface
Collapse of foam and continued interaction with surface microlayer of river	~900 / hour of skimmer box deployment assuming flow of 0.2 m/s	Depends on river velocity
Concentration of compounds in surface microlayer as compared to bulk river water	10 – 100	Depends on compounds present and depth of river
Concentration due to deflation of foam following collection	3- 10	Depends on sampling method used

These large concentration factors also increase the possibility of synergistic effects between compounds resulting in higher toxicity than would normally occur. There is also evidence that the water resulting from the deflated foam has different basic water quality characteristics compared to those of the ambient water. For example, Hickey (2009) reported that deflated foam was anoxic, had a higher pH (7.4 vs. 6.9) and contained 1300-times more suspended solids compared to a grab sample from the same location (Hickey, 2009). The high solids content reflects particles that were pre-concentrated and particles that are formed as the foam collapses. Krassoi (2010a) also reported low dissolved oxygen concentrations in the deflated foam (as low as 42%). This is not to suggest that the results reported by Scammell and Bleaney are attributable to anoxia or high-suspended solids, but to highlight that the characteristics of waters being tested vary considerably from the water in the river and can affect toxicological response of organisms.

Scammell informed the Panel that no measurement of the final sample volumes were made as the investigation was more a qualitative assessment of toxicity rather than an investigation into the concentrations present. This is a fundamental problem with the work, in that the toxicological response is directly related to the concentration of toxicants. By concentrating the samples many orders of magnitude beyond environmental relevance, the investigators have produced results which are not able to be interpreted with respect to the natural environment.

The Panel makes the following observations with respect to the high concentration of the foam samples:

- The ecotoxicity results from the foam samples collected in the skimmer box have no relevance to the ecosystem due the extreme concentration of the samples during sampling. The presence of toxicants in the concentrated collapsed foam does not imply that ecotoxicological impacts will be associated with the uncollapsed foam as it exists in the river and is transported to the estuary. The Panel notes that there are many natural substances in rivers, including fatty acids, waxes and lignin-derived phenolics which accompany the decomposition of leaf litter in any catchment and if concentrated to the extent of these samples would be expected to be toxic to sensitive test organisms (Wegner and Hamberger, 2002). These compounds may include natural surfactants, and a range of hydrophobic compounds (Mills *et al.*, 1996). These can be transported through the water column along with entrained air giving rise to foams at the surface in low concentrations. Foam formation might be exacerbated in waterfalls or other areas where entrainment of air can occur. Some of these compounds will have toxic properties in high concentrations to some aquatic organisms. For example, there is evidence in the literature that plant-derived (but non-eucalypt) foam from catchments in Europe has been found to impart toxicity to freshwater cladocerans when foam was concentrated over 50-times (Wegner and Hamberger, 2002). As discussed in Section 3.5.3, concentrated eucalypt leachate can produce a toxicological response on test organisms.

- The particulates (sediments) contained in the foam samples and considered to be the source of the toxicity by Scammell (2010), are created within the skimmer box as a result of concentration and deflation of the foam. The composition of this material is likely to differ in composition from the 'natural' sediment carried by the river. This is important as Hickey (2009) suggests that toxicity will occur if the sediment concentration in the river is increased three-fold. This is clearly not the case if the composition of the particles in the skimmer box and river differ;
- The poor chemical match between leaf leachates and foam components (Hickey and Stewart, 2010) suggests that any observed toxicity in the foam is not derived from fresh leaves, but more likely from the products of microbial degradation of leaf litter and other vegetation both in the more quiescent areas of the river, but could also include terrestrial runoff. Photochemical processes in the exposed foam could also transform compounds to products with potential toxicity at high concentrations. These are natural processes that occur in rivers and soils everywhere, but the products will differ depending on the local vegetation.
- The natural concentrations of foam observed in the river system were extremely low, so without the pre-concentration achieved, it is unlikely that any aquatic organisms would exhibit any toxic effects.
- The toxicity was observed to be associated with fine particulates. This is consistent with the demonstrated findings that the collapse and concentration of foams and surface films produces fine particles. In seawater, bubble 'implosion' resulted in the formation and aggregation of fine particles in the size range 2-32 μm (Johnson and Cooke, 1980; Wotton, 1984). Aggregation might be responsible for the reported loss over time of toxicity to cladocerans, which prefer particles the size of algae (< 2 μm). There could also be a minor contribution from fine material scavenged in the foam in the river;
- The presence of man-made chemicals at extremely low concentrations in the rivers could also be concentrated to 'toxic' levels in sampled foams using the skimmer box approach, but a screen for common pesticides found none as discussed below.

4.3.2 Potential for multiple toxicants

The toxicity of the foam samples can readily be accounted for by the extreme concentration of natural compounds in the skimmer box. However, there is some evidence for the presence of other compounds in some of the foam samples tested which warrants recognition. The claim in the Executive Summary of the Scammell report that the foam contained no man-made chemicals is a loose extrapolation. In their analysis of the foam samples, Advanced Analytical looked for a suite of pesticides and herbicides, and at the detection limit of their methods, none of those in the suite could be detected. Indeed the mass spectra obtained from both LC and GC separations indicated the presence of a large number of compounds whose origins could not be identified. These may or may not be natural plant-derived materials.

There is evidence both for and against the presence of pyrethroids in the concentrated foam samples collected on March 3 and 24, 2005. Evidence in support of their presence in the sample includes PBO enhancement in ecotoxicity tests and the rapid decline of toxicity in the sample, consistent with the high degradation rate of pyrethroids. Circumstantial evidence includes the timing of collection of the PBO-positive samples (late summer) which could coincide with the aerial spraying season (no records available), with PBO enhancement disappearing in samples collected later in the year, possibly after spraying activities ceased. Evidence to the contrary includes:

i. the possibility that PBO enhancement of ecotoxicity could also be related to the effect of methanol, added with PBO, on the toxicity to sensitive test organisms;

ii. no pyrethroids were detected in foam samples from the catchment (S. George, N. George, Water Intake) at the 0.1 µg/L reporting limit by DPIWE in February 2005;

iii. experimental toxicity coincides with low flow and disappears with high flow which does not support runoff from spraying as a source of toxicity; and

iv. the toxicity in samples is short-lived even when PBO enhancement is absent, suggesting that the short lived toxicant is not a pyrethroid.

Quarterly and high-flow monitoring by DPIPWE between 2005 and 2010 for the pyrethroid pesticide α-cypermethrin has not detected its presence at the 0.1 µg/L reporting limit at the Water Intake site in the lower George River. This does not rule out the presence of α-cypermethrin, since Crane *et al.,* (2007) reported that it is toxic to cladocerans at around 0.003 µg/L (NOEC= 0.1 ng/L). Its half-life in waters is around 1 day due to photolysis, but it attaches to particles very readily.

Eucalyptus oils cannot be eliminated as potential toxicants in the samples as these compounds have been identified by DPIPWE in GCMS analyses of foam from the George River catchment. Scammell dismisses these compounds as potential toxicants because the toxicity remains after volatiles have been driven off by bubbling nitrogen through the sample. This technique will not remove oils which have higher boiling points so cannot be confidently excluded. There is also the issue that organics in the samples were extracted using methanol, which does not recover all organics.

Although all plant oils cannot be ruled out, the major oils detected by DPIWE (2005) 1,8-cineole and β-pinene are unlikely to be the sole source of the ecotoxicity, as the estimates of their concentrations contained in the foam samples (0.005 to 0.500 mg/L) are below those associated with slight toxicity (1,8-cineole ≅ 6.25, mg/L; β-pinene ≅ 0.625) or acute toxicity in *Daphnia* (1,8-cineole ≅ 12.5, mg/L; β–pinene ≅ 1.25, DPIWE, 2005). The Crystal Creek samples also contained elevated levels of aluminium and iron which can affect the test organism.

The use of methanol in a large number of the experiments (dosing of PBO, extraction of organics) raises concerns about the potential impact this reagent may have on the ecotoxicity results. Methanol is relatively non-toxic to *Ceriodaphnia* at concentrations below 0.3%, but may show toxicity above this level (M. Adams, CSIRO, private communication). The concentration of methanol in samples and controls in the Scammell investigations ranged up to 1%, and there was a lack of evidence of systematic controls that would clearly preclude methanol as a potential ecotoxicant in some of the samples. The Panel does not consider this as a major issue but rather a confounding one in some of the tests.

