

Sewerage treatment and the engineering establishment

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Published in Brian Martin (editor), *Confronting the Experts*
(Albany, NY: State University of New York Press, 1996), pp. 13-43

Sewerage experts

To be able to relegate the entire job of secondary treatment to a few holes in the end of a submarine pipe and the final disposal of the effluent to a mass of water into which the fluid is jetted, and to accomplish this without material cost of maintenance and none for operation, presents a picture of such great allure as to capture the imagination of the dullest and justify extensive exploration into the ways and means of satisfactory accomplishment.¹

The sewerage engineers in Sydney, Australia, like many of their colleagues throughout the world, believed that the ocean should be used for sewage treatment. The rhetoric of the Sydney Water Board — that the ocean was “the world’s most efficient purification plant”² — reflected an attitude that permeated the organisation. By the time I began studying the issue in 1985, the use of the ocean for sewage treatment had led to the serious pollution of Sydney’s most popular beaches and the heavy organochlorine contamination of fish in nearshore waters.

I had decided that the development of Sydney’s sewerage system would be a good case study for a PhD.³ A study of the decision-making processes surrounding the development of Sydney’s sewerage system offered an opportunity for me to combine my engineering training and experience with my new interest in the relationship between science, technology and society. I wanted to find out to what extent technology is shaped by social and political considerations.

I was more interested in studying engineers and engineering than being an engineer but I found my engineering background was not

only useful in understanding the engineers I was studying but that it helped in reducing the barriers between us when I began interviewing engineers from the Water Board and the State Pollution Control Commission (the regulatory authority for the State of New South Wales (NSW)). Generally I was accepted as non-threatening because of my engineering background. Engineers in both the Board and the Commission were quite frank about their views of the public and the role of the engineer, although they were careful about what they said to me about their employers’ policies. At no time did any of the people I interviewed at these two organisations admit any misgivings about the ability of the proposed extended outfall scheme to solve the problems of ocean and beach pollution. Nor did they criticise any other Water Board or government policies.

When I began my research the extent of the health and environmental problems caused by sewage in Sydney’s coastal waters had been hidden from the public but complaints persisted about the most visible pollution. The Board had begun construction of three deepwater outfalls in 1984 that would extend existing shoreline outfalls two to four kilometres out to sea. The pipes would be laid beneath the sea bottom and the sewage would emerge from a number of diffusers rising from the end of the pipes. The sewage, which contains 42% industrial waste, would remain barely treated, with only 10-15% of the solids removed. The ocean, the engineers assured everyone, would do the rest.

The Water Board engineers were able to convince many people of this because sewerage engineers were the acknowledged experts when it comes to dealing with sewage. Sewage collection, treatment and disposal had

become part of the professional territory of the engineer in the nineteenth century and despite the divergent fields of knowledge which bear on sewage decisions today, including epidemiology, toxicology, oceanography, marine biology, and many others, engineers have maintained their domination of the area.

Engineers were called in to build and design the first sewerage systems in many European, US and colonial cities when the idea of sanitary reform became popular in the mid-nineteenth century. At the time there had been high infant mortality rates and outbreaks of epidemics in many densely populated cities where there was no running water and no reliable and effective means to deal with human wastes. Contrary to popular opinion, the marked increase in life expectancy achieved in these cities during the nineteenth century was not due to the advances of the medical profession, but rather to the engineering works constructed at this time.

In the nineteenth century, whilst engineers designed the pipes, ideas about how to deal with the human wastes, particularly once they had been removed from people's residences, were openly debated by the public and almost anyone could become an expert in the field by studying the issue carefully and writing about it. People from various professions, including doctors and lawyers, wrote books and articles on the subject. This is very different from the situation today when discussion is limited to which engineering solution should be used in a particular situation. Engineers today define what is feasible — what can and can not be done — and which technologies are appropriate. They also attempt to ensure that their preferred solutions are implemented.

The authority of sewerage engineers as a profession, with its own body of specialist knowledge, emerged in the 1870s when two British engineers published books with the term "sanitary engineering" in their titles. This was followed shortly after by an American book.⁴ Attempts were made to exclude non-engineers from the field: tradespeople because of their non-scientific knowledge base, physicians because they were unable to execute engineering works, and public health

officials and municipal bureaucrats because they did not have sufficient breadth and depth of training. Sanitary engineers were to be civil engineers with additional knowledge of physical and natural sciences.⁵

The aptitude of engineers, however, particularly with respect to sewage treatment, was not immediately apparent, even in the nineteenth century. Sewage treatment involved biological and chemical processes that scientists and others felt they had a claim to. For example, towards the end of the nineteenth century some scientists, biologists in particular, threatened to take control of sewage farming as the biological mechanisms of sewage farming became better understood.⁶

Despite the enormous popular appeal of sewage farming in the nineteenth century and to the present day (because it makes agricultural use of the nutrients and water in the sewage) engineers were not inclined to favour it as a method of treatment because it was unpredictable, less controllable and less closely aligned to their traditional skills than more artificial methods of treatment. The "naturalness" of a sewage farm, which appealed to some sections of the public, was not a desirable attribute to engineers who sought to harness and control nature with their technologies and thereby claim expertise in sewage treatment.

The triumph of engineers in taking control of sewage treatment marked an end to sewage farming as a feasible treatment option in most Western countries. As a group, sewerage engineers (also called public health engineers and sanitary engineers) preferred certain technologies and methods and virtually ignored others. They favoured water-carriage methods to transport the sewage to the nearest waterway for disposal despite considerable public opposition in some cases. Treatment methods were developed to ensure that the sewage, when discharged into a river, would not use up too much oxygen and choke the river or create a nuisance because of a build up of rotting matter. A large variety of treatment processes were soon reduced down to a manageable few that were arranged into primary, secondary and tertiary stages.

Where engineers were able to use the sea for disposal they avoided treating the sewage altogether because the sewage would be diluted and decomposed in the sea. Engineers always sought the cheapest solutions and preferred not to install treatment if the ocean would do it for them. Their defence of this practice was initially quite flimsy and unconvincing but over the years it has become more sophisticated with the addition of complex oceanographic studies which are designed to show that sewage will be diluted, dispersed, carried away by currents, remain submerged beneath the ocean surface, oxidised and treated by the ocean and generally rendered harmless.

Engineering proofs

In 1985 I became interested in how Water Board engineers had managed to consistently claim for decades that sewage was being carried away by a southerly current and diluted and decomposed far away from the beaches when it seemed obvious to anyone who watched the movement of the sewage fields that the sewage often came onto the beaches. And it must have been obvious to those who went swimming on such occasions.

My historical research showed me that even before the first ocean outfall had been built in 1889 people who lived near the sea had seen garbage and offal disposed of at sea come back onto the beaches. The letters to the newspapers at the time showed that many people did not believe the engineers' claims that the proposed outfall near Bondi Beach would not cause any pollution of the beach.

