SCIENCE & RESEARCH SERIES NO. 31

CONSERVATION GUIDELINES FOR ASSESSING THE POTENTIAL IMPACTS OF WASTEWATER DISCHARGES TO WETLANDS

by

Dr J G Cooke

Published by
Head Office,
Department of Conservation,
P O BOX 10-420,
Wellington

ISSN 0113-3713
ISBN 0-478-01283-7

National Library of New Zealand
Cataloguing-in-Publication data

Cooke, J. G.
Conservation guidelines for assessing the potential impacts of wastewater discharges to wetlands / by J.G. Cooke. Wellington [N.Z.] :
Head Office, Dept. of Conservation, c1991.
1 v. (Science & research series, 0113-3713 ; no. 31)
Includes bibliographical references.
ISBN 0-478-01283-7
1. Land treatment of wastewater--Environmental aspects. 2. Waste disposal in the ground--Environmental aspects. 3. Wetlands--New Zealand. 4. Wetland conservation—New Zealand
I. New Zealand Dept. of Conservation. II Title. III. Series: Science & research series ; no. 31.
333.91814

Keywords: wastewater, discharges, guidelines, impact, wetlands, review

TABLE OF CONTENTS

CONSERVATION GUIDELINES FOR ASSESSING THE POTENTIAL IMPACTS OF WASTEWATER DISCHARGES TO WETLANDS[1]

by

Dr J G Cooke

Water Quality Centre, DSIR Water Sciences, P O Box 11-115
Hillcrest, Hamilton

SUMMARY

This report is intended for Conservation Officers responsible for the assessment of the potential impacts of a wastewater discharge to a wetland.

The report is divided into two main sections. Chapter II reviews the ecological impacts which wastewater discharges may have on wetlands. The material in Chapter II is intended to be suitable for either conservation officer or scientist who wish to obtain an overview of the subject. Some general guidelines are also given on the effects which a wastewater discharge may have on other wetland functions.

Based on the review, Chapter III presents some practical guidelines for undertaking an assessment of a waste discharge proposal. This chapter is split into two main sections; the first being the 'preliminary screening' of a proposal. The level of evaluation relies largely on existing data and can be carried out by DOC staff. Based on the findings of the preliminary screening, a more detailed evaluation of certain aspects of the proposal may be justified. An outline of the elements that may be required for such an evaluation are given in the second section of Chapter II. It is likely that the responsibility for carrying out any detailed evaluation will rest with the discharger. Therefore this section is provided more as a guide to assisting in the selection of the elements which DOC may consider require further evaluation, rather than a guide on how to carry them out.

A flow diagram is given at the end of Chapter III which can be used to 'audit' potential discharges, and to gauge the degree of effort required to evaluate such applications. Some resource material is provided in appendices, Included are some references to wastewater composition, a glossary of technical terms used in the text, and a compilation of suggested specialist contacts.

---

[1]**Contract funded by Waikato Conservancy, DOC. Report prepared September 1988.**

I. INTRODUCTION

A. Wetlands - a definition

In their 1983 report, a task group commissioned by the Environmental Council[42] defined "wetlands" as:

A collective term for permanently or temporarily wet areas, shallow water and land-water margins. Wetlands may be fresh, brackish or saline, and are characterised in their natural state by plants and animals that are adapted to living in wet conditions.

Although this definition is general enough to describe wetlands for policy and legislative purposes, it is worth emphasizing that the main characteristic of wetlands that differentiates them from other types of waterbody† is the intimate association between land and water. Thus, although lakes, rivers, and estuaries may have wetland margins, their response to wastewater inputs is determined dominantly by aquatic processes. In wetlands, by contrast, response to wastewater inputs determined by a fine balance between terrestrial and aquatic processes.

B. The need for this document

The Environmental Council report[42] noted that New Zealand's indigenous wetland resources have been, and continue to be, severely depleted. The task group reviewed the ways in which wetlands were "exploited, farmed, or used" in New Zealand, and although they noted that wetlands were being used for solid-waste disposal and as spoil dumps, there was no mention of wastewater discharge to wetlands.

† Lakes, rivers, estuaries

1. Increased interest in the use of wetlands for disposal of wastewaters

Since that time, however, the concept of using wetlands for the disposal of wastewaters has become increasingly popular. The reason for this is twofold. Firstly it is now recognised that wetlands can be extremely cost-effective at removing a variety of pollutants from wastewaters. Secondly there is increasing understanding of the Maori perspective on waste disposal, which opposes direct discharge of sewage[¶] into natural waters because it is an affront to its wairua[§] and therefore affects the mana of those who use it. Land application is the traditional Maori method of waste disposal and wetland wastewater treatment is more acceptable than other conventional treatment methods.

These two factors have led to a proliferation of schemes ranging from primary treatment of sewage from small Northland communities,[26] to large scale tertiary treatment in combination with spray irrigation.[!!] Wetlands are also currently being used for disposal of industrial wastewaters, an example of which is the disposal of coal mine wastewaters into Kimihia wetland near Huntly.

2. Prediction of future pressures on wetlands

In the U.S. natural wetlands are generally classified as 'waters of the US', which means they are afforded the same protection as other waterbodies with respect to wastewater additions. Despite this, the USEPA recognises that wetlands can serve as a low cost alternative to advanced[‡] wastewater treatment prior to discharge into a lake, river, or estuary[3]. There is now sufficient evidence to suggest that NZ planners and engineers will follow the U.S lead and that there will be increased pressure to utilise natural wetlands for waste disposal. For example, the use of wetlands in this manner was one of the alternatives considered for disposal of treated sewage from Auckland City. Also natural wetlands are, in effect, being used for post-tertiary nitrogen treatment in the Rotorua situation.

¶ Irrespective of the form of conventional treatment

§ Spirit

!! Rotorua City Sewage Disposal Scheme

‡ But not secondary

3. Review of resource statutes

Although we cannot predict the outcome of the review of resource statutes currently in progress with any certainty, it is likely that legislation arising from the review will take wetland-specific functions into account. For example, the draft (MWD)[§] Water and Soil Bill (June 1986) has provision for any water body to be given special protection[¶] where such a water has an outstanding special purpose of a scenic, scientific, or recreational character. Clearly many wetlands could meet these criteria, and it is therefore timely to question how discharge of wastewater may have a direct bearing on the suitability of the waterbody for the specific use envisaged.

4. Promotion of constructed wetlands

There is, currently in New Zealand, a sustained effort towards marketing the use of constructed wetlands for wastewater treatment. It is argued by proponents of constructed wetlands that they provide a cost-effective alternative to conventional waste treatment systems, especially for rural or beach settlements where the cost of conventional treatment systems cannot reasonably be met by the community. Constructed wetlands cannot be compared with natural wetlands in terms of diversity of habitat and range of functions which they fulfill, nevertheless it is true to say that the treatment processes occurring in constructed wetlands also occur in the natural situation. In theory, at least, constructed wetlands afford better control over these treatment processes, and therefore greater removal efficiencies can be achieved. In addition constructed wetlands have the advantage of not threatening the ecology of a natural wetland, and conversely may even provide additional wildlife habitat.

Constructed wetlands are beyond the scope of this document, but it is noteworthy that there is an increasing body of evidence to suggest that they are not the panacaea for all wastewater treatment[39]. Venus[39] cautioned on the use of such systems for large-scale applications in New Zealand, until further research has been done.[!!]

Although it is not the purpose of this document to provide a means of evaluating constructed wetland proposals, the similarity to the 'treatment' processes

---

[§] A departmental document only. It was never introduced into Parliament.

[¶] Class S

[!!] Using endemic species

occurring in natural wetlands[§] will enable the astute reader to put the claims made by proponents of constructed wetlands into some perspective.

5. Conflict with conservation?

Wetlands are also known for their important functions and values in the natural environement[42]. Wetlands provide a valuable habitat for many plant and animal species as well as performing important hydrologic and pollutant buffering. functions. The protection and maintenance of these functions is one of DOC's main tasks with respect to wetlands and has provided the impetus for the commissioning of this report.

Given that wetlands have these important functions, the conservationist may justifiably ask "why use wetlands at all for the disposal of wastewaters?" The cynical answer to this might be that it is because it is 'convenient' to do so. While this may be the case in some instances it should also be recognised that there are also a number of valid reasons why wetlands are considered for wastewater management. These are:

(i) A wetland may be the only aquatic system available for discharging wastewater. In some areas,[¶] the soils and/or groundwater levels may not be conducive to land application. These physical factors in combination with the Maori views on waste disposal may make wetland disposal the only reasonable alternative.

(ii) For sewage disposal schemes where nutrient removal is a major requisite, there may be a choice between advanced conventional treatment with surface water disposal, and secondary treatment with wetland disposal. In the Rotorua situation, advanced treatment plus land and wetland disposal, was the preferred option due to a combination of cultural, scientific and economic factors.

(iii) For partially drained or altered wetlands, wastewater discharges may restore flows thereby achieving wetlands restoration/preservation as well as wastewater treatment objectives. This appears to be the case in the Coal Corporation discharge of the Huntly East mine waters to Kimihia wetlands. Without the continuation of the discharge, the wetlands would cease to exist.

---

§ See Chapter II

¶ e.g. Parts of Northland

C. Who should read this report and how is it structured?

There are, therefore, instances where a reasoned case can be made in favour of using a natural wetland for wastewater disposal, and in some cases, wastewater treatment. The job of Conservation Officers is to decide whether such use will detrimentally affect other wetland functions, and if so, to put up an equally reasoned case why discharge to the wetland should be opposed. This report is intended to aid Department of Conservation (DOC) staff in making such an evaluation.

In giving these guidelines it must be recognised that what we are talking about is basically an assessment of risks. Wetland ecosystems are extremely complex and, in many respects, poorly understood. Therefore in a lot of instances the satisfactory resolution of a particular issue is a complex matter and best handled by a specialist. There are, however, a number of preliminary analyses which can be made which will establish whether or not there are significant grounds to oppose a particular discharge proposal. This report concentrates on these preliminary analyses. Sufficient information is also given to provide an 'outline' for a detailed evaluation of a discharge proposal. This should provide sufficient background to enable DOC staff to audit the contribution of a specialist consultant, and/or suggest additional aspects which need to be considered for a detailed evaluation.