4.3.3 Potential for *E.nitens* to be the source of the toxicant

The Panel has considered the potential for *E. nitens* to be the source of toxicity in the foam. Based on the presence of toxicity in the foam from Crystal Creek, which does not have eucalypt plantations, it is highly unlikely that *E. nitens* could be the sole contributor to the observed toxicity and this is supported by the latest testing by NIWA (Hickey and Stewart, 2010). The Panel has also considered evidence which shows that the composition of oils from *E. nitens* is similar to Tasmanian native eucalypt species, suggesting that if oils are a stressor, then it will occur if *E. nitens* or other native eucalypts (e.g. *E. globulus)* are present in the catchment. Plant-based bioassays of soil leachates from under *E. nitens* and *E. globulus* trees in plantations also showed no significant differences between the species. In conclusion, there is no demonstrable evidence suggesting that *E. nitens* would be more likely to produce oils or toxic compounds as compared to Tasmanian native species.

The Panel has not found any studies which investigate the impact of a single aged monoculture of eucalypt trees on water quality in a catchment. Indirect evidence that has been considered is that the re-establishment of forests following a fire, which initially includes a high number of individuals of the same age and species, has not been identified as a potential threat to water chemistry. The Panel recognises that the vegetation in a catchment will influence water chemistry of rivers, and that any large monocultures (e.g cropping, pasture, horticulture, plantations) are likely to be reflected in changes to water chemistry. However, in the case of the Scammell (2010) investigations, the overwhelming factor contributing to the ecotoxicity of the foam is the huge artificial pre-concentration of naturally derived organic matter.

4.3.4 Other comments on foam results

The Panel makes the following additional comments with respect to the concentrated deflated foam test results:

- The results presented by Scammell (2010) from other catchments do not represent a paired-catchment experiment, as numerous characteristics differ between the George River and other catchments. The George River catchment is underlain predominantly by granitic type rocks which produce distinct types of soils and support a vegetation complex distinct to the St Helens hinterland. The first catchment investigated by Scammell and Bleaney, which drains into Lake Augusta, is situated on the Central Plateau, is underlain by dolerite, and supports alpine vegetation. The second creek investigated is located in St Marys and characterised by a range of non-granitic rock types, including dolerite and limestone, and supports some eucalypts, but generally drier vegetation types as compared to the George River. It is also likely that the sampling methodology differed between the catchments, which will affect the results. If the earliest design of the skimmer box was used (as is evident in the photo of the site near Lake Augusta in the report), the foam is less likely to be toxic due to less efficient concentration in the box. Based on these fundamental differences between the catchments, the Panel considers the results from the paired catchment investigations to be of limited value;
- Methanol will not extract the very non-polar (more lipid soluble) organic compounds that may also be present in the collapsed foam. These require a more non-polar solvent, such as hexane or dichloromethane. Dichloromethane was used by the analytical laboratory in their analysis of the foam constituents, but not in the toxicity testing. The effect of incomplete extraction of toxicants appears to have confounded the interpretation of add-back experiments on S. George River-foam collected on March 3, 2005, where four times the extracted concentration had to be added back to achieve the same toxicity as originally present in the sample.
- The majority of toxicity of the deflated foam to cladocerans was found to be associated with its constituent fine particles (Scammell, 2010). There is a basic flaw in an experiment which takes contaminants that were originally attached to particles, dissolves them in a solvent and expects the toxic behaviour to be the same when added back to the original water. The mechanism of toxicity in cladocerans is likely to differ for particulate vs. dissolved contaminants, and there has been no consideration of what this mechanism might be or how toxicity might differ for organisms such as algae which cannot ingest particles.
- The methanol extracts were subsequently analysed using high performance liquid chromatography (HPLC) coupled to mass spectrometry (LCMS) to attempt to identify those toxicants in the methanol extracts. Amino acids were identified and ratios between the amino acids were similar between the leaves and foam. The Panel consulted Professor Adrian West, a professor in biomedicine and expert in protein chemistry at the University of Tasmania, School of Medicine about this finding. His opinion was that the amino acid fingerprint in rivers is likely to reflect that of the surrounding vegetation and that all C3 higher plant vegetation is likely to give a similar fingerprint. This is because the major input into rivers is usually leaf material and the major proteins in leaves are involved with photosynthesis, a process very similar across all C3 plants.
- DPIPWE undertook toxicity testing of skimmer box foam samples and used gas chromatography/ mass spectrometry (GCMS) to identify a range of compounds including globuol, 1,8-cineole, β-pinene, palmitic acid, oleic acid and stearic acid, cresol, ethylphenol and indole. It is not clear whether the investigation by Advanced Analytical also identified these compounds. Scammell (2010) states that these compounds were absent in any toxic methanol fraction, but no evidence is provided.
- The presence of similar peaks on chromatographs of foam samples and of extracts of *Eucalyptus nitens* leaves does not constitute evidence that these compounds are exclusively derived from the *E. nitens* in plantations, as the composition of *E. nitens* is similar to other native species (See Section 3.5.1);
- The method used to extract compounds from *Eucalyptus nitens* leaves for several of the investigations, by crushing and then extraction using methanol, is very different from the processes that naturally degrade leaves;

4.4 What is the environmental impact of the water and foam on the ecosystem?

The Scammell (2010) results along with other catchment investigations indicate that the water quality in the George River is non-toxic and generally good. The long record of invertebrate monitoring in the South George River and the Ransom River provides the best indication of overall ecosystem health, and this monitoring has consistently found the rivers to be at or close to 'reference condition'. The monitoring shows no degradation in macroinvertebrate health over the period 1997 – 2009 which includes the time period of concern as identified by Scammell (2010) and the oyster farmers. The invertebrate communities are subjected to the natural conditions of the river, including foam and the – surface microlayer of the river. The good health of the ecosystem as compared to the 'toxic' nature of the concentrated foam highlights the irrelevance of the ecotoxicological findings to the natural environment.

The Panel reviewed the reports associated with the aetiology of Tasmanian devil facial tumour disease which were prepared in 2005. The Scammell (2010) findings provide no evidence for a link between water quality in the catchment and aetiology of the disease in the devils.

The review by the Panel has not identified any environmental risks associated with the Scammell (2010) results, but has identified potential risks to the environment associated with chemical usage in the catchment. The potential (but largely undocumented) widespread usage of chemicals in the catchment associated with agricultural, domestic, forestry and municipal activities, combined with the poor condition of the riparian zone (Figure 18) over much of the length of the George River increases the risk of chemicals entering the river system and being transported downstream. The presence of herbicides during high flow events in the George River (DPIPWE, 2010b) may be symptomatic of poor catchment management (inappropriate chemical usage in the catchment exacerbated by a degraded riparian zone). With good water quality management practices, pesticides should not be detected in source waters used for drinking water supplies (AWQG, 2010). This issue is discussed in Section 4.7.2.

Figure 18. Google Earth images of the George River showing agricultural lands bordering the river and narrow riparian zone. Top photograph shows South George River, lower photo shows George River upstream of Water Intake (WI) site (red dot). River flows from left to right in photosgraphs.

4.5 Pacific oyster health

4.5.1 Impact of foam on oysters

The findings of Scammell (2010) have no direct relevance to Pacific oyster production due to the highly concentrated nature of the foam samples, the long river distance between the upper catchment and the areas of oyster production, and the chemical changes that occur as river and estuarine waters mix. It is also important to recognise that estuarine foams differ compositionally from river foams and are predominantly polysaccharides derived from algal and phytoplankton exudates rather than organics and surfactants from terrestrial vegetation. Although **there is no evidence to suggest that bay foams at environmentally relevant concentrations pose a threat to the environment,** their toxicity has not been directly examined.