The engineering textbooks and expert writings of the late nineteenth century indicate that engineers were well aware of the fact that sewage would rise to the surface of the ocean (because it had a higher temperature and lower specific gravity than sea water) and flow in the direction of the wind, which could be onshore.⁷ The textbooks recommended that engineers study the currents and tides with the use of floats. But I found it puzzling that they instructed that the floats be kept submerged so that they would not be affected by the winds.⁸ If the sewage travelled in the direction of the

wind, why did they not want the floats to travel in the direction of the wind?

In Sydney, engineers used such float studies to argue that the sewage would be carried away by the southerly current even though there was a predominant on-shore wind in summer. After the first ocean outfalls had been built evidence that the engineering predictions had been wrong inevitably emerged. As the sewage comes to the surface of the sea it forms a field with sharply defined edges which can be differentiated from the sea water by its discolouration. The fields can be observed to travel in one direction or another from adjacent headlands and if onshore winds are blowing it is easy to trace their course onto nearby beaches. Other signs of pollution are also readily visible. Floating solid material in the water and grease balls on the sand are two obvious examples. Smell and greasy feel are other good indications of the presence of sewage.

Despite these obvious indicators, for almost one hundred years the Water Board engineers persistently denied that the pollution resulted from those outfalls. They explained that the sewage could not have come from the outfalls because of the southerly current that would have carried it away. Their theoretical predictions were given more weight than the real evidence that contradicted them. From then until the present day, the obvious pollution was blamed on passing ships, algae, beachgoers and stormwater drains. It is difficult to understand such denials except in terms of deception of the beachgoing public. And such deception relied on the authority of expertise to gain the support of the wider public.

In the summer after I began my research, the Water Board spent half a million dollars telling the public how its deepwater outfalls were going to clean up the beaches. The deepwater outfalls would, they said, end sewage pollution of the beaches (which the Board now belatedly admitted came from the outfalls). This message appeared in television and magazine advertisements that were always visually splendid. Pristine beaches and beautiful people evoked a promised future of

unpolluted beaches.

As in the past, it was claimed that the sewage would be carried off by the southerly current and treated in the ocean through dilution, oxidation and biodegradation.⁹ It all sounded rather similar to the historical material I had been reading. But there was a new element this time. The Board was predicting that the deepwater outfalls would keep the sewage field submerged. If the sewage was submerged beneath the surface of the ocean, it would not be blown in the direction of the wind.

The Board's claims were based on the existence of a thermoclyne, or difference in densities, in the coastal waters off Sydney. The idea was that sun-warmed waters on the surface would be less dense than the cooler, deeper waters and therefore would not mix with them. Sewage released into those deeper, denser waters would be trapped beneath the surface of the ocean, under the layer of warmer water and carried southwards by the ocean current. This theory had originated in the United States when it had been discovered that the Los Angeles deepwater outfall seemed to work this way most of the time.

However, it was apparent that conditions off the coast of California were different from the conditions in the coastal waters off Sydney. For one thing, the current coming from the north of California came from the cold northern regions and provided more difference in temperature and therefore density from the sun-warmed layer on top. In Australia the northern current came down from tropical waters and so was much warmer to start with. Would the difference be enough to keep the field submerged off Sydney? And if it was, would the current really carry it all away?

One person who claimed it wouldn't was Tom Mullins, a marine chemist at the University of Technology, Sydney. He said that there was no single unified south-going current off Sydney but rather a series of eddies and other irregularities. A wording change in a Water Board's public relations brochure also made me suspicious. An early brochure stated that:

the effluent/seawater mixture moves away from the initial dilution zone under the influence of ocean currents. In Sydney, these currents are not normally directed onshore during the summer months.

A reprint of the same brochure was changed to:

the effluent/seawater mixture moves away from the initial dilution zone under the influence of strong offshore ocean currents during the summer months.

I examined the oceanographic studies undertaken by the Board's consultants, Caldwell Connell. In two studies, one in 1976 and one in 1980, Caldwell Connell had measured currents at various depths where the outfalls would be discharging. These studies showed that even the deepwater currents were going towards the shore for 30-50% of the time during the summer. Yet they ignored their own evidence and concluded that in the long term the sewage discharges would be carried southward.¹⁰ I questioned the Board's engineers on this point and was told that although the currents were going towards the shore, they turned when they got close to the shore and headed southwards. This assumption was based on theory but had not been tested empirically.

Even if you accepted this, there were significant differences between the claims in the engineering reports and those being made by the advertisements. For example, while the advertisements said sewage pollution would be eliminated, the reports predicted that the sewage fields would still come onto the beaches when the field surfaced and there was an onshore wind. This would happen, the reports stated, for a small amount of the time in summer and forty per cent of the time in winter, when many people still go to the beach and surf.

My suspicions were further aroused when I discovered a retired Commission scientist, Robert Brain, who had studied the Water Board's models in detail and who argued that they were wrong. Brain had given an honest appraisal of the Water Board's predictions

when asked by his superiors at the Commission but now realised that was not what they wanted. He claimed he had subsequently been victimised, moved sideways and his career ruined as a result. He told me that at one stage, whilst he was away on holidays, his personal files were gone through and some material removed. Commission engineers, whom I interviewed, tried to discredit Brain but I discovered during the course of my research that Brain had actually been highly thought of by senior Commission engineers before he questioned the Water Board's predictions.

This discovery happened one day when I was researching in the Commission's offices, and had asked to look at some files from a few years before. They were brought up from the bowels of the building by a junior officer and placed on a desk where I set to work, reading through them and taking handwritten notes. In the files I found a 1980 memo by the Principal Engineer for Water, Wastes and Chemicals saying that he believed that there were only two Commission officers with the necessary expertise to undertake the assessment of the Board's models and calculations and Brain was one of them. Another memo from the Principal Engineer stated that he could not find anything wrong with Brain's criticisms and that the Commission should not ratify the Board's proposals until the issues raised had been resolved. "Otherwise in the event of a public inquiry, the Commission might justifiably be subjected to serious criticism."

I was feverishly writing all this down when a senior Commission officer who had been observing me, came up to me and asked me to stop as I had been given the files by mistake. He said he needed to consult the Commission lawyer about whether I could look at these particular files. He tried to explain that Brain had been discredited and that the material I was looking at was not relevant. He took the files away and asked me for my notes. When I refused he wasn't sure what to do and let me keep them. After that I was only allowed to see parts of the files that had been given prior approval for my perusal by the Water Board.

Vested interests

This sort of behaviour only encouraged me to delve deeper. Why was the Commission protecting the Board? They were the regulators and were supposed to be concerned about public health and environmental protection. Why were they so committed to the deepwater outfalls? Was it because both organisations were dominated by engineers? Were they subject to the same pressures from their political masters? Some more historical research allowed me to see another part of the puzzle.