The report is divided into 2 main sections. Chapter II reviews the ecological impacts which wastewater discharges may have on wetlands. The material in Chapter II is intended to be suitable for either conservation officer or scientist who wish to obtain an overview of the subject. Based on the review, Chapter III presents some practical guidelines for undertaking an assessment of a waste discharge proposal. This chapter is intended to be used primarily by conservation officers charged with assessing whether a particular waste discharge proposal will constitute an unacceptable threat to wetland values. A flow diagram is given at the end of Chapter III which can be used to 'audit' potential discharges, and to gauge the degree of effort required to evaluate such applications. Some resource material is provided in appendices. Included are some references to wastewater composition, a glossary of technical terms used in the text, and a compilation of suggested specialist contacts.

II. ECOLOGICAL IMPACTS OF WASTEWATER DISCHARGES TO WETLANDS - A REVIEW

A. Functions and uses of wetlands

Since the primary reason for DOC involvement in assessing wastewater discharges to wetlands is to be an advocate for their protection, it is pertinent to ask how wetlands are different from other aquatic systems. Why is it necessary to have separate guidelines for discharges to wetlands and rivers for example? The answer lies in the soil! And also the water. That is, wetlands represent a transition between fully terrestrial and fully aquatic ecosystems. As such they are usually hydrologically slow-moving systems, as opposed to the free-flowing nature of most rivers and streams. Their functions and uses cover a broad range of ecological, water quality and hydrological values (Table 1).

1. Geomorphology

Wetlands can fulfill an important role in erosion control. By dampening the peak flows during flood events, wetlands can help reduce the loss of sediment by scour and bank erosion downstream. The Lammerlaw and Lamrnermoor plateaux in eastern Otago are examples of mountain wetlands which help perform this important function. Additionally, by acting as giant sponges during wet periods, they help to sustain water flow of the catchments they supply during periods of drought.

2. Hydrology

As well as dampening the magnitude of flood waves, wetlands also diminish the total volume of flood waters by acting as a temporary store. The Whangamarino wetland system in the Waikato is used in this way. When in flood, part of the Waikato river is diverted into the swamp via Lake Waikare. The water re-enters the Waikato some 3-4 weeks later by which time the flood has passed.

TABLE 1 Primary wetland functions and values

1. Geomorphology	
	Erosion control
2. Hydrology	
	Flood control
	Saltwater intrusion control
	Groundwater supply
3. Water quality	
	Water quality enhancement
4. Ecology	
	Wildlife habitat
	Habitat for threatened and endangered species
	Waterfowl breeding habitat
	Freshwater fisheries
	Aquatic production
	Nutrient material cycling
5. Cultural resources	
	Maori values
	Harvest of natural products
	Recreational resources
	Landscape values

The volume of water contained in wetlands also creates a groundwater pressure that can prevent saltwater intrusion into public water supplies. This is important especially in coastal holiday communities where freshwater wetlands interface with an estuarine environment.

The role of wetlands in groundwater recharge is dependent on the type of wetland. Some wetlands are completely isolated from the groundwater system whereas others are a continuum of it. Floodplain wetlands may contribute to groundwater recharge by overbank storage.

3. Water Quality

The ability of wetlands to act as natural filter systems for nutrients and other pollutants is the reason for their use in waste management systems. It should be appreciated in any evaluation of potential wastewater additions, that many wetlands are already performing a valuable function in enhancing the water quality of runoff waters. This point is elaborated further in section B.

4. Ecology

Wetlands provide habitat for a very large number of plant and animal species, their numbers being out of all proportion to the size of the resource. Of the birds which are regular visitors to New Zealand or are permanently resident and breeding, 22% have wetlands as their primary habitat, and a further 5% have wetlands as an important secondary habitat. Several birds, such as bitterns, and rails, depend for their very survival on largely unaltered wetlands. The Environmental Council report[42] noted that some of these birds are rare[§]. and there are others, such as the fernbird, which may be considered endangered.

Wetlands are also important in the life cycle of commercial fisheries such as whitebait[¶], and vital to the increasingly rare mudfishes which spend all their lives in freshwater wetlands.

Some of our freshwater wetlands also provide habitat for rare and endangered plants. The tallest of our native trees, the kahikatea is now seen only as scattered remnants on lake margins and in wetlands where once it covered whole flood plains[42].

[§] For example 25% of the NZ bittern population lives in the Whangamarino wetland.

[¶] Inanga, and Kokopu

Other plant species may definitely be considered endangered, for example the giant jointed rush *(Sporodanthus* sp) which is only found at Moanatuatua bog (Waikato), the Kopuatai peat dome (Hauraki) and Chatham Island.

It may be noted that despite the broad range of ecological, water quality and hydrological values that wetlands possess, present legislation does not acknowledge these wetland specific considerations. Typically if classified, wetlands are associated with the use classification of the adjacent water body.

5. Cultural resources

Wetlands have always had particular significance to the Maori. Their significance to Maori communities extends beyond simply a source of food. For centuries Maoris harvested flax to make clothing and mats and also other plants for their herbal properties. One or two cottage industries utilizing flax still remain.

The preservative properties of swamp environments have led to many important discoveries of Moa skeletons and Maori artifacts. The likelihood of wetlands being a repository of such records of the past is an important consideration where waste disposal is being considered.

The use of wetlands by duckhunters is well known and appreciated. Perhaps less appreciated is the increasing use of wetlands for passive recreation. The general public and tourists are coming to appreciate the immense beauty of some of our wetlands, particularly where they have been made more accessible by the provision of carefully designed boardwalks. Examples of such walks include the Mangrove walk at Waitangi, the Dobson nature walk at Arthurs Pass and a wetland walk in the Whangamarino wetland (lower Waikato).

B. Changes to wetland functions arising from waste discharges

While not every wetland will possess all the functions and values listed above, the existing values must be identified for every site being considered for waste disposal. Only by identifying these functions, can a rational judgement be made on the likely impact of a wastewater discharge. The remainder of this chapter reviews the effects of wastewater discharges on wetlands which have been reported in overseas studies, and discusses implications of these results in the context of impacts to wetland functions.

Changes to wetlands arising from wastewater discharges that may lead to unacceptable conditions or can serve as indicators of change are listed[37]:

- Changes in species composition
- Nuisance growth of algae
- Alteration of organic accumulation rates
- Heavy metal accumulation in food chains
- Net export of nutrients and suspended solids
- Groundwater contamination
- Indication of pathogen problem
- Damage to adjacent ecosystems
- Downstream eutrophication

These changes are manifest principally through impacts of wastewater on the hydrology, water quality, and ecology of the wetland.

1. Hydrology

Unless a wastewater has a toxic component, it is typically the changes to the hydrological regime which has the most impact on wetland ecology. Excessive changes to the hydraulic loading of a wetland can either convert the wetland to a different wetland type, or severely damage the wetland to the point where plant and animal assemblages are threatened[6].

Change to the hydrologic regime can manifest itself in several ways. Firstly, marked changes in water velocity will affect the deposition of sediment, undermine vegetation, and cause erosion, all of which will influence plant zonation[30]. Increases in velocity also may decrease the areas of stagnant water, increase oxygen circulation, which will in turn lead to an increase in species diversity. Secondly, the residence time of a wetland may be changed by wastewater additions. The residence time is, in effect, an index of the availability of a parcel of water. This is reflected to some extent in the availability of plant nutrients, dissolved oxygen and organic matter. Thirdly, wastewater additions may influence the seasonal rise and fall of the watertable[§].

[§] The hydroperiod

If the wastewater is a major component of the water budget then the natural hydroperiod may be masked. This may affect the diversity of plant life in a wetland since higher diversities are encountered where water levels fluctuate, particularly with a marked period of drawdown which encourages germination[40].

Additionally, increases in the total water volume brought about by wastewater additions may increase the frequency and depth of flooding. The depth of water also has a bearing on nutrient removal. Nutrient (and other pollutant) removal requires intimate contact between the wastewater and the wetland soil, litter and vegetation[30]. Any increase in water depth will decrease that contact and lead to a reduction in pollutant removal efficiency.

2. Water quality

The water quality impacts of wastewater loading to wetlands pertain primarily to organics, nutrients, metals, pathogens and suspended material.

a) Organics

Wastewater additions affect the organic regime of a wetland principally in two ways. Firstly so long as there is oxygen (or an oxidant) in the water column or at the sediment-water interface, wetlands will oxidise organics from the wastewater. Natural wetlands have been reported to remove from 70-96% of the influent BOD of secondary-treated sewage[36]. However, such oxidation is achieved at a price, namely the depletion of dissolved oxygen in the water column. This can have a deleterious effect both on fauna and flora (see later section on Ecology). Secondly, wetlands are believed to be detritally-driven systems[36]. Wastewater additions may induce changes in detrital cycling since the microorganisms responsible for degradation of the detritus are highly sensitive to pollutional stress and environmental conditions[17]. However, the results of studies on wastewater impacts on detrital cycling have been contradictory[36], with one showing that there is a build up of dead plant material in the litter layer of a wastewater-treated wetland, but another showing no difference in litter build-up in treated and untreated sites. The long-term effects of wastewater on detrital cycling are not known at this time.

b) Nutrients (nitrogen and phosphorus)

Nutrient transformations enable wetlands to assimilate increased levels of nutrients from wastewater sources. Nutrients can undergo a myriad of transformations in a wetland. In fact all transformations which can occur in conventional waste treatment systems can also occur in wetlands. In order to understand the possible problems associated with nutrient loading from wastewaters it is necessary to understand the principal transformations of nutrients occurring in wetlands. "Transformations" is underlined to emphasize that with the exception of two mechanisms nutrients which enter wetlands are retained by them, albeit in an 'unavailable' state. The two exceptions by which nutrients are permanently removed from the wetland are ; (1) hydrological export, and (2) denitrification. While hydrological export represents a permanent loss from the wetland ecosystem it may represent a gain to other ecosystems downstream. This in fact represents one of the main problems of excessive wastewater nutrient loading to wetlands; that of export to sensitive waterbodies downstream.