The investigations do highlight the elevated concentrations of compounds in the surface microlayer of waterways, and the ability of foam to adsorb contaminants, both of which may be relevant to oyster health in the bay. Because the oyster farms are situated at the downstream end of the catchment, they will be subjected to runoff from all catchment activities, including agriculture, domestic, forestry, and municipal activities, as well as inputs from slipways, boats and sediments in the bay. The closer leases are to inputs from the catchment, the more susceptible they are likely to be to contaminants and other stressors associated with riverine inputs.

The Pacific oyster is a facultative anaerobe that can close and live anaerobically when exposed excessively to fresh water. If rumbling (physical tumbling of oysters to enhance growth) or grading (passing through sieves) of oysters has damaged the shell margins preventing the shell from fully closing, this may reduce the ability of the oyster to close and increase the risk of exposure to compounds associated with river water, foam, or the surface microlayer.

There is no evidence to suggest that the foam per se in the George River is detrimental to oysters, however, it is possible that chemicals and compounds associated with the foam could be an additional stressor to oysters under certain conditions. The accumulation of wind-driven foam in Moulting Bay associated with certain rain and wind patterns does provide a potential pathway for oysters to become exposed to toxicants associated with the foam, albeit at concentrations much lower than those measured with the skimmer box in the South George. Because foam floats on the water surface, intertidally cultured oysters will be exposed to it for a brief period during every tidal cycle as the water level either recedes to expose or rises to cover the oysters. For waters containing foam, it is the falling tide that is likely to have the greater effect as foam and associated compounds may be trapped on the exterior of the shells that are then are out of the water and exposed to air where the foam could collapse, dry, and be photochemically degraded. The effects of these events at the expected low exposure concentrations are unknown.

4.5.2 Link between catchment activities and oyster health

Plantation timber started in the George River in the early 1990s largely in the South George sub-catchment, but did not begin to cover large areas until after 2000 (see Table 10). When Pacific oyster ill-thrift was first noted in Georges Bay, in about 1997, there were fewer than 200 ha of plantations in the catchment, less than 1/10th of what is present today. The large mortality event associated with the flood in 2004 did follow a large increase in plantations over the previous two years, and a summer of aerial spraying in the South George catchment, but other catchment inflows, including sediment input were extreme during this event and no evidence has been found for a single factor causing the kill.

The Panel suggests that it is important to understand other catchment changes which may impact oyster health, with a major one being the increase in oyster production over the same time period. As discussed in Section 3.7.1, and shown in Figure 8, Pacific oyster production in the bay has tripled since ill-thrift was first reported in 1997. Of note is that beginning in 2000, considerable oyster production began in the Pelican Point area, which is close to the mouth of the bay and less exposed to chemicals of catchment origin. The increased Pacific oyster load in the bay, and the changes in distribution of oyster production also need to be considered when identifying reasons for poor oyster health. For example, the same food source is now supporting 3-times as many oysters in the bay. The production figures also demonstrate that the flood had no long-term impact on oyster production in the bay.

Other substantial changes to the bay which may have affected oyster health are also discussed in Section 3.7.1

Table 11. Plantation forestry in the George River catchment (data provided by Private Forests Tasmania and Forestry Tasmania).

Site	Cumulative Plantation Area, ha				
	1997	1998	2000	2004	2009
South George	724	765	887	1243	1483
North George	345	387	431	554	749
Powers Rivulet	90	91	135	319	499
Other	1	1	7	79	191
Total plantations	1160	1244	1460	2195	2923
Total forestry	180	300	1100	3300	6200

4.5.3 Multiple stressors

The Panel's review of available information and the Scammell (2010) findings support previous findings that there are likely to be multiple stressors acting on the oysters in Moulting Bay. In the past the known stressors have included: salinity, grading and spawning, with additional potential stressors including the composition and nature of sediments in the bay, time left out of water following grading, algal composition and toxic blooms, tributyltin, other antifoulants herbicide and / or insecticide runoff from the catchment and oyster nutrition. Viruses (have also been linked to oyster mortalities overseas (Sauvage *et al.*, 2009).

Many people interviewed in relation to Pacific oyster health issues have expressed a concern that multiple environmental factors may be involved in the oyster mortalities. To obtain a better understanding of the interactions of multiple stressors, it is recommended that future research include a multifactorial experiment where tanks of oysters are progressively exposed to an increasing number of stressors. The experimental conditions should replicate field conditions as closely as possible, including tidal exposure of oysters. However, matching experimental to field conditions will be challenging, especially for concentrations of toxicants. A range of toxicant concentrations from predicted low to high values may need to be investigated.

Foam present in the bay should be included as one of the potential stressors because although river foam has been found to be non-toxic at environmentally relevant concentrations, foam does have the potential to concentrate and transport toxicants (albeit at much lower concentrations than produced in the skimmer box). The composition of bay foam differs from that of river foam.

Foam and associated compounds should be included as one of the stressors investigated, but it is important that environmentally relevant concentrations are used, rather than the extreme concentrations used by Scammell (2010).

The Panel concludes that the best risk management approach for maintaining a viable Pacific oyster industry in the bay is for good catchment management such that the water entering the bay is maintained at a high quality, and for the industry to better understand and manage stressors not associated with water quality (temperature, grading and handling, stocking densities, algae, viruses, water circulation).

4.5.4 Knowledge gaps

With respect to Pacific oyster health, the Panel has identified the following knowledge gaps:

- The effect of multiple stressors on oyster health and production. The GRWQ Panel investigations have found that there is no evidence of environmental risk associated with river foam at 'natural' concentrations. However, bay foam should be included as a potential toxicant in any multi-stressor experiment for the following reasons:

  i. Foams have the capacity to concentrate and transport toxicants present in the surface microlayer of the bay (although not to the same degree as the skimmer box);

  ii. Runoff into Georges Bay from a wide range of activities (agriculture, domestic, forestry, municipal), has the potential to introduce contaminants into the bay which under certain weather conditions could be concentrated and transported by foam; and,

  iii. Observations by oyster farmers link the presence of foam to oyster mortalities in the bay.

  iv. The Panel stresses that any multi-stressor investigation should use bay foam, which is presumed to be plankton-derived polysaccharide material and different in composition to the river foam, at environmentally relevant concentrations.

- If bay foam is found to be a significant stressor in a scientifically robust multi-stressor experiment, then additional information on the organic contaminants in the bay is warranted. This could be completed through the deployment of passive samplers near the oyster leases which have the capacity to collect organic contaminatns over a period of several days

4.6 What are the human health implications of the water and foam on the St Helens community?

4.6.1 General comments from Panel

The strong emphasis placed by Dr Bleaney on pesticides in the St Helens drinking water during discussions with the Panel was in contrast to the information presented in *Australia Story,* where it was postulated that the observed toxicity in foam in the George River was related to toxins from *E. nitens* plantations in the George River drinking water. This connection was suggested as all other potential toxicants, including insecticides and herbicides (pesticides), had been eliminated, leading Dr Scammell to summarise the toxicity findings on concentrated river foam in the catchment on *Australian Story* as follows:

> *We effectively eliminated all possible known man-made and naturally occurring toxins that have caused problems in the literature. These include all the pesticides, they include metals, they include blue-green algal toxins, they include toxins from funguses, they include fungicides, so on and so forth. Everything that we knew could cause toxicity we had eliminated'.*

In the final report presented to the Panel (Scammell, 2010) and in subsequent discussions with the Panel, D. Scammell supported this conclusion. This opinion was also strongly supported by the ecotoxicologists who completed the investigations, i.e. that the toxicity in the concentrated foam samples is not associated with pesticides or other man-made chemicals or metals. Dr Bleaney acknowledges the lack of evidence for pesticides but considers them a potential risk due to ongoing use in the catchment. Dr Bleaney stated:

> *'In the beginning, after the oyster kill, we actually thought it was just pesticides and we went looking for those. And although we didn't find any at the time, we know that pesticides are still being aerially sprayed in the water catchment; they're still being ground sprayed, and it adds to the complexity of the picture (Australia Story transcript).'*

When discussing the lack of statistical evidence showing higher rates of cancer or other diseases in St Helens as compared to Tasmania as a whole, Dr Bleaney suggested that what is occurring in St Helens was possibly occurring throughout the State, and even the western world.

