Saline Discharges into Natural Wetlands in Western Australia

Preliminary Review of Issues and Options

Report to the
Department of Environmental Protection

Mark Coleman

actis Environmental Services

33 Anstey St
Mundijong WA 6123
08 952585806

1 Preamble

The salinisation of the ground water in Western Australia has raised a broad spectrum of problems for agricultural management. A number of trials have been undertaken over the last 20 years aimed at reducing land degradation and the accumulation of salts in local water bodies. They fall into two categories, either discharge enhancement or recharge reduction. The time needed for these mechanisms to negate the problem is not known, or if they will be a hundred percent successful in reducing the salinisation of groundwater and therefore reducing the salinisation of surface water and agricultural land. This discussion paper concentrates on the impacts of saline discharge water on the existing saline wetlands.

Discharge enhancement is a valid tool in the management of salinisation and water logging in Western Australia's farming land. There is some dispute as to the economic viability of the solution but while agricultural businesses are willing to spend money on landcare works which increase the discharge of saline water from their farming land and saline water is being redirected, then discharge will need management.

To many people, salt is "bad" and in many cases it is a sign of a deteriorated environment. The point that this report would like to make is that a natural salt system is a valuable and unique ecosystem. Any management plan for discharge of saline groundwater should consider the impact on the natural ecosystem, and social amenity of the current salt systems. Furthermore the extraction of salts from groundwater can be commercially viable.

The great variety of water bodies in WA makes a global management system difficult to implement. For instance, the management of the catchments to the west of the Darling Scarp is quite distinct from the catchments to the east. The latter are often slow to drain, and often drain to land locked evaporative basins. Table 1 outlines some personal observations of the characteristics of the two regions. The point being made is that there is a variety of ecosystems, and the management strategy and tools need to be applicable under the same management plan.

Table 1 Characteristics of Discharge Catchment

Characteristic	**Western Catchments**	**Eastern Catchments**
Water Use Quality Priority	Human/Industrial	Agricultural
Drainage Head	Significant	Small
Relative Discharge Period	Rapid	Slow
Natural Watercourse	Seasonal	Event Dependant
Residual Vegetation	Low	Very Low
Primary Water Course Conservation Location	Riparian	Discharge Area
Catchment Size	Medium	Extensive
Land Ownership	Crown/Freehold	Freehold/Leasehold (crown)
Allotments	Generally <1000 ha	Generally >1000 ha

The following discussion is not exhaustive. Many topics are known by the proposed readers, such as potential social amenity of waterbodies and conservation issues. This discussion illustrates the unique aspects of saline waterbodies in connection with discharge of saline groundwater principally from Western Australian agricultural land.

1.1 Characteristics of a Saline Evaporative Basin

Some discussion is needed on the evaporation of saline water as it an important part of the topic and is often little understood.

The evaporation of water from an exposed water body is much more effective than from wet soil. The sun's energy is largely reflected from bare soil with only a small amount utilised in evaporation and warming of the soil. As the water body becomes deeper, more and more of the energy is utilised in raising the water body's temperature and in replacing the enveloping water vapour. If saline groundwater (approximately seawater concentration) were pumped into an impoundment, about 10mm of freshwater would be lost over the surface on a warm summer's day in the Western Australian wheat belt .

Figure 1 Saline Evaporative Basin – Wheat belt

The wheat belt has more evaporation than precipitation, so that any impoundment would dry out unless constantly replenished with low salinity water. The volume of water in an impoundment would therefore decrease as evaporation removed freshwater into the atmosphere. The relative proportions of these mass movements are given in Table 2. This table shows that of the initial 1000 L, ninety percent of the brine volume is lost as evaporation to the point of sodium chloride saturation, and ninety seven percent if the evaporation continues to magnesium saturation, the point that most wheat belt saline lakes reach in early summer. (The remaining liquid at this stage is very low in sodium and high in magnesium, and it can be used as a concentrated soil conditioner.)

