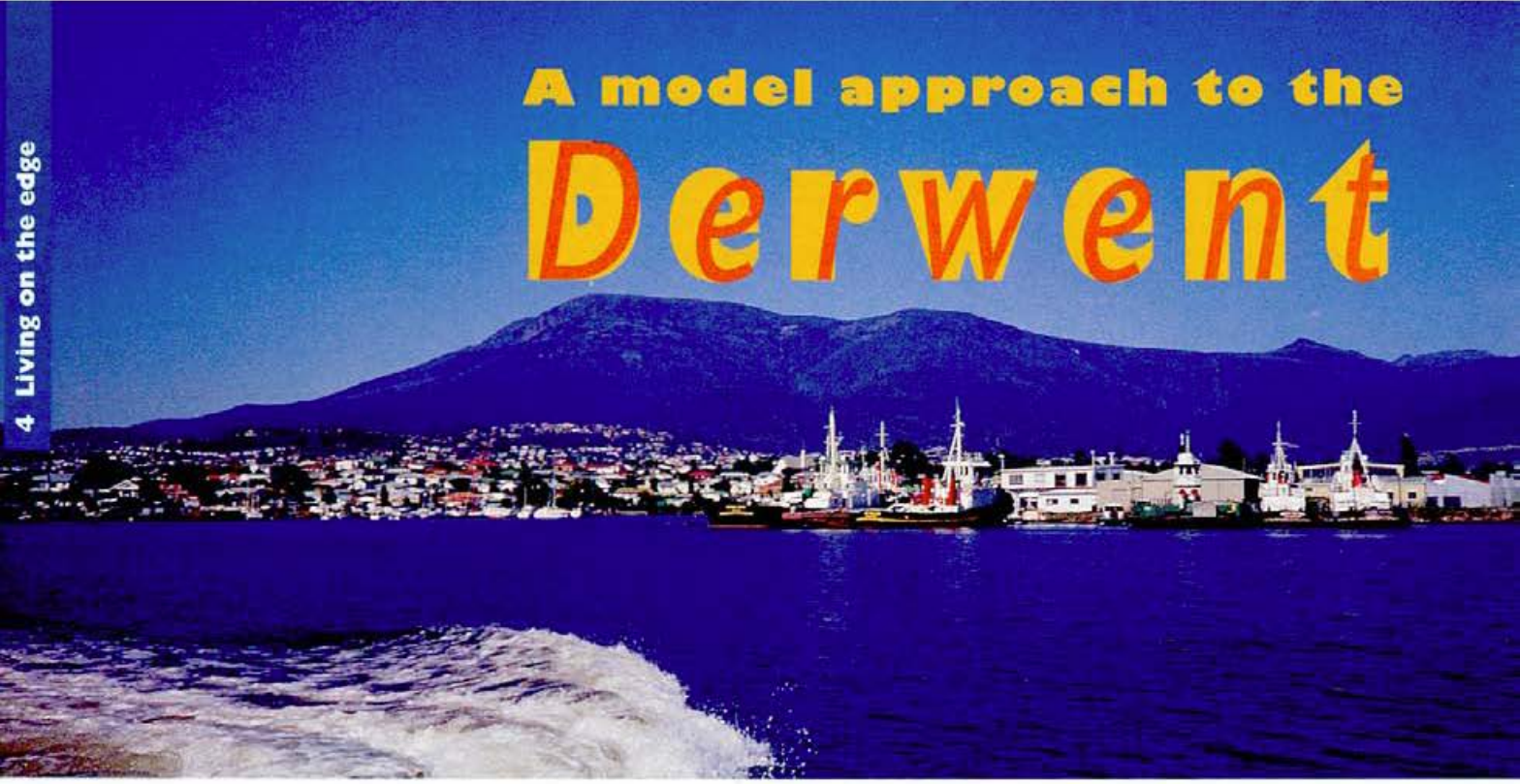
# A model approach to the Derwent



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Pollution problems that had long simmered in Tasmania's Derwent River boiled over in October 1988 when sludge washed ashore in parts of the estuary. Immediately, anti-pollution measures were given more teeth, and urgent research activities were launched to solve the problem.

Analysis of the sludge found it to be composed mainly of organic matter from fibrous paper mill effluent, heavy metals from other industrial discharges, and sewage-derived organic matter.