Denitrification is the only mechanism whereby nitrogen added to a wetland in wastewater can be permanently lost from the aquatic environment. Denitrification is a bacterially-mediated process in which nitrate is reduced to nitrogenous gases[§]. Denitrification within wetland riparian zones has been demonstrated to be a significant mechanism for reducing the nitrate-N export in runoff from pasture catchments in New Zealand[9], however for it to be effective as a loss mechanism in wetlands receiving wastewater, the wastewater nitrogen must exist, or be converted to, the nitrate form. For most organic-based wastewaters, such as sewage, works effluent, dairy-shed effluent, the majority of the nitrogen is present in reduced forms (organic and ammonium nitrogen) unless the wastewater is extensively oxidised[¶] prior to discharge. Under aerobic conditions the ammonium from the wastewater can be converted to nitrate by another bacterially-mediated process called nitrification. Theoretically, opportunities for oxidation, and therefore nitrification, within the wetland are limited. The organic-rich sediment together with the slow-moving nature of the water effectively limits the amount of oxygen present in the water column. Oxygen transfer into the sediment by diffusion from the overlying water is limited to the top few millimetres[15].

Despite the anaerobic environment, it is known that significant oxidation does occur within wetland sediment. It is thought that wetland plants provide the means of transporting oxygen into the sediment[1,35]. Wetland plants use this

---

[§]Principally nitrous oxide and nitrogen.

[¶]For example in oxidation ponds or aerobic lagoons mechanism to maintain root aeration and also as a means of ameliorating soil toxins such as hydrogen sulphide[15]. It is likely ,however, that some of the oxygen that diffuses into wetland roots leaks out into the rhizosphere and creates an aerobic layer similar to the one formed at the sediment-water interface. One Indication that this process actually occurs is the commonly observed oxidation of iron on the roots of wetland species[23]. It is likely that this export of oxygen through root surfaces is also responsible for oxidation of nutrients and may, indirectly promote the loss of nitrogen through nitrification/denitrification.

It should be noted that uptake of nutrients by the wetland plants themselves does not appear to be an important loss mechanism for nutrients *per se*[33,21]. Studies reviewed by the above authors showed that only 2 -18% of N and P applied in wastewater to natural wetlands could be accounted for by plant uptake with a median of approximately 5%. In any case the losses of nutrients by this pathway are only temporary as eventually the nutrients entrapped in the vegetation will be mineralized and returned to the ecosystem[18,10]. Much higher nutrient uptake rates have been reported[28], but these were managed systems in which the plant material was harvested. Emergent macrophytes are capable of quite high nutrient uptake rates when the plants are young, however the uptake rate drops off markedly with age of the plant.

The principal mechanism for phosphorus removal from the overlying wetland water involves the physical chemical factors of precipitation or sorption. The extent of phosphorus sorption to the sediments depends primarily on the content of extractable iron and aluminium[29]. In a wetland used for wastewater disposal for the first time the 'apparent' loss of phosphorus may be high. However, as the sites for P sorption are used up, the degree of P removal will diminish. Further, if there is a marked change in the redox conditions at the surface of the wetland sediment[¶], then the P which has been sorbed will be released back into the water column and will be exported from the wetland. Even for wetlands unaffected by any wastewater discharge, the release of P due to anaerobic conditions can result in P exports >0.4 kg/ha/yr[31], which is within the range of P exported from terrestrial catchments in New Zealand[8].

The other main effect which can be expected from excessive wastewater loading is a decrease in nutrients retention. Increases in the BOD load to a

---

¶ The aerobic sediment-waler anaerobic

§ Particularly phosphorus

wetland beyond the capacity of the system to process that BOD will result in complete anoxia of the overlying water column. This will result in chemical reduction processes occurring at the sediment-water interface, and a return of previously sorbed phosphorus to the water column[30]. Thus the amount of phosphorus exported from the wetland will increase which in turn can lead to increased eutrophication of downstream water bodies. Some guidelines on the expected nutrient removal efficiency as a function of loading rate are given by Nichols[25]. However the actual nutrient removal performance of specific wetland types cannot be accurately predicted[36], although a recent paper indicated that significant progress has been made for specific cases[20].

It should be stated in conclusion, that wetlands are not final sinks for all nutrients discharged to them. Rather they transform, remove, store and release various forms. This fact needs to be borne in mind when considering the potential ecological impact of high-nutrient wastewaters both to the wetland, and 'downstream' ecosystems.

c) Heavy Metals

Heavy metals are of concern because of their potential adverse impacts on ecosystems. Normal domestic sewage has low levels of heavy metals and does not usually cause any toxicological problems. Similarly, wastewaters from agricultural processing industries are not a problem in this regard. However industrial wastewaters may contain unacceptably high concentrations of heavy metals, as they may runoff from urban catchments[43]. The environmental consequences of heavy metals in the New Zealand aquatic environment have been reviewed by Smith[32].

Heavy metals entering wetland ecosystems may experience three immediate pathways of transport and translocation: (1) plant or animal uptake, (2) movement to groundwaters, and (3) immobilisation onto the sediment. Aquatic plants will assimilate certain heavy metals from waters but not others. In addition different parts of the plant will accumulate different metals at different rates[22].

Changes in pH and Eh influence the solubility of metals and determine whether metals are retained or released by the sediments. While some metals, such as lead, may well be retained or released by wetlands under conditions of low loading rates, others such as zinc and cadmium, may pass through the ecosystem[14]. In general wetlands will act as a limited sink for heavy metals[4], but as with nutrients, perturbations to the wetland such as lowering the water table or inducing completely anaerobic conditions can result in release of metals from the sediments. The factors governing whether metals will be stored or released from wetlands are complex and beyond the scope of this document. However, there is sufficient evidence in the literature that discharging high levels of heavy metals into a wetland should be avoided[36], because of the potential to bioaccumulate.

d) Pathogens

Public health considerations are not the direct concern of the conservation officer. Nevertheless, some of the issues that effect public health also have a bearing on disease transmission to wildlife and also the use of the wetland for recreation.

Wetlands have been widely credited with an ability to achieve substantial[§] reductions in indicator bacteria such as faecal coliforms and faecal streptococci as well as seeded bacteriophage[13]. Scheuerman[cited 37], also found significant reductions in viruses by sorption to sediments. However he also noted that the binding was not permanent and viruses could also be released.

While data exist to indicate the potential for public health problems arising from wetlands discharges, no reports of disease resulting directly from discharges have been sighted by the author.

3. Ecology

The important biological components of wetlands are the vegetation, benthic macroinvertebrates, fish and wildlife.

a) Flora

What then are the ecological implications of the changes in water quality which may ensue when wastewaters are applied to wetlands? Wetland plants like other plants are adapted to a certain environment. Plants which are adapted to a nutrient-poor environment are stress tolerators that have a low growth potential, are poor competitors and respond slowly to the additional availability of resources such as nutrients[5]. It is therefore likely that excessive wastewater addition to a nutrient-poor wetland systems such as peat bogs or salt-water marshes, will result in competition from species which can utilise the high

---

[§] 90-99%

nutrient levels more efficiently. Such species are likely to be aggressive and form monocultures [7]. Such changes are insidious rather than dramatic. For example Valiela et al[38] showed that increasing fertilization (N and P) levels in plots of a salt-marsh community resulted in a drop in species diversity from 11 in the control plots to 4 in the plots receiving the highest levels of fertilizer. These changes were brought about not by any toxicological effect, but rather by alterations of common ecological processes such as nutrient uptake, competition, and grazing. Thus contrary to what may be expected, an increase in nutrient levels may result in a <u>decrease</u> in biomass production of the original plant community as a shift to a new community takes place[2,36].

It is also possible that physiological changes within wetland plants may be induced from excessive nutrient loading. For example it has been suggested that high concentrations of nitrate-N[§] have been responsible, in part, for the die-back of reeds in the Norfolk Broads of Englnd[24]. The nitrate is thought to disturb the schlerenchyma/parenchyma balance in the stems of the reeds causing them to break more easily. Crook et al[11] have found that the rhizomes of *Phragmites australis* were similarly weakened which allowed clumps of reedswamp to break away.

The best documentation of impacts of wastewater on wetland vegetation is derived from the Florida wetland studies[12]. Impacts were noted in the structure, productivity and biomass components of wetland vegetation. Differences in structural characteristics between cypress domes receiving sewage effluent and control domes were most easily detected in those compartments with short turnover times. For example, leaf biomass in the "sewage dome" was 1.4 times higher than in the control dome. At a recent conference, Odum[27] commented that more profound ecological changes in vegetation were difficult to detect on a short time scale and could take 20 years or more to become apparent. Other studies have shown extensive growth of algae and floating plants in wetlands receiving wastewater[37], with other plants declining in density from increased competition, thus altering community structure. Increased primary production could also have an indirect effect on the seedbank due to competitive elimination by species that form monocultures e.g. *Typha* spp and *Phragmites*[40]. Wastewater was reported increase the *Typha* (cattails) and *Lemna* (duckweed) biomass approximately 30% at the effluent outfall of a Michigan marsh[19]. No effects on woody species were noted in this short term study. However tree ring analysis showed depressed growth rates of Cypress

---

[§] > 10 mg/l

trees during the addition of raw and primary sewage to a hardwood swamp in Florida over a period of about 20 years[34].

On a long-term basis, subtle effects have been difficult to detect. Most stress observed in wetlands systems (tree kills etc) has been related to hydrologic modifications[§], the introduction of industrial wastes, or increased sediment from stormwater runoff from poorly controlled industrial developments or mining[¶].

b) Fauna

Any changes to the structure and composition of vegetation will induce changes to the animals which inhabit the wetland. Marked changes to the flow rate and water level may of themselves impact on wildlife. The kinds of changes induced are extremely complex and difficult to quantify. In general, major wildlife impacts can result from changes to: rate; (1) the structure and composition of vegetation, (2) the amount of edge; and (3) the availability of food[37].

Changes in flow rates may change the types and densities of escape cover. Water level changes may force changes in the distribution and composition of plant species. Thus changes in flow rates and water levels determine, in part, changes in the structure and composition of vegetation and availability of food.

Increases in nutrient levels can alter macroinvertebrate, algal and insect populations[12]. Changes in pH and alkalinity may impact fish populations and plant species composition. Increased sedimentation may eliminate submerged plants[41], and depress normal levels of algal and invertebrate populations. The above impacts could eventually lead to changes in species diversity through alterations in the quality and quantity of available food[16].

Case studies on the effects on animals have been somewhat contradictory. Kadlec[19] reported some shifts in species richness or diversity after ten years of a wastewater discharge in the North-Eastern USA with some increases in small mammal abundance but a decrease in the diversity of microflora and fauna. Overall there was decrease in diversity of animals. However other workers in the southeast US[16], showed that most benthic invertebrates, fish and juvenile amphibians were eliminated from a cypress swamp receiving effluent rich in

---

[§] Especially change in the hydroperid

[¶] e.g.[41], Lake Whangape, a New Zealand example organic matter. Insects concentrated near the centre of the swamp which increased the number of frogs present, but anaerobic conditions limited tadpole development. Several migrating bird species increased in numbers during the winter and spring because fly populations increased. It would appear that the apparent difference in the results of these two studies may be due to differences in the degree of pretreatment and loading rate.