Table 2 Relative Constituents of Evaporated Seawater (1000L)

Salinity	**Seawater**	**NaCl Saturation**	**MgCl2 Saturation**
Dissolved Solid (kg)	38.7	37.2	14
Brine (L)	1000	112	30
Water (L)	988	99.7	34.8

Impoundments can therefore act as reservoirs of saline water. Once the salt has moved into an impoundment it will be concentrated, except in extreme flood conditions. Seepage is an issue, but in general the impoundments seal after a period of a few years. Seepage is significant but minor to the other mass flows.

At magnesium saturation, there is a 30 times reduction in volume of the brine. If the porosity of the soil is estimated at five percent, then an impoundment would hold at magnesium saturation, salt equivalent to 600 times its storage volume in seawater saturated soil.

1.2 Impact of Saline Discharges on Natural Water Courses

A saline wetland does have a conservation value - different from a freshwater wetland, but the biomass and species diversity in a saline wetland can be just as large and important as in a freshwater wetland. Many species of birds rely on the saline wetlands in the wheat belt to breed and feed, many of the birds are migratory, using the saline wetlands as stop overs in equatorial migrations. The extreme environmental pressures encourage opportunistic ecosystems, triggered by events such as storms and the like. The species that occupy this niche are usually unique, and have many biochemical and physiological properties that have not been fully investigated.

The influence of discharge water can be extrapolated from known data. A decision can then be made on whether the impact will significantly alter the natural water body if the status of the natural water body is known . Where the receiving waters do not approximate evaporated seawater this is a very difficult decision, especially if ionic composition is an issue. For instance, it would be difficult to model the effect of concentrated chloride ions going into a relatively rare carbonate lake. It would involve modelling of complex chemical interactions. In this case, preserving the status quo would seem prudent.

In many cases the additional water will encourage biomass and species diversity growth and would not be a problem. In fact, “eco-engineering” may be justified in creating a saline wetland effect with gradually increasing salinity, as found in commercial saltfields. The increased diversity of habitat will increase the species diversity, particularly with the larger invertebrates and macrophytes.

The concentration of salts into one area is an advantage if the process is to go one step further and the salt is actively extracted for commercial reasons. This requires more sophisticated concentrating areas and a brine quantity sufficient to make salt harvesting feasible. However it would no longer be a “natural” wetland.

Storing the salt in impoundments is not the complete answer to the disposal of saline discharge water. In some circumstances the concept would be appropriate and in others it would be unworkable. For instance, where the drainage falls naturally to a saline wetland that will not be impacted by an increased salt load, drainage enhancement seems a natural solution. Also, where one wetland in a chain of wetlands has more conservation value than another, one part of the wetland can be sacrificed to preserve the other parts. Discharge is not a favourable solution where the impact detracts from the natural impoundment.

2 Management Options for Saline Groundwater

2.1 Land Management and Discharge Enhancement

The problems of saline groundwater have been well covered in publications, such as the "Western Australian Salinity Action Plan". Rising ground water reduces the productivity of farming land, destroying freshwater wetlands and natural habitats. The salinity of the water increases as the water table rises to less than a meter or so from the surface, impacting on the water supply to communities and the natural watercourses.

The fundamental solution is to remove the water. Reducing recharge, enhancing the discharge or a combination of the two can do this. Both are understood fairly well. The problem lies in balancing the multiplicity of solutions in a heterogenous environment. Recharge reduction, such as perennial crops, tends to be a long-term solution, while discharge enhancement tends to have a more immediate response with long-term maintenance problems. Recharge reduction should always be addressed but there are often situations where discharge enhancement will more rapidly "normalise" the changing salt and water balance in the agricultural areas of Western Australia.

Why address discharge enhancement when recharge reduction will ultimately provide many of the solutions to salinisation of land? Firstly, recharge reduction will not be one hundred percent successful in reducing the rising groundwater salinity. Secondly, the damage done in the time for recharge reduction to have an effect may be irreversible. Thirdly, recharge reduction may not be a solution at all, but merely a mechanism to delay salinisation into the very long term. Discharge enhancement physically removes salt from the local area whilst recharge reduction attempts to re-store the salt into some undefined reservoir. Lastly, discharge enhancement is a facet of current agricultural practice.