New effluent and sewage treatment processes introduced in recent years have helped to reduce pollution in the Derwent. Nevertheless, a lot of research is yet to be done to chart a total picture of the interactions between the estuary and human inputs. A comprehensive knowledge of such interactions will be crucial to developing ways of handling rural, industrial and domestic activities so that they have a minimum impact on water quality.

One of the major studies of the Derwent is the Estuarine Mixing Models project, a component of CSIRO's Coastal Zone Program. The project draws together past and ongoing research by CSIRO and other institutions, State and local governments, and local industry.

The Estuarine Mixing Models project follows two streams. One team is looking at physical transport models. These simulate the physical characteristics that drive water along the Derwent estuary. Other teams are examining selected pollutants and naturally-occurring chemicals in the river: their amounts and concentrations in surface waters and in sediments; their sources; how they move along the estuary; and where they finally go.

Dr Edward Butler of CSIRO's Division of Oceanography says the two streams of work will be tied together through the development of computer models to assist environmental managers. The models will help to explain the sources of pollution; what happens when chemical pollutants interact with the water and its biota; and how the water movements affect the final destination of the pollutants.

'The models will help managers decide the best way of treating discharges and the best place to put sewage or effluent outfalls,' Butler says.

The leader of the Estuarine Mixing Models project, Dr Denis Mackey, is discussing with the Hobart Metropolitan Councils Association and the Tasmanian Department of Environment and Land Management the prospects of developing a holistic management strategy for the Derwent estuary, using the knowledge built up by the project.

## Physical transport models

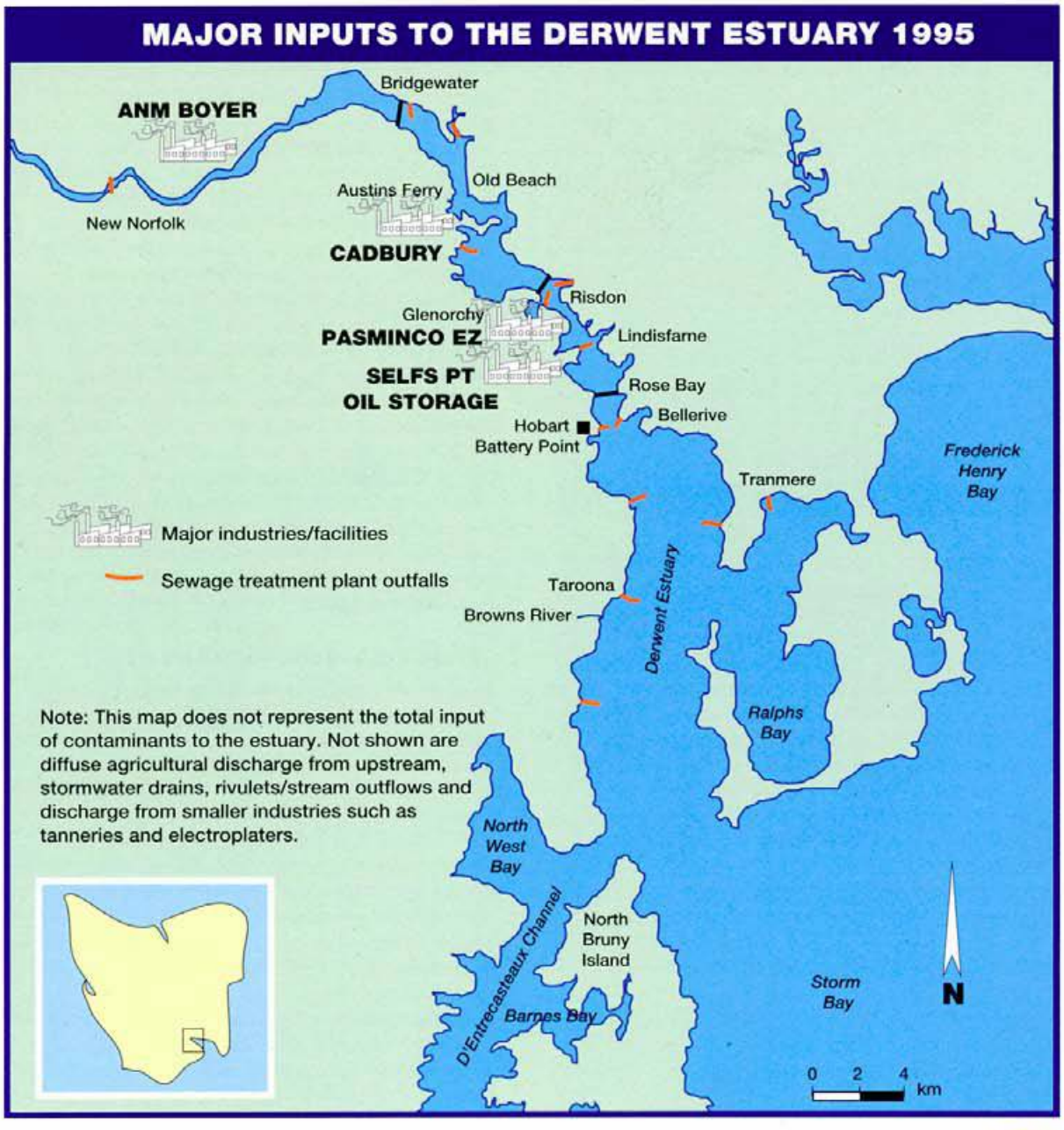
The movement of water in estuaries depends on several factors including tides, winds, river flow, bottom topography and the shape of the coastline. In the Derwent, less-dense freshwater from the catchment flows seaward on the surface, and denser seawater flows landwards underneath, creating what is called a salt wedge estuary.