The only New Zealand study on the impact of wastewater discharges to wetland fauna arises from the Paihia scheme where approximately 2000 m^3/day is discharged into wetlands within Waitangi state forest. Northland Catchment Commission (pers. comm.) noted that fauna before the discharge was sparse, possibly because of the relatively high acidity of the water (pH 4.0 - 5.0). The only common invertebrates found were the "back swimmer" *Sigara arguta,* and the "pond skater" *Microvelia* sp. Twelve months after wastewater was first applied to the wetland, the average pH at noon was 7.2 and fauna included mosquito fish, *Gambusia affinis,* and frog tadpoles, *Hyla* sp in moderate densities. This would appear to be a case where changes in water chemistry have had a major impact on the ecology of the wetland.

c) Conclusions

The above literature review shows that impact of wastewaters on the ecology of wetlands can be quite variable. Change to wetland vegetation is rarely apparent over short time periods, whereas changes to faunal assemblages can be quite rapid. Some ecological change to a wetland due to a wastewater discharge are inevitable. The task of those charged with conserving wetlands is to determine whether or not the changes which will occur due to a particular discharge are acceptable or unacceptable. This determination is not a trivial exercise. In many cases the scientific data from which to base such management decisions is simply inadequate. Despite the complexity of the ecosystems we are concerned with, there are a number of analyses which will indicate whether the discharge is unacceptable. These guidelines are outlined in the next chapter.

C. Potential impact of wastewater discharges on wetland summary

Having reviewed the literature on the impacts of wastewater discharges to wetlands, let us now return to the wetland functions identified in Table I and recap on the potential for wastewater discharges to effect those functions.

From the summary of potential impacts (Table II) it can be seen that wastewater discharges to wetlands can have major negative impacts on their use for groundwater supply, water quality enhancement, a habitat for rare and endangered species, and recreation and aesthetics. Negative impacts, but with less certainty may also arise on their use as a wildlife habitat, freshwater fishery, and the value with which they are held by the Maori. Obviously, not all of these functions will be important with every wetland discharge. The following chapter will give some guidelines on how to assess specific cases.

TABLE II Potential impact of wastewater discharges on wetland functions (see Table 1).

Wetland function	Comments	Rating*
Erosion control	Unlikely to have significant impact unless major vegetation changes occur due to toxicity, high turbidity, or hydroperiod fluctuations	0
Flood control	Unlikely to have significant except as for erosion, or unless wastewater flow a major component of total wetland flow	0
Saltwater intrusion control	Unlikely to have any effect unless wastewater significantly raises the watertable. Any effect will be beneficial	+1
Groundwater supply	A potential for major impact. Would require major investigation of geohydrology if wetland thought to be groundwater source, especially if a potable source	
Water quality enhancement	Wastewater discharge has potential to limit enhancement of water quality from diffuse sources. Any effect dependent on assimilative capacity of wetland for 'pollutant' in question.	-2

Endangered species habitat	Potential for major impact. Unless such impact can be refuted this is sufficient cause to oppose discharge	-3
Waterfowl breeding	Unless a toxic component to waste there is likely to be a beneficial effect for most nutrient-poor wetlands because of increase in food supply. Some potential for disease transmission	+1
Wildlife habitat	Impact will vary according to wetland type and the species therein. Since some change is likely, the impact is likely be detrimental to endemic animals	-?
Freshwater fisheries	May be positive, negative, or neutral depending on species, wetland type and composition of wastewater	-0+
Aquatic production	Will generally increase in long term though at the expense of species shifts. Degree of increase depends on wetland type	+1
Nutrient cycling	Cycling will increase unless a toxic component present Increase in cycling will result in greater nutrient export which may be deleterious to downstream ecosystems	-?
Maori values	Impact will depend on local tradition. Whether the wetland has been a source of food, herbal medicines, flax, or is a repository for taonga tuku iho ¶	-?

¶ Treasures that have been left.

Harvest of natural products	A potential public health risk. Site management and degree of treatment may mitigate this concern	-1
Recreation and aesthetics	Potential for major limitation due to access restrictions. Also decrease in floral species diversity likely to devalue the wetland aesthetically	-3

* This rating is a subjective tool used by the author to rank effects from a 'typical' New Zealand wastewater. i.e. High in nutrients, low toxic potential, domestic sewage, animal processing wastes. It is used here only to identify impacts to wetland functions and should not be used for specific cases. Guidelines for identifying such impacts are found in Chapter III. A scale of -3 to +3 has been used where -3 indicates a major negative impact on that particular function. -? indicates a negative impact, the likely magnitude of which is difficult to generalize.

III. GUIDELINES FOR ASSESSING POTENTIAL WASTE DISCHARGES TO WETLANDS

A. Introduction

In Chapter II we reviewed the impacts which wastewater discharges can have on wetland functions. In this chapter we develop guidelines for assessing a potential waste discharge, based on the information presented in the review.

An assessment of a waste discharge can be carried out at two levels. The first level requires only a preliminary screening of the waste discharge proposal. This level of evaluation should be able to be carried out by DOC staff and will be relatively inexpensive.

The second level is a detailed evaluation of selected aspects of the proposal if justified by the results of the screening process. It is likely that some elements of a detailed evaluation will need to be carried out by outside consultants and may, therefore be an expensive exercise. It is, therefore, crucial that major areas of concern be identified during the screening process and that questions relating to areas of uncertainty be explicitly formulated.

Regardless of who is to pay for it, the decision whether or not to proceed with a detailed evaluation depends largely on the results of the screening process. By balancing the perceived values of the against the perceived risk of allowing a discharge to proceed, DOC staff should be able to decide whether there is no case for opposing the application, whether there is a clear-cut case for opposing the application, or whether there are too many uncertainties associated with the discharge proposal and that a detailed evaluation of these uncertainties is warranted.

B. Preliminary screening

There are a number of relatively simple analyses that can be undertaken that will readily indicate whether a discharge is acceptable or unacceptable. The main purpose of this analysis is to identify the extreme cases, i.e. those in which no deleterious impacts can be predicted, and those in which a major impact on a particular wetland function can be predicted from existing data and understanding.

In both of these cases, the commitment of further significant resources to evaluate the discharge proposal is not warranted.

The principal issues that should be addressed from a conservation viewpoint during the preliminary screening process are: (i) The wastewater characteristics and management objectives, (ii) the type and value of the wetland, (iii) the environmental condition of the wetland and its perceived sensitivity to the discharge, and, (iv) perceived alteration to wetland functions and values.

If there are any major limitations on the part of any of these facets then discharge to the wetland may be unacceptable.

1. Wastewater management objectives and characteristics

There are two principal reasons why wastewater is discharged into a wetland. Firstly the wetland is considered an integral part of the wastewater treatment process. Secondly, treatment is done prior to discharge and the wetland simply acts as a receiving water i.e. no additional treatment is required by the wetland. It is important to define which role is anticipated for the wetland as this will have a significant bearing on later analyses of the perceived sensitivity of the wetland to the discharge and its assimilative capacity. This may be especially important if Water and Soil legislation is changed to take account of wetland-specific uses.

It is also important to obtain a detailed characterisation of the potential discharge[§] to the wetland. Based on this theoretical characterisation, there are three main areas for concern. These are (i) There are potentially toxic pollutants in the wastewater stream, (ii) the wastewater flows may significantly alter the existing hydroperiod and, (iii) water chemistry changes (e.g. pH) will threaten the viability of the wetland ecosystem.

References for determining whether or not a waste constituent is considered toxic are found in the appendix A. An accurate determination of whether or not wastewater flows will affect the hydroperiod are part of the detailed evaluation procedures. However for the purposes of this preliminary screening process, a 'back-of-the-envelope' calculation will suffice, e.g. If the wastewater flow constitutes less than 5% of the wetland inflows at baseflow then one can conclude that it is unlikely to impact on the hydroperiod whereas if it constitutes greater than 40% then wastewater flows will almost certainly affect

§ Both its chemistry and volume

the natural hydroperiod. Between these extremes the situation is not as clear-cut and may require further detailed analysis. This calculation depends of course on the identification and measurement of wetland inflows. If there are significant groundwater sources then this may not be possible and some surrogate measurement may need to be made, i.e. Outflow with some allowance for evapotranspiration.

Determination of potential water chemistry changes is also more likely to be part of a detailed evaluation. All that is required in the screening process is an indication as to whether a detailed evaluation is necessary. This can be gauged from the wastewater characterisation. As for a water balance, a theoretical mass balance can be done for constituents of potential concern in order to see whether they will constitute a significant proportion of the total load on the wetland. A mass balance estimate can be done simply from a knowledge of the wetland's catchment area, the principal land uses within the catchment, and published values of the amounts of the constituent expected in runoff per unit area. There is a reasonable amount of New Zealand data to make estimates of nutrient loads. However there is little data available on metals, organics or pathogens. Where a wastewater is known to contain significant quantities of toxic metals or organics there is no need to do a comparative mass balance. References to sources of information on catchment loads are found in appendix A.

For constituents in which a mass balance approach is not appropriate (e.g. pH) only broad guidelines can be given. Many wetland types have a large buffering capacity with respect to pH. Therefore pH is likely to be a problem only when the pH of the waste is extreme and/or there is a large volume of waste relative to the total volume of water in the wetland. In general, wastewaters within a pH range of pH 5.5 to 8.5 are unlikely to cause problems (due to pH alone) except for specific wetland types (see below).

2. Wetland Type

The identification of wetland type is a fundamental element in screening upon which many other elements in the screening process depend. For example the sensitivity of a wetland to a wastewater discharge can often be gauged from a knowledge of wetland type. High country bogs, for example, are often ombrotrophic[§], and therefore would be expected to be especially sensitive to

---

[§]Receive the majority of their nutrients from rainfall nutrient additions. Estuarine wetlands occupy a unique position in that they are intimately linked with both riverine and marine ecosystems. Therefore one would need to be especially careful with waste constituents that can bioaccumulate in the food chain. Hydrologically-isolated wetlands could be expected to be especially sensitive to changes in the hydroperiod.