The last reason is the most pressing reason. Many government and private resources have already been allocated to enhancing the removal of saline ground water from problem areas, often to the detriment of areas further down stream. Whether these resources have been utilised efficiently in many cases is a matter of contention. The immediate problem is that the discharge, whether intentional or natural, is impacting on downstream water quality. Without active discharge enhancement, the natural movement of groundwater and run off is having a significant impact on fresh water systems. The question remains as to what is the implication of this discharge.

Figure 2 Constructed Drain - Tammin

The options in disposing of the saline groundwater once it has been collected are:

- discharging through natural water courses to the sea, or
- impounding the saline water in an evaporative basin with the option of commercial extraction of the salts from the brine. The impoundment may be constructed or natural, however it is enhanced by some modification of the landform.

Both options have important environmental and legal ramifications. It is the environmental ramifications of discharging saline water into local impoundments and management options that is the focal point of this report.

2.2 Commercial Exploitation of Discharge

2.2.1 Salt Recovery

The salt in the wheat belt originated, to the best of our knowledge, as traces of sea salt dissolved in water vapour blown inland that subsequently precipitated as rain. Through the process of evaporation, the salt has been concentrated to a level that affects the productivity of the land. All this is known, what is interesting is that the salt may have left the sea eons ago or relatively recently. Most brines retain the same relative ionic composition as seawater. This is not surprising as seawater represents the Earth's average ionic balance for salts soluble in water. Commercially there is no great advantage in dealing with salts with a seawater ionic ratio unless it is very much concentrated.

Figure 3 Salt Harvest Dampier Salt Pty Ltd

Sometimes, often enough to be encouraging, brine is found with a very different composition. The changes may only be minor in the early stages of the evaporative pathway. The water may pass through a carbonate rich substrate that reduces the calcium concentration and increases the alkalinity.

This may have the effect of producing a sodium chloride salt with no calcium impurity. This makes the salt more valuable as there are no processing costs. The Pink Lake in Esperance is one such lake which produces salt with negligible calcium salts (gypsum) although the exact mechanism is unknown. The salt field at this lake has a commercial advantage over fields that must contend with the additional step of processing the salt.

Figure 4 Pink Lake Esperance

The brine left over from an unusual fractioning is also likely to be commercially valuable. Some of the more common evaporative salts are listed in Table 3.

Table 3 Seawater evaporites (Duda and Rejl 1990)

Mineral	Carnallite	Sylvite	Halite	Epsomite	Hexahydrite
Class	Halide (Chloride)	Halide (Chloride)	Halide (Chloride)	Sulphate	Sulphate
Chemical	$KMgCl_3.6H_2O$	KCl	NaCl	$MgSO_4.7\ H_2O$	$MgSO_4.6\ H_2O$
Hardness	2-3	2-3	2-3	2-3	2-3
Taste	bitter	Bitter-saline	saline	Bitter-saline	Saline to bitter-saline
Colour	colourless to brown	White to reddish	white to reddish	White to reddish	White, light green
Transparency	transparent to translucent	Transparent to translucent	transparent to translucent	Transparent to translucent	Transparent to translucent
Lustre	vitreous, greasy on fracture	Vitreous	vitreous greasy	Vitreous silky	Pearly
Crystal	orthorhombic	Cubic	cubic	Orthorhombic	Monoclinic
Solubility	in water, creaks as dissolving	In water	in water	In water	in water
Fracture	conchoidal	Conchoidal	conchoidal		Conchoidal
Cleavage	absent, but plates may separate	Perfect	perfect	Perfect	Perfect
Other	fusible, tinges flame violet	Fusible, tinges flame violet	splatters when heated, tinges flame yellow	Becomes dull in air, clean only with alcohol	Alters to epsomite in air

All of the above chemicals have a commercial value. The point being made is that the saline water may be, and this should be tempered with a bit of commercial reality, a valuable resource. The recovery of salt from groundwater is interesting because there is a social value in removing the salt and water. A financial “break even” situation may be a good solution because of the concurrent social and conservation gains that flow on.