In considering Dr Bleaney's stated observations, the Panel contacted other general practitioners in the region. Although the health experience of other general practitioners in the region was shorter than that of Dr Bleaney, they noted no abnormal rates or trends in diseases or cancers. Characteristics of the community which were mentioned as being relevant to health issues by the general practitioners included the transient nature of the population, with the population tripling over summer, the large number of retirees, and the high incidence of cigarette smoking, obesity and poor diet. One general practitioner did note that there appears to be a high rate of immunological diseases including rheumatoid arthritis, but that this was common across Tasmania. This observation is consistent with an investigation being completed by the Menzies Research Institute Tasmania entitled *Tasmanian Systemic Sclerosis Epidemiology Study* (TASSiE). The study is described on the Menzies' website as follows:

> *Scleroderma and Mixed Connective Tissue Disease (MCTD) are related autoimmune diseases which can have a devastating impact on health. They are characterised by abnormalities in the small blood vessels, which can result in poor circulation to the hands and feet, skin breakdown, skin thickening and tightening, joint pain and swelling, lung fibrosis, kidney disease and pulmonary hypertension. It ranges from very mild changes in circulation in the hands in winter, to rapidly progressive disease leading to respiratory or cardiovascular death. We have set up this study to prove our impression that scleroderma/MCTD is more common in Tasmania than other areas in Australia, and so far it seems we have about four times as many people with the condition per head of population than other states. We will be looking at possible genetic explanations for this observation. The study will also describe the nature of cardiovascular and respiratory disease in scleroderma/MCTD, and the effects of some of the newer medications on the different elements of these connective tissue diseases* (Menzies Research Institute Tasmania, 2010).

To evaluate Dr Bleaney's observations, the Panel has reviewed the existing health studies completed for the region between 2004 and 2009, including a recently completed *Summary of the St Helens Water District Cancer Investigation for the George River Quality Panel, June 2010.* (discussed in Section 3.1).

Using the available information, the Panel has considered three human health issues:

1. Does drinking treated water from the George River pose a risk to human health, with respect to the issues raised in *Australian Story,* or from herbicides or pesticides in the George River?
2. Does contact with untreated river water from the George River pose a risk to human health?
3. Is there evidence of higher rates of disease in St Helens compared with other communities as suggested on *Australian Story*?

4.6.2 Drinking water quality

In assessing the potential hazard of drinking water, the Panel finds there is extensive evidence in Scammell (2010) and consensus amongst the ecotoxicologists involved in the testing of the George River that there is no ecotoxicity associated with river water samples from the George River. Ecotoxicity is only associated with highly concentrated river foams and associated particulates, and disappears when fine particulates are removed. This finding is consistent with other investigations (Hickey, 2009, DPIWE, 2005), and underscores the non-toxic nature of the untreated bulk water supply for the St Helens community. It should be noted that the concentrations of contaminants causing ecotoxicity are typically orders of magnitude below those causing human toxicity as evidenced by the differences between ecosystem protection and drinking water guidelines.

As an extra precaution, the Panel assessed the potential exposure of the community to the natural river foam through the drinking water supply. The Panel has concluded that the risk of exposure is exceedingly low due to the following factors:

1. Water is drawn from the George River at the Intake site via one of two sub-surface intakes. This mode of intake precludes the intake of surface films or foams into the water supply.
2. It is only the particulates in the concentrated foam which have been found to cause toxicity to sensitive test organisms. During water treatment particulates are very effectively removed from the raw water using flocculant and settlement so the risk of human exposure to any particulates in the water supply is very low;
3. The transit time for water through the St Helens water treatment system varies through the year and with distance from the water treatment plant. In summer, transit times of ~1 day may occur for areas close to the reservoir, whereas approximately 3 days is the norm during the non-summer seasons (Ben Lomond, pers. comm.). As the ecotoxicant degrades rapidly with time (3-5 days), this is an additional factor protecting the water supply;

With respect to herbicides and insecticides, neither has been detected in the George River at the Water Intake during quarterly baseline monitoring (2005 – present) (DPIPWE, 2010b). Herbicides (but not insecticides) at concentrations well below the *Draft Australian Drinking Water Guidelines* (NHMRC / NRMMC, 2009) have been detected in the George River at the Water Intake on several occasions during high flow events (DPIPWE, 2010c). The occasional detection of herbicides at concentrations below the human health guideline values is not desirable, and probably reflects misuse or spillage within the catchment, but does not constitute a human health hazard. Excursions above the guideline level would need to occur over a significant period to be a health concern, as the health-based guideline is based on long-term effects and carries a high level of precaution (NHMRC / NRMMC, 2009).

The potential exposure to low concentrations of herbicides associated with high flow events is minimised by the management of the water treatment plant, in that when possible, water is not pumped for treatment during high flow events, with the supply coming from the treated reservoir. For example, during the flood event in January 2005, water was not pumped from the George River between January 28 and January 31 (Inches, 2004).

The Panel also considered the potential impact of metals on the St Helens water supply, as iron and aluminium have been suggested as affecting ecotoxicological results (Bowman, 2010), and the area is historically a mining district. There is no evidence of elevated iron concentrations in the St Helens drinking water supply. Prior to the establishment of the current water treatment plant, aluminium was occasionally found in excess of the Australian Drinking Water Guidelines (NHMRC/NRMMC, 2004), but there is no evidence that any harm was associated with these brief exceedances as the guideline is based on aesthetic rather than health considerations (WHO, IPCS, 1997). Historically St Helens was a tin mining area. In addition to anthropogenically derived TBT, tin-containing sediment might be expected in the lower reaches of the Georges River and its estuarine areas. Despite this, there is no evidence that excess inorganic tin or its salts are present in either river water, drinking water, or estuarine water.

The Director of Public Health implemented the use of Powdered Activated Charcoal (PAC) as an additional step in water treatment at the St Helens treatment Plant in February 2010. This was in response to community concern raised by the airing of *Australian Story*. The

Panel has found no evidence of water quality issues in the raw drinking water supply of St Helens which necessitate the ongoing use of PAC in the water supply system. However, analyses of raw and treated water from the plant before and after installation of the PAC were not available for the Panel to assess, and it is recommended that these measurements be made for a wide range of parameters prior to discontinuation of PAC treatment.

The Panel cannot comment on the acceptability of untreated water drawn from the George River or other unregulated water supplies for drinking purposes as each source requires a separate evaluation as to its suitability for potable use.

4.6.3 Contact with water from the George River

Given the non-toxic nature of the George River to sensitive test organisms, the Panel concludes that the health risk associated with primary or secondary contact with the George River water is negligible.

4.6.4 Incidence of disease in the St Helens community

The Panel has relied on human health investigations conducted by DHHS and others over the past 10 years. Dr Bleaney provided human health information in 2005 to the DHHS. This information was investigated by DHHS and externally reviewed by Dr Sims at Monash University. The investigations concluded that the health trends identified by Dr Bleaney were consistent with demographic trends in the St Helens community, and reflected the socioeconomic profile of the region. No additional data have been present by Dr Bleaney for review by DHHS or the Panel.

The recent 2010 investigation by DHHS into cancer rates in the St Helens and Break O' Day community found that colorectal cancer was the most common cancer in the Break O'Day region, and that rates were higher than expected based on the age distribution and socioeconomic characteristics of the community. However, within the region serviced by the St Helens drinking water supply, the rate was within the expected confidence interval of analysis (e.g. statistically the rate was within the expected range). Overall cancer rates within both the Break O'Day and St Helens communities were also within the expected ranges. The Panel recognises that cancer rates show variability over time, and the low overall number of cases makes robust statistical analysis difficult, however, based on the available evidence there is no indication of increased cancer rates or of a cancer cluster within the St Helens community.