When the Commission had been formed in 1972 it had been charged with implementing the Clean Waters Act and cleaning up Sydney's waterways which were severely degraded with industrial waste. The Commission had achieved this feat by requiring firms that were discharging their wastes into the rivers and creeks to divert their wastes into the sewers. The Water Board obliged the Commission by allowing those firms to do this and in this way the industrial waste was removed from the rivers to the ocean. The Commission was somewhat beholden to the Board for this and could hardly turn around and penalise the Board for the huge quantities of toxic materials that were now pouring into the ocean from the Board's outfalls nor for the resulting marine pollution. Instead it actively helped the Board to keep knowledge of the resulting fish contamination from being made public.

I found that the Commission placed no formal restrictions on what toxic material the Board could put into the sea. The guidelines for toxic materials were expressed in concentrations in the environment rather than total amounts. When I multiplied the concentrations by the actual flows and claimed dilution factors I found that under the guidelines the Board could have discharged huge quantities of heavy metals and organochlorines, in some cases more than the total amounts produced in NSW. Even so some substances, particularly organochlorines, were approaching those limits. However, the deepwater outfalls would ensure further dilution of the sewage and meant that the amounts of toxic waste that could be discharged under the guidelines,

when the deepwater outfalls were built, would increase dramatically.

When the choice was made between upgrading sewage treatment onshore or building deepwater outfalls that would delegate this task to the ocean, the Board had chosen deepwater outfalls and the Commission, after seeking advice from one of their consultants, a retired engineering professor, agreed. Upgrading the treatment to secondary treatment would not only have been more expensive but would have required restrictions on industrial waste being allowed into the sewers because secondary treatment utilises naturally occurring micro-organisms that are sensitive to toxic waste. The deepwater outfalls enabled industry to keep using the sewers as a cheap toxic waste disposal service.

The problem with using the ocean to treat the sewage is that most people don't like swimming in a de facto sewage treatment plant because they think it might be unhealthy. The Commission told the public that coastal waters could be presumed to be bacteriologically safe for swimming if aesthetic criteria were met; in other words, no undisintegrated faecal matter or other materials "clearly of sewage origin" should be allowed into bathing areas and also no "noticeable" turbidity or discolouration of bathing water attributable to sewage and no "perceptible smell." After some delving I discovered that this view was based on a 1959 study undertaken in the UK. I found that this study was still referred to in Britain, Australia and New Zealand as the classic paper on the subject yet it didn't take much research to uncover a continuing debate amongst international experts on the extent to which sewage polluted water posed a health hazard. There was also plenty of more recent research and developments in the field of virology reaching conclusions contrary to the 1959 study. For example, I discovered that epidemiological studies in the US since that time demonstrated significant risks of bathing-associated disease in recreational waters that are mildly contaminated with sewage. In 1980 a US EPA spokesman claimed that

surveys of 30,000 bathers and non-bathers contacted on beaches in New

York and Boston revealed statistically significant increases in cases of vomiting, diarrhoea, nausea, fever and stomach aches among swimmers who had bathed in polluted waters... The results show a strong link between bacteria counts in the water at the time of bathing and subsequent health of the swimmers.¹¹

I also tracked down a paper given at an International Conference on Water Quality and Management for Recreation and Tourism in 1988 which summarised data collected by the NSW Health Department between October 1983 and April 1987. Salmonella was detected in 183 out of 1058 (17%) samples tested at Sydney's eastern suburbs swimming spots and beaches. Moreover, the Health Department's monitoring of bacteria levels at beaches found that the same beaches were unsatisfactory for swimming for between 29% and 83% of the time, depending on the beach and whether it had rained in the previous 24 hours (when the sewers overflowed and the treatment plants were bypassed).

However during this time the Water Board's Annual Reports showed that the beaches were meeting standards most of the time. How could this be? The standards the Board was referring to were standards set by the Commission which were different in significant ways to the Health Department criteria. I found that the Health Department classified beaches satisfactory for bathing or unsatisfactory on particular days whilst the Commission standards used a statistical measure that allowed days of heavy pollution to be covered up. I was able to use raw sampling results from the previous summer to show that whilst the Commission standards were being met some beaches were in fact unsatisfactory for swimming according to the Health Department for half the time.

I could find no record of the Health Department telling the public of its contrary findings or undertaking any sort of study to find out what the implications of their sampling were in terms of human health. As far as I knew, and this has been confirmed since, no epidemiological study had been

carried out of swimmers in Australian waters. Without such a study, the Water Board and the Commission were able to continue claiming that beaches which met Commission standards were not a health hazard.

Although many beachgoers knew the beaches were polluted and that they occasionally got sick from swimming, the government experts were seldom challenged by outside experts, either engineers, doctors or scientists. I found that formal complaints had been regularly made by the beachside councils behind the scenes but the councils were reluctant to take any public stance that might advertise the fact that their beaches were polluted and thereby turn away potential residents or visitors and beneficial business in the area.

Lack of evidence

If you're going to use the ocean for sewage treatment, it seemed to me that it was vital to consider the fate of viruses and toxic materials that enter the ocean in this way. Yet over more than a decade whilst the Board's consultants, Caldwell Connell, undertook their detailed studies of Sydney's oceans, these areas were almost completely neglected. Their million-dollar feasibility study¹² was heralded by the Board as the most comprehensive study of its kind ever undertaken in Australia. They studied the biological characteristics of marine life in some detail, examined the composition of the water and its concentrations of oxygen and nutrients and they mapped out the topography and geology of the coastal region. But they did not study viruses, pathogenic bacteria, nor the toxic content of marine life in the area.

Viruses, Caldwell Connell said, were difficult and costly to test for and testing could not be carried out without specialist assistance.¹³ So why didn't they get that specialist assistance as they had in other areas? Sewerage engineers recognise the limits of their knowledge and increasingly draw on the expertise of environmental scientists and others, by hiring them, using them as sub-consultants or drawing on their literature. But this use of other experts is often subordinated to their own ends. I found the engineer-

dominated government authorities and the engineering firms they worked with were highly selective in their usage of other experts, often drawing on them merely to justify their proposals and cover their failings, or not using them at all as in this case.

Having admitted their lack of expertise in the area of viruses, Caldwell Connell assumed that viruses would not live long in the ocean and their numbers would "diminish rapidly through treatment, dilution and natural die-off."¹⁴ Yet the textbooks said that the treatment Sydney sewage received would not reduce the numbers of viruses and I uncovered several studies that showed that viruses could live for months in sea water, whereas the faecal coliform¹⁵ that Caldwell Connell did study die off in a matter of hours. Caldwell Connell admitted that there was very little evidence that related "faecal coliform concentration to the incidence of water borne disease" but studied their die-off rates "as a matter of convenience."¹⁶ I found this extraordinary. How did they get away with it?

Their study of the fate of toxic material was similarly lacking. I know that whilst organic matter does eventually decompose in ocean water, heavy metals and organochlorines tend to persist in the environment, accumulate in seabed sediments and bioaccumulate in the food chain. Yet this possibility was not properly investigated by Caldwell Connell who stated in their feasibility study that "a detailed investigation of levels of pesticides and heavy metals in the marine environment is beyond the scope of this study."