The sorts of salts that are likely to be recovered from “salty” water are:

Common salts

- sodium chloride,
- magnesium sulphate,
- magnesium chloride, and
- calcium sulphate.

Less common salts

- sodium carbonate,
- magnesium carbonate, and
- sodium bicarbonate.

2.2.2 Aquaculture

Brine as ground water flowing from bores is quite often near to seawater concentration. This brine, unlike seawater, does not have any organisms that will kill cultured fish and shellfish. This is an advantage in breeding and fattening cultured marine animals. This concept is being explored by a project run by the Coorong Shire Council in SA. The idea is that the aquaculture provides the cash flow for funding the project, with community benefits from a reduced water table and local employment. A synergistic approach has much to recommend it, and may reduce the capital barriers and risk in actively discharging from the aquifer. The brine still has to be disposed of by evaporation or filling a local evaporation basin, but the cost of bores has been offset by the rapid cash flow from the aquaculture.

A large number of species can be cultured. Other than all of the estuarine species and some pelagic species, there are a number of hypersaline species such as *Artemia salina* (brine shrimp) that are a valuable commodity and grow in salinities up to seven times that of seawater. Algal species such as *Spirulina* and *Dunaliella* sp. are also candidates but lack of technical knowledge and equipment will be a barrier to new producers.

Figure 5 Candidate for Aquaculture (Artemia sp. brine shrimp)

2.3 Social Amenity

There are number of social uses of saline wetlands. The more obvious are active uses of the wetlands like the racing of both cars and boats on salt lakes. There are less active pursuits such as bird watching and photography. It is interesting to note that one of the first Ramsar sites was a constructed salt field. The list of uses is extensive.

Figure 6 Recreational Use of Saline Lake - Rockingham

2.4 Natural Water Courses

From a conservation point of view the discharge of saline groundwater into natural watercourses may have a significant impact. Obviously if the saline discharge is directed into a freshwater body then there will be changes that are, by most standards, detrimental. However, most lakes and water bodies in Australia are saline. They represent a broad array of different biological and chemical environments, some of which are sensitive to subtle changes in the inflow water. If freshwater/saltwater was the only criterion used to judge the impact of a discharge on a water body, then the species diversity and biomass in many saline lakes in Western Australia could be considerably depleted or changed by the inappropriate use of saline wetlands.

2.5 Management Implications

There are a number of considerations for management when extracting saline groundwater, such as preservation of natural systems, salt exploitation, recreation and aquaculture. Any decision on the discharge of saline groundwater into an artificial or natural impoundment must be consistent with the management objective for that wetland.

Therefore, the best management practice would be to formulate management objectives after identifying any unique attributes of the proposed discharge area. The objectives would dictate the guidelines for discharging saline groundwater into those areas. This implies that there must be some classification system that recognises the unique aspects of saline water bodies. This is consistent with action described in the State's policy (action 1.13) "…to develop a wetland evaluation process, including identification of beneficial uses and management objectives…" (Wetlands Conservation Policy for Western Australia, p.16). The classification for a wetland would indicate the management objective, whether it is designated for commercial, conservation or "enhanced" purposes.

3 Classification of Saline Wetlands

3.1 Geomorphic Classification Systems

The classification of wetlands is an important tool in the management of these ecosystems. This is recognised by the state government policy statement, that proposes to "…develop and promote the use of a single classification system…" and "…prepare inventories of the wetlands…" while "…evaluate[ing] wetlands on a continuing basis as knowledge becomes available and circumstances change…" (actions 1.10,1.11 and 1.14, respectively, Wetlands Conservation Policy for Western Australia, p.16).

