WATER QUALITY MANAGEMENT

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Introduction

Since comprehensive legislation for water conservation came into force more than 20 years ago, management of water quality in New Zealand has been undertaken almost exclusively through the administration of water rights. This has resulted in a type of management primarily concerned with pollution control, specifically the regulation of pollutants from point source discharges, rather than one dealing with all aspects of water quality problems such as eutrophication, chronic and cumulative effects of pollutants and different cultural needs. In recent years, as the need for 'clean water' has outgrown local water resources in some regions and as New Zealanders have become more environmentally aware and more vocal in their demands for higher standards of environmental quality, limitations of both the water rights system and of the Water and Soil Conservation Act 1967 (and Amendments) have been recognised.

Regardless of what is being managed, successful management attempts to optimise the use of available resources to satisfy objectives. The over-riding objective of water resource management, and hence water quality management, can be cogently argued as being to promote and protect desirable water uses and values, including uses made by natural flora and fauna, while maintaining options for the future (Auckland Regional Authority, 1983a; McBride, 1985; Ministry of Works and Development, 1986).

This report focuses on three perceived deficiencies in the present legislation concerning water quality management which prevent this objective from being fully achieved. Firstly, public perception of water quality and public involvement in water quality management are inadequately addressed in the Act, especially with respect to the early stages of decision making. Secondly, use of the capacity of water to assimilate wastes is one of the major uses defined in the Act and the use with the greatest potential to degrade water quality. However, this use is not based on adequate knowledge of the actual processes occurring or on the constraints imposed on these processes by external factors. Thirdly, control of diffuse source pollution, a potentially major determinant of water quality, is not specifically addressed. Details of water pollutants, additional comments on the present legislation, an account of the process of assimilative capacity and of the importance of monitoring are reviewed in the appendices.

The report is written with two purposes in mind: to clarify the ideas of the authors and their colleagues on this broad topic; and to provide a basis for ongoing research into areas that will contribute to the development of policies for water quality management by the Ministry for the Environment.

2. Perceptions of water quality and water pollution

An individual's perception of a feature in the environment, whether natural or man-made, depends on many interacting variables. These include the individual's cultural, educational and social background, the type and extent of their use (or non-use) of the feature, the surroundings and how these affect the individual and the feature, and the number of other similar features nearby. The attitude towards the feature may change through time as knowledge is amassed or uses and values change. Perception of 'quality', an abstract and relative term, can be expected to be even more complex and subject to individual bias.

In the minds of the public, water quality is often taken to be synonymous with water pollution. An impression of water quality is likely to include not only the present appearance of the water and its surrounds but also any knowledge, whether factual or otherwise, of what may have been added to it at some time in the past and of what is being added to it now. This is reflected in the pilot study of Happs (1986) who showed that perceptions of surface water quality by users and residents in the Hamilton area differed markedly and were complex, subjective and biased. Happs suggested many interrelated factors lead to a subjective understanding of water quality and that many people may have difficulty in agreeing with scientifically-based conclusions. Public perceptions of groundwater quality are just as subjective and people often have greater difficulty agreeing with contrary scientific evidence (M.C. Freeman, Scientist, North Canterbury Catchment Board and Regional Water Board, pers. comm.).

Amongst scientists, there is increasing agreement that water quality can be defined by the physical, chemical and biological characteristics of water (measurable quantities) necessary to promote and protect desired (beneficial) water uses and values (Ministry of Works and Development, 1986; Novotny and Chesters, 1981; Ward and McBride, 1986). Following on from this definition, water pollution is defined as a change in the physical, chemical or biological condition of the water which detracts from any use made of or value placed on the water (derived from the draft Water and Soil Conservation Bill, (Ministry of Works and Development, 1986).

Measurements of water quality based on previously established criteria are objective (although their interpretation may contain subjective elements). However, a definition of acceptable water quality will always be subjective, because any measurements needed to determine the suitability of water depend on the uses made of it, or values held, by different individuals and groups. Any attempt to manage water quality is further complicated by the fact that the characteristics of water that are necessary to sustain a particular use are often incompletely known, and where values are of concern, particularly spiritual and aesthetic values, these can never be adequately measured. It is therefore important to be aware of and to take into account the views of interest groups and concerned individuals.

Until recently the majority of those who make decisions concerning water quality management have not considered people's views other than when specifically required to under the Act (from applicants and objectors to water rights, classifications and conservation orders) or in very wide terms (the "... best public interest ..." Palmer 1984, p.867). At present there is no legal requirement for water managers to do otherwise, yet increasingly, major policy decisions on water resources that depend on public approval and support for their effective operation are being made by water boards. Because there are no statutory guidelines for such decisions (principally water and soil management plans) many boards follow the procedures outlined for preparation of District Schemes in the Town and Country Planning Act 1977 which allow for public input via formal submissions only. Few water boards or local authorities attempt to inform and involve the public throughout the development of a proposal or canvas or consult informally with community interest groups on their views. Exceptions include the Auckland Regional Authority, North Canterbury Catchment Board and Levin Borough Council, the latter concerning spray irrigation of treated sewage effluent (Green, 1987). There have also been very few studies done on what level of water quality people find acceptable for particular uses and what level they would prefer.

In the early 1980s research was undertaken by scientists at the Water Quality Centre, Hamilton, to develop scientific relationships between water colour and clarity (i.e. the appearance of water) and water quality (e.g. Davies-Colley and Wilcock, 1983; Davies-Colley et al., 1984). This research was primarily to allow scientific criteria to be developed to replace one of the many vague and very subjective standards for classified water in the Schedules attached to the present water and soil legislation.

More recently, water appearance has also been seen as an integral part of how the public, especially recreationists, perceive water quality. Because of the popularity of water-based recreation in New Zealand, research at the Water Quality Centre concentrated on the question of whether the appearance of water influenced decisions about the suitability of that water for various recreational uses. To answer this question in regard to lake use, water appearance attributes were used to devise a scheme for classifying the appearance of North Island lake waters into three classes (good, adequate and poor) (Vant, 1987). Observation of recreationists' behaviour at a number of these lakes has shown that the intensity of water-based recreation is not affected by the appearance of degraded or unattractive water, except for swimming. Observation alone does not give any information about the quality of a recreational experience. However, results of the National River Angling Survey also showed that angling intensity was not affected by unattractive conditions, but that the quality of the angling experience was affected (Tierney, 1987). High use water bodies are generally near towns and cities, easily accessible and with suitable facilities. Regardless of the appearance of the water and scenic attractiveness they give recreationists the opportunity to pursue their activity when available time is limited (Tierney, 1987). The question remains whether recreationists, in general, are indifferent to poor water appearance or whether they tolerate it because they see no other option, but would prefer higher quality (Vant, 1987).

The relative importance of various factors concerning water quality may be perceived differently even by specialists. A postal survey (Gerbeaux, 1987) suggested that the main uses or management problems of a given lake are ranked differently by aquatic scientists and lake managers. The scientists tend to identify problems in their own field of speciality. This could lead to confusion in the setting of management priorities.

In addition to the potentially diverse views of individuals, different cultures may view the water quality of the same water body in different ways. Many New Zealanders, especially those who do not use water for recreation may, if they think about it at all, consider discharge into flowing water of secondary-treated sewage effluent an effective, socially acceptable and environmentally safe means of waste disposal. The traditional Maori belief is very different. Some Maori people believe that all waste should be disposed of on land because pollution of a water body is 'contrary to the spiritual value of that body of water and its bestowed use derived from that value' (Patrick, 1987). Since 1975, the relevance of this and other traditional beliefs concerning natural resources held by certain of New Zealand's indigenous people has been increasingly recognised, initially by investigations into Maori grievances by the Waitangi Tribunal and more recently in statutory provisions (e.g. Environment Act, 1986) and in case decisions. The very significant High Court decision by Justice Chilwell concerning water right issues in Huakina Development Trust v. Waikato Valley Authority & Bowater (1987) 12 NZPTA 129, recognises that the '(Waitangi) Treaty and Maori spiritual values are part of the fabric of New Zealand society, to be taken into account in all land and planning issues' (Palmer, 1987). However, Maori metaphysical values are given the same priority as other uses and values in such issues. The implications of this decision on land use, water quality management (especially that of groundwater), policy formation, and the issuing and renewing of water rights have yet to be realised.