In the environmental impact statements¹⁷, which were also prepared by Caldwell Connell, the possibility of bioaccumulation of toxic substances was dismissed as unlikely since no serious accumulation of these toxic materials had been observed in sediments near the existing outfalls. But I found they had hardly even looked for sediments. They had only taken samples in three places for analysis of toxic contamination and these were some distance away from the existing outfalls. In a confidential report that I uncovered, the Commission noted that "The statistical significance of single samples and the validity

of a sampling technique which does not segregate undisturbed surface material must be brought into question.”

Caldwell Connell assigned no importance to the fact that elevated levels of heavy metals and DDT were found in the sample taken nearest to the largest outfall at Malabar and argued that this material “appeared to be deposited only during periods of low current velocities and was dispersed under the normal current regime.” These meagre observations were sufficient justification for Caldwell Connell to assume that toxic material did not accumulate, despite the obvious evidence that it had.

By studying the responses of government departments to the environmental impact statements I found that they were less optimistic than the Board and its consultants. A major concern of the Department of Mineral Resources was the potential accumulation of deposits of solid particles which might in turn lead to a concentration of heavy metals and toxic chemicals. They were sceptical of the claims that ocean current velocities/settling times/particle sizes were such that wide dispersion of solid particles would occur. “It is difficult to understand that these particles do not go somewhere specific where they accumulate.”

The Australian Museum, which had conducted ecological surveys of nearshore waters for the Water Board, claimed that particles from the diffusers which fell into the mud/clay range would be likely to be deposited in a relatively stable region of mud and that heavy metals and other industrial wastes which might behave like mud or clay sized particles were likely to also be deposited in this stable zone of muddy sediment. Such materials could then be assimilated by benthic organisms and enter the tissue of fish passing through the area. “Such a situation could be harmful since the professional fishing grounds of Sydney are located in this region.”

I knew of at least one survey that had been done of fish contamination whilst Caldwell Connell had been conducting their massive feasibility study and this showed that heavy metals were accumulating in the fish. I

uncovered a Caldwell Connell internal report of a meeting to discuss the survey, published well before the completion of the feasibility study, which stated that “It was agreed that, while the data only represented analyses of individual specimens, levels of heavy metals and pesticides detected in this small number of samples were such as to suggest that a potential public health threat or environmental hazard might exist within the study area...”¹⁸ Yet there was no mention of this in the feasibility study and no further surveys undertaken by Caldwell Connell. The only public report of the fish survey that I could find was in the 1979 environmental impact statement which stated: “Whilst the statistical significance of the 1973 survey is not able to be clearly established the results are encouraging in that they indicate that no serious environmental problem existed even prior to the full implementation of source control of restricted substances...”¹⁹ A very different public interpretation!

On the whole I found fish contamination reports the hardest to obtain. Some had been done by the Fisheries Research Institute (part of the Department of Agriculture) and never published. These were not mentioned in the environmental impact statements despite their direct bearing on the environmental impact of the proposed deepwater outfalls. If toxic material was accumulating in fish life, as the few reports I managed to get hold of indicated, then the deepwater outfalls would be putting the same toxic material further out to sea, closer to the commercial fishing grounds. One study of pesticides in fish caught near the outfalls²⁰ seemed impossible to track down, even with the help of a member of parliament. It had been carried out in 1979 but was not published till 1989 after I told the newspapers of its existence. Needless to say, it revealed contamination of fish above Australian standards.

My involvement

As I neared the completion of my research it was obvious to me that there was a major sewage pollution problem in Sydney waters that had largely been covered up by the

experts and the organisations they worked for. It also seemed that the deepwater outfalls, far from solving the problem, were likely to cover it up even more by removing some of the visible evidence of the pollution. It seemed imperative that I go public with my findings. Whilst I was undertaking my research I had refrained from making public statements about the sewage pollution or the outfalls. Instead I kept the environmental group Stop The Ocean Pollution (STOP) informed so that they could campaign against the outfalls more effectively.²¹ (STOP was a small group of beachgoers, surfers and environmentalists.)

It became evident that the Water Board suspected this connection when, at one interview, Water Board public relations people confronted me about my environmental affiliations, producing notes of a talk I had given at a seminar at the University of Wollongong which had been attended by about twenty people. They said that I had apparently been influenced by members of STOP. They told me that I should not listen to them because they didn't know what they were talking about. They proceeded to put me right about what a good job the Board was doing.

It was partly because the Board's public relations people were so successful at undermining STOP's credentials that journalists were reluctant to report their statements regarding the scientific basis of the extended outfalls. They repeatedly asked STOP members if there were any 'experts' that they could refer them to.

My decision to speak out was not a difficult one. In many respects, although I was trained as an engineer, I have been far freer than most to challenge my fellow engineers since, as an academic and writer, my career prospects are not dependent on endearing myself to the engineering profession or gaining employment in an engineering firm or government department. I could understand that engineers and scientists employed by the Board or the Commission, who might have felt uncomfortable with what was going on, could not speak out because they were concerned about their jobs. One or two seemed very nervous just

talking to me.

There were rumours about engineers who were critical of the proposed outfalls but they remained well hidden. Back in the 1970s when the idea of the deepwater outfalls was fairly new the *Daily Telegraph* had reported that "private and government civil engineers" had criticised it arguing that it would do little to solve the pollution problem.²² Such critics had not been willing to put their names to their criticisms, however. Most sewerage engineers in Australia are employed by government departments or instrumentalities and those who aren't are consultants dependent on those same government departments for work, or academics dependent on them for research funding. So critics face the possibility of severely limiting their career prospects. Those engineers who are not employed as sewerage engineers still face disapproval and censure from the engineering profession. It is an unwritten part of the engineering ethos not to criticise works designed by other engineers, because this may reflect badly on the profession.

John Tozer, a structural engineering consultant, found this when he criticised a proposal to build an outfall near his home at Look-At-Me-Now headland in northern NSW. In 1990 he was found guilty of breaching the engineer's code of ethics because of his public criticisms of the local council engineers who supported the scheme. He was subsequently eased out of the Association of Consulting Engineers, Australia (ACEA). Recently Tozer was publicly admonished by the Institution of Engineers, Australia (IEAust) for failing to uphold the honour and dignity of the engineering profession because he used "intemperate language" in a private letter he wrote to the Premier that criticised the outfall. The letter was on his business letterhead and identified him as an engineer.

After I began to be quoted in the newspapers in 1989, I too was accused of breaching the engineering code of ethics. I was phoned one evening by a senior member of the Institution of Engineers and accused of not upholding the dignity and honour of the profession and speaking outside my area of

competence (despite the fact I had just done a doctorate on the subject). The caller threatened to make a formal complaint against me.

The Institution of Engineers also sought to publicly support the Water Board engineers. Its president issued a press release that read, in part:

I deplore the denigration of Australian engineering endeavours which seems to occur too frequently these days. Innovative projects of this type should be recognised and supported by the community.