In considering all of the available information, the Panel makes the following comments regarding human health issues in the St Helens community:

- There is no evidence of ecotoxicity in the input water to the St Helens water treatment plant;
- There is no identifiable mechanism through which river foam can become concentrated to the degree tested by Scammell (2010) and enter the water supply system;
- Should any particulates associated with the concentration of foam (or other runoff in the catchment) enter the water intake, the water treatment system is very efficient at removing particulates via coagulation, flocculation and filtration;
- There are statistics of varying quality relating to the health of the St Helens and Break O'Day community, and in general the sample sizes are very small which can make systematic study very difficult. However, none of the available data show any impact that supports a health risk to the community;
- Because there is no identifiable exposure pathway, nor recognisable health impact, it is not possible to develop a targeted human health investigation. If additional or different health information becomes available which indicates either a potential exposure pathway or a potential health impact, then a targeted human health investigation would be warranted;
- Based on epidemiological experience, it is highly unlikely that one underlying factor via one exposure pathway (drinking water) could be responsible for the wide range of diseases suggested by Dr Bleaney as having increased across the board (but for which no statistical evidence has been found);
- It is also worth noting that many of the diseases suggested by Dr Bleaney as having increased in the community have no known linkages to the environmental exposure to contaminants.

4.6.5 Water supply risk identification and management

The Panel concludes that no human health risks have been identified associated with the George River water supply. However, given the configuration of the catchment, with the water intake located downstream of a wide range of agricultural activities, and the poor state of the riparian zone over much of the river, it would be prudent to implement catchment management actions to reduce the risk of man-made chemicals or agricultural and urban runoff entering the waterway. These actions could include enhancement of the George River riparian zone, and continual improvement in the use and management of agricultural and silvicultural products, including stricter and more transparent requirements for reporting of chemical usage.

4.7 Other findings

4.7.1 Lack of publically available information

In assessing risks to the health of the George River ecosystem, St Helens water supply and Pacific oyster health in Georges Bay the Panel found it difficult to consider chemical usage in the catchment due the limited availability of records. Forestry records were voluntarily provided by all forest operators in the catchment dating back to 2006, with sporadic records available prior to this date. The Break O'Day Council voluntarily provided records of chemical usage dating back approximately 18-months. In contrast, no records were available pertaining to the actual usage of chemicals in agricultural areas. The Panel was able to obtain general information about what was typically sold into the district, and in what quantities, only due to the voluntary cooperation of a chemical supply company.

Under the Tasmanian Code of Practice for Aerial Spraying (ASCHEM, 2000), records detailing aerial spray operations are required to be maintained for a period of only 2 years. There is no legal requirement for spraying records to be transferred with a property if it changes ownership, although the Panel has been informed that records may be transferred in the forestry industry as part of the sale, or as part of an environmental management plan or forest certification process (P. Taylor, pers. comm.).

4.7.2 Need for improved catchment management

Overwhelmingly, the issues investigated highlight the need for improved catchment management and a better understanding of how activities in the catchment affect downstream users. Similar to many catchments in Tasmania, the George River is a multi-use catchment supporting a wide range of economic activities as well as providing the drinking water for the community. As pressures increase on water and land resources, the risk of water quality issues arising also increases. Although improved catchment management and better record-keeping associated with chemical usage has been highlighted by catchment reviews, investigations into Pacific oyster health, and drinking water risk assessment, there has been no response or action by Government concerning these issues.

The present water quality in the George River catchment is good, however ongoing vigilance is required to ensure that this status is maintained.

4.8 Conceptual site model

To summarise the issues investigated, the George River Water Quality Panel developed a conceptual site model of the Georges Bay catchment based on the evidence obtained as part of this investigation (Figure 19). This is a standard process that is recommended in undertaking a monitoring and assessment program (ANZECC/ ARMCANZ, 2000b). The model shows all of the factors and pathways which can affect water quality in the George River. These include the contribution of natural organic matter from eucalypts and other vegetation in the catchment, sediment from bank and land erosion, and runoff and discharge from agricultural, domestic, municipal or silviculture activities. The more hydrophobic (not able to be dissolved in water) of these contaminants can be transported to the surface microlayer of the river system where they accumulate. This surface film is extremely thin and contains a low concentration of foam bubbles formed from entrained air rising to the surface. The compounds in this surface film do not exhibit toxicity to sensitive biota such as cladocerans (water fleas), unless highly concentrated over 1000-times and collapsed (deflated) which transforms the foam in to fine particles.

The river water itself is not toxic to biota and does not represent a threat to human health via the drinking water supply. Any particulates which are present in the water supply occur at low concentrations and would be effectively removed by the drinking water treatment process, presenting no human health risk.

The model also shows that within Georges Bay, water quality can be affected by runoff from the land, inputs from the sewage treatment plant, boats and slipways, and the movement of sediment and any associated contaminants. Similar to the river, many contaminants, if present in the bay, will be concentrated in the surface film of the bay where they can become associated with foam floating in the bay (this foam differs in composition from river foam). The wind-blown movement of this foam is one mechanism which could move contaminants around the bay and affect water quality.

Another process which affects water quality in the bay is the mixing of fresh and salt waters and foams near the mouth of the river which results in the deposition of fine–sediments. These fine particles may contain elevated concentrations of any contaminants entering from the catchment.

The concentrations of these particles are not likely to be sufficient on their own to harm Pacific oysters. There are, however, a number of other stressors that affect oysters and the collective effect of all of these might contribute to some of the problems with oyster mortality. Other stressors include freshwater, temperature, toxic algae, handling, spawning, antifouling agents, resuspended sediments and food sources.

The model demonstrates the inter-connectivity between the catchment, river and bay, and highlights how a healthy bay is dependent on a healthy river system.

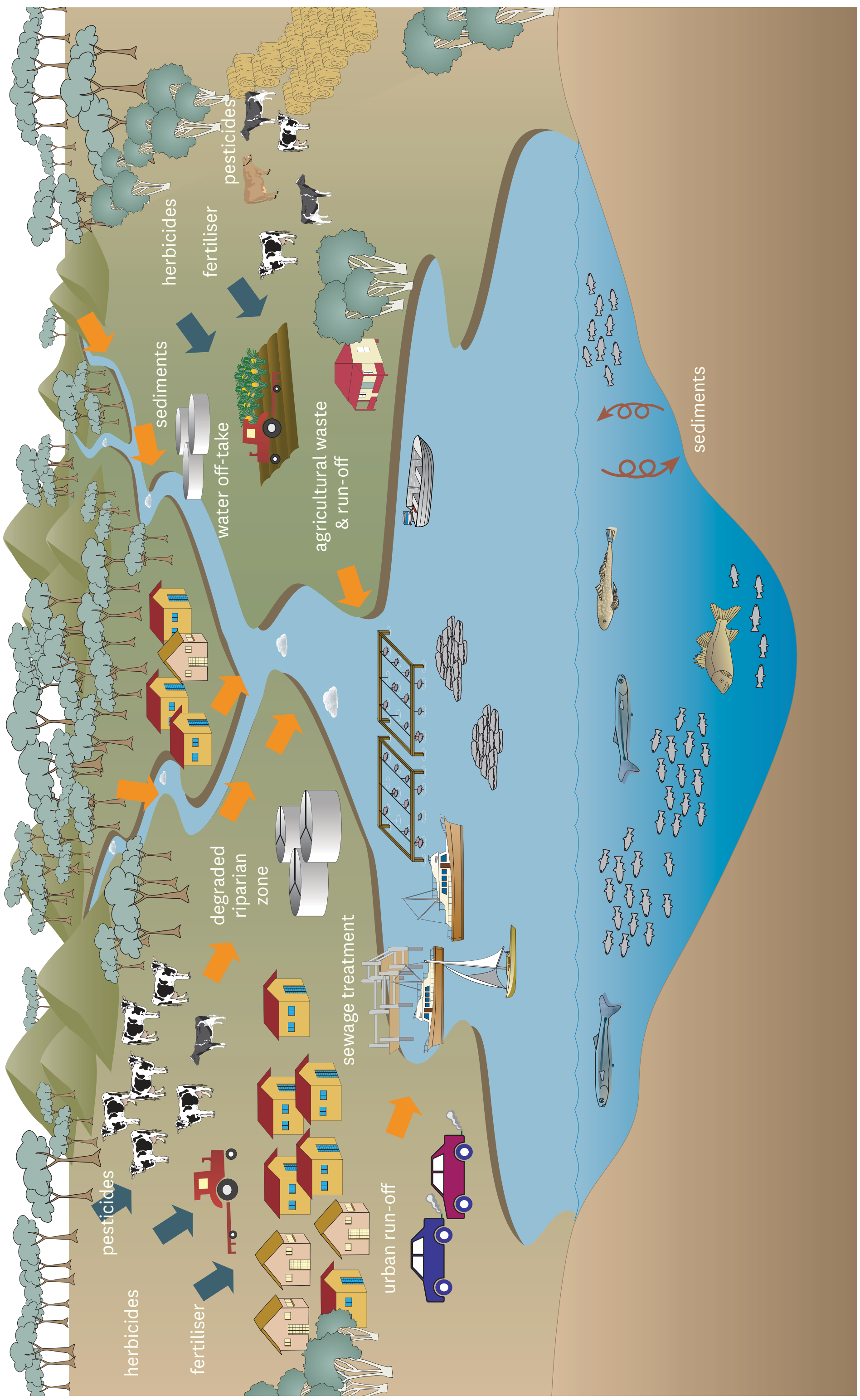


Figure 19. Conceptual site model of the George River catchment.