At present in New Zealand only classified waters and those on which conservation orders have been placed have uses (and values in the case of conservation orders) defined and protected by law (Water and Soil Act 1967, s. 20A-I, s. 26A-KA). Even this legislation does not prevent the land from being used in a way that negates the effect of the classification or conservation order. For the majority of inland and coastal waters there is no statutory requirement to define desired uses and values or to give priority to any specific use or value; the present and probable future use of the water is usually taken as the basis for decision making.

Integration of people's perceptions, attitudes and values with scientific expertise is essential for meaningful water quality management. Without knowing how people perceive and act towards changes in water quality, water managers cannot know what factors are most important for protecting and enhancing people's values, or at what point they need to step in to prevent deterioration of the water below a level acceptable to the public; nor can they know what is the minimum level of habitat recovery acceptable on economic and social grounds. With increasing involvement of the public in water quality issues managers also have a responsibility to inform and educate.

3. Use of assimilative capacity

Assimilative capacity (or processing capacity) is the ability of the natural environment to accept potential pollutants without impairing its beneficial uses or values. The term is most often applied to aquatic systems as a type of natural waste management, especially of point source discharges. Soil systems also have the ability to process wastes and are also used for effluent treatment. Until recently, there has been a general lack of real understanding of the many constraints which restrict unlimited use of this capacity. For aquatic systems, such constraints include the affect of land use practices (diffuse discharges), the extent of downstream transport of pollutants, the health of the aquatic biota and changing social values. Efficient use of a water body's assimilative capacity requires there to be minimal environmental or social damage with minimal costs to the majority of water users. In the last few years the public has begun to question whether this capacity is being used efficiently.

The present major water quality management legislation, the Water and Soil Conservation Act 1967, specifically recognises discharges of waste or heat into natural water or onto the land or into the ground as one of a number of major beneficial uses (s. 20(5c,ca), s. 21(3); see also Appendix 2). However, the statutory intent of the Act, as interpreted by the courts, is to keep such discharges within limits so that existing water quality is maintained or improved, and as far as possible the biota and ecology of the receiving waters are protected, unless a reduction in water quality is justified in the public interest (Palmer, 1984). Concern over whether waste disposal is a 'beneficial' use of water or whether any reduction in water quality is justifiable in the public interest, either in general or for specific water bodies, has increased in the 1980s, principally as a result of extensive media coverage of environmental quality issues and greater awareness of the value of clean water.

Recreationists, especially anglers, conservationists and a number of Maori people have become increasingly outspoken over continuing degradation of surface water quality, while conflict between all users has escalated in regions where water of acceptable quality is becoming scarce. As a result of changing community expectations and the availability of improved waste management technology, an increasing number of regional water boards have included stricter water quality conditions on both new and renewed water rights. With the recognition in the High Court that Maori traditional values concerning natural water, including spiritual values, should be given equal weight along with all other uses and values during water right hearings, the use of surface water bodies, other than wetlands, for processing wastes may become even harder to justify. Even before this decision at least two regional water boards (in Rotorua and Auckland) were considering alternative options for sewage disposal to specifically take into account Maori values. Already a number of sewage treatment systems in Northland have incorporated wetlands (which are seen by Maori communities as land rather than aquatic systems) as a means of improving the quality of sewage effluent (Venus, 1986). Maori groups will be seeking a total ban on disposal, through sea outfalls, of raw and primary treated sewage in the near future (The Christchurch Press, 1 March 1988).

The benefits of large-scale, land-based effluent disposal systems are slowly being recognised by non-Maori, as well as Maori, people. In-house treatment of wastes by industry, especially agricultural and horticultural processing plants, and land disposal of sewage from small towns is increasing. However, the liquid must eventually find its way to some water body and it is still not uncommon for contamination of groundwater or surface waters to occur as a result of overloading or scheme failure, especially of community sewage treatment schemes (Ayrey and Noonan, 1983; Wilcock, 1984). There is a definite requirement for greater awareness of the available information concerning design of land treatment systems, and of the need to understand the particular features of each site and effluent, if such systems are to become more common.

Recent court decisions concerning both terrestrial and aquatic environmental matters, including those concerning Maori values, clearly reflect current community expectations for greater environmental protection and conservation (i.e. 'wise' or sustainable use). To justify use of the assimilative capacity of a natural surface water body for waste management, water managers need to be able to set precise and flexible conditions that are both appropriate for the specific receiving water and flexible (e.g. flow-related river discharges), and which prevent the discharge from impairing other preferred uses including, if possible, future uses. Setting these conditions requires a much better understanding of the actual processes of assimilative capacity (see Appendix 3) than is currently the case for many managers and needs to be based on objectives that define publicly-preferred priorities for use. The potential capacity to assimilate wastes is principally a function of the combination of natural characteristics unique to each water body and the uses to which the water body and its surrounding catchment are put. Because of this, it is important that water managers have adequate knowledge of both the present water quality of the receiving water, especially the condition of the aquatic biota and their habitat, <u>and</u> of the major present and likely future uses of the water and its catchment and the probable effects of these uses on the water body. Then, where waste disposal is considered a desired use and a water right is granted, conditions imposed will be appropriate.

A more detailed account of the process of assimilative capacity and its potential use in water management is presented in Appendix 3.

4. Diffuse source pollution

Currently water rights control only point discharges of water or waste; control of diffuse (non point) source pollution other than soil deposits[1] is not addressed by any legislation. Yet, as has been found in the U.S.A., water quality may remain poor after all point discharges have been stopped (Smith et al., 1987). Assimilation of natural waste materials washed off land or deposited from the atmosphere is one of the intrinsic functions of water bodies, but where all or most of the assimilative capacity of receiving waters is assigned to point source discharges, there may be little or no capacity left to assimilate these background diffuse source flows. During low flow conditions, whether natural or induced, the diluting benefit of water is reduced and aquatic biota are often seriously stressed; assimilative capacity above background levels may be nil. Where diffuse source loads are excessive as a result of human activity, or are of a toxic nature, the aquatic biota in the receiving water may be modified to such an extent that both the potential assimilative capacity for point source discharges and the value of the water for other uses are considerably reduced.

Surface runoff from land is the primary source of diffuse pollution; diffuse discharges are thus characteristically intermittent and generally related to severe rainfall events. Stormwater runoff may cause both short-term deterioration in the quality of the receiving waters (high sediment and pathogen loads, algal growths from increased nutrient levels etc.) and short-term acute or long-term cumulative effects such as those caused by toxic heavy metals, hydrocarbons and pesticides (Miller, 1983).

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[1] Soil Conservation and Rivers Control Amendment Act 1959, part II, ss. 33-38.

Urban stormwater discharges, arising from runoff from impervious surfaces during storm events, may contain a pollution load greater than that found in diluted sewage (Auckland Regional Authority, 1983b; Novotny and Chesters, 1981). Other potential sources of diffuse pollution include large-scale wind erosion of exposed soil; accidental or intermittent events such as slips, spillages, illegal rubbish dumped into drains or natural surface waters; groundwater from solid-waste disposal sites; irrigation; polluted rainwater; and mammal and bird droppings, and wind blown debris (Thompson, 1983).

The importance of all these contributions to water quality, in terms of the potential reduction in beneficial uses, needs to be assessed if allocation of assimilative capacity between point and diffuse sources is to be undertaken effectively.

In New Zealand, agriculture, horticulture and silviculture are by far the main sources of diffuse pollution, although urban sources of toxic heavy metals and hydrocarbons may have much greater local impact. In rural catchments diffuse source pollution is mostly associated with excessive nutrient applications to soil and disturbed and unprotected lands. This means that control of this type of pollution is essentially a land-based activity (Thompson, 1983). While control may involve management of an entire catchment to minimise overland flow, natural factors such as slope, soil fertility and texture, drainage, type of vegetation cover and stream bed/bank erosion may result in poor correlation between land management and quality of runoff (Thompson, 1983). Management therefore usually needs to be concentrated in the more hydrologically active areas of the catchment (Ward, 1986), those areas of surface saturation or impervious areas which generate surface runoff, and in the zone nearest the receiving water (the riparian zone). Areas of surface saturation are especially sensitive to disturbance and their use and drainage is now known to cause often massive changes in both the quality and quantity of water which reaches downstream users.