Australian engineering ability and performance is recognised throughout the world as being of the very highest calibre, with the Water Board in Sydney having its share of distinguished engineers. It is important to Australia's competitive performance that, where deserved, Australian engineering excellence is supported by our mass media. I believe the Ocean Outfalls project deserves this support.

It was later revealed that this man's consulting firm had been retained by the Water Board as management consultants on the deepwater outfall project.²³

Nevertheless, after this initial reaction, the Institution of Engineers itself has sought to hear and incorporate my views. I was invited to join the Institution's Environmental Engineering Branch committee the following year, at the suggestion of the same President. (I have been a member ever since and became chairperson in 1992.)

The Institution's magazine, *Engineers Australia*, did a feature story on the outfalls controversy in February 1989, which covered my views fairly and promoted some discussion in the letters section. One letter said "it has continually amazed me that the debate is being carried out by laymen with nary a word from the professionals. Of all the people who should be able to provide information to the public, civil engineers are the best placed yet are noticeably silent."²⁴ (It had obviously escaped his attention that I was a civil engineer.)

When my book *Toxic Fish and Sewer*

Surfing was published later in the year,²⁵ the editor of *Engineers Australia* gave it a favourable review. I received a much less favourable review in the magazine of the Australian and New Zealand Association for the Advancement of Science (ANZAAS), *Search*. It was written by a government scientist who was an inventor of a sewage treatment process I had criticised. He called the book a "polemic against engineers in general and the Sydney Water Board in particular" and stated:

As one who has watched the events from a safe distance, it is clear to me that the debate has been maintained at an emotional level, with a propensity for exaggeration and limited vision being displayed by both sides. While I found the book both entertaining and informative, the more I read the more uncomfortable I became, as the tone became shriller and the close personal involvement of the author with the issue more obvious.²⁶

I was subsequently invited to speak at an ANZAAS Seminar on "Sydney's Strangled Sewerage System" and later to speak at the Institution of Engineer's Annual conference. I was well received at both although subject to some angry questions, particularly from Water Board employees and sympathisers.

Controlling the interpretation of information

During the course of my research at the State Pollution Control Commission I had come across some figures for levels of organochlorines in fish caught near Sydney's main outfall at Malabar. They were in the business papers for a meeting of the Clean Waters Advisory Committee which was a committee of representatives of various government departments and government appointees representing selected interest groups which advised the Commission.

I copied the figures down without knowing their meaning since there were no standards included with them but when I later compared them to the National Health and Medical Research Council (NH&MRC) maximum

residue limits I was astounded at how high they were. Two out of three species of fish which were tested were over the NH&MRC limits and one species, the red morwong, was over the limits for benzene hexachloride (BHC) by 122 times on average (8 samples of each species were tested) and over the limits for heptachlor epoxide by an average of over 50 times.

When Alan Tate, from the *Sydney Morning Herald* — Sydney's quality daily newspaper — interviewed me a couple of months later for a story he was writing on sewage pollution, I pulled out the figures to prove to him that there was already a pollution problem caused by industrial waste being discharged through the sewage outfalls. Tate was keen to publish the figures but could not rely on my notes alone. He needed to authenticate them. He made his own inquiries and finally found one person in the Commission who said he could confirm the figures. The person then changed his mind because he was concerned about his job. Tate rang him several days in a row without success until the day before the figures were due to be published. Tate suggested to the person that all he had to do was cough if the figures were correct. He coughed.

Tate then rang the Water Board to tell them he had the results of the study and was warned by a senior Water Board officer that the *Herald* should not publish the results because they were open to question. The officer said that the Board thought the BHC, found in such high levels in the red morwong, might really have been lindane (a specific form of BHC) and therefore only slightly over the limits. (The maximum residue limits for lindane are much higher than for other forms of BHC). Tate then rang the Australian Analytical Laboratories, which had performed the analysis, and was told that there was no doubt that the substance in question was non-lindane BHC.

The results of the study which had been done in 1987 were published for the first time the next day, 7 January 1989.²⁷ Not only had the Commission kept the results of the study secret for more than a year, but several other

government departments, through their representatives on the Clean Waters Advisory Committee, had known of the findings. Yet there had been no leaks. It later emerged that the Minister for the Environment had instructed the Commission not to reveal results of the study in its Annual Report.²⁸

It also emerged that Water Board officers had met with Commission officers in May 1988 and a memo of the meeting stated that "spearfishermen consuming red morwong caught at Malabar could be at some health risk"²⁹. Yet the results were not even given to the Australian Underwater Federation when it wrote to the Commission in September 1988 asking for results of the study. Their letter said that their members, including spearfishermen, had noticed that red morwong caught near the outfalls had mushy, tainted flesh and they were concerned about whether they were safe to eat.³⁰

The Board's planning manager later defended their decision not to inform the public of the results:

The criticism that by withholding the study results the board was potentially putting public health at risk had to be weighed up against the risk of causing unwarranted public concern and panic.³¹

The significance of the study was that the Water Board engineers had been claiming for several years that toxic industrial waste did not accumulate in the marine environment near Sydney and therefore the extension of the outfalls would not cause a pollution problem in deeper water, closer to the commercial fishing areas. Several previous studies that had also shown accumulation of organochlorines (particularly dieldrin and DDT) and heavy metals (particularly mercury and cadmium) in fish caught near the outfalls had also been suppressed.³²

With full knowledge of all these results the Board went ahead and published an advertisement for the extended outfalls which referred to the ocean as "the world's most efficient purification plant" and stated:

This is also the world's largest and most natural treatment plant, and it has some

of the most experienced employees as well. Hundreds of species of fish and other marine organisms exist here to do little more than thrive on breaking down the pre-treated effluent discharged into the ocean off Sydney.³³

Even after the leak to the *Sydney Morning Herald*, the Water Board, the Department of Agriculture (responsible for fisheries), and the Health Department continued to down play the significance of the study. Water Board officers claimed, "The results obtained from this study were from a very small sample number and were not compared to any sample with a known concentration. It is not unusual for studies of this nature to have high errors associated with them due to natural variations within the sample population."³⁴ They claimed that the large amounts of heptachlor epoxide found in the study were really a sulphur compound.³⁵

A second study, that had been carried out in 1988, had sampled red morwong at varying distances from the three major outfalls and included a comparison of four different laboratories so as to meet criticisms of Australian Analytical Laboratories, which had done the analyses for the first study. The study concluded that only that laboratory and one other accurately detected a wide range of organochlorines. It showed different organochlorines accumulating in the fish above the NH&MRC limits, particularly chlordane and hexachlorobenzene (HCB).