These actions recognise the administration and technical advantage of using a single classification, while acknowledging the need for flexibility and dynamic change in the identification process. The paradox of trying to artificially partition a spectrum of wetland types is acknowledged by the Government's policy statement.

The current quasi government publications use a "hierarchal scalar" classification system for wetlands after Semeniuk (1987), principally based on geomorphological characteristics. The concept of using geomorphological features is logical as morphological features are usually obvious. That is, a basin filled with water is normally a lake and other features such as geological origin follow. The 1987 classification was further expanded to include, in total, thirteen categories (Semeniuk and Semeniuk, 1996). The main difference was to separate intermittent from seasonal wetting. This, it is felt, is unnecessary and seasonal should remain a subset of intermittent along with episodic flooding. Similarly palusmont seems to be unnecessary in addition to paluslope.

The Western Australian State Government appears to be accepting this classification system without any serious peer review or evaluation of alternatives.

This is of concern as there are some marked differences between this classification system and those in current practice elsewhere in Australia. The major difference is the use of the criterion of seasonal and permanent waterbodies as a prime determinant in the classification.

The Semeniuk classification attempts to divide wetlands into classes, which by their nature form a spectrum of types. The trouble is that most other definitions such as "A lake is a shallow to deep inland depression containing fresh or saline water either permanently or temporarily (either seasonally or episodically)" (Williams pers. comm.) do not give a definite distinction: for example, between a lake and sump. The problem is in the nature of wetland types, which are intrinsically variable. Semeniuk (1987) attempts to resolve this problem but creates the situation where a little brook in southern Australia is now a "river" and a major waterway in the northern area is now a "creek". In fact, pedantic application of the definition would mean that there would be few rivers, or lakes for that matter, in Western Australia.

Furthermore, the application of the classification to salt lakes is not clear. Often during the dry season the top of the water table is somewhere between the surface of the salt crust, and the insoluble sediment layer forming the base of the lake when it is flooded. If the salt crust is considered ground level then all salt lakes are sumplands. If the permanent base is considered ground level then the salt lakes can be differentiated into classes with different hydrological properties.

The principal objective of a classification system is to make discernible classes on a logical basis from a larger group. If a lake is defined as not being dry at the surface then nearly all lakes in WA except for a few in the south west, become sumplands. More importantly, the larger more substantial salt lakes, such as the Pink Lake are not distinguishable from small seeps that do not leave a significant salt crust. Pedantic arguments about definitions aside, the classification system would be more useful if the definition of a lake included the notion of the water table being higher than the permanent ground level.

The concept of suites used in current Western Australian wetland descriptions is a useful management tool. The concept is based on the determination of a number of (key) attributes for a wetland series. As these characteristics of a suite of wetlands are mostly of geomorphic origin, they are often common to those used to define the class of wetland. The suites are a result of a "system" rather than a definitive approach to wetland classification. A number of authors, for instance Hill et al. (1996) and the Department of Environmental Protection's wetland evaluation method (Bulletin 374 and 686) have described wetland values. In general terms, they deal with the major attributes of a wetland.