Urban and suburban areas within a catchment traditionally contain a large portion of impervious surfaces (roofs, recreational areas, roads, industry yards, etc.) which generate surface runoff even during small rain events. Almost all substances deposited on these surfaces that are not removed by cleaning, wind or decay will eventually end up in surface runoff most of which is collected and discharged through stormwater drains into nearby surface waters or groundwater (Novotny and Chesters, 1981). Although stormwater discharges from sealed areas can require water rights (usually in the form of a general authorisation), the issue of discharges from unsealed areas is less clear. For residential and light industrial areas conditions on water rights, if imposed, have usually been minimal. Reducing the quantity of and improving the quality of stormwater runoff in established urban areas is very difficult because many options are too costly or are impractical to implement retroactively. In addition, natural environment issues are often seen as less important than economic or social issues (Auckland Regional Authority, 1983b; Weeks and Crockett, 1983). Even in new urban developments there may be only minor use of the many structural and non-structural land-based management options available (e.g. maintenance of buffer strips along banks of water bodies, porous pavement, retention basins, etc., Auckland Regional Authority, 1983b; Weeks and Crockett, 1983) because water quality may not have been a major consideration during development of the Regional and District Schemes. However, for some specific areas, concern over the effects of stormwater discharges to surface waters or groundwater is leading to development of policies which will result in imposition of stricter conditions on water rights and stricter District Scheme Performance Standards (M.C. Freeman, pers. comm.; Auckland Regional Water Board, 1987).

In the management of diffuse source pollution in both rural and urban areas, there is clear need for those who make decisions about water quality and use to co-ordinate with those who have control over land use within a catchment. In addition, managing diffuse discharges, the sources of which are usually impossible to trace or prove, requires more than regulatory controls on property owners or technical or monetary assistance; social factors which enhance individual and group co-operation become important. This is because diffuse source polluters, from individuals to large industries and local authorities, exhibit conflicts between self-interest and the public good, between short- and long-term planning goals, and between attitudes and actions (Cary, 1983). To facilitate co-operation, people need to be provided with information via a range of communication channels, both formal and informal, about the causes and consequences of the problem and the appropriate management practices which they can undertake or support. At the same time it is important for managers to understand and take into account the point of view of the people in their region so that resistance to proposals is reduced. People who are aware of all the issues involved and who feel they have some influence on the adoption of land management options for diffuse pollution control may be more willing to support an increase in present costs, such as restrictions on land use or increased rates, because they can foresee the benefits which will accrue to themselves, to their children and their community.

5. Conclusions

Water quality is more than the characteristics defined by scientifically-determined standards. It is also a function of people's perceptions and attitudes towards, and uses for, any given water body. One of the major potential causes of deterioration in water quality is the use of receiving waters to process discharges of wastes from point sources. The capacity to assimilate these wastes without significant damage to social or ecological conditions is a function of the natural characteristics of each receiving water or part thereof, and the uses of the water and catchment. Diffuse pollution is a major determinant of this capacity because it contributes significantly to the pollution load already present when point source discharges are considered.

Current legislation concerning water quality primarily addresses control of point source discharges of wastes by conditions on water rights. The importance of maintaining a healthy biota so that such a use does not preclude other desirable uses needs greater emphasis. The legislation does not deal adequately with diffuse source pollutants since effective control must be land-based, nor does it make sufficient allowance for the understanding of people's perceptions and values concerning water quality and inclusion of these into management options.

There is a need to reform the present approach to water quality management. Firstly, scientific expertise must be integrated with people's perceptions, attitudes and values. Secondly, the full social and environmental costs of using water for waste treatment must be considered along with the benefits accruing to the discharger. Lastly, where necessary, the option to control land use in order to restrict man-induced pollution from diffuse sources should exist. These controls on land use necessitate much better co-ordination of land, air and water management than occurs at present.

In this paper we have looked at three perceived deficiencies in the current legislation concerning management of water quality that prevent full achievement of the principal objective of such management, that is to promote and protect desirable water uses and values, including intrinsic uses and future uses. Our review has shown that problems do exist in these three areas and that alternative management procedures are available, and it highlights some of the issues that will need to be considered when deciding between management options. We have not attempted to provide answers. However, we do consider that to integrate these management activities, the comprehensive review of the legislation now being undertaken by the Ministry for Environment is necessary. We would also like to re-emphasise the need for improved mechanisms for inclusion of social and individual values into determinations of preferred water quality.

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Appendix 1: Pollutants, their sources and impacts

Pollution in New Zealand has tended to be a localised or regional problem rather than a national one since workable pollution control legislation came into force with the Water and Soil Conservation Act 1967. With Government restructuring, all resources are being managed more and more at the local or regional level. Although local and regional bodies have different priorities and demands placed on them in their respective areas, recent developments at the national level, including the current economic and market forces approach, growing public awareness and concern for environmental quality, new technology and the increasing recognition in law of the extent of Maori rights, require development of a more cohesive yet flexible national policy.

Historical emphasis on agriculture rather than heavy industry, low levels and uneven distribution of population and industrial development, abundant high quality fresh and coastal waters and a maritime climate have all contributed to a pollution load lower than other developed countries. However, within the last decade the potential for serious pollution impacts has grown. The type and quantity of pollutants has expanded dramatically as a result of increased use of synthetic chemicals, new technology, and growth in both the light and heavy industrial sectors. New technology is potentially beneficial, but entails high risks including new forms of pollution (World Commission on Environment and Development, 1987). Incidents with potentially disastrous consequences to human health and the environment similar to those occurring in more industrialised countries have already happened in New Zealand (e.g. I.C.I. fire, Penrose, Auckland, 1985). Smaller scale hazardous events such as those that occur during transportation and storage of chemicals occur regularly (Williams, 1985). Yet within New Zealand and overseas there is a popularly held belief, due in large part to our food export and tourist promotions, that New Zealand has a 'clean' environment - which implies that no significant problem exists.

This appendix has been restricted to an overview of <u>water</u> pollution management in New Zealand. However, as most pollutants enter water indirectly from air or land, cross media aspects are an integral part of this study.

The most important pollutants in New Zealand waters, their sources and impacts are shown in Table 1. Details of potential problem toxic wastes are shown in Table 2. The major types of pollutant (from Table 1) are discussed below.

Table 1. Impact of water pollutants (adapted from Baldwin, 1985).

Pollutant and source	Impact
Biodegradable organics from agricultural industry and human sewage	Oxygen depletion, degradation of aquatic habitat, foul odours
Nitrate and phosphate from agriculture, industry and urban wastes	Eutrophication, oxygen depletion
Suspended and deposited sediments and solids from soil erosion, industry and urban wastes	Siltation, degradation of aquatic habitat
Toxic substances (see Table 2)	Chronic and acute toxicity to aquatic organisms, foul odour and taste, domestic water not usable
Metazoa, protozoa, bacteria viruses from human and animal wastes	Infectious diseases e.g. poliomyelitis; diarrhoeal diseases
Heat from industrial cooling	Oxygen depletion, change in aquatic habitat

Table 2: Toxic wastes that are a potential problem for New Zealand waters.

Toxicity	Waste	Source
High human toxicity	PCP (pentachlorophenol) CCA (copper/chromium/ arsenic)	Timber treatment
	Organic solvents	Degreasing, general industrial use, dry cleaning
	Cyanides Chromium sludges	Metal finishing and tanning
	Organochlorines Organophosphates phenoxy herbicides, etc.	Pesticides and herbicides
	PCB's (polychlorinated biphenyl's)	Electrical equipment
	Asbestos	Buildings
	Pharmaceutical wastes	Hospitals, universities, chemical industry
Low human toxicity	Boron wastes Shavings and sawdust	Timber treatment
	Acids and alkalis	Chemical and metal finishing
	Bitumen wastes Oil and tar sludges	Petroleum industry
	Sulphides	Tanning wastes

POLLUTANTS

Biodegradable organics are substances whose breakdown by micro-organisms and fungi requires oxygen and which will, if in sufficient volume or concentration, result in seriously depleted oxygen concentrations in waters. Even a moderate drop in oxygen levels may cause degradation of the aquatic environment. Point and diffuse discharges from many sources are implicated. The problem of depleted dissolved oxygen concentrations in waters is not necessarily solved even if all discharges are stopped because their effect is inextricably linked to that of organic sediments (Hellawell, 1986). Not only do the upper few millimetres of previously deposited sludges and sediment exert an oxygen demand but, if disturbance and aeration of the much thicker anaerobic sediments takes place (for example as the result of a storm or even scouring by a clean water source), oxygen demand may increase by several orders of magnitude (Novotny and Chesters, 1981). In New Zealand, sewage discharge into sheltered waters from boats with holding tanks or chemical toilets is a widespread and growing problem (e.g. The Christchurch Press, 10 December, 1987) that causes localised anaerobic conditions. The visual presence of biodegradable organics and a visibly degraded environment both reduce the aesthetic and amenity value of water bodies considerably.