5. Advice and recommendations

1. **The Panel concludes that no additional research regarding the highly concentrated river foam is required to clarify the issues raised on *Australian Story*.** The extreme concentration of the foam samples more than accounts for the toxicological response present in the samples (‘*Dose maketh the poison*’, Paracelsus). Based on the natural concentrations of foams and associated contaminants in the environment, no threat from them to the ecosystem, Pacific oysters, or human health has been identified,

2. It is apparent that Pacific oysters growing in Georges Bay are subject to multiple stressors including temperature, grading, fresh water, toxic algae, turbidity, oyster stocking densities, TBT and other antifouling agents and other catchment-derived contaminants. River or bay foam, and associated contaminants, may be an additional but minor stressor.
   However, given the capacity of foam to collect and concentrate contaminants (although to a far lesser degree than the skimmer box samples), and the observations of oyster farmers which link foam to oyster mortality events, **the Panel recommends that if further investigations into the cause of oyster mortalities are undertaken, they include a scientifically robust multi-stressor experiment which incorporates bay foam (and associated contaminants) as a potential stressor. If bay foam is found to exert a significant impact on oyster health, then additional monitoring of organic contaminants in the bay is warranted.** The Panel emphasises the importance of using environmentally relevant concentrations of foam (and associated contaminants), and not ones that are artificially enriched by virtue of the collection method.

3. The issues raised by *Australian Story* and the subsequent high level of concern in the community is symptomatic of a catchment in which there is a lack of transparency and available information about catchment activities and how these activities may impact water quality. These activities include agriculture, forestry, land (including domestic) and marine based activities and activities by local government. The problem is multi-faceted, and includes:

   - The lack of one clear responsible entity for coordinated catchment management activities that could conduct independent audits of catchments;
   - A lack of easily accessible records outlining chemical usage from all sources in the catchment;
   - A lack of demonstrable evidence that chemicals in the catchment are being used in an environmentally responsible manner;
   - Degraded areas of the catchment and riparian zone where runoff and contaminants could enter the river and potentially pose a risk to the drinking water supply.

   The Panel recommends that improved and co-ordinated catchment management and administration be considered as a matter of priority and that information on the use of chemicals in the catchment be recorded by all users and records made available as required to assist with catchment monitoring and the security of water supply.

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Appendix 1

Premiers Letter

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Premier

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Tasmania

Mr John Ramsay
Chair
Environment Protection Authority
GPO Box 1550
HOBART TAS 7001

26 FEB 2010

Dear Mr Ramsay

You will be aware of the recent "Australian Story" report on water quality in the Georges River, which focused on toxicity in surface foam linked to eucalyptus plantations in the catchment. The Director of Public Health, Dr Roscoe Taylor has recommended to Government that a process be established to address the scientific research issues raised in the "Australian Story" ABC television program. Dr Taylor has further recommended that I invite you, as the independent Chair of the Board of the Environment Protection Authority (EPA) to oversee the gathering of the evidence and its assessment by relevant experts.

It is clear that public concern regarding the report on the studies carried out by Drs Bleaney and Scammel warrant further investigation and it is likely that further research will be required to ensure that the implications of the findings reported in the program are clear, and that the people of St Helens can have confidence in the safety of their drinking water. It is important that the issue is considered objectively and scientifically and that the public can have confidence in the findings of the review and any further studies that are undertaken.

Therefore, I request that you establish and convene a suitably qualified panel to:

1. Review the results of the research carried out by Drs Bleaney and Scammel and any other relevant studies;
2. Decide whether any further characterisation of toxins in water and their source or toxicity studies are required to help determine whether the toxicity reported on "Australian Story" represents a significant risk to:
    a. drinking water supplies, in St Helens (or more broadly given that many water catchments in the state will contain significant areas of eucalypts);
    b. shellfish culture in Georges Bay or more broadly;
    c. aquatic ecosystems.

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3. Commission or facilitate the undertaking of any such studies by suitably qualified and independent scientists; and
4. Provide an interim and final report to the Government on the findings of the review and any further studies carried out. The final report should include recommendations as to any actions or policies arising from the investigation.

I will leave selection of the panel to your judgment but it should include representatives with expertise in water quality, public health, aquaculture, the chemistry of eucalypts and environmental toxicology. The panel will also need to consult with all relevant stakeholders.

While I understand that there are complex scientific issues involved and that any further studies required are likely to take time, it is also important that the matter is handled expeditiously to address community concerns. To that end, an interim report addressing points 1 and 2 above should be submitted to the Government of the day as soon as possible, but by the end of May 2010. If further studies or research is required priority should be given to those required to boost confidence in the safety of drinking water supplies.

I appreciate that this task will require resources above and beyond those currently available to you through the EPA, and that the full extent of these will not be known until the panel has been convened and defined the nature of any further studies required. I am prepared to commit my Government to providing adequate resources to carry out this brief.

Yours sincerely

David Bartlett MP
Premier

Appendix 2

Panel CVs

Professor Michael R Moore
(Environmental Toxicology)

Professor Moore is one of Australia's foremost authorities on environmental toxicology and water quality. He is chair of Water Quality Research Australia and is Honorary Professor in 'smartWater' at Griffith University. He was past Director of the National Research Centre for Environmental Toxicology. He is also Emeritus Professor in the University of Queensland, Adjunct Professor in Queensland University of Technology and Adjunct Professor in the Faculty of Science, Sunshine Coast University.

Prof Moore is a registered toxicologist (Eurotox and Institute of Biology, United Kingdom), has a PhD in Medicine and was awarded a Doctorate in Science in the field of biochemistry in medicine. He has trained in Clinical Pharmacology in the Royal Postgraduate Medical School. He was a director of the Australian Centres for Health Risk Assessment and founder member of the Australasian College of Toxicology and Risk assessment.

Prof Moore's research interests include the toxicology of metals, risk assessment, air and water quality, alcoholism, cyanobacterial toxins and disorders of porphyrin metabolism.

His knowledge and expertise has been sought in a variety of areas and he is currently a member of boards, advisory groups and working parties including the Australian Pesticides and Veterinary Medicines Authority Advisory Board, the Advisory Committee on Prescription Medicines and chair of the World Health Organisation (WHO) Working Party on Chemicals of Concern.

Dr Graeme Batley
(Water Quality)

Dr Graeme Batley is a Chief Research Scientist with CSIRO Land and Water, based at Lucas Heights, NSW. He is an international leader in the environmental chemistry of trace contaminants in natural water systems, with particular emphasis on heavy metals and their chemical forms, fate, transport, bioavailability and ecotoxicology in waters and sediments having over 360 research publications cited some 5400 times.

Dr Batley is the former director and co-founder of the Centre for Environmental Contaminants Research (CECR), a program which brings together CSIRO's extensive expertise in research into the contamination of waters, sediments and soils.

Dr Batley was a member of the team who won the Land and Water Australia Eureka Prize for Water Research in 2006 and was awarded the CSIRO Medal for Research Achievement, the same year.