This interlaboratory study raised even more disputes. The Minister for Agriculture wrote to the Minister for the Environment after both studies had been reluctantly released in March 1989 to express his concern about the continuing publicity being given to the contamination of fish. He argued that very small errors in technique or measurement could seriously flaw the results when measuring minute amounts of chemicals in fish. He argued that reports of both studies were potentially erroneous because they had not been refereed "in the standard scientific manner";

I would appreciate it if you would ensure that media reporters are fully aware that these reports do not have the scientific standing that is being attributed to them... we should take all possible action to prevent the continuation of the unsubstantiated reporting which is doing so much needless damage to one of our State's most important industries.³⁶

An independent referee's report, subsequently procured, generally approved of the studies saying that the "basic nature of the problem has been adequately identified and evaluated."³⁷ Another review was made by the Director of the Southern California Coastal Water Research Project. He had no major criticisms of the studies. He agreed that both showed that red morwong were contaminated near the outfalls. He suggested, as a public relations strategy (and as a way of shaping perceptions of the meaning of the results):

After evaluating the best world-wide evidence for health risk from the various organochlorines, you might want to release to the press a comparative table to put the risks in line with others commonly accepted by the public.³⁸

In a different report he advised the government:

The recent events in Sydney indicate a route of communication to the public from the scientists should be developed. This may reduce the "scare" from the press and shield the fishing industry from impacts produced by false or inaccurate media reporting.³⁹

In the past the Board could be fairly confident about getting its press releases published and its version of events reported. The Board's public relations department had a comfortable relationship with the media, putting out the occasional brush fire with their version of the facts, and that version was almost never challenged by journalists. 'Serious' papers like the *Sydney Morning Herald* could be relied upon not to report unsubstantiated claims and to give preference to 'expert' opinions from government officials.

But in 1989 things had changed. The government and its advisers were well aware that the *Sydney Morning Herald* journalists and some television journalists were coming to me for interpretation of data, reports and anything else that they found or that the government released that had to do with sewage pollution. Alan Tate from the *Sydney Morning Herald* had originally been referred to me by the local Friends of the Earth office. He found that I was a reliable source of information and continued to come to me. Other journalists soon followed and I became one of the people that journalists sought to provide an environmental point of view. STOP members were also now credible sources of information for the media and part way through 1989 STOP purchased a fax machine through which they could put out media releases. These releases were fairly successful at gaining news coverage now that STOP had become known to the media.

The government sought to avoid alternative interpretations by imposing their own at the time of release of reports, particularly those likely to be damaging. Shortly after the results of first bioaccumulation study were published in the *Sydney Morning Herald*, a reporter asked a senior Board scientist whether figures given by the Board for concentrations of toxic substances in discharged effluent in one of their recent reports included the portion of these toxic substances in sludge which was also discharged into the ocean. He was told by this scientist that of course they did, and "You don't think I would let them be published if the sludge was not included do you?" I attempted to prove to the reporter that the Board's spokesman was lying and he made further inquiries at the Board. He was told by a puzzled public relations officer that the Board's engineers were rushing round and that the Board was in a state of chaos. The next day the same scientist admitted that the sludge figures had not actually been included in the report and that "an honest mistake" had been made in telling the reporter otherwise.

That same week Ian Wallis of Caldwell Connell came up to Sydney and the Board held a press conference. The *Herald's*

reporter, Alan Tate, claimed that virtually everything Wallis said during their meeting "was useless as far as reporting the issues at hand" and Paul Bailey, the paper's environment writer, said that if they had reported the meeting they would have reported Wallis's admission that further treatment would have to be investigated eventually for the ocean outfalls. Yet many Water Board people were incensed that Wallis, the expert, did not receive any coverage in the *Sydney Morning Herald* and took this as a further sign that the *Herald* was biased and was conducting some sort of vendetta against them.

The relationship between the Board and the *Herald's* key sewage pollution investigators continued to deteriorate. In a subsequent screaming match between Tate and the Water Board's public relations manager, the public relations man alleged that Bailey had admitted in the meeting with Wallis that he had no understanding of how the extended ocean outfalls worked and hadn't realised the complexity involved. Tate denied this but the same story was reported in the Board's internal magazine, *Aquarian*, except that this time it indicated that it was Tate who admitted he had no understanding of the project. Tate was incensed but no doubt it did wonders for the morale of Water Board employees who felt besieged by the *Herald*.

In the meantime the Board had given the *Herald* some figures for concentrations of toxic substances in sludge but in a form that was difficult to interpret. I studied the figures, comparing them to other information I had, and decided they were not credible, but I was unable to prove them to be false. A few days later the Commission admitted that it didn't require the Board to monitor the sludge for toxic material and the Board's monitoring manager was reported as saying that the Board did not know much about the concentration of toxic material in sludge discharged through its outfalls. "We have started looking at this in the past few weeks" he said.⁴⁰

At the beginning of March, the Board placed a full page advertisement in the *Herald* which claimed that 70% of the volume of industrial discharge which could contain

damaging wastes had been controlled by their Trade Waste policy and that this meant that “this waste may no longer be discharged to the sewers or drains.” Such a statement was patently untrue. Neither the 70% of industrial discharge nor the damaging wastes were prevented from entry into the sewers under the Trade Waste Policy. I pointed this out to journalists and the Board was forced to admit, shortly afterwards, that the advertisement was “certainly ambiguous” and “should be clarified.”

The *Sydney Morning Herald* had begun labelling its articles on the issue “Sydney’s Watergate” and the Minister tried to reassure a press conference that there would be no more cover-ups or lies. Indeed, he said: “We are determined the Water Board will tell the truth, the whole truth and nothing but the truth and if that requires, as Richard Nixon once described it, minor correctional statements as we go along, then they will be taken.”⁴¹

The Board also tried a number of ways to stem the bad publicity. Apart from direct threats of legal action it was rumoured that Water Board executives were lobbying senior executives of the *Sydney Morning Herald* to get the series of damaging articles stopped. Early in the piece the Board’s managing director accused the *Herald* of ignoring press releases and statements made by the Board and other government organisations. The Board placed full page advertisements in various papers and their managing director, Bob Wilson, was worked off his feet with radio and television interviews. Senior Board executives were forced to work late hours and weekends to cope with the crisis.

Individual journalists were subject to various forms of manipulation by Water Board public relations staff. For example, one was subject to an angry phone call during which his professional ethics were questioned and he was told that it was unlikely that any Water Board employees would want to talk to him in future. Ten minutes later the same person rang him back and in quieter tones asked him to excuse the first call but to understand that everyone in the Board was under extreme pressure. He was told that at least one

employee was under doctor’s orders to remain at home because of stress related illness which was attributable to what was happening. Not surprisingly the journalist was very upset by this call and he considered what he was doing very carefully but his colleagues rallied round him and encouraged him to disregard what they saw as an effort to intimidate him.