3.2 Descriptive parameters of saline wetlands

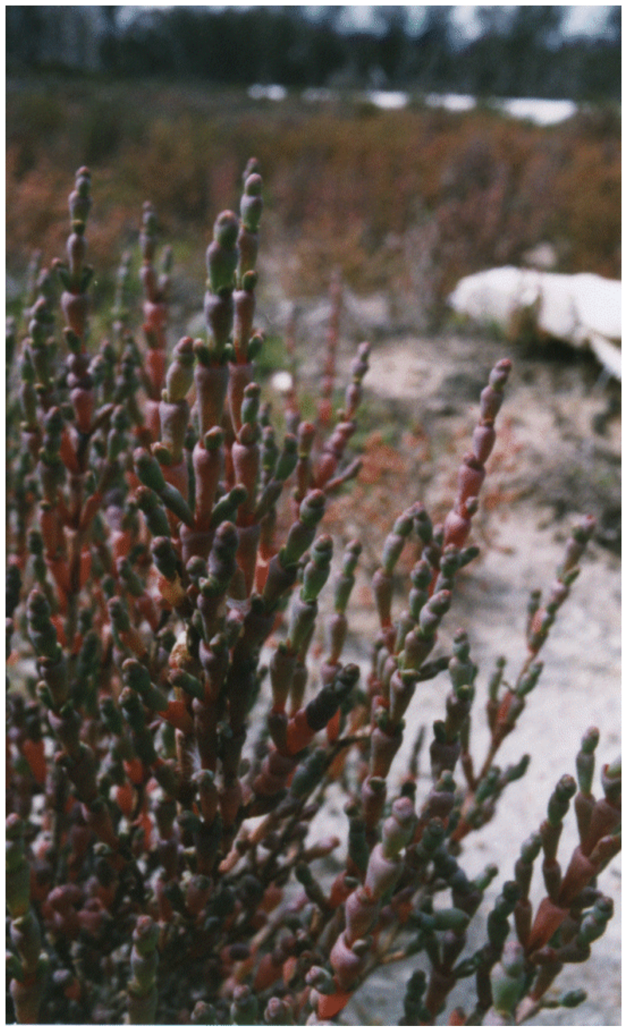
For saline wetlands there are some attributes that need further elucidation. The following points for saline wetlands are additional to the key attributes of generic wetland descriptions.

From this information saline lakes can be classified, and the potential for conservation and discharge of saline ground water assessed. One parameter that is often measured but rarely has much value is dissolved oxygen. The dissolved oxygen levels are very dependent on temperature and salinity, and these can change rapidly in saline lakes.

3.2.1 Conservation value

Some saline environments are unique for aesthetic reasons or are part of a larger conservation plan. For instance, one lake in southeast South Australia, which has a salt crust for most of the year, has freshwater reeds growing in the middle of all the salt. There is nothing unique about the salt or the reeds, but together they are unique and the relationship should be preserved. The presence of stromatolites/strombolites is another example. The evaluation of uniqueness should also extend to the surrounding vegetation. Some samphires are rare and endangered but the true distribution has not been mapped due to lack of research.

Figure 7 Halosarcia sp. Southern Wheat Belt Wetland



Most saline wetlands are important breeding and feeding grounds for birds, particularly the waders. Migratory waders make use of the extensive wetlands in Western Australia as they migrate from one hemisphere to the other. Obviously a lake on the migratory pathway is more valuable than one which forms part of the avifauna catchment. Some birds use salt lakes as roosting areas, such as the Cape Barren Geese in southern South Australia, while one thornbill is found only in some samphire marshes, and there may be other examples.

Specific conservation attributes need to be noted for saline wetlands. These may not be similar to conservation values for freshwater wetlands.

3.2.2 Ionic balance

The ionic balance in a saline wetland is quite delicate. By just changing the dominance of one seemingly trivial ion, as the brine concentrates, the final composition of the brine at sodium chloride saturation can be radically different. This in turn will affect the biology and chemistry of the wetland. For instance, if the sulphate is not present in the brine at the final stages of evaporation, then the carbonate alkalinity of the brine could be seriously reduced. This would support quite a different microenvironment than the more normal sulphate system (methane?). Conversely, low calcium might favour the release of nutrients from the sediment and could result in a dominance of sulphate reducing bacteria.

There is not a lot known about the relative major ionic concentrations and their impact on the saline flora and fauna. However, there is definitely a relationship. Even less is known about the importance of the trace minerals found in most ground water. Anecdotal evidence is that the flora in the middle salinity saltfield ponds around Australia varies quite significantly. Sometimes *Spirulina* sp. dominates and sometimes *Oscillatoria* sp., and at other times, green algae of various genera are the dominant species. (All these species incidentally have commercial value in intensive cultures.) In all of these fields the major ionic composition was similar and constantly monitored, so the inference was that a more subtle influence was taking place.