Organic matter entering groundwater (usually through failure of land-based effluent disposal systems) may cause effects that last for many years because of slow breakdown. If the organic matter has a high level of biochemical oxygen demand the water rapidly deoxygenates and there is no source of replacement oxygen. Further degradation of organic matter in the resulting anaerobic conditions relies on denitrifying and sulphate-reducing bacteria. The dissolution of other components such as iron in the aquifer may also result because of decreased pH and lack of oxygen, causing further water quality problems (Tebbutt, 1983).

Nitrogen (N) and phosphorus (P) are considered the principal limiting nutrients for plant and algal growth. In New Zealand about 70% of the N and about 50% of the P originate from diffuse agricultural sources (Rutherford et al., 1987), although some central North Island waters receiving discharges from freshwater springs have naturally high levels of phosphorus (Forsyth and Howard-Williams, 1983). Excess nutrient inputs have already led to accelerated eutrophication i.e. over-stimulation of plant growth, in many lakes, reservoirs, and estuaries where nutrients, as well as other pollutants, accumulate (Kirk, 1982). Algal blooms, slimes and scums, and excess aquatic plant growth impact on most consumptive and instream uses and values of water.

Suspended sediment, principally from diffuse sources, is the most widespread pollutant of surface water in New Zealand. Many rivers, especially those of East Cape, North Island, and those arising in the Southern Alps, South Island, characteristically carry high sediment loads during high flows (up to 50,000 t km^{-2} yr^{-1}; Griffiths and McSaveney, 1983) as a result of natural erosion processes (Whitehouse, 1984).

Erosion rates for developed agricultural land mostly range between 10 and 1,000 t km^{-2} yr^{-1} (Griffiths, 1981, 1982), but are higher on the east coast of the North Island, on Banks Peninsula and in parts of Marlborough (Duncan, 1987). Topsoil and subsoil contain one or more percent of organic matter, available nutrients as fractions of a percent, and locally may contain significant amounts of pesticides and toxic heavy metals. Sediments, especially organic sediments, also trap nutrients, particularly P, and toxic substances which may be released later into the water column. In many parts of New Zealand, additions of P to water through runoff and soil erosion from pasture were thought to reach more than 10% of maintenance fertiliser phosphorus levels (Ward et al., 1985). Suspended sediments and sediment deposits affect not only aquatic biota and wildlife but also impair most of the major beneficial uses of water including reservoir lifetimes, both water contact and non-contact recreation, agricultural irrigation and domestic and industrial water supply.

Larger, inorganic solid material such as human refuse is not only unsightly but poses a growing threat to the environment. Much of the research on this threat has been concentrated in the marine environment and plastic materials especially, are implicated in the death of marine mammals, birds, fish and crabs which ingest or get entangled or trapped in jetsam (Mattlin and Cawthorn, 1986). The potential harm to wildlife and larger aquatic fauna is not restricted to the sea; it is just as great for inland waters from litter dumped beside or in lakes, rivers and estuaries.

Toxic substances cover a very wide range of materials, including toxic heavy metals, inorganic compounds and synthetic organic chemicals. All have the potential to directly poison or accumulate in aquatic organisms.

Of the 18 heavy metals (including the metalloid arsenic) which are both very toxic and readily accessible, eight are being mobilised by man into the New Zealand environment at rates greatly exceeding those of natural geological processes. These are chromium (Cr), copper (Cu), nickel (Ni), zinc (Zn), mercury (Hg), cadmium (Cd), lead (Pb) and arsenic (As) (Smith, 1986). In low concentrations the first four metals are essential to life while the latter four are non-essential but tolerated. At higher concentrations (still only mg l^{-1}; p.p.m.) specific to each metal, organism and, for aquatic biota, dependent on the physical and chemical condition of the waterbody, all are toxic. Aquatic organisms are continually immersed in water and many are able to concentrate metals from food and water; concentrations which protect these organisms are much lower than the levels necessary to protect human consumers of water.

Natural sources of toxic heavy metals in New Zealand are from weathering, erosion and geothermal and volcanic activity. Background levels of Hg and As are naturally high in some central North Island waters receiving geothermal discharges. Mercury levels in trout from these waters often exceed the limit for human consumption (0.5 mg kg^{-1}, Brooks et al., 1976); similarly, naturally high Hg levels in freshwater eels in Coromandel waters have been recorded (Tracey and van den Broek, 1987).

Human activity through geothermal power development and mining has added significantly to these background levels. Aside from these two sources Smith (1986), in a comprehensive review of heavy metals in the New Zealand aquatic environment, listed transport, industry, urban runoff, municipal wastes, dump leachates and agriculture as the main human-induced sources of toxic metals. Two of these, urban stormwater runoff and sewage discharges (including local discharges from large abattoirs, dairy factories, etc.) were considered to be potential problems requiring further investigation and monitoring. Both sources may contain large metal loads because of their large volumes; of particular concern are discharges to lakes, estuaries and groundwater. Although the toxicity of some metals is reduced considerably in the presence of suspended organic material (including humic substances) in surface waters, the subsequent decomposition of this material and tendency for anoxic conditions in the substrate may release the metal creating a toxic habitat for benthic organisms (Hellawell, 1986). If secondary treatment takes place much of the load is removed from sewage effluent and is contained in the sludge. Depending on the final disposal site of this sludge, local contamination of water may occur.

Overseas, urban runoff is often regarded as a more serious potential water pollution problem than municipal sewage (Kennedy and Williamson, 1986). This is probably also true for New Zealand as untreated stormwater is usually discharged directly into the closest receiving water. Contamination of stormwater with timber preservative (see Table 2) due to mismanagement at timber treatment plants is still recorded regularly in New Zealand, although totally enclosed and roofed drainage systems are becoming more common; yard runoff from fertiliser works, metal re-smelting factories and other small industries can cause local contamination; and very high levels of Cd, Cu, Pb and Zn, principally from vehicle usage, have been recorded during the first flush of both residential and industrial urban runoff (Kennedy and Williamson, 1986).

Localised metal toxicity damage to aquatic biota from point discharges still occurs (Smith, 1985). Smith (1986) also noted several large diffuse source inputs to water that are potentially hazardous and require investigation, namely losses during production and use of superphosphate fertiliser (Cd contamination), antifouling paints from moored boats and boat yards (Cu, tin, Pb, Zn) and air-borne sources (principally Pb). A long-term pollution problem may also exist in some areas from the slow release of toxic metals from previously contaminated sediments.

Some 70,000 - 80,000 synthetic chemicals are estimated to be in common use throughout the world although no complete inventory has been made (World Commission on Environment and Development, 1987). In New Zealand, the number of synthetic organic chemicals in use, and hence potentially in the environment, is unknown but growing. These include many chemicals which have not been adequately tested before release for either health hazard or environmental toxicity; many, such as P.C.B.'s, dieldrin (more toxic than D.D.T., but unlike D.D.T. not in restricted use in New Zealand), endrin, heptachlor and other insecticides, have known very high toxicity and persistence; and others, such as 2,4,5-T and 1080 which have been banned from use in their country of origin (although from 6 August 1987 2,4,5-T is gradually being phased out in New Zealand). At present only the number of veterinary, pharmaceutical and agricultural chemicals in use are known because they are registered (e.g. in 1983, 668 different agricultural chemicals were registered under 3,224 trade names; Agro-Research Enterprises, 1983). No list is available of structural and process chemicals such as those used in the plastic, paint and food industries, as chemical solvents, fire retardants, etc., or of chemicals entering New Zealand along with imports. Annual amounts used, even of registered chemicals is known only for a few specific chemicals.

Although many synthetic organic chemicals are degradable some, such as P.C.B.s and D.D.T. and its derivatives, are now found in low amounts everywhere on earth (Novotny and Chesters, 1981). Major diffuse sources are agricultural and urban runoff and atmospheric fall-out either through direct deposition or following drift, volatilisation or wind erosion; point sources are industry, agricultural discharges, sewage effluents and sludges and dump leachates. Contamination of groundwater with toxic organics, especially volatile organics, is a major problem in Europe and North America yet there is still very little known about their degradation and mobility in subsurface waters (Pettyjohn, 1987). In New Zealand, monitoring of groundwater for potentially toxic chemicals has been rare, being undertaken only in instances of suspected contamination. However, such monitoring has shown that the risks are real. For example, in the North Canterbury area one limited survey of three domestic bores down-gradient from a disused tip showed one bore had 0.41 mg m^{-3} of 1,1,1-trichloroethane, an organic solvent. Although much lower than the U.S. EPA Drinking Water Standard for this solvent of 200 mg m^{-3}, its presence is likely to be indicative of other pollutants not tested for. (M.C. Freeman, pers. comm.)