When further fish contamination results were released to the public in July, it was at a press conference held by the Minister of the Environment. This time the Minister had an expert, a university professor, at the press conference to ensure the correct interpretations were conveyed to the media. The study had been of heavy metals in red morwong caught near the outfalls. Despite the fact that most of the fish sampled were over NH&MRC limits for mercury the Minister stated that the study showed there was no toxicological threat to humans from heavy metals discharged in effluent from ocean outfalls.⁴²

The university professor compared average levels of mercury in the Sydney fish to the highest levels found in fish from Minamata Bay in Japan where more than one hundred people died and hundreds more were sick from mercury poisoning after eating the fish there. He concluded that “treated sewage as presently discharged does not constitute a hazard in terms of heavy metal accumulation.”⁴³

The media left the press conference with the impression that the new report gave the fish a clean bill of health. The professor’s statement that one would have to eat 50 kilogrammes of red morwong a week continually “to get any real trouble” was shown on every television news broadcast that evening. The Minister for the Environment was even reported in the *Sydney Morning Herald* the next day as saying that the “study proved that the effluent which was being discharged from treatment plants at Malabar, Bondi and North Head was not deemed to be a health hazard for the fish.”⁴⁴

The problem was the public was not being told was that these red morwong were the very same red morwong that had been kept in a refrigerator since being analysed for and found

to be heavily contaminated with organochlorines earlier. These fish were far from being safe to eat. Fortunately, at the time I had easy access to the media and I was given a chance to point this out in the *Sydney Morning Herald* and on one of the commercial television channels. After this the professor backed away from the statements he had made about the fish being safe to eat. He was reported as saying:

I didn't mention the organochlorines because it was not in my brief and I wouldn't talk about them anyway... I made my comments on the basis that if there was no other contaminating factor, then the fish would be all right to eat... Obviously if there are organochlorines I think anyone who ate the fish from there would be very foolish.⁴⁵

Outcomes

The events of early 1989 came as a shock to the Water Board. The initial stories in the *Sydney Morning Herald* in January 1989 triggered other articles and stories in every media outlet in Sydney, as well as the national and international press, including *Time* magazine. People came forward with revelations about other Water Board coverups and journalists conducted their own investigations into various aspects of the story. Alan Tate and Paul Bailey at the *Sydney Morning Herald* won awards, including the prestigious Walkley award for their series of investigative articles on sewage pollution.

Many television celebrities, musicians, sporting stars and others added their voices to the cry of outrage over the pollution. Some doctors finally spoke up. The *Sun-Herald* ran a feature on beachside doctors, more than half of whom had reported an increase in ear infections, gastro-enteritis and viral infections. Most linked these problems to beach pollution.⁴⁶ A month or so later, a group of 80 doctors, led by Peter MacDonald, called upon local councils to close 15 northern suburbs beaches until they could be proved safe.⁴⁷ (Peter MacDonald was elected to State Parliament at the following election as an

independent after campaigning strongly on the issue of sewage pollution in his electorate.)

Beach culture and seafood restaurants were an essential part of Sydney's identity but now people no longer knew whether it was safe to go swimming, surf-lifeguards threatened to walk off the job, and the fishing industry was losing an estimated half a million dollars each week as people turned away from seafood in droves. It was said that tourists were still visiting Sydney's famous beaches "but only for quick strolls rather than long days at the beach where they once splurged on ice-creams, hot dogs and souvenirs."⁴⁸ It was claimed that takings from shops and businesses at the beachside suburb of Manly were down 15% on the year before and some people were threatening legal actions. Property sales were also reported to be affected by the pollution publicity and some residents believed that real-estate prices were being affected.⁴⁹

Various journalists and reporters were threatened for reporting on the pollution. Surf Reporter John Ellis (radio station 2MMM) received such a threat from a Manly businessman who claimed to represent 20 Manly businesses that had been adversely affected by Ellis's warnings to people not to swim at Manly. Kirk Willcox, long time member of STOP, lost his job as surf reporter at radio station 2JJJ at about this time, because the Australian Broadcasting Corporation said it could no longer afford surf reports. "It's ironic" Willcox said "that I've been thrown off the air at this time — when ocean pollution has finally become a front-page issue. Now I have no avenue to voice my opinion."⁵⁰

On Good Friday 1989, almost a quarter of a million people gathered at Bondi Beach for a rock concert, the "Turn Back the Tide" Concert, staged as a protest against the pollution of Sydney's beaches. Some of Australia's leading singers and musicians donated their time and talent to the cause and the hundreds of thousands of young people, who had come along despite the occasional showers and overcast conditions, bellowed out their indignation as speakers from the stage condemned the authorities for allowing the

beaches to deteriorate so badly.

To the Water Board officers, the whole episode from the *Herald's* first revelations on 7 January to the 240,000 strong attendance at the Turn Back the Tide Concert on 24 March was just a media beat-up. After all nothing substantial had changed from the previous year. For example, Water Board officer Leigh Richardson was reported as saying that the sudden interest in water pollution was largely a figment of the media's imagination.⁵¹ And many others besides wondered why there was suddenly so much interest in sewage pollution. Was it just that the papers were short on stories?

However, the politicians were not so immune from public opinion and the government initiated an independent review of the Water Board proposals, although the Minister was careful to assure the Board engineers that he was not bowing to public pressure:

Although the review has come at a time when there has been considerable public debate over the role and achievements of the Water Board and the levels of pollution of Sydney's beaches, the review is not a response to those public comments or pressures.

The purpose of the review... is to ensure that the reputation of the Board and its employees is preserved and that the Board is not seen to be acting as "judge and jury" on matters of public controversy relating to its operations.⁵²

The successful tenderer for the review, the US based engineering firm Camp Dresser and McKee, was announced in March 1989. Their local Australian affiliate, Camp Scott Furphy Pty. Ltd., have had a long association of doing work for the Board including work on treatment plants, according to the Municipal Officers Union. Camp Dresser and McKee representatives, who were working out of the offices of their Australian affiliate, told me that they disagreed with US legislation that requires secondary treatment of all municipal discharges going into the ocean, because secondary treatment may only provide a small improvement over primary treatment. In

Boston, they probably would not have recommended secondary treatment but it was mandatory under the legislation.

Nevertheless, Camp Dresser & McKee confirmed many of my own findings and found the Water Board's extended outfalls would not solve the sewage pollution problems in Sydney. They recommended that treatment at the main outfalls be upgraded, although they stopped short of recommending secondary treatment. They also recommended that \$6 billion be spent on the Board's sewerage system over the following twenty years. In December 1989, the government announced that it would be spending more than \$7 billion over the next 20 years to clean up water pollution in Sydney and surrounding areas.

Conclusions

Many people would like to excuse the Water Board engineers from responsibility for what has been happening on the beaches and in the oceans because, after all, it is the politicians and the Board members who set the budgets and it is other agencies who set the standards to be met. The engineers were only doing their job in coming up with a technological solution that would meet the required standards within the monetary constraints. Yet I found that engineers played an active role in shaping public perceptions and moulding impressions. Their studies set out to justify, legitimate and sell the technological solutions which they preferred, ones that used the ocean for sewage treatment.

For years the Caldwell Connell studies convinced politicians, other government authorities and a whole range of laypeople that the consequences of the deepwater outfalls had been thoroughly researched and that they would work as promised. The Board was aided in this by other government experts and politicians who helped them to keep the extent of existing marine pollution secret.