Most brines have a sea water evaporite ionic composition, that is, the ionic composition is the same as if seawater was evaporated to the same salinity. If the brine does not have a sea water composition then the brine may be commercial important as different salts become available and the ionic dominance can be quite unique.

The impact of saline discharge from agricultural land or mining effluent may be to change the composition of the brine in the lake. This may change both the biology and potential commercial value of the brine/salt.

The ionic composition of the brine needs to be determined. The ratio of the common ions should be compared to seawater and the effect of the effluent extrapolated. From this information it will then be possible to gauge the potential impact of the effluent on the biology and chemistry of the wetland.

3.2.3 Nutrient load

Most saline lakes rely on a vertical nutrient cycle. Organic material moves down the water column to the sediment, while reactive phosphate, a by-product of anaerobic decomposition in the sediment moves up through the water column.

Aerobic photosynthesising algae and bacteria typically colonise the upper layers of the sediment, overlying several layers of Cyanobacteria utilising the decreasing bandwidth, down to the purely anaerobic layer of sulphate reducing bacteria. The bottom layers are typically high in dissolved nutrients. This anaerobic "band" moves into the water column at night, creating a spike of activity in the early morning.

Figure 8 Cyanobacteria from Benthic Mat

This regime is disturbed when a high nutrient load is directed from off farming land or from mining operations into the lake. Often the lake will then become eutrophic, fragmenting the rigid vertical layering. It is in this state that the “toxic blue-green algae” blooms occur and the odour given off can be offensive to the human nose. At salinities of up to five times seawater concentration, such a bloom may kill birds and fish. In general terms, environments that change rapidly tend to favour “weed” species and, in the case of variable nutrients in saline ponds, the blue-green bacteria fill this niche.

The ionic composition has an impact on the nutrient balance. In the hypersaline range especially, the solubility of phosphates is controlled by the concentration of ions such as calcium.

Any contribution of saline water to a wetland must take into consideration the relative nutrient loads and whether the wetland will become eutrophic as a result.

3.2.4 Sediment load

The discharge from agricultural land is often high in sediment. Sheet erosion is a common problem depositing tonnes of topsoil into natural watercourses. This sediment must end up in the wetlands. Other than the chemical purity of the soil, there is also the problem that the gradual build up of material will change the flow characteristics of the wetland and fill in the impoundment. This is often not an immediate problem, as most lakes are robust. Problems will arise if the build up is rapid and the topography is sensitive to small changes. For instance, the lake may have adjacent shallow areas that support extensive salt marshes. If the deeper sections were to be filled by sediment then the summer boundaries of the lake may radically shift, covering and killing salt marsh vegetation. There is some evidence to suggest that some samphires require specific soil properties, so a rapid sediment input may encourage specific species.

A build up of sediment also has implications for flooding and other physical considerations, such as shading and encouraging phytoplankton.

The sediment load of the discharge water must be considered in the context of the geomorphic characteristics of the receiving wetland.

3.2.5 Species diversity and biomass

It is known that the algal diversity of saline wetlands varies but very little is known about the processes in natural saline wetlands.

The salinity characteristics will determine much of the species diversity. Planktonic surveys in very saline wetlands, plus macrophyte and invertebrate surveys in the less saline areas will be adequate for characterising the biota. Key species identification may be enough to characterise the wetland.

Some saline wetlands form very important feeding locations for migratory birds. Several saline lakes are RAMSAR sites because of their important role in providing habitats and food for birds. Lake Eyre, for instance, became a huge pelican breeding ground during its last major filling. The usefulness of a wetland and its immediate environs to birds should be assessed. The key difference between saline and freshwater wetlands is that, although both form important feeding grounds for birds as they evaporate, the saline wetlands provide an easy source of food with changing salinity, and very little when they dry out. Freshwater lakes, on the other hand provide most of the food when they are drying out.