The classification of wetlands, as with most areas of classification, can be incredibly complex, or relatively straightforward. A fairly simple classification system based on landform as a primary function is currently in use by DOC for the WERl (Wetlands of Ecological and Representative Importance) system. WERl is a computerized database with information on some 2500 wetlands throughout New Zealand[¶]. Eventually it is proposed to have this database available to all DOC offices through the DOC computer network (DOCNET) however currently this database can only be interrogated through DOC Central Office[!!]. WERI also has stored information about the perceived importance of the wetland. Internationally, nationally, regionally, or locally important; and whether there are threatened plant or animal species present in the wetland.

3. Environmental condition and sensitivity

For the purposes of screening a potential discharge to a wetland the most cost-effective strategy in the first instance is to gauge its general environmental condition. The general environmental condition refers to its current state and functions. Primary are pollutant sources to the wetland, signs of stress to the vegetation and changed use patterns and hydrologic interconnections. There are few unaltered wetlands left in New Zealand and therefore it is imperative that those which do remain in a pristine state should inherently be afforded a higher measure of protection. The use of Land Resource Inventory maps[§] for example, can be used to assist in determining the degree of development around a wetland and hence whether it may be considered 'pristine'.

Major limitations to wetland discharge on the basis of existing or anticipated environmental sensitivity are:

[¶] DOC Central Office suggest that field staff be aware of the limitations of the various assessment procedures for classifying wetlands for local/regional/national importance. It needs to be stressed that WERI is only a guide and each wetland needs reassessment.

[!!] See Appendix C

[§] See Appendix C

(i) The wetland is extensively channelized. Such a wetland is unsuitable for wetland discharge because the additional flow caused by the discharge will exacerbate the channelization. This is likely to lead to erosion of wetland vegetation at the channel margins. Additionally, such systems would be unsuitable for discharge where preservation of downstream waterbodies was a primary concern since little pollutant retention would be expected in an extensively channelized wetland.

(ii) Existing vegetation patterns suggest that the wetland is sensitive to changes in flow. A high species diversity is indicative of pronounced natural hydroperiod. An assessment needs to be made of whether the volume of wastewater will 'dampen' the hydroperiod which would result in a decrease in species diversity.

(iii) Evidence from an existing discharge into the wetland or adjacent wetland of the same type suggests that the wetland will be sensitive to changes in water chemistry.

4. Wetlands values and uses

It is important to identify the major values and uses of any wetland being considered for wastewater disposal. Estimates should be made of the degree to which the primary wetland functions and values listed in Table I will be impacted by the wastewater discharge[¶]. Much of this assessment will be qualitative, based upon the characterisation (both chemical and hydrological) of the potential discharge, and what is known about the effects of similar discharges in other situations. Recreation and aesthetic uses of the wetland should not be overlooked in this evaluation. In many cases DOC regional and district offices will be a repository for the information needed to predict these impacts, however Catchment Authorities Regional Councils can also provide this kind of information. The local Hapu, or Maori District Council should also be consulted with in order to get the Maori perspective on the discharge proposal.

[¶]See a general assessment in Table II.

C. DETAILED EVALUATION

The screening process may identify the need for a more detailed environmental evaluation. The extent of the evaluation will depend on the size and nature of the proposed discharge, the perceived value of the wetland in question, and the perceived environmental risk of allowing the proposal to proceed.

Whereas the screening process is largely a desk exercise, a detailed evaluation could involve a considerable amount of field work. Procedures for conducting components of a detailed evaluation are beyond the scope of this document. Details are given here as to what may be required rather than how to achieve the results. The reason for taking this approach is that the responsibility for carrying out the detailed evaluation, where it is deemed necessary, rests with the discharger. Therefore this section is provided more as a guide to assisting in the selection of the elements which may require further evaluation, and how they can help to answer specific questions, rather than as a guide on how to carry them out.

It should be pointed out that that the most opportune time to carry out elements of a detailed evaluation is as part of an Environmental Impact Assessment (EIA), or other technical document in support of a water right application. Although there is no legislative requirement for an applicant to provide an EIA for a waste discharge proposal[¶] it is often in the applicant's best interest to do so. To the author's knowledge there is no formalized procedure for DOC to liaise with a potential discharger at an early stage in order to voice concerns and, if necessary, arrange a technical investigation. In the absence of such formal arrangements, DOC staff should set up informal links with the local catchment authority in the first instance and waste discharge applicants in the second instance. It is generally more productive for interested parties to meet in a consultation process to resolve difficulties rather than in the confrontational situation of a hearing. However if the establishment of informal links proves difficult, and if the kind of information required by DOC is not forthcoming at a water right hearing, then DOC staff should explicitly point out this deficiency, supported if necessary, by their own technical witnesses.

The principal elements which may require further scientific investigation in order to predict impacts to wetland functions are:

[¶] Except to obtain a mining licence

(1) Hydrology
(2) Water quality
(3) Ecology
(4) The soil characteristics

1. Hydrology

It cannot be stressed enough that understanding the hydrology of the wetland is a key to understanding the system as a whole and consequently to predicting the likely impact of a wastewater on the wetland. In cases where there is some doubt as to the effect of a discharge on the wetland response a more rigorous hydrological analysis may be justified.

Hydrological information which may be important to such an analysis is; (i) The pathways of water through the wetland;

(ii) The water budget , and
(iii) Determination of the hydroperiod.

a) Hydrologic pathways

The inputs of water, the pathways which the water takes through the wetland, and its mode of exit are all potentially important in determining wastewater impacts. Hydrologic interconnections, or the lack thereof, influence assimilative capacity, residence time in the wetland and the nutrients and materials transported. It also has a bearing on the kinds of effects that may be manifest in different parts of the wetland. In a hydrologically open wetland, wastewater flows will follow a preferential path and the degree of assimilation anticipated may not actually occur. If this is suspected then a tracing study may be useful in indicating preferential flow paths.

Hydrologically isolated wetlands present a different type of concern. Flushing in such systems is dependent entirely on evapotranspiration, rainfall, and groundwater interactions. Therefore overloading the system with excessive flows or pollutants presents a higher risk than for most open systems. Groundwater recharge may be more likely and should be considered in perched, isolated systems.

Measuring groundwater interactions with wetlands is a difficult task. Few wetlands have direct connections with deep aquifers. However, some wetlands are located in recharge zones and could have an impact on groundwater quality. An examination of topographic maps or aerial photographs could indicate whether this is a possibility, however an experienced groundwater hydrologist will probably be required to study the aquifer system if this is considered a critical issue.

b) Water budget and hydroperiod

A water budget is needed to assess how much water a given wetland will be able to accept without severe stress. This quantity of water is directly relevant to the hydroperiod of the wetland.

The water budget equation may be written as:

$$S_t = P + Q_1 + Q_L + G_1 + W - Q_2 - G_2 - E$$

where:

S_t = volume change of water stored in the wetland during a specified time interval, t[§]
P = precipitation volume falling in the wetland
Q_1 = surface water volume flowing into the wetland
Q_L = lateral overland flow flowing into the wetland
G_1 = groundwater volume flowing into the wetland
W = wastewater volume to be applied to the wetland
Q_2 = surface water volume flowing out of the wetland
G_2 = groundwater volume flowing out of the wetland
E = volume leaving the wetland

By calculating the water budget, the major hydrologic interconnections and sources of inflow become clear and residence time can be calculated.

For hydrologically open systems, estimations of depth, velocity, area of inundation and residence time may be calculated using a derivation of Manning's equation[37].

[§]All other variables over time, t

2. Water quality

The collection of water quality data may be justified where there is doubt over the sensitivity of the wetland to the discharge, or to the impact which the discharge may have on some wetland functions, particularly that of pollutant buffering.

The assessment of background water quality provides a benchmark against which impacts and future changes can be compared. It is important to assess the distinction, if relevant, between ambient water quality and natural background conditions. This involves determining whether ambient water quality conditions represent natural conditions or modifications caused by other pollutant sources. If the ambient water quality has been affected by other point or non-point sources then this may indicate that the wetland has a lower capacity to assimilate the wastewater discharge under consideration.

Just as in water quality assessments of rivers, it is important to make the distinction between low flow and flood flow conditions. It is desirable to have access to seasonal water quality data. However the decision whether or not seasonal influences are likely to be important should be made in the light of preliminary screening, and on the perceived risk of seasonally-influenced degradation. Similarly, the kinds of analyses needed vary depending on the perceived risk. USEPA[37] recommend a two tier structure for analytical parameters with the first tier[§] being mandatory for those situations in which a small domestic sewage discharge is anticipated for a relatively large hydrologically-open wetland.

However the adoption of a mandatory suite analyses does not appear appropriate to the New Zealand situation, unless wetland-specific water quality standards are introduced. Rather it is better, in my view, to list the types of analyses which may be done and the reason why it may be desirable to analyse them (Table III).

[§] Dissolved oxygen, BOD, water temperature, faecal coliforms, suspended solids. pH.

Table III Possible water quality determinants applicable to wastewater wetland issues

Parameter(s)	Reason for analysis
pH	Environmental sensitivity of flora and fauna
Dissolved Oxygen/BOD	Response to existing organic load in order to predict response with wastewater addition
Suspended solids/turbidity	Environmental sensitivity of flora and fauna to existing situation in order to predict ecological response to turbid wastewater
Faecal coliforms/faecal streptococci	Identification of existing sewage discharges into wetland and the degree of faecal pollution from wildlife
Nitrogen species	nutrient removal, nutrient budget, downstream management
Phosphorus species	nutrient removal, nutrient budget, downstream management
Heavy metals	industrial component, toxicity bioaccumulation
Organic chemicals	industrial component preservatives, horticultural runoff (herbicides and pesticides)
Un-ionised ammonia	fish toxicity
Chloride/bromide	water movement tracer

Planning and carrying out a water quality survey which will give meaningful results is not a trivial exercise. The taking of single samples at the inlet and outlet of a wetland is of little use because of the large heterogeneity of a wetland. The location of sampling points is important but only very general guidelines can be given here. The most important considerations in determining sampling sites are; (i) the projected area of impact of a wastewater, and (ii) the hydraulic gradient in the wetland. Typically, sampling sites are located up gradient and down gradient of the potential discharge site. Thus it is important to know the hydraulic gradient of the wetland in advance of conducting a water quality baseline survey. If the protection of downstream waterbodies is a prime objective then the outlet(s) of the wetland should be included in the study.