It was therefore not surprising that most of the early opposition to the deepwater ocean outfalls had come from people who were philosophically opposed to the idea of ocean disposal because they felt it wasted resources,

rather than people who argued that the outfalls would not clean up the pollution. Environmentalists tended to put forward reuse and recycling alternatives without challenging the claims made by the Water Board engineers and their consultants for the deepwater outfalls scheme. Because those engineers retained their credibility as experts, they were able to authoritatively dismiss the alternatives as being too costly and not feasible.

It wasn't until the credibility of the Water Board engineers had been attacked that discussion of alternatives could take place. In fact a large range of new treatment technologies, which were not previously part of the engineer's normal repertoire, emerged following the initial burst of publicity in 1989. Some of these were taken up by the Water Board, trialled and considered for implementation, particularly those that avoided the need for biological treatment that might be sensitive to toxic materials in the sewage.

However, the Board engineers are still to be convinced that the ocean is not a suitable place for sewerage treatment. An annual environmental levy of \$80 per ratepayer was raised to cover the new measures that were recommended by Camp Dresser and McKee and were being demanded by the public. The Board is now planning to spend only 28% of the levy (\$137 million) on reducing ocean pollution and has during this time paid the NSW government \$200 million in dividends. Four years after the decision to clean up the waterways, the Board had still not decided how the treatment plants would be upgraded. The deepwater outfalls were intended to make the problem of sewage pollution less visible and now this has been achieved, I think the Board is hoping people will be happy with less treatment.

At a recent Pricing Tribunal Seminar in Sydney, Bob Wilson, General Manager of the Sydney Water Board said that the Board's main problem was the "emotionalism of the environment." The media fanfare surrounding ocean pollution was based on emotion and had distorted the picture of what the Board considered were the real problems. "Unless we get the science right" he said, "emotion can take

over." What Wilson was concerned about was that the government might be swayed by public opinion to set different priorities from those that he and the experts advising him hold.

It is not the emotionalism of those wanting to protect the environment that we have to worry about, but rather the emotional attachment that some experts have to outdated ideas, professional autonomy and status. Sewerage experts need to learn to respect community concerns for the environment and incorporate them in their designs, not dismiss them as an emotional fallacy.

Notes

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2. Water Board advertisement, *The Good Weekend* (supplement to the *Sydney Morning Herald*) (12 December 1987).
3. The PhD was carried out in the School of Science and Technology Studies at the University of New South Wales.
4. Joel Tarr et al., "Water and Wastes: Retrospective Assessment of Wastewater Technology in the United States 1800-1932," *Technology and Culture*, vol. 25, no. 2 (1984): 246-247.
5. *Ibid.*
6. See for example, T. P. Anderson Stuart, "Anniversary Address," *Royal Society of NSW*, vol. 28 (1894): 16-19.
7. For example, Henry Robinson, *Sewerage and Sewage Disposal*, London: E. & F. N. Spon (1896); Baldwin Latham, *Sanitary Engineering*, London: E. & F. N. Spon, (1878, second edition).
8. Robinson, *op cit.*: 45.
9. For example, The Water Board, *Clear Water. Clean Sand*, brochure; MWS&DB, *Deepwater Submarine Outfalls To Protect Sydney's Beaches*, brochure.
10. See for example, I. G. Wallis, "Ocean Currents Offshore from Sydney," *Sixth*

Australian Conference on Coastal & Ocean Engineering, IEAust (1983): 210.

11. *New Scientist* (16 July 1981).
12. Caldwell Connell, *Sydney Submarine Outfall Studies*, MWS&DB (1976).
13. *Ibid.*: 149.
14. *Ibid.*: 12.
15. Faecal coliform are naturally occurring organisms found in human wastes that are used as an indicator of the presence of sewage.
16. *Ibid.*: 34, 149.
17. For example, Caldwell Connell, *Environmental Impact Statement, Malabar Water Pollution Control Plant*, MWS&DB (1979).
18. Caldwell Connell, *Reconnaissance Survey of Heavy Metal and Pesticide Levels in Marine Organisms in the Sydney Area* (October 1973).
19. MWS&DB, *Environmental Impact Statement, Bondi Water Pollution Control Plant* (1979).
20. Fisheries Research Institute, *Organochlorine Pesticide and Polychlorinated Biphenyl (PCB) Residues in Fish and other Aquatic Organisms in New South Wales*, Part II, Department of Agriculture (undated).
21. I had friends in STOP and in 1989 became a member and spokesperson for STOP myself.
22. *Telegraph* (Sydney) (17 January 1977).
23. *Sydney Morning Herald* (27 February 1989).
24. *Engineers Australia* (21 April 1989): 4.
25. Sharon Beder, *Toxic Fish and Sewer Surfing*, Sydney: Allen and Unwin (1989).
26. A. J. Priestley, Review, *Search*, vol. 21, no. 3 (April/May 1990).
27. Alan Tate and Paul Bailey, "Fish off Sydney Beaches Polluted," *Sydney Morning Herald* (7 January 1989): 1.
28. SPCC, Annual Report 1987-88: 30.
29. Bioaccumulation of Organochlorine Pesticides Near the Malabar Ocean Outfall, Meeting Notes (18 May 1988).
30. Letter from Australian Underwater Federation to W. Forrest, Deputy Director, SPCC.

31. Dietrich Georg, "Engineers Criticised for not Going Public on Pollution," *Engineers Australia* (26 January 1990): 16.

32. For details of these, see Beder, op. cit., chapter 3.

33. Water Board advertisement, *The Good Weekend* (supplement to the *Sydney Morning Herald*) (12 December 1987).

34. Cover note on early copies of 1987 Bio-Accumulation Report.

35. For example, Bob Wilson, Managing Director of Water Board, Sewage Summit, Bondi Pavillion (18 February 1989).

36. Letter from Minister for Agriculture and Rural Affairs, Ian Armstrong, to Minister for the Environment, Tim Moore (13 July 1989).

37. Letter from D. W. Connell, Griffith University, to Peter Fagan, Water Board (4 September 1989).

38. Letter from Jack Anderson, Southern California Coastal Water Research Project, to Tony Misckiewicz, Water Board (24 July 1989).

39. Jack Anderson, "Overview of the Planned Environmental Monitoring Programme," (1989).

40. *Sydney Morning Herald* (17 January 1989).

41. *Sydney Morning Herald* (8 March 1989).

42. Press Release from Minister for the Environment, Tim Moore (3 July 1989).

43. Evening news, all channels (3 July 1989).

44. *Sydney Morning Herald* (4 July 1989).

45. *Sydney Morning Herald* (6 July 1989).

46. *Sun-Herald* (12 March 1989).

47. *Sun-Herald* (16 April 1989).

48. *Sydney Morning Herald* (28 January 1989).

49. *Sun-Herald* (16 April 1989).

50. *Sydney Morning Herald* (26 January 1989).

51. *Sydney Morning Herald* (28 January 1989).

52. *Aquarian* (April 1989).