Scientists have so far developed two physical transport models. The first is an extension of a model previously used in the Derwent to simulate the fate of both pulp mill effluent and sewage. The model is of the 'inverse' type and uses the natural saltiness of the estuary to plot the currents, which are then used to predict the fate of effluents.

CSIRO's Dr John Hunter says such models have been used throughout the world for more than 25 years. They are particularly robust because they depend strongly on field observations.

The second and more sophisticated model is a hydrodynamic model which provides three-dimensional distributions of velocity, temperature and salinity. It also shows concentrations of tracer chemicals under conditions of varying river flow, solar heating, winds, atmospheric pressure and tides. This model is already being used by industry and local councils.

The Australian Newsprint Mills (ANM) has used the hydrodynamic model for two purposes: to study the




dispersion of effluent from its existing outfall, and to predict the dispersion pattern after a proposed secondary effluent treatment facility comes on-stream. The company provided CSIRO with data from a pilot-scale facility, which was then run on the hydrodynamic model. The company's data was combined with the results of CSIRO's studies on the chemical characteristics of pulp mill effluent (see *Sewage and organic contaminants* section on page 14).

ANM, Australia's only newsprint producer, is jointly owned by Rupert Murdoch's News Ltd and Fletcher Challenge Ltd. It has two mills, one at Boyer on the north bank of the Derwent, and the other at Albury on the New South Wales/Victorian border. The Boyer mill is an integrated pulp and paper mill, established in 1941.

The company has installed a primary effluent treatment process which involves the passage of effluent through clarifiers to settle out suspended solid materials. It also involves chemical treatment to remove some of the toxic components in the effluent before it is discharged into the upper estuary.

Dr Desmond Richardson, principal research chemist at ANM, says the company is set to install a $30 million secondary treatment process, in which micro-organisms break down organic material in the effluent before discharge. The facility is scheduled for commissioning in 1998.

'The results of CSIRO's modelling work have enabled us to draw up specific design parameters for the secondary treatment plant to help us meet river water quality guidelines well into the next century,' Richardson says. 'The model is the best we have tried in terms of being able to predict things to the degree and the accuracy we require.'

The model has also been used to study effluent dispersal from several possible outfall sites for the proposed upgraded Rokeby sewage treatment plant, located in Ralph's Bay in the lower Derwent estuary.

CSIRO's Dr Stephen Walker says that while the mixing models are being validated in the Derwent, they are being designed so that they can be applied to other estuaries around Australia.

'Our ultimate model will be a collection of computer codes incorporating the general physical laws that

characterise water movements. These laws are the same for estuarine bodies everywhere so that the model can be used anywhere in Australia by including data that describe characteristics in specific regions,' Walker says.

## Heavy metals

During the past two years, the Estuarine Mixing Models project has helped expand the database on selected chemical pollutants and organic compounds found in the water column and sediments of the Derwent estuary. Among those being investigated are heavy metals, particularly mercury, zinc and cadmium.

The problem with mercury was recently highlighted when scientists found high concentration levels in the upper to middle reaches of the Derwent estuary. Levels were found to be consistently higher than the 100 nanograms per litre recommended by the Australia-New Zealand Environment and Conservation Council (ANZECC) for protection of aquatic ecosystems. This was despite the industries' compliance with State guidelines on mercury discharge.