Dr Batley is a Fellow of the Royal Australian Chemical Institute, Member of the Australasian Society for Ecotoxicology and a Board Member of the Society of Environmental Toxicology and Chemistry (SETAC) Asia/Pacific and has served on numerous advisory panels, and is currently a member of the Independent Expert Group on Gunns Paper Mill Project for the Department of the Environment, Water, Heritage and the Arts. He also currently chairs the Working Group revising the Australian and New Zealand guidelines for toxicants in waters and sediments.

Professor Jim Reid
(Chemistry of Eucalypts)

Prof Reid is internationally regarded for his research on the genetic and hormonal regulation of plant growth. Much of his work focuses on plant development, developmental genetics and plant hormone physiology, as well as ecological genetics and the breeding of eucalypts.

He is the former Dean of the University of Tasmania's Faculty of Science, Engineering and Technology and is the University's inaugural appointee to the position of Distinguished Professor for his outstanding and sustained contribution to his discipline.

Prof Reid was awarded the University's Distinguished Service Medal for his contribution to the creation of three forest-related CRCs. He was Director of both the Temperate Hardwood Forestry and the Sustainable Production Forestry CRCs and is currently on the Board of the Forestry CRC.

He has served on numerous national and international committees and is currently on the Council of the International Plant Growth Substances Association. His work has been recognised by the awarding of the David Syme Research Medal by the University of Melbourne and the Royal Society of the Tasmania Medal.

Prof Reid is a Fellow of the Australian Academy of Technological Sciences and Engineering, is an editor/associate editor of three international plant science journals and is an ISI Highly Cited Researcher.

Dr Christine Crawford
(Aquaculture)

Dr Crawford is the Program Leader Natural Resource Management at TAFI (Tasmanian Aquaculture and Fisheries Institute), University of Tasmania.

She has been involved with shellfish aquaculture research and development for more than 25 years, mostly in Tasmania but also in other Australian states and overseas. Recent research projects on shellfish aquaculture include an environmental risk assessment of shellfish farming and the effects of salmon and shellfish farming on the benthic (sea bed) environment. She is a member of the Editorial Board for the international journal 'Aquaculture'.

Dr Crawford's present areas of research are Ecosystem Effects of Aquaculture and Estuarine Ecology. They include the effects of finfish and shellfish aquaculture on the marine environment and techniques to monitor impacts, monitoring special and sensitive marine and estuarine habitats, effects of land-based activities on estuarine health including environmental flows, and working with community groups to improve estuarine condition.

She is a former Board member of NRM South, a recipient of the Vice-Chancellors Award for Outstanding Community Engagement and has served on a number of state, national and international committees. She chairs the External Program Advisory Council for the Aquaculture Collaborative Research Support Program, USA.

Dr Crawford is currently supervising a number of projects including investigating water use across a catchment and effects on estuarine health and productivity, nutrient and phytoplankton data from Storm Bay to support sustainable resource planning, and developing methods for assessment of estuarine health to inform management.

Professor John McNeil
(Public Health)

John McNeil is the head of the Monash University School of Public Health and Preventive Medicine based at the Alfred Hospital in Melbourne. His background is in epidemiology, clinical pharmacology and cardiovascular research.

He is currently a member of the boards of the Colonial Foundation, the International Society of Cardiovascular Pharmacotherapy and Water Quality Research Australia. He is a previous member of the Boards of Alfred Health, the Metropolitan Ambulance Service and the Victorian Public Health Research and Education Foundation.

He has been a member of ministerial committees reporting on renal failure services, organ transplantation and medical staff salaries. He also serves on scientific committees for the Red Cross Blood Transfusion Service, the National Blood Authority, the Therapeutics Goods Administration and the Australian Commission for Safety and Quality in Healthcare.

John Ramsay
(Convenor)

John Ramsay is the inaugural Chair of Tasmania's independent Environment Protection Authority (EPA) established in July 2008.

He has extensive experience in public administration and environmental management.

Mr Ramsay is director of his own consulting company providing services in health, human services, environment, planning and natural resources. He has also been Secretary of three government agencies and has extensive experience as Chair of state and national councils, committees and advisory groups relevant to environmental management issues.

Dr Lois Koehnken
(Co-ordinating Scientist and Consultant to the Panel)

Dr Koehnken is a nationally recognised expert on waterways, providing technical advice on water quality issues and interpretation of water quality data to government and industry.

She has more than 20 years' scientific experience in hydrology, geomorphology and geochemistry in rivers, lakes and estuaries. She holds a PhD from Princeton University and has spent her career investigating how catchment activities and changes to hydrology affect sediment movement and water quality in rivers and estuaries. Dr Koehnken has worked for universities in Australia and Venezuela and environmental agencies in several countries. For the past 10 years she has been the principal of the Hobart-based Technical Advice on Water, a small independent consulting company which provides scientifically-based advice on waterway issues to government, industry and the community.

Her recent work has included the development of toxicity tests for use in the acidic, organic-rich waters common in Tasmania, and investigating the dispersal of historic mining wastes and the availability of metals and other pollutants in contaminated sediments of rivers and estuaries. Other projects include water quality and geomorphic impact assessments of proposed dams in Tasmania and development of environmental flows based on geomorphic and water quality considerations. Dr Koehnken is currently a member of the Tasmanian Marine Farm Planning Review Panel.

Appendix 3

Documents received and reviewed by the panel

Documents received by Panel associated with Scammell (2010) investigations

DOC ID	DESCRIPTION
SCAMMEL 1	Scammell Tasmanian Investigations Part 1 – Final
SCAMMEL 2	Scammell Tasmanian Investigations Part 2 – Final
SCAMMEL 3	Scammell Tasmanian Investigations Part 3 – Final
SCAMMEL 4	Ecotox laboratory report January 2005 TR0167_1
SCAMMEL 5	Ecotox laboratory report January 2005 TR0167_2
SCAMMEL 6	Hickey, 2010, SETAC Seville presentation
SCAMMEL 7	Advanced Analytical Laboratories, Investigation of the Tasmanian Water samples by LCMS
SCAMMEL 8	Ecotox, Questions posed by the Panel concerning testing performed by Ecotox Services Australasia Pty Ltd
SCAMMEL 9	J Marshall sampling notes
SCAMMEL 10	Ecotox, Summary of ecotox testing with Cineole and Pinene
SCAMMEL 11	Advanced Analytical Laboratories, analytical results associated with Scammell (2010) investigations

Document received from the Department of Human Health Services

DOC ID	DESCRIPTION
DHHS 1	Advanced Analytical Australia P/L report dated 2 August 2006
DHHS 2	Letter to Dr Alison Bleaney dated 5 October 2005
DHHS 3	Report on assessment of rapid water testing kits
DHHS 4	AST report dated 14 April 2005
DHHS 5	Letter to Dr Alison Bleaney dated 5 October 2004
DHHS 6	Thyroid cancer
DHHS 7	Draft interim report 17 September 2004 – St Helens connective tissue disease and haematopoietic malignancy incidence
DHHS 8	Letter to Prof Don Bursill dated 7 September 2005
DHHS 9	AST report dated 29 October 2004
DHHS 10	Disease cluster investigation St Helens
DHHS 11	Email dated 25 October to Jock Barclay
DHHS 12	Letter from Monash University re neurological problems in St Helens (Sims)
DHHS 13	Email dated 6 October 2004 from Brian Inches
DHHS 14	Letter to Dr Alison Bleaney dated 22 September 2004
DHHS 15	Toxicity of Tasmanian water samples