Figure 9 Waders in Constructed Wetland

3.2.6 Hydroperiod/Depth Profile

Some wetlands are dry for many years and others do not dry out at all. All this encourages species with different strategies for coping with the radical change.

The deeper the brine, the slower the physical chemistry changes due to evaporation and precipitation. Saline water retains more energy as heat than freshwater because, as water becomes more saline, the water vapour is reduced meaning less energy lost through replacing the water vapour envelope. It would not be unusual for the brine temperature to reach 40 degrees Celsius during a summer’s day. Therefore the physical (hydrological) dimensions of a wetland are an important factor in determining biological amenity.

3.2.7 Salinity profile

The salinity profile is an important parameter. Some lakes change from magnesium saturation in summer to sodium saturation in winter, while other lakes are almost fresh for part of the year to perhaps sodium saturation at the end of summer.

The challenge will be to resist the proposal to discharge salty water into a lake that only sometimes becomes saturated with sodium chloride. The discharge may well make the lake saturated with salt for most of the year destroying the diversity of niches that occur throughout the changing seasons and salinities.

Much of the Western Australian work quotes Hammer (1986) as proposing a system classifying the salinity range into a number of groups. If there is a need to separate the range, Hammer’s 1986 work is satisfactory, but in his work the term hypersaline referred to brines with a salinity above 50 ppt and he did not break the range further by using the term “brine” (W.D. Williams pers. comm.). Biologically there is a case to divide the range further by including a term to describe the range from 100 ppt to 350 ppt (sodium chloride saturation) but the term brine is totally unsuitable for this use. Perhaps the term hypersaline could apply to the range from 100 ppt to 350 ppt, and another be allocated to the range from 50 ppt to 100 ppt. A suggested classification that is more consistent with common usage and Greek/Latin languages is

Oligosaline	<1000 ppm salinity
Meiomesosaline	1000-3000 ppm salinity
Mesosaline	3000-20000 ppm salinity
Pleiomesosaline	20000-50000 ppm salinity
Polysaline	50000-100000 ppm salinity
Hypersaline	>100000 ppm salinity

3.2.8 Geomorphic attributes/profile

All of those dimensions used in classifying wetlands are important when evaluating a saline wetland. Most of these are interrelated with the attributes already mentioned and geomorphic changes will obviously have a flow on effect.

3.2.9 Social value

This incorporates a number of issues, such as heritage, recreational and ethnic values. Many waterbodies are used for recreational purposes and having a greater volume of water is not necessarily an advantage. An example would be the cancellation of the Todd River Regatta this year because of rain. Others would be salt lake regattas and speed trials for cars and the like.

This section is only dealt with briefly as saline water bodies have many things in common with their freshwater counterparts in this area.

3.3 Discussion

The above attempts to describe or note some of the more obvious impacts of discharging saline water into a saline wetland. An environmental audit preceding an impact assessment should include a mass balance of the water and salt mass. A model facilitating the generation of gross balances of water, ions and sediment of the wetland would be useful. From this, impacts on various uses can be assessed.

4 References

Duda, R. and Rejl, L. 1986; *Minerals of the World*; Crown Publishers, New York.

Hill, A.J., Semeniuk, C.A., Semeniuk, V. and Del Marco, A., 1996; *Wetlands of the Swan Coastal Plain Volume 2a*; Western Australian Waters and Rivers Commission and Department of Environment.

Hammer, U.T., 1986; *Saline Lake Ecosystems of the World*; Dr. W Junk Publishers.

Semeniuk, C.A, 1987; Wetlands of the Darling System-A geomorphic approach to habitat classification: *Journal of the Royal Society of Western Australia* Vol 69 p 95-111.

Semeniuk, C.A., and Semeniuk, V.; *The geomorphic classification of wetlands*; in: Hill, A.J., Semeniuk, C.A., Semeniuk, V. and Del Marco, A., 1996; *Wetlands of the Swan Coastal Plain Volume 2a*; Western Australian Waters and Rivers Commission and Department of Environment.