Butler, who leads a team that gathers data on chemical pollutants, says his group is trying to determine the sources and causes of high mercury levels.

'Evidence so far points to the sediments as the most likely host of mercury accumulated over the years, which is then re-suspended into the water column,' Butler says.

'Trace metals have accumulated from more than 40 years of effluent discharge from the ANM pulp and paper mill, and nearly 80 years of discharge from the zinc refinery operated by Pasminco's Electrolytic Zinc Company. There are many other possible industrial sources.'

Butler says the team is trying to understand the dynamics of water in the Derwent in an attempt to establish how mercury that is tied up in the sediments becomes re-suspended into the water. This would help managers determine how this re-suspension might be controlled.

'There is also a need to find out if there are sources of mercury other than the known industries, and in the longer term, to find out how mercury in the Derwent is taken up by aquatic organisms,' Butler says.

Zinc and cadmium have also been traditional problems in the Derwent. The Electrolytic Zinc refinery has contributed to this problem. Zinc pollution reached its height in the early 1970s when a scientific working group (CSIRO, the University of Tasmania and the departments of Environment and Health) found high levels of zinc, cadmium and copper in Derwent oysters and fish. The company was implicated as its plant at Risdon was the only industry dealing with zinc.

Oyster farms at Ralph's Bay, about 15 kilometres downstream of the refinery, were forced to close down, at a heavy out-of-court expense for Electrolytic Zinc.

Although the refinery's wastewater is now recycled and treated, and complies with State guidelines on effluent discharge, scientists continue to find instances when zinc levels in the Derwent estuary exceed ANZECC recommendations. This is especially true at the bottom half of the estuary.

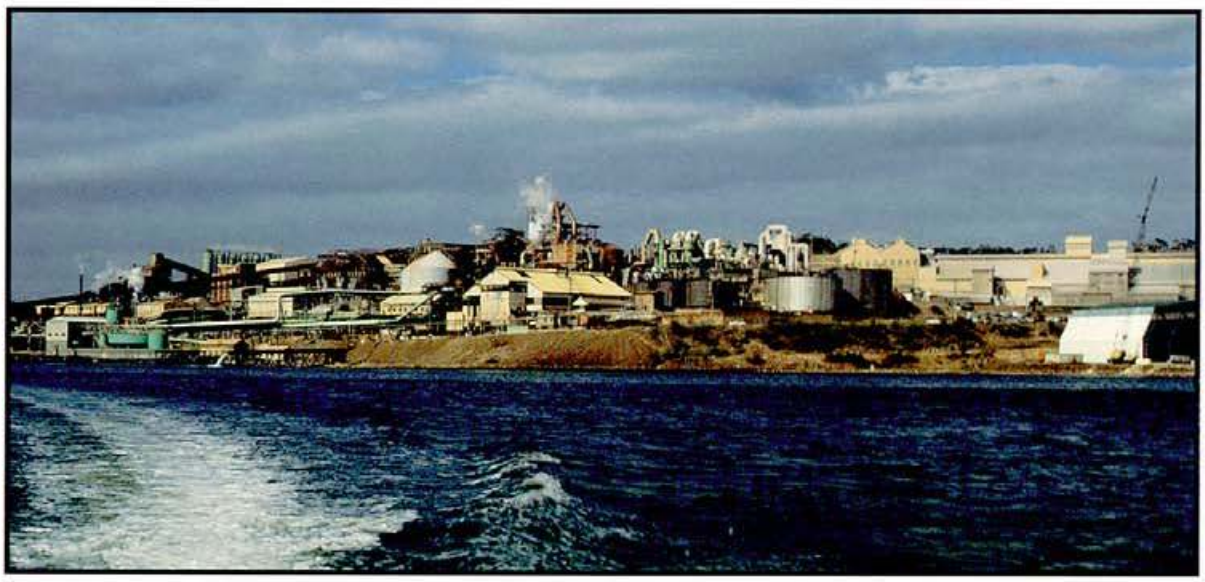
Butler says his team has so far identified the likely path of zinc along the river. Scientists are now trying to understand the factors that may help control zinc levels, whether they are natural or introduced factors. For example, there is some evidence that the binding of heavy metals with sewage may sequester some of the metals' harmful effects.