Common hazardous substances potentially toxic to aquatic biota as well as detracting from human beneficial uses are acids, alkalis, oils and greases. Most freshwater aquatic species prefer a pH near neutral but even the more sensitive species can withstand a pH in the range 6.0-8.5 (6.7-8.5 in marine waters - 1968 U.S. EPA criterion for fish protection; Novotny and Chesters, 1981). Even within this range, changes in pH may have significant indirect effects through modification of the toxicity of other pollutants such as toxic heavy metals, ammonia and cyanide present in the water or sediment (Hellawell, 1986). Although some direct industrial discharges of mineral acids and alkalis still occur (especially from the dairy industry), spills during manufacture, transport or use by industry are the major source. Toxic effects are usually local. Acid rain from burning of coal (the majority -2.7 x 10^{6} t per annum - at Huntly and Mere Mere Power Stations) is not considered a problem in New Zealand because most coal used is low in sulphur (0.8% weighted mean, Smith, 1986). The potential for nitric acid fall-out (derived from nitrous oxides from automobile exhausts and industry) has not been investigated. Oil and grease in quantity sufficient to coat wildlife, biota and sediment are potentially lethal and some oils may be directly toxic at p.p.m. levels (Hellawell, 1986). The present collapse of traditional markets for recycled oil (Allen and NZPA, 1987; N. Oetgen, Managing Director Glydol Oil, Christchurch, pers. comm.) and for grease from the food and wool scouring industries has increased the potential for serious localized but nationwide pollution incidents.

Bacteria and viruses from human and animal wastes reach water primarily from point sources - discharges of sewage and agricultural effluent. However, both urban and rural land runoff carrying bacteria and viruses bound to soil (but still infectious) and in animal faeces can be a potentially large local water problem (Novotny and Chesters, 1981).
A large proportion of bacteria and viruses survive secondary treatment of sewage and, mostly bound to suspended sediment, can travel long distances (20-25 km) in both fresh and marine waters (Lewis et al., 1986a,b). Filter feeders, including commercial shellfish, can concentrate these pollutants. Recent local shellfish studies suggest that although bacteria are removed by cleansing in unpolluted water for five days, viruses are not (Lewis et al., 1986b). Waters containing water-soluble humic substances derived from wetland and organic soils (peats, mulches) are not effective in removing viruses from solution (Novotny and Chesters, 1981). Micro-organisms can penetrate alluvial gravels into groundwater and have been known to travel up to 300 m a day (Sinton, 1984). There have been many recorded instances of health problems caused by microbiological contamination of groundwater used for drinking water both in Europe and North America (e.g. Craun, 1979; Krider, 1987).

Addition of heat to water may cause heat stress or death of sensitive cold water species such as trout, increase the toxicity of many poisons, and may deplete oxygen directly or by enhancing the rate of microbial respiration in organically enriched water. Warm water may also increase the rates of growth and development of certain species, especially some introduced plant and fish species (Hellawell, 1986). Aside from natural geothermal waters, major sources of heat in New Zealand are industrial cooling water and electrical power generation.

New Zealand has three thermal power stations. Thermal effluent from the largest, the 1000 MW Huntly Power Station on the Waikato River, is having an impact on fish movement. Harper (Electricorp, pers. comm.) reports that definite movements of fish into and out of the thermal plume have been observed at different times of the year. Also migratory fish are affected in the summer months when water temperatures are high and the thermal plume lies in the migration path. The extent of these impacts is unknown. Fish larvae suffer high mortality when they pass through the power station. This is both a thermal and mechanical effect and its significance depends on the amount of river water flowing through the station and from which part of the river it is taken.

SOURCES OF POLLUTANTS

The agricultural industry provides the bulk of the pollutant load in New Zealand. Dairy factories, cowsheds, piggeries, meat works, tanneries, woolscours and food processors are still major point sources of organic pollution even though most of these now treat their wastes to some extent before discharge. The first four of these agricultural sources have been estimated (Rutherford et al., 1987) to discharge to lakes and rivers a total load of organic material, N and P (1.8, 1.8, 2.6 million population equivalents (p.e.) respectively) equivalent to half the load produced from human sewage (4 million p.e. for each of these substances, including 1 million p.e. from industry). The remaining effluent (5.6, 3.2, 2.8 million p.e. respectively) produced from these agricultural point sources is mostly disposed of on land as liquid or solid wastes. Accumulation of urine and dung associated with animal containment areas, and land application of effluent, reduce pollutants entering surface waters but often contaminate local groundwater aquifers with nitrates and micro-organisms (Sinton, 1984).

Sediment derived from wind and soil erosion is the largest diffuse source of water quality degradation in New Zealand (Painter, 1978). Vegetation clearance for agriculture, soil disturbance by tillage or poor land management are major contributors. Distinguishing loss of nutrients due to erosion from other diffuse sources is difficult. Rutherford et al. (1987) have conservatively estimated losses of phosphorus from developed agricultural land (10.1 mill. ha.), using a value for available P for unfertilised New Zealand soils, of 0.01-1 kg ha^{-1} yr^{-1}. Other diffuse sources - dung and urine from livestock, fertilisers and nitrogen fixation from grazed pasture - contribute large amounts of nutrients to surface and groundwater (McColl, 1982). Diffuse source P and N losses from improved pasture of 4.4-24 million p.e. (3,000-16,000 t yr^{-1}) and 13-25 million p.e. (50,000-140,000 t yr^{-1}) respectively, have been estimated (Rutherford et al., 1987). Both are markedly higher than point sources.

Irrigation further increases loss of nutrients through leaching (Close and Woods, 1986). Irrigation is by far the dominant consumptive use of water in New Zealand (Heiler, 1985) and its use, particularly in horticulture, is growing rapidly. There is a lack of reliable information on the effects of horticultural practices on water quality in New Zealand although Burden (1982) recorded high nitrate concentrations in groundwater under horticultural land receiving nitrogenous fertiliser.

Diffuse sources of pollutants can not be directly controlled through the present water legislation (but see page 9).

Both the agricultural and horticultural industries use large amounts of herbicides and pesticides, with some compounds having residues with potentially hazardous consequences. The amount and type of pesticides reaching surface waters from agricultural land are primarily functions of the persistence of the compound used, intensity and length of time pesticides have been applied and transport mechanisms from the area of application to receiving waters (Novotny and Chesters, 1981). Until mid-1986 few studies had been carried out on the fate of chemical residues in New Zealand (e.g. Burnett, 1972; Dacre and Scott, 1973; Hughes et al., 1986). The first estimates of pesticide useage in New Zealand are being compiled by staff at the Water Quality Centre, Hamilton. Studies to examine effects of insecticide residues on aquatic life and on 2,4,5-T residues and breakdown products on farmland are currently underway in the Waikato-Bay of Plenty region (Wilcock and Fox, 1987). Many other pesticides used in New Zealand have a greater potential for harm than 2,4,5-T. They also need investigation.

Apart from agricultural industries the other major point source of organic material, suspended sediment, N and P and the major source of disease-causing micro-organisms is human sewage. Of the 197 sewage treatment plants serving populations greater than 1,000, 96 discharge to rivers or lakes with estimated organic material (expressed as 5-day biological oxygen demand, BOD_5), N and P loads of 0.2, 0.6 and 0.7 million p.e. respectively (Rutherford et al., 1987). An estimated 100-130,000 households use individual septic tanks. Because most New Zealanders live or holiday near the coast about 60% of domestic sewage and industrial wastes are discharged to estuaries or coastal waters (Ferrier and Marks, 1982). Poor wastewater discharge practices - no treatment or primary treatment only - exist in many areas in New Zealand (Rutherford, 1984; Calloway, 1985; Quinn, 1985 in Rutherford et al., 1987) and many approved works suffer from major limitations in use (Wilcock, 1984). Failure of septic tank and soakage systems through poor design, construction or maintenance (Fox, 1984), or as a result of inadequate control by local and regional authorities (MacCleod, 1984), especially as regards siting, is common throughout New Zealand. Although usually local in impact, such failures can seriously affect both groundwater quality (Ayrey and Noonan, 1983; Burden, 1984) and surface water quality (Fish, 1987; Ministry for the Environment, 1987).

Where industrial effluents containing heavy metals, toxic organics, oils, etc., are mixed with domestic sewage the efficiency of the sewage treatment may be affected, disposal of sludge becomes a problem (Harding, 1984) and the impact on receiving waters, and benthic organisms in particular, may be considerable (Hellawell, 1987). Further sources and impacts are mentioned in the previous sections on toxic heavy metals and toxic organics.