The spatial heterogeneity is only one of the problems associated with planning a water quality sampling programme for a wetland. The other is that the chemistry of the samples taken can also vary temporally. Significant sources of temporal variation likely to affect a wetlands water quality sampling programme are:

(i) Diurnal variation (changes occurring during the course of a day). Dissolved oxygen data is especially susceptible to diurnal influences.

(ii) Seasonal variation. Temperature effects may influence microbially-derived chemical species. E.g. nitrate.

(iii) Storm events. Dilution of some species and concentration of others due to scouring of sediment.

(iv) Drawdown. Increased mineralization of organic species may be expected during a period of drawdown.

Further sources of information on the design of water quality sampling programmes are given in the appendix A and C.

3. Ecology

The baseline ecological status of a wetland may be needed in order to; (i) establish whether there are any rare or endangered species present in the wetland, (ii) establish the present ecological condition of the wetland in order to predict any ecological damage arising from the proposed discharge.

It is important for any ecological evaluation that one have a clear understanding of the objectives otherwise much time can be wasted and much unusable data collected. The purpose of this section, therefore is to alert the reader to the kinds of data which will be the most useful to address the issue at hand.

It has been emphasized in previous sections that one of the main impacts of wastewater flows to a wetland may be due to changes in the flow regime. Such changes may be seasonal in nature i.e. wastewater additions are more likely to impact on summer drawdown conditions than they are on winter flood conditions. Therefore, given that one has limited resources and time, in which to complete a baseline survey, it is more sensible to conduct the survey during summer months. There are no hard and fast rules about this, however, and one has to gauge in advance what ecological problems may arise.

The ecological subcomponents that are significant in wetlands may be broadly listed as; vegetation, invertebrates, fish, and wildlife.

The predominant vegetation can be identified by conducting transects. Based on this Inventory of vegetation type and distribution an assessment should be made of how sensitive the vegetation is to hydrologic and/or chemical perturbation. This can then be combined with predictions of changes in the hydrologic and chemical environments to arrive at a prediction of the impact of the discharge on the vegetation. A similar exercise can be done with wildlife and fish though it should be noted that due to the inherent variability and mobility of these animals, data collection within the time frame required for an Environmental Impact Assessment is not always feasible. Therefore such an assessment could only be based on existing studies, reported sightings etc. Possible seasonal limitations of such data should be considered since seasonal fluctuation in watertable is also very important to wildlife. Water levels determine feeding opportunities, timing of breeding and the area of habitat available to each species.

4. Soil characteristics

Determination of the soil characteristics of a wetland is something which needs to be done only if pollutant retention is a consideration in an assessment. This is likely to arise if the protection of downstream waterbodies against nutrient enrichment is an issue. Wetland soils are important in this regard because the soil is the site where most of the microbial and chemical activity takes place. The major distinctions which can be made in the soil characteristics are whether they are mineral or organic in nature since each has different ion exchange characteristics.

The correlation of soil type with chemical retention characteristics is not a simple matter, because it depends on the oxidation state of the soil/sediment in question. For example it was mentioned in the literature review that flooded organic soils will, in general terms be considered a net source of phosphorus over time. Other soil characteristics that may be important are the texture and permeability, soil depth, and the presence or absence of impermeable pans.

5. Predicting assimilative capacity

The ultimate aim of any assessment of the potential impact of a wastewater on a wetland is to predict whether or not the wetland can assimilate the waste without sustaining ecological damage. The term "assimilative capacity" can be used in different senses. Firstly, the term is often used by waste treatment engineers to describe the ability of the wetland to retain the pollutants discharged into it. However from a conservation standpoint this is not an appropriate use of the term unless the wetland is determined to have no significant values of its own except as a buffer to downstream ecosystems. Therefore we wish to use the term as an index of how the structure of the wetland may be affected. Therefore to predict the overall assimilative capacity of a wetland is quite unrealistic given our present level of understanding of wetland processes. However it is feasible to predict the assimilative capacity of a particular component of the ecosystem for a particular wastewater component. In order to make such predictions it is necessary first to understand the processes controlling the assimilation of the pollutant, secondly to know the rates at which these processes are occurring and thirdly to know the ecological consequence of the predicted level of incorporation.

it may be appreciated that the quantitative determination of assimilative capacity in the sense described above will require a level of analysis additional to that typically required for impact assessment. It is likely, however, that there will be increasing demand for more quantitative impact assessments. By understanding which processes are likely to be most important in causing environmental degradation, and attempting to quantify those processes, we will be in the best position of advocacy for conserving our wetlands.