## Sewage and organic contaminants

Besides heavy metals, the Estuarine Mixing Models project is investigating the levels of dissolved nutrients, including the different forms of nitrogen and phosphorus, and a suite of organic contaminants.

The results of a 12-month monitoring program (The Derwent Estuary Nutrient Program, begun in 1993 by the Tasmanian Department of Environment and Land Management) indicate that nutrient levels in the Derwent estuary are elevated, due to a combination of natural and anthropogenic sources, particularly discharges from sewage treatment plants. Despite the elevated nutrient levels, however, the potential for nuisance algal growth appears to be limited by poor light penetration, associated with the turbid waters of the Derwent River.

CSIRO scientists have found high levels of total organic matter in the middle and upper parts of the Derwent estuary. In the upper estuary, the main organic pollutant is pulp fibre so resin acids are the focus of investigations. These are organic compounds in pines



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released during pulp production. They are toxic to fish at concentrations of only a few milligrams per litre so amounts released into the water need to be minimised.

A team led by Dr John Volkman used gas chromatography-mass spectrometry to measure the concentration of resin acids in different parts of the estuary. In the first stage of this technique a gas chromatograph is used to separate the complex mixtures of organic constituents present in the waters and sediments. The separated compounds are then identified by the characteristic spectra they produce when broken into fragments by bombardment with electrons in the mass spectrometer.

The testing revealed that resin acid concentrations decrease rapidly downstream from the mill. Volkman says this is due to a combination of factors including dilution, degradation by chemical and biological processes and settling into the sediments. Dilution is strongly influenced by the mixing of fresh and salt waters, and by the tide.

Information such as this will aid the decision on where ANM should put the outfall of its new effluent treatment plant. These details are also expected to be used by the company and the State Department of Environment and Land Management as baseline data against which to measure changes in the quality of the Derwent after the commissioning of the new facility.

### Tracking sewage flows

While pulp fibre is the main organic pollutant in the upper estuary, the middle and lower sections (from Newtown Bay to Taroona), are severely contaminated by sewage. The Estuarine Mixing Models project aims to determine how sewage is transported along the estuary and where it accumulates. The data obtained can be used to predict appropriate sewage loads and optimal outfall points.

Sewage contamination is traditionally determined by measuring the level of faecal coliform bacteria. However, the reliability of microbial indicators has increasingly been questioned. It is also time-consuming, taking at least 48 hours to give results. 'There's little point in saying to swimmers: the beach was dirty two days ago,' says CSIRO's Dr Peter Nichols.

Nichols and his colleagues have successfully applied an alternative chemical method to trace sewage-derived organics from outfalls in Sydney, Port Phillip Bay and now the Derwent. The method uses a compound called coprostanol, which is derived from cholesterol. Coprostanol is the product of bacterial transformation of cholesterol in the intestines of humans and some higher mammals.

Nichols says coprostanol has proved to be a sensitive indicator of sewage pollution since it binds well to faecal matter in water. It can also be traced in aquatic systems for considerable distances.

Using coprostanol as tracer, CSIRO's Rhys Leeming found that at sites between Sandy Bay and the Tasman Bridge, sewage concentrations were very high. Coprostanol averaged 900-1000 parts per billion (ppb) of sediment. Such values are similar to coprostanol concentrations found adjacent to Sydney's deep water ocean outfalls. Average concentrations decreased from Sandy Bay to Taroona and Kingston. Background levels of 10 ppb were found in Storm Bay. These data indicate a significant accumulation of sewage-derived organic matter near Hobart and indicate how this material is transported in the estuary. They can be also used as a yardstick for measuring the effectiveness of planned upgrades to the city's sewerage system.

The environmental problems in the Derwent estuary occur to a lesser or greater degree in most of the waterways near Australia's main urban centres. The methods developed here are readily applicable to other areas and have already found application in Port Phillip Bay and in coastal waters off Sydney. The CSIRO team plans to use them to address a range of water and sediment quality issues associated with other uses of Australia's coastal areas such as the rapidly-expanding aquaculture industry.

**Sampling the Derwent estuary.**

**Top: The Division of Oceanography's 'sewage sampling team', Rhys Leeming, Val Latham and Mark Rayner, with a Conductivity Temperature Depth (CTD) profiler and Niskin sampling bottles.**

**Above: A sea surface micro-layer sampler deployed from a rubber dinghy. This rotating teflon drum skims the surface layer and is an important device for measuring concentrated organics and metals.**