The timber industry also potentially provides considerable pollutants to waterways. Pollution from normal forestry activities are principally diffuse and include sediment loss during initial vegetation clearance (e.g. increases in sediment yield up to 100-fold in north Westland hill country, O'Loughlin et al., 1980), harvesting operations, general road construction and maintenance, and direct and indirect water contamination following application of fertiliser and other chemicals (Cornish, 1983). Timber treatment produces chemical wastes including toxic metals and sludges with high human toxicity along with less toxic boron wastes, shavings and sawdust. Six of the seven pulp and paper mills discharge treated effluent to rivers, a total pollution load equivalent to a city of 100-300,000 people (Rutherford et al., 1987). Where the effluent is also discoloured as a result of the process, or contains significant amounts of sulphur and organic acids, aquatic communities may be harmed.

IMPACT OF POLLUTANTS ON THE AQUATIC ENVIRONMENT

The impact of pollutants on the aquatic environment is outlined in Table 1. Large amounts of organic waste discharged into water leads to oxygen depletion which may ultimately affect all animals. Feeding and growth rate of juvenile fish are reduced when dissolved oxygen levels are less than 50% saturation and, if low oxygen levels exist for any length of time, death of most aquatic animals ensues. Anaerobic bacteria multiply under these conditions producing compounds such as ammonia, methane or hydrogen sulphide. Both ammonia and hydrogen sulphide are potentially toxic to aquatic biota; both may cause tainting of the water and foul odours. Excessive algal and aquatic plant growth as a result of nutrient inputs from sewage and runoff from developed land, may also produce oxygen depletion especially at night when respiration occurs in the absence of photosynthesis. When these plants die, decomposition by bacteria increases the oxygen demand and levels in the water remain low.

The effect of suspended sediment on the biota is dependent on the nature of the material, including its size, density, potential for bacterial decomposition, nutritive value, toxicity, the quantity present and its duration (Hellawell, 1986). Suspended sediment alters aquatic environments, primarily by reducing light penetration and hence productivity of algae and macrophytes (with a consequent reduction in the biota dependent on them for food, shelter and support), changing heat radiation, blanketing the stream, lake or estuary bottom, and retaining organic materials and other substances that create unfavourable conditions for existing local benthic organisms (Hellawell, 1986; Novotny and Chesters, 1981). Sediment deposition reduces benthic community diversity and indirectly affects fish populations by changing or reducing their food supply, burying eggs and eliminating spawning areas and preferred habitats. Slow exchange of nutrients, particularly phosphorus, and some toxic substances adsorbed onto sediments may occur under aerobic conditions, with greatly enhanced rates of released under anoxic conditions or during resuspension. Deleterious effects of adsorbed substances may be displaced both in time and space when suspended sediments are transported away from their source.

Many pollutants (nutrients, organic chemicals, etc.) are quickly broken down by bacterial, chemical and/or photochemical processes (within 30 days; Allan, 1986a). Those that persist or are transformed into other pollutants are classified as 'conservative' materials while those that degrade with time are 'nonconservative' (Novotny and Chesters, 1981).

Toxic heavy metals and many toxic organic contaminants are conservative. Many conservative toxic organics have low water solubility and high lipid solubility (lipophilic) but some metals such as copper, zinc and cadmium and some organics, particularly those of low molecular weight, are readily soluble given the right physical and chemical conditions and are therefore potentially very mobile in the environment. If these substances enter and remain in groundwater the cost of remedial action can be prohibitive and effects can be long-term relative to a similar incident occurring in a surface water body. This has already happened in some areas of New Zealand, for example the CCA spillage in Masterton in 1981 (Shearer, 1985). In Christchurch, some deterioration of groundwater quality near the disused Waimairi tip has been attributed to leachate from the tip - probably a consequence of the still continuing practice in New Zealand of tipping into open groundwater. (M.C. Freeman, pers. comm.). Recovery of the aquifer is dependent on a variety of factors including contaminant type and amount, and the hydrogeology of the aquifer (for instance, whether the aquifer is unconfined or confined, or whether it discharges to surface waters).

Lipophilic contaminants in surface waters may be bioconcentrated directly from the water column by plankton or they may be strongly and rapidly adsorbed onto sediments and particulate matter (principally clay and organic particles) (Allan, 1986b; Hart, 1983). Until surface sediments are buried, a number of physical, chemical or biological mechanisms, such as a simple change in pH or methylation of toxic heavy metals by bacteria (Hart, 1983) or anoxic conditions, can release toxic contaminants back into the water column. Filter and detritus feeders which ingest particulate matter directly often accumulate large amounts of toxic substances which can be passed up to the food chain to fish and man. Resuspension of sediments through storm events, dredging, disturbance by sediment dwelling biota or current, wave and wind action, increase the chances of interaction with biota (see also page 43). Biota in areas where sediments naturally accumulate are particularly susceptible. One area of growing concern in New Zealand at present is the contamination of the water column from very highly toxic, bioaccumulating tributyl tin and other organotin compounds. These are slow release biocides used in anti-fouling paints for boats (Armstrong, 1987).

Nonconservative toxic organics are often readily mobile, but are usually degraded before they reach water (Allan, 1986a). However, if they enter water directly or persist long enough to be taken up by aquatic biota they or their degradation products may have a dramatic short-term impact on aquatic ecosystems e.g. fish kills. Higher organisms, including man, are unlikely to be at risk unless such compounds enter drinking water supplies.

Toxic substances vary in their effect on aquatic organisms. They may cause immediate death, death over a period of weeks after brief exposure (e.g. Abel, 1980), changes in behaviour or reproductive capacity, or they may not harm the organism but accumulate in it to levels which may harm consumer organisms including man. The responses of any particular organism is complicated and depends upon the nature of the substance, its concentration, physical and chemical conditions of the water, length of exposure and sensitivity of the organism to that substance. It becomes very difficult to predict accurately the responses of biota to given toxic substances (Hellawell, 1986).

It is clear that with any increase in the amount and type of pollutants in the New Zealand environment, protecting the health of aquatic systems for their own sake and for the benefit of New Zealanders will become an increasing problem. Many new chemicals used are not detectable using broad spectrum physical or chemical testing, and biological monitoring, though effective, is costly. Improvement of pollution control at source, especially of diffuse pollutants and hazardous materials, is preferable to relying on improved detection of pollutants after they have entered aquatic systems and caused damage.

Appendix 2: Comments on the Water and Soil Conservation Act 1967[1]

Direct and indirect discharges of waste, or water containing waste or heat, into New Zealand natural waters are controlled by the terms and conditions imposed on water rights[2]. These stipulate the level of pollutants that the water right holder may legally discharge into a particular water body. Regional water boards, and, in the case of an appeal, the Planning Tribunal, grant water rights and the regional water boards administer them within the meaning of the Water and Soil Conservation Act 1967 with amendments. Without a right it is an offence to discharge waste. Since 1983 penalties have become much more severe but because of the difficulty of bringing an actionable case, water boards are not at present finding it worthwhile to prosecute many incidents (E.R. Wood, Chief Executive, North Canterbury Catchment Board, pers. comm.). Some catchment authorities are, however, now using injunctions to stop certain acts (M.C. Freeman, pers. comm.).

Among other functions, water boards are directed to promote the protection of water supplies and the conservation and most beneficial uses of natural water within their region including multiple use, and to have due regard to recreational needs and the safe-guarding of scenic and natural features, fisheries, and wildlife habitats (s. 20(5c) & (6)). They are also directed to safeguard natural water from the risk of damage to the aquatic community from discharges of waste or water containing waste or heat (s. 20(5d)). Some of these objectives are in conflict but no special priorities are conferred under the Act. Following the 1983

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[1] Much of this section is based on Palmer (1984) which should be referred to for a more complete coverage of the law as it stood in late 1983.

[2] Notified uses are not controlled by water rights. These are uses of water which were exercised within the three years before September 1966 and were notified in writing to Regional Water Boards before April 1970. They are lawfully authorised and, at present, water boards have no power to control them. They are still common in every region in New Zealand and some, such as untreated or poorly treated sewage discharges and large scale abstractions, can have a serious effect on water quality. Mining privileges are a special type of water right which retain a right of priority, a right of sale, and over which water boards have no powers to vary the terms and conditions originally imposed without compensation. Virtually all are for water abstraction.