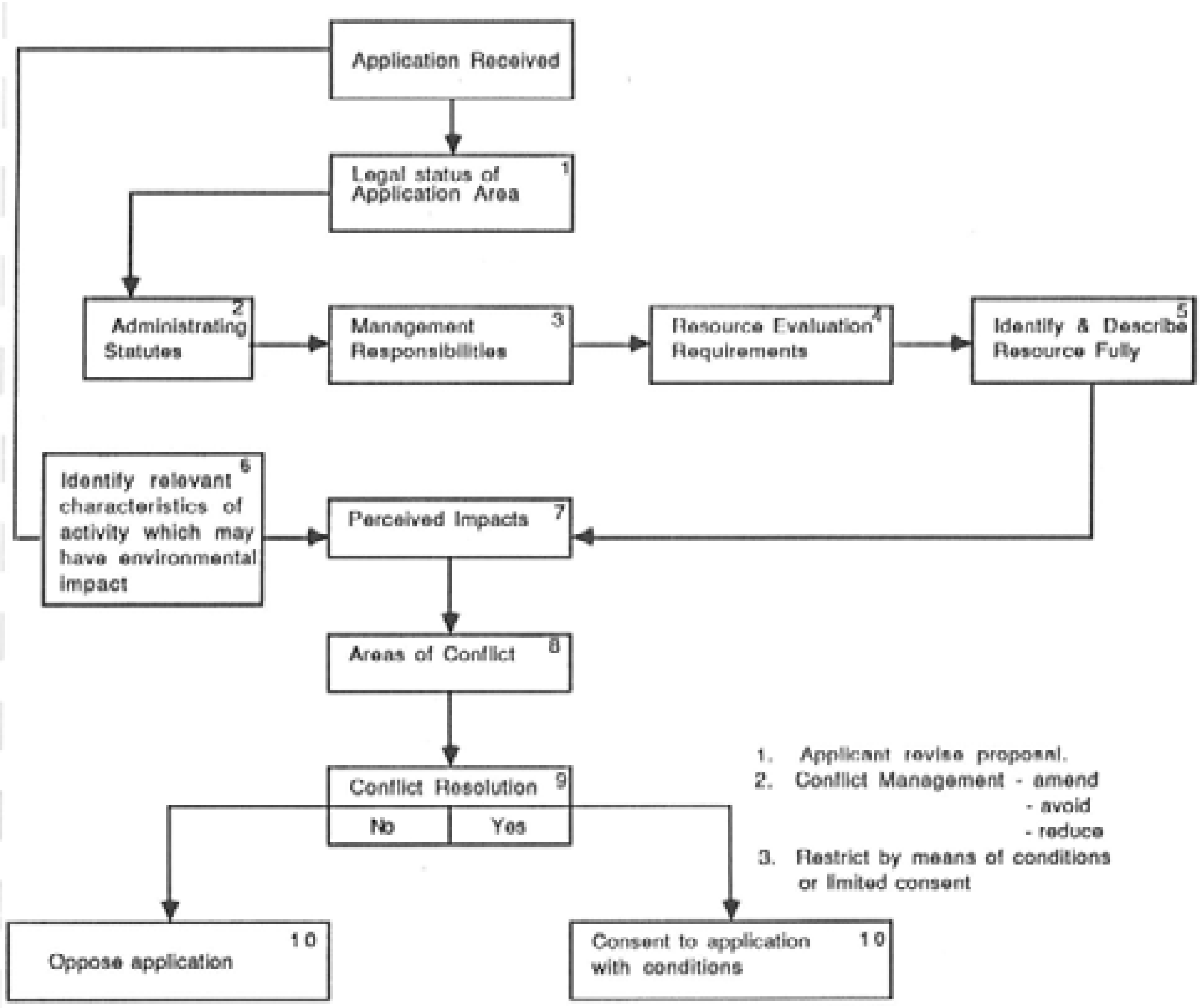
D. SUGGESTED AUDIT TRAIL FOR WASTEWATER/WETLANDS PROPOSALS

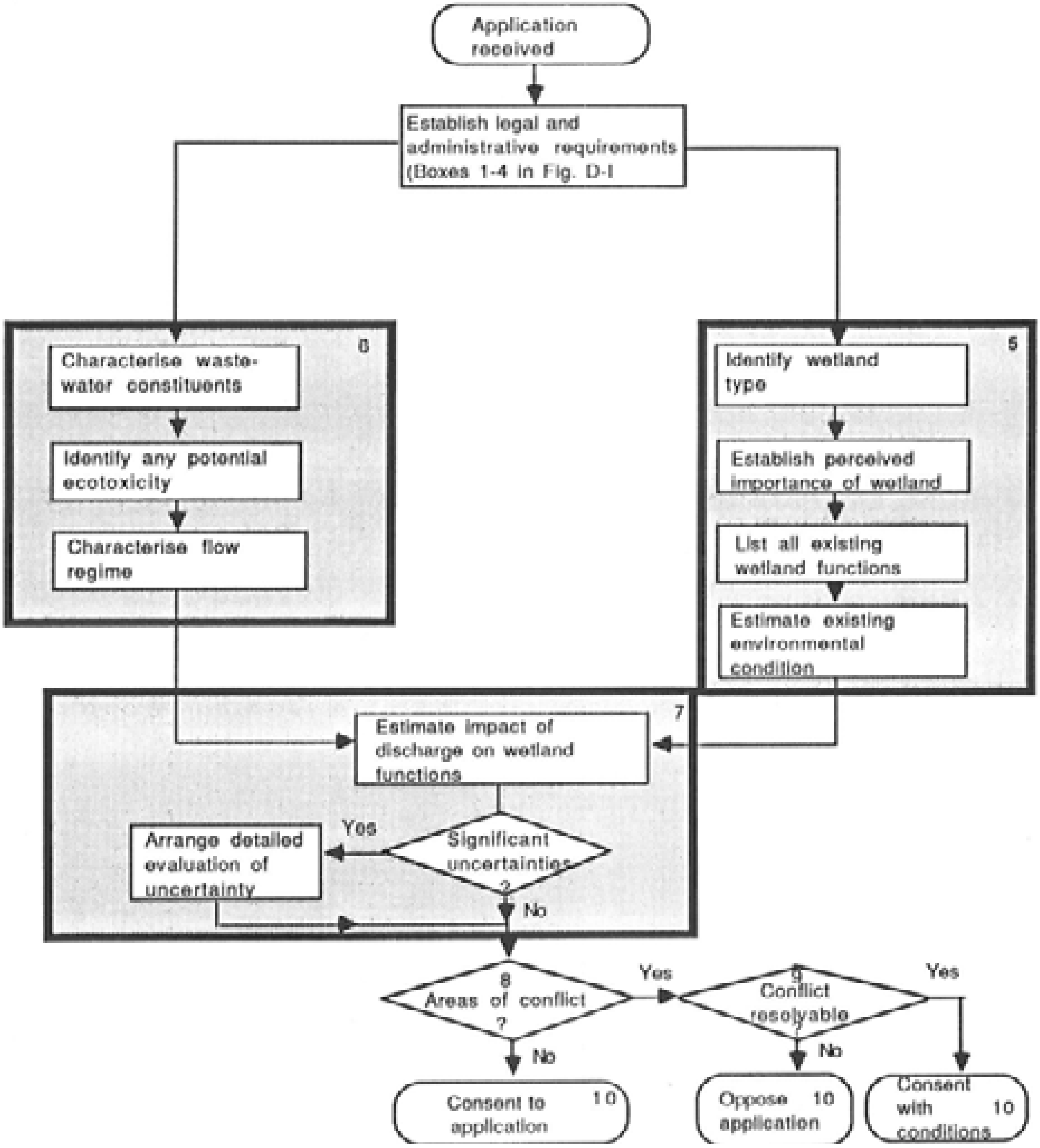
The Department of Conservation now has in place general methodology for auditing applications for activities in which DOC has statutory responsibility to manage (e.g. mining on DOC land), or for those in which DOC only has an advocacy role (e.g. water right applications).

This methodology is presented in Figure D-1.

A suggested flowchart for specifically dealing with applications to discharge wastewaters to wetlands is given in Figure D-11. The numbers at the top of boxes (or group of boxes provide a point of reference to Figure D-1.

Figure D-1. Department of Conservation Application Processing Methodology




Application received
Establish legal and administrative requirements (Boxes 1-4 in Fig. D-I
6
Characterise waste-water constituents
Identify any potential ecotoxicity
Characterise flow regime
5
Identify wetland type
Establish perceived importance of wetland
List all existing wetland functions
Estimate existing environmental condition
7
Estimate impact of discharge on wetland functions
Significant uncertainties ?
Yes
Arrange detailed evaluation of uncertainty
No
8
Areas of conflict ?
Yes
9
Conflict resolvable ?
Yes
No
No
Consent to application 10
Oppose application 10
Consent with conditions 10

IV. REFERENCES

1. Armstrong, W. 1964. 'Oxygen diffusion from the roots of some British bog plants', *Nature 204:* 801-802.

2. Bayley, S.E.; Zoltek, J. Hermann, A.J.; Dolan, T.J. & Tortorgh, T.J. 1985. Experimental manipulation of nutrients and water in a freshwater marsh: Effects on biomass, decomposition, and nutrient accumulation', *Limnology and Oceanography 30:* 500-51*2.*

3. Best, G.R. 1987. 'Natural wetlands-Southern Environment: Wastewater to wetlands, where do we go from here?' pp 99-120 *In: Aquatic Plants for Water Treatment and Resource Recovery* K.R. Reddy and W.H. Smith (Eds) Magnolia Publishing Inc. Orlando, Florida.

4. Boto, K.G. and W.H. Patrick Jr 1978. 'Role of wetlands in the removal of suspended sediments', In: Wetland function and values: the state of our understanding. *American Water Resources Association Technical Publication No TPS 79-2.* Minneapolis USA.

5. Brinson, M.M. and F.R. Westall 1985. 'Application of wastewater to wetland', *Water Resources Research Institute Report No 5* North Carolina State University, Raleigh 27 pp. In: *Aquatic Plants for Water Treatment and Resource Recovery* K.R. Reddy and W.H. Smith (Eds) Magnolia Publishing Inc. Orlando, Florida.

6. Chan, E.; Bursztynsky, T.A..; Hantzsche, N and Y.J. Litwin 1980. 'The use of wetlands for water pollution control'. MERL-ORD, Cincinnati, Ohio.

7. Clunie, N.M.U. 1983. Waimango Swamp, Karikari: Vegetation and sewage disposal', *Botany Division DSIR, Unpublished Report.*

8. Cooke, J.G. 1980. 'The effect of land use on water quality in New Zealand', pp14-30 In: *Land use in relation to water quantity and quality,* Proceedings of a Seminar, Nelson Catchment and Regional Water Board.

9. Cooke, J.G. and A.B. Cooper 1988. 'Sources and sinks of nutrients in a New Zealand hill pasture catchment III Nitrogen.*Hydrological Processes* 2: 135-149.

10. Cooper, A.B. and J.G. Cooke 1984. 'Nitrate loss and transformation in 2 vegetated headwater streams'. New Zealand Journal of Marine and Freshwater Research 18: 441-450.

11. Crook, C.; Boar, R.; & Moss, D. 1983.'The decline of reed swamp in the Norfolk Broadland: causes, consequences and solutions', Norfolk Broads Authority BARS 6: 70 pp.

12. Ewel, K.C. and Odum, H.T. (Eds) 1984. Cypress Swamps 472 pp. University Presses of Florida, Gainesville, Florida.

13. Gersberg, R.M.; Brenner, R.; Lyon, S.R. & Elkins, B.V. 1987.'Survival of bacteria and viruses in municipal wastewaters applied to artificial wetlands', pp 237-245, In: *Aquatic Plants for Water Treatment and Resource Recovery* K.R. Reddy and W.H. Smith (Eds) Magnolia Publishing Inc. Orlando, Florida.

14. Giblin, A.E. 1985.'Comparison of the processing of elements by ecosystems, II Metals', pp 158-170 In: *Ecological considerations in wetlands treatment of municipal wastewaters.* P.J. Godfrey et al. (Eds). Van Nostrand Reinhold (N.Y.)

15. Good, B.J. and Patrick, W.H. Jnr 1987. 'Root-water-sediment interface processes.' pp 359-372 In: *Aquatic Plants for Water Treatment and Resource Recovery* K.R. Reddy and W.H. Smith (Eds) Magnolia Publishing Inc. Orlando, Florida.

16. Harris, L.D. and C.R. Vickers 1984.Some faunal community characteristics of Cypress ponds and the changes induced by perturbations. pp 171-185 In: Ewel, K.C. and Odum, H.T. (Eds). Cypress Swamps 472 pp. University Presses of Florida, Gainesville, Florida.

17. Hodson, R.E.; Maccubbin, A.E.; Benner, R. & Murray, R.E. 1985. 'Microbial transformations of detrital carbon in wetland ecosystems: Effects of environmental stress', pp 277-297 In: *Ecological considerations in wetlands treatment of municipal wastewaters*. P.J. Godfrey et al. (Eds). Van Nostrand Reinhold (N.Y.)

18. Howard-Williams, C,; Davies, J. and Pickmere, S. 1982. 'The dynamics of growth, the effects of changing area and nitrate uptake by watercress *Nasturtium officinale* Br. in a New Zealand stream', Journal of Applied Ecology 19, 589-601.

19. R.H. 1987 'Northern natural wetland water treatment systems' pp 83-98 In: *Aquatic Plants for Water Treatment and Resource* Recovery K.R. Reddy and W.H. Smith (Eds) Magnolia Publishing Inc. Orlando, Florida.

20. Kadlec, R.H. and Hammer, D.E. 1988.'Modeling nutrient behaviour in wetlands', *Ecological Modelling 40*: 37-66.

21. Kelley, J.R. and Harwell, M.A. 1985. 'Comparison of the processing of elements by ecosystems, I Nutrients', pp 133-157 In: *Ecological considerations in wetlands treatment of municipal wastewaters*. P.J. Godfrey et al. (Eds). Van Nostrnd Reinhold (N.Y.)

22. Lyngby, J.E. and Brix, H. 1988.'Heavy metals in eelgrass (Zostera marina L.) during growth and decomposition', *Hydrobiologia*: in press.

23. Mendelsosohn, I.A. and Postek, M.T. 1982.'Elemental analysis of deposits on the roots of Spartina alterniflora loisel' *American Journal of Botany* 69: 904-912.

24. Newbold, C.; Fry, G.; & Cooke, A. 1986.'Tackling agricultural pollution - the difficulties facing conservationists in Great Britain', pp 296-314 In: *Effects of Land Use on Fresh Waters*. J. F de L.G. Solbe (ed) WRC/Ellis Horwood (Pub).

25. Nichols, D.S. 1983. 'Capacity of natural wetlands to remove nutrients from wastewater'. Water Pollution Control Federation Journal 55:495-505.

26. Northland Catchment Commission 1986.'Wetland sewage treatment systems in Northland,' *Water and Wastewater Treatment Plant Operators Newsletter* 26(4): 11 -23

27. Odum, W.E. 1987. 'Research and development needs -ecological considerations', pp 1016-1018 In: *Aquatic Plants for Water Treatment and Resource Recovery* K.R. Reddy and W.H. Smith (Eds) Magnolia Publishing Inc. Orlando, Florida.

28. Reddy, K.R. and W.F. DeBusk, 1987.'Nutrient storage capabilities of aquatic and wetland plants', pp 337-357 In: *Aquatic Plants for Water Treatment and Resource Recovery* K.R. Reddy and W.H. Smith (Eds) Magnolia Publishing Inc. Orlando, Florida.

29. Richardson, C.J. 1985. 'Mechanisms controlling phosphorus retention capacity in freshwater wetlands', *Science* 228: 1424-1427

30. Richardson, C.J. and Nichols, D.S. 1985. 'Ecological analysis of wastewater management criteria in wetland ecosystems.' pp 351-391 In: *In considerations in wetlands treatment of municipal wastewaters.* P.J. Godfrey et al. (Eds). Van Nostrand Reinhold (N.Y.)