DOC ID	DESCRIPTION
DHHS 16	AST report dated 2 September 2004
DHHS 17	AST report dated 25 November 2004
DHHS 18	Report on St Helens Water Supply & sampling for pesticides/herbicides
DHHS 19	AST report dated 23 July 2004
DHHS 20	History what happened
DHHS 21	Letter dated 18 July 2007 from Rae & Partners re water quality in George's Bay
DHHS 22	Demographic and Health Analysis of the Northern Region – Research and Analysis Report no 4 of October 2000
DHHS 24	AST report dated 5 March 2010
DHHS 25	AST report dated 5 March 2010
DHHS 26	AST report dated 5 March 2010
DHHS 27	AST report dated 5 March 2010
DHHS 28	Review of water samples from rivers in St Helens locality
DHHS 29	Environmental Technology Verification Report – November 2003 (Aqua survey)
DHHS 30	Environmental Technology Verification Report – November 2003 (Eclox)
DHHS 31	Surface water toxicity report
DHHS 32	Drinking Water Quality Management Plan – St Helens
DHHS 33	Scientists comments of eucalyptus chemistry
DHHS 34	Sample location map
DHHS 35	St Helens aluminium
DHHS 36	Catchment studies in George's Bay (Chris Hickey)
DHHS 37	Khalil and Winder 2008
DHHS 38	Letter dated 21 March 2005 to Stephen Salter of Break O'Day Council
DHHS 39	E-mail dated 28 February 2010 to Chris Hickey, NIWA
DHHS 40	Cancer Registry data for Break O'Day and St Helens to 2007
DHHS 41	Cancer Registry Data regarding Waldenstrom's Anaemia Tas vs Australia
DHHS 42	Letter dated 15 March 2010 Response to St Helens Chamber of Commerce
DHHS 43	Chemistry results for raw and treated water March 2010
DHHS 43a	Email accompanying water quality results
DHHS 44	Email from R. Taylor re commissioned research
DHHS 45	Griffith University, Role of toxicity testing in identifying toxic substances: A framework for identification of suspected toxic compounds in water
DHHS 46	St Helens Cancer Report June 2010
DHHS 47	Laboratory report tin in water supply

Documents received from the Department of Primary Industries, Water, Parks and Environment

DOC ID	DESICRIPTION
DPIPWE 1	DPIWE (2001) TBT in Oysters grown at Georges Bay, St Helens
DPIPWE 2	Meeting Notes TBT Strategy Meeting 2001-2002 (Paper file)
DPIPWE 3	Results and correspondence on DPIWE testing for TBT on boats, oyster flesh, water and soils, 2001-2003 (Paper file)
DPIPWE 4	Scammell M (2002) TBT Contamination of Shellfish Growing Areas, Field Investigations 25th to 28th March 2002 – Final Draft
DPIPWE 5	DPIWE (2002) Draft Oyster Health Sentinel Monitoring Program
DPIPWE 6	DPIWE (2002) Inter-tidal Foreshore Monitoring – Georges Bay
DPIPWE 7	Noller, B.N. (2003) Critical review of the environmental fate of TBT and its toxicological effect on the Pacific oyster Crassostrea gigas including at Georges Bay and other Tasmanian locations. National Research Centre for Environmental Toxicology,
DPIPWE 8	Mortimer Munro R (2003) – Review of the Noller report - Critical review of the environmental fate of TBT and its toxicological effect on the Pacific oyster Crassostrea gigas including at Georges Bay and other Tasmanian locations
DPIPWE 9a,b,c	DPIWE (2004) Draft Georges Bay Oyster ill thrift & mortality
DPIPWE 10	DPIWE (Feb 2004) Final Report – Oyster Mortalities in the Georges Bay Marine Farming Development Plan Area.
DPIPWE 11	Percival, S. (2004) Oyster Health in Georges Bay: Collation and analysis of data. Department of Primary Industries, Water & Environment.
DPIPWE 12	Ricci P. F (2004). Review of Percival Report
DPIPWE 13	St Helens Marine Farmers, Dr A Bleaney and Dr M. Scammell (2004). Environmental Problems Georges Bay, Tasmania
DPIPWE 14	Ricci, P.F (2004). Review of Drs A Bleaney and M. Scammell report (BSR), compiled by Dr Scammell.
DPIPWE 15	DPIWE / DIER (2004) REVIEW OF THE SCAMMELL REPORT, Aerial Spraying in the George River Catchment
DPIPWE 16	Ricci, P.F (2004) Review of DPIWE's Response to the Scammell Report
DPIPWE 17	Freshwater Systems (Peter Davis) (2004) A commentary on the Scammell Report
DPIPWE 18	Dr A Bleaney Letter to the Editor (2004) re DPIWE's Response to the Scammell Report
DPIPWE 19	Meeting notes – Percival Report Recommendations Group (13 Aug 2004)
DPIPWE 20	DPIWE (2004) Internal Report - Preliminary Assessment of Stock Mortality, Georges Bay MFDP (12/13 February 2004)
DPIPWE 21	DHHS (2004) Draft Report on St Helens Water Supply & Sampling for Pesticides/Herbicides
DPIPWE 22	(Un-authored and Undated) Surface Water Sampling Method – relating to Scammel and Bleaney water testing (first folio in 105236 vol 3)
DPIPWE 23	Letter from Bleaney to Break O Day Council (25 Jan 2005) re ecotoxicoloigal tests and water sampling , including results
DPIPWE 24	DPIWE (2005) Analytical results and report on water sampling in George River
DPIPWE 25	Noller, B.N and Ricci P.F. (2006) Report on Critical Review of Water Quality Georges River Catchment - Final Draft. National Research Centre for Environmental Toxicology,
DPIPWE 26	DPIPIWE, Water and Marine Resources Division (2010) Correspondence and results from the George River AUSRIVAS and sampling results
DPIPWE 27	Annual Waterways Report George Catchment
DPIPWE 28	Ecotox results (2005) George River and Crystal Creek tox results
DPIPWE 29	Forest Practices email re Forest Practice Plans in George River catchment

DOC ID	DESCRIPTION
DPIPWE 30	DIER email re historic toxicity in George River
DPIPWE 31	Baseline pesticide monitoring results (on DPIPWE WIST website)
DPIPWE 32	Flood pesticide monitoring lab results (on DPIPWE WIST website)
DPIPWE 33	Pesticide follow up monitoring lab results (on DPIPWE WIST website)
DPIPWE 34	Doyle et al.,(2008), The Tasmanian River Catchment Water Quality Initiative: Report on pesticide fate and behaviour in Tasmanian environments, Tas Instit. Agricultural Research (TIAR)
DPIPWE 35	Kookana et al., (2008), The Tasmanian River Catchment Water Quality Initiative Pesticide Impact Rating Index (PIRI) risk indicator for minimising off-site migration of pesticides, CSIRO Land and Water Science Report 30/08.
DPIPWE 36	Volker, P. and Trainer, E., (2008), The Tasmanian River Catchment Water Quality Initiative: Development and validation of a Pesticide Impact Rating Index (PIRI) for Tasmania, Forestry Tasmania.
DPIPWE 37	DPIPWE, (2008), Extent of pesticide use in Tasmania
DPIPWE 38	St Helens Waste Water Treatment Plant Review

Miscellaneous Documents

DOC ID	DESCRIPTION
MISC 1	Potts *et al*., (2010), Leaf oil chemistry, Biobuzz 10
MISC 2	Potts and Brooker, (2010), Seed germination on filtrates from soil sampled beneath trees of Eucalyptus globulus, E. nitens and their F1 hybrid. Technical Report 203, CRC for Forestry.

Data received by Panel

The following data were requested by and provided to the Panel.
Any requests for these data should be directed to the entity holding the information.

DOC ID	DESCRIPTION
DATA1	Forest Practices Authority – Forest Practices Plans information for George River catchment, areas, dates, land uses, includes non-plantation forestry
DATA2	Forest Enterprise Plantations in George River; map, areas, dates of establishment, seed provenance and chemical usage
DATA3	Forestry Tasmania information for George River catchment, areas, dates of establishment, chemical usage
DATA4	Forestry Tasmania seed provenance information
DATA5	Gunns Ltd Plantations in George River: map, areas, dates of establishment, seed provenance and chemical usage
DATA6	Private Forests Tasmania Private plantations within the George River catchment, species, area, date of establishment
DATA7	Field measurements associated with DPIPWE George River ecotoxicity investigation
DATA 8	George Bay Pacific oyster production records (DPIPWE)
DATA 9	Modelled river flow for George River 2003 – 2006 (DPIPWE)
DATA 10	Break O'Day Council Chemical usage data sheets
DATA 11	Chemical's sold into 7216 post code
DATA 12	Private Forests Tasmania, 2010, Response to request for additional information - notes on Pyengana plantations

www.georgeriverwater.org.au

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