Amendment to the Act, when a member to represent Maori interests was appointed to the now abolished National Water and Soil Conservation Authority (NWASCA), Maori perspectives in relation to natural water were expected to be specifically included in proposals concerning water and soil conservation issues. However, no guidelines or procedures for such inclusion under the terms of the Act were given and many water boards saw little need to change their approach to Maori objections, claims and issues (Patrick, 1987). This stance was backed by case history, especially the decision of the Planning Tribunal in Minhinnick v. Auckland Regional Water Board ((1982) N.Z. Recent Law 190), which ruled that Maori spiritual values or metaphysical concerns could not be taken into account during water right applications (Palmer, 1987), thus prevented legal recognition of nontangible Maori values. The recent overruling of this decision by Justice Chilwell in the High Court (June 1987) goes a long way towards full recognition of Maori values not only with respect to the Water and Conservation Act but in the Town and Country Planning Act, including maritime planning matters. As with other uses and values no special weight is given to Maori values.

If the water has been classified, a regional water board is required to place conditions on water rights to discharge waste to ensure that at least the standards set for the receiving water are maintained. However, because of differences of opinion in the meaning of legislation pertaining to classification, an administrative decision in 1975 has restricted new classifications to those specifically requested (e.g. Stewart Island 1985). At present, only six water regions in New Zealand - Southland, North Canterbury, Wellington, Waikato, Bay of Plenty, and Northland - contain classified waters.

Where water is unclassified the existing water quality may be relevant to the imposition of conditions on water rights. However, justification for refusing or for setting conditions on a water right only to maintain existing water quality, can lead to conflict between water boards and existing or intending dischargers.

Overall, the maximum social benefit appears to be the underlying premise for the whole system of regulation. "Whether the receiving waters are classified or not, the statutory intent is to maintain or improve existing water quality unless a reduction can be shown to be justified in the public interest" (Palmer, 1984, p.874). However, to gauge what the public wants in the way of water quality under the present formal system of public participation through submissions is difficult. Many people are unaware of their right to object to water right applications and even fewer would regularly read the 'public notices' in the local newspaper (where applications are notified) or feel capable of submitting a written objection. The still widely held expectation that water boards are maintaining water in the highest possible state also works against public involvement in the water right process. Without public input, as objections, conditions imposed on water rights for discharge of wastes into unclassified water usually tend to be justified according to the present use to which the water is put or to the perceived view of community expectations by water board staff and/or members. This may lead to downgrading of water quality against 'real' general community expectations.

Water boards are concerned about the absence of statutory guidelines about priorities. They are required to make value judgements on behalf of the community often without definition of community, regional or national priorities. The Bay of Plenty Regional Water Board noted in 1978 that some definition of community priorities could be obtained if the water boards were required to prepare water allocation plans for their regions and if such plans were given statutory force. These plans and more recently, comprehensive water and soil resource management plans were funded and encouraged by NWASCA (since April 1, 1988, this function has been assumed by the Ministry for the Environment) but neither have been reinforced by legislation. Until late 1987 at least seven catchment authorities had prepared or were preparing catchment management plans with enforcement of policies either through the incorporation of the policies into the Regional Scheme (as in Auckland and as intended in North Canterbury), or more usually through the present powers of the water boards.

Other statutes relevant to water quality management are:

Clean Air Act 1972
Coal Mines Act 1979
Conservation Act 1987
Defence Act 1971
Environment Act 1986
Fisheries Act 1983
Harbours Act 1950
Health Act 1956
Local Government Act 1974 and Amendment 1979
Marine Farming Act 1971
Marine Pollution Act 1974
Mining Act 1971
Soil Conservation and Rivers Control Act 1941
Swamp Drainage Act 1915
Tasman Pulp and Paper Company Enabling Act 1954
Town and Country Planning Act 1977

Special purpose legislation to control hazardous materials and activities (see Hide and Ackroyd, 1988, p.7), especially:

Dangerous Goods Act 1974
Fire Services Act 1975
Pesticides Act 1979
Radiation Protection Act 1965
Toxic Substances Act 1979

The relevance of these Acts and their limitations are discussed in a review of legal aspects of land and water management (Auckland Regional Authority, 1983b).

Appendix 3: Assimilative capacity of aquatic ecosystems: processes and monitoring

The capacity of water bodies to assimilate wastes washed off land or from atmospheric sources is a natural function, but not principally a function of water itself. Although some potential nonconservative pollutants, including many inorganic chemicals and a number of toxic organic chemicals such as pesticides are chemically, photochemically or physically broken down in surface waters (Matsumura and Krishna Murti, 1982) , the greatest volume of wastes, biodegradable organics are degraded by biota - principally benthic (bottom dwelling) bacteria, fungi and other micro-organisms. Assimilative capacity is thus nearly totally dependent on a healthy biota. (The biota in turn is dependent on some organic and nutrient input for survival, but there is a limit to the type and amount that can be processed without causing deleterious stress or system damage.) Degradation products and other potential pollutants such as plant nutrients are either utilised by degrading organisms, algae or other aquatic biota, mineralised near the source of input, or transported elsewhere. Through the process of internal recycling a variable but often high proportion of the carbon and nutrients deposited in flowing water will eventually end up in wetlands, lakes, estuaries or coastal waters. For pollutants which reach groundwater assimilation may be very slow or nil (Sinton, 1984), because of a paucity of bacteria and other micro-organisms.

For point source discharges into surface water a right to discharge would normally have conditions imposed on the effluent so that beyond a specified mixing zone, receiving water quality (as defined by a number of measurable parameters) remains within certain limits or unchanged. (Where rights to discharge wastes to groundwater are concerned, somewhat different conditions may be imposed on the water right holder, for example to supply an alternative drinking water supply to dwellings that would otherwise have had access to uncontaminated water.) Some loss of water quality is allowed within the mixing zone while contaminants and water mix. In most instances, it is principally dilution rather than assimilation which occurs within this zone (below some discharges only a very restricted, modified biota may be present). However, water quality outside this zone may also be significantly changed, even for discharges of secondary treated wastes, because excess biological growth, caused b oversupply of nitrogen and phosphorus, often occur downstream of thi zone. In some instances, most of the initial breakdown and utilisatio occurs well away from the discharge (McBride and Rutherford, 1983 Rutherford et al., 1987). Further processing (internal recycling) ma occur and reoccur from the input source to final removal from the aquati system through decay of algae and other plant material and release o dissolved nutrients, scouring of sediments by flood flows with consequen release of nutrients, viruses and buried organic matter, etc. Iner solids, such as plastics, and conservative compounds, which do no degrade or degrade very slowly, accumulate in areas of slow flowin water, especially wetlands, lakes and poorly flushed estuaries. Conservative chemicals, including a number of commonly used pesticides an compounds containing toxic heavy metals, may be internally recycled an continually available to biota (and thus to wildlife and man) for man years.

For classified water, receiving water quality is determined by and base on sets of standards - a list of physical, chemical and biologica parameters which must be conformed with - relative to the intended use o the water. While determination of water quality of unclassified water would usually be based on the same parameters, there is no lega requirement to do so. Water boards are expected to use results of wate quality determinations based on these parameters, especially dissolve oxygen, in an attempt to allocate the assimilative capacity of th receiving water between alternative point discharges while maintainin water quality to protect other desirable water uses (Kirk, 1982) However, there are considerable inadequacies in using the requirement specified in the standards for this purpose. These are as follows:

1. Some of the factors are inadequate for assessing the suitability o water for a particular use; for example monitoring faecal colifor bacteria to assess pathogenic contamination is now considered to giv only a very rough estimate of potential human harm (Auckland Regiona Authority, 1983d; Sillars, 1986).

The limits for three parameters are entirely subjective, i.e. objectionable odour, conspicuous change in natural colour or clarity (although objective methods are available for measuring odour, colour (Wilcock and Davies-Colley, 1986) and clarity (Streamland 56, 1987)). These standards are largely inoperable because of the range of interpretations possible.

A further three very important and easily measured parameters affecting water quality and assimilative capacity are not included in the standards, presumably because the majority of sources are diffuse. These are the plant nutrients N and P (both dissolved and particulate forms), and suspended solids.

. The inherent variability in the behaviour of the substances and parameters defined in the standards between different waterbodies, between different reaches of a waterbody, during different weather conditions, and both diurnally and seasonally, means that the single value or range given is often inadequate in providing even a rough estimate of overall water quality (Auckland Regional Authority, 1983d).

. Only destruction of natural aquatic life by concentrations of toxic substances are limited even though it is now known that stress or death of aquatic biota may occur at least as frequently as a result of the total loading of toxic materials, especially of conservative substances.