31. Richardson, C.J. & Schwegler, B.R. 1986. 'Algal bioassay and gross productivity experiments using sewage effluent in a Michigan wetland', *Water Resources Bulletin 22:* 111-120.

32. Smith, D.G. 1986. 'Heavy metals in the New Zealand aquatic environment: A review', *Water & Soil Miscellaneous Publication No 100.* NWASCA Wellington.

33. Spangler, F.L.; Fetter, C.W. Jnr and Sloey, W.E. 1977. 'Phosphorus accumulation-discharge cycles in marshes.' *Water Resources Bulletin* 13: 1191-1201

34. Stewart, K.K. and Ornes, W.H. 1975. 'Assessing a marsh environment for wastewater renovation', *Journal of Water Pollution Control Federation 47:* 1880-1891.

35. Teal, J.M. and Kanwisher, J.W. 1966. 'Gas transport in the marsh grass, Spartina alterniflora', *Journal of Experimental Botany 17:* 355-361.

36. U.S. Environmental Protection Agency 1983. 'Effects of wastewater treatment facilities on wetlands in the Midwest', *EPA-905/3-83-002* 385 pp (Fiche).

37. U.S. Environmental Protection Agency 1985. 'Freshwater wetlands for wastewater management handbook', *EPA 904/9-85-135* 516 pp (Fiche).

38. Valiela, I,; Teal, J.M.; Cogswell, C; Hartman, J.; Allen, S.; Van Etten, R.; and Goehringer, D. 1985. 'Some long-term consequences of sewage contamination in salt-marsh ecosystems', pp 301-316 In: *Ecological considerations in wetlands treatment of municipal wastewaters. P.J.* Godfrey et al. (Eds). Van Nostrand Reinhold (N.Y.)

39. Venus, G.C. 1987. 'Wetland wastewater treatment; A review. Study tour April-May 1987', published by G.C. Venus – Environmental Consultant - Whangarei, N.Z.

40. Whigham, D.F. 1985. 'Vegetation in wetlands receiving sewage effluent: The importance of the seedbank.' pp 231-240 In: *Ecological considerations in wetlands treatment of municipal wastewaters.* P.J. Godfrey et al. (Eds). Van Nostrand Reinhold (N.Y.)

41. Wells, R.D.S. , Vant, W.N. and Clayton, J.S. 1988. 'Inorganic suspensoids and aquatic macrophytes in Lake Whangape, New Zealand', *Verhandlugen. Int. verein. Limnol.* in press.

42. Wetlands Task Group of the Environmental Council 1983. 'Wetlands: A Diminishing Resource', G.K. Stephenson (Convenor), *Water and Soil Miscellaneous Publication No 58,* NWASCA, Wellington.

43. Williamson, R.B. 1985. 'Urban stormwater quality II. Comparison of three New Zealand catchments', *New Zealand Journal of Marine and Freshwater Research 20:* 315-328.

V. APPENDICES - RESOURCE MATERIAL

A. Wastewater composition

Each wastewater discharge has a unique composition which is dependent upon the characteristics of the influent, and the degree and type of treatment. It is incumbent upon the discharger to provide a characterisation of the composition and volume of wastewater expected. There may be occasions where it is desired to know the range in concentration and mass expected of a constituent for a particular type of wastewater.

References to this type of information are:

1. Bond, R.G. & Straub, C.P. (eds) 1974. 'Handbook of Environmental Control. Volume IV Wastewater Treatment and Disposal', CRC Press Inc.

2. Vanderholm, D.H. 1983. 'Properties of Agricultural Wastes', Chapter 2 In: *Agricultural Waste Manual: New Zealand Agricultural Engineering Institute Report No. 32,* Lincoln College, N.Z.

3. Wilcock, R.B. (ed) 1984 'Land treatment of wastes - Proceedings of a seminar Hamilton, 7-9 February 1984', *Water & Soil Miscellaneous Publication No. 69.* NWASCA, Wellington, N.Z. (Particularly papers by Quinn [sewage], Parkin et al. [dairy factory wastes], Russell et al. and also Burden [meat works wastes].

Reference 1 is useful for obtaining the range of values reported in the international literature and also contains data for some wastewaters which are relatively uncommon in New Zealand (e.g. coking plant, electroplating). References 2 and 3 contain NZ-derived data for a range of municipal and agricultural wastes.

An additional reference;
US EPA 1986 'Quality criteria for water 1986', *EPA 440/5-86-001.*

is the most authoritative source for information on the concentration limiting various water uses for virtually all known chemical pollutants.

Other useful references, several chapters of which may be applied to wetlands are;

Hoare, R.A. 1983 (Ed) 'Design of water quality surveys', *Water and Soil Miscellaneous Publication No 63* NWASCA, Wellington.

and,

Vant, W. N 1987. 'Lake Managers Handbook', *Water and Soil Miscellaneous Publication No 103. NWASCA,* Wellington.

B. Glossary of technical terms

AERENCHYMA Specialized tissue in some wetland plants characterized by walled cells and large intercellular air spaces.

ANGIOSPERM Flowering plant.

ANOXIA Deficiency of oxygen tissue.

BENTHIC Bottom dwelling.

BIOASSAY A method for quantitatively determining the concentration of a substance by its effect on growth of a suitable animal, plant, or microorganism under controlled conditions.

BOD_5 Common abbreviation for 5 day biochemical oxygen demand. A test commonly used to characterize the amount of available organic carbon by. measuring the amount of oxygen utilized by aerobic microorganisms during growth on a sample of the wastewater.

COLIFORMS Colon bacilli, a group of bacteria commonly used as indicators of faecal pollution

DENITRIFICATION A bacterially-mediated process by which nitrate is converted to nitrogen gases; principally nitrous oxide and nitrogen. The process will only proceed in the absence of oxygen.

DETRITAL SEDIMENT Accumulations of organic and inorganic (wetlands mainly organic) products of weathering and erosion.

DRAWDOWN The magnitude of the change in watertable level resulting from the removal of water.

Eh – see redox potential

EUTROPHICATION The process whereby waterbodies become progressively enriched with plant nutrients either naturally by maturation or artificially by fertilization.

EVAPOTRANSPIRATION Discharge of water from the earth's surface to the atmosphere from the combined processes of evaporation and plant transpiration.

HYDROPERIOD The variation in waterlevel of a wetland due to the extremes of drawdown and flooding.

INFLUENT The wastewater entering a treatment system.

MICROCLIMATE Climatic influence of a small area of land or landform. E.g. wetlands of Florida are attributed with causing the high incidence of thunderstorms.

NITRIFICATION Bacterially-mediated process whereby ammonium is converted to nitrate in the presence of oxygen.

OMBROTROPHIC Obtaining nutrients solely from rainwater.

OXIDATION The combination of oxygen with a substance, or the removal of hydrogen from it. The term is also used more generally to include any reaction in which an atom loses electrons; e.g. the change of a ferrous ion, Fe^{2+}, to a ferric ion, Fe^{3+}.

PARENCHYMA A tissue of higher plants consisting of living cells with thin walls that are agents of photosynthesis and storage.

PATHOGEN A disease-producing microorganism

pH A term used to describe the hydrogen ion activity of a system; in dilute solution activity is essentially equal to concentration and pH is defined as $-\log_{10}[H^+]$ where $[H^+]$ is the hydrogen ion concentration in moles per litre; a solution of pH 7 is neutral whereas less than 7 is acid and greater than 7 is alkaline.

REDOX POTENTIAL An electrochemical measurement of the state of oxidation of a system (e.g. wetland sediment is usually rich in organic matter, devoid of oxygen and will have a highly negative redox potential).

RHIZOSPHERE The immediate environment, or zone of influence surrounding plant roots and characterized by increased microbial activity.

RIPARIAN ZONE The area immediately adjacent to a waterbody. E.g. stream bank or lakeshore.

SCHLERENCHYMA Fibrous (supporting) tissues of higher plants.

SEEDBANK The gene pool of seed-bearing plants.

SORPTION A general term used to encompass the physical chemical processes by which ionic material adheres to surfaces.

SUSPENSOIDS General term describing material suspended in a water column.

TROPHIC Term describing the degree of enrichment of a water body. WASTEWATER General term for aqueous wastes. There are no implications as to the degree (if any) of treatment.

ZONATION Arrangement of organisms in biogeographic zones. In wetlands this often arises in response to a hydraulic gradient.

C. Some suggested specialist contacts.

Impact of wastewaters on wetlands

Dr Jim Cooke	Water Quality Centre Division of Water Sciences, DSIR Hamilton
Mr Bill Vant	As above
Dr Bryce Cooper	As above

Wetland Water Quality

Dr Jim Cooke	Water Quality Centre Division of Water Sciences, DSIR Hamilton
Dr Clive Howard-Williams	Taupo Research Laboratory Division of Water Sciences, DSIR

Wetland Botany

Dr Peter Johnson	Botany Division, DSIR Dunedin
Mr Keith Thompson	University of Waikato Private Bag Hamilton
Dr Nigel Clunie	Botany Division, DSIR Kaikohe
Dr Clive Howard-Williams	Taupo Research Laboratory Division of Water Sciences, DSIR

Wetland Wildlife

Dr Hugh Robertson	Ecology Division, DSIR, Lower Hutt
Dr Murray Williams	Department of Conservation Science Directorate Wellington

Wetland Hydrology

Mr Keith Smith	Water Quality Centre, Division of Water Sciences, DSIR Hamilton

Dr Derek Goring	Hydrology Centre Division of Water Sciences, DSIR Christchurch

Estimation of Catchment Loads

Dr Bruce Williamson	Water Quality Centre Division of Water Sciences, DSlR Hamilton

Land Resource Inventory and Remote Sensing

Mr Peter Stephens	Soil conservation Centre, Aokautere Division of Land and Soil Science, DSIR. Palmerston North

Ecotoxicology of waters and wastewaters

Dr Chris Hickey	Water Quality Centre Division of Water Sciences, DSIR Hamilton
Dr Dave Smith	As above

Pesticide and Herblclde Runoff

Dr Bob Wilcock	Water Quality Centre Division of Water Sciences, DSlR Hamilton.

Design of Water Quality Sampling Programmes

Mr Graham McBride	Water Quality Centre Division of Water Sciences, DSIR Hamilton
Dr Rick Pridmore	As above

WERI (Wetlands of Ecological and Representative Importance)

Mary McEwan

Department of Conservation
Science Directorate, Wellington.