. Most importantly, the distribution, diversity and condition of aquatic biota, the major determinants of assimilative capacity, are not required to be considered when measuring water quality (unless a concentration of toxic substances is involved).

ariability in physical and chemical parameters and biota is due to omplex interactions between the intrinsic properties of individual water odies, historic factors such as previous storm events, population ynamics of biota, and external modifiers. External modifiers include ater abstraction, land use, especially of hydrologically active areas and of riparian land, and climate. For any part of an individual surface aquatic system, i.e. wetland, stream, river, lake, estuary, or coastal waters, and often for individual reaches of these ecosystems, a unique combination of physical, chemical and biological components is present. Physical components include flow rate, water velocity, flushing rate and pattern, depth, substrate or bed characteristics and presence and extent of stratification. Chemical components include pH, percentage saturation of dissolved oxygen, background and concentrations of the major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}), the plant nutrients P (PO_4^{2-} and low molecular weight organic P compounds) and N (NO_3^{-} and NH_4^{+}), and dissolved organic matter (including humic acids). The sum total of physico-chemical components, along with external influences and historic factors, determine the diversity and abundance of flora and fauna present within a reach at any one time and thus potential assimilative capacity.

Measurement of specific physical and chemical components of water, as is conventionally undertaken at present, is usually easier than undertaking a biological investigation and the results are perceived to be more specific and more restricted in their interpretation than results derived using biological methods (Carter, 1984). However, even comprehensive sampling of physico-chemical parameters (and such sampling is rarely undertaken) necessitates making assumptions on the interactions which occur between these parameters and the biological components of the aquatic system. Such assumptions may well prove wrong. For example reducing the biochemical oxygen demand in discharges to the Manawatu River did not result "...in the expected decrease in community respiration and dissolved oxygen depletion" (Rutherford _et al._, 1987, p.156). Although the biomass of sewage fungus organisms decreased, the nutrients remaining in the waste stimulated growth of algae which have higher respiration rates than sewage fungi.

To obtain adequate knowledge of the capacity of the aquatic system to process wastes without deleterious change or damage it is essential that at least some critical assessment is made of the species, condition and productivity of the biota of both the water body as a whole and of individual reaches into which point sources are discharged. Although the commitment of time and human resources in biological surveillance is high the information content of the results is also high when data analysis methods are adequate (Hellawell, 1986). Since biota are continuously exposed to all the variations in environmental quality their response is an integrated one: they reflect the impacts of extremes of stress and respond to intermittent discharges and sustained low-level pollutant loads, all factors which may go undetected by periodic physico-chemical monitoring. Furthermore, the condition of the biota is directly related to the amenity value of the water body; a person's perception of water quality may be highly dependent on the presence or absence of biota such as fish, aquatic plants or algal scums.

At least eight of the 19 catchment authorities have tried to correct their lack of information concerning aquatic biota in their regions by employing biologists to carry out both baseline studies (assessments) of species presence and condition, and biological monitoring. Most authorities have also attempted to overcome the other inadequacies inherent in the standards in different ways. These include creating (and acting on) polices designed to protect natural waters. Examples are:

(1) prohibiting all discharges of toxic substances into natural waters if a sewage system is available (although many sewage systems in New Zealand just move the toxic substance to another water body, usually the sea but in some cases to groundwater),

(2) encouraging re-use of waste water or effective land treatment of waste,

(3) requiring dischargers to find alternative means of disposal during summer low flows.

Some authorities include additional or alternative parameters to those mentioned in the standards in monitoring programmes and in conditions for water rights.

Even though many authorities, scientists and water managers do not consider the standards, in their current form, adequately protect the aquatic system or maintain water quality at the level now desired by many New Zealanders, some still consider classification and hence the standards an adequate protection of water quality (e.g. Southland

Catchment Board; Wellington Regional Council (W.R.C. have put forward a proposed classification for the region's coastal and fresh waters -Davis et al., 1985)). Perhaps the major reason for continued classification of waters is the statutory basis of the classification system.

The only way accurate information can be obtained on the condition of waterbodies is via water quality surveys and monitoring. The information obtained from monitoring programmes is not only necessary for effective management but can also influence the way management is undertaken (McBride, 1985). Of particular relevance in this regard is the major inter-agency project (Water Quality Centre, Hamilton, Hydrology Centre, Christchurch and MAFFish) to develop a model relating periphyton, invertebrate and fish abundance to the hydraulic and water chemistry characteristics of New Zealand rivers, due for completion in late 1989. Of the 100 rivers initially surveyed 17 have been chosen, on the basis of nutrient status, to be sampled monthly for one year. The information gained should enable water managers to objectively predict, for the first time, the most probable type of community which will result from given changes in a number of conventionally measured environmental parameters. It should also allow development of flexible receiving water standards for rivers. When applied correctly (which assumes an adequate understanding of the biology of the receiving water) these will allow water managers to come closer to achieving minimal environmental damage at lowest cost (i.e. efficient use of assimilative capacity) than at present.

The majority of monitoring undertaken by water boards is compliance monitoring to check whether effluent standards attached to water rights, or classified standards set for receiving waters, are being met. Monitoring is also often undertaken before a major water right is granted and dischargers may be required to monitor specified variables in their own discharge as a condition of their water right. However, most water boards undertake monitoring only after problems occur. Although it has been estimated that $5 million/year is spent on water quality monitoring in New Zealand (Ward and McBride, 1986), few organisations have regular monitoring programmes.

Effluent and receiving water standards are based on scientifically-derived criteria, which are maximum (and/or minimum) values of specific parameters (e.g. pH, dissolved oxygen) or concentrations of pollutants in surface waters which give a defined degree of protection to specific beneficial uses of that water. For toxic materials, criteria are now generally based on acute (death) and chronic (affecting behaviour, growth, reproduction, etc.) toxicity tests, with the former being used to derive long-term values by using an 'application' or 'safety' factor (Hellawell, 1986). These application factors usually err on the side of safety because they are meant to protect aquatic organisms (and man) in the natural environment from the limitations of using data derived from standardised laboratory-derived toxicity tests. Such limitations include the modifying affect of other materials - sediments, suspended particulates, organic matter - which may heighten or reduce the effects observed in the laboratory, the effects of untested or unknown chemicals or the unexpected or interactive effects of tested chemicals, and the variable responses exhibited by organisms, especially the responses of non-test species (Hellawell, 1986).

The criteria developed by the U.S. Environmental Protection Agency (EPA) for toxic heavy metals and some toxic organic chemicals are usually used as guidelines by regional water managers in New Zealand when assessing the existing or possible effects of discharges on receiving water quality. However there is no explicit legal requirement for their use and the actual decisions by water boards are often made on an arbitrary basis (e.g. Smith, 1986, p.54), often with little regard for protection of aquatic life. Recent studies on heavy metal accumulations in some Coromandel streams have also shown that EPA criteria for heavy metals based on hardness are not always adequate to protect New Zealand aquatic life (Livingston, 1987).

More research is needed on the effects of heavy metal discharges in New Zealand aquatic systems (Penny, 1987; Smith, 1986) while the effects of toxic organic substances on New Zealand biota are barely known, being limited to studies of a few pesticides (e.g. Solly and Shanks, 1969; Wilcock and Fox, 1987). It has recently been proposed (Livingston, 1987) that to set adequate water right conditions for toxic substances in New Zealand, with our current state of knowledge, substantiated water quality criteria (such as U.S. EPA criteria) should be used or taken account of when setting discharge levels and at the same time the acceptable degree of ecosystem stress should be ascertained for uses and values defined (after discussion with community interest groups, water managers and dischargers) for the receiving water. Monitoring of the receiving waters and biota would establish how well the system is responding to the set parameters. Allowance should be made in the conditions for levels of discharge to be adjusted, to zero if necessary, in an iterative process.

Where use of assimilative capacity to process wastes is recognised as desirable adequate knowledge of the potential capacity should be obtained prior to its use if possible, using both physico-chemical and biological parameters. Although regional water boards generally agree that forms of biological monitoring are useful additions to the methods available for assessing water quality, they perceive a need for standardisation of sampling techniques, development of procedures for correlating biological parameters with physico-chemical ones and assistance with sampling programme design, with emphasis on objectives (Carter, 1984). Greater scientific guidance to aid the process of setting adequate conditions on water rights for discharge of toxic substances is also required until such time as criteria are defined for New Zealand aquatic ecosystems or overseas criteria are used to formulate legal standards.