PART A

PROJECT GUIDELINES AND DECISION SUPPORT FOR SUSTAINABLE USE, CULTIVATION AND CONSTRUCTION OF WETLANDS

PART A

Table of Contents

List of Figures

1
INTRODUCTION

1.1 WETLAND DEFINITION

The Convention on Wetlands of International Importance Especially as Waterfowl Habitat 1971 (Ramsar Convention) defines wetlands as follows:

> *"areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters"*

(Article 1.1, Ramsar Convention)

1.2 PRESENT STATUS OF WETLANDS IN SOUTH AFRICA

Wetlands have been identified as the third most important life support system on Earth (The World Conservation Strategy, IUCN, 1980). Because of South Africa's narrow coastal strip, there are few lowlands and associated wetlands. Yet over half of the few wetlands of South Africa have been already destroyed (Breen and Begg, 1989). Because wetlands act as vast sponges to hold water run-off, wetland loss is of serious concern for a country which is essentially arid (the average annual rainfall of ~500 mm is ~350 mm below the world average, (Cowan, 1995)). In consequence of wetland and general water mismanagement, it has been estimated that SA will run short of water by the year 2030 (Lindley, 2001).

1.3 PRESENT STATUS OF NATIONAL POLICY ON WETLAND USE

Considering the present rate of wetland loss in SA, it is crucial to have a national policy to guide management and conservation of remaining pristine wetlands, and the sustainable use of other types of wetlands. Broad objectives of the Ramsar Convention include that each contracting party (of which SA is one) should stem loss of wetlands and promote wise use of wetlands (Cowan, 1995).

The Sub-directorate Ecosystems of the Department of Environmental Affairs and Tourism is responsible for the South African Wetlands Conservation Programme. One of their eight sub-programmes include forming a national policy on wetlands. The Ramsar Convention will be accepted into South African legislation through the Wetland Conservation Bill after amendments. Another important subprogramme is that on interdepartmental co-ordination where the state departments most obviously involved would be the Department of Water Affairs and Forestry, the Department of Environmental Affairs and Tourism, and the Department of Agriculture.

1.4 EXISTING LEGISLATION AND GUIDELINES ON WETLAND USE

Although a broad variety of wetlands exist in South Africa, and South Africa has acknowledged the importance of wetlands by acceding to the Ramsar Convention, its legislation is not comprehensive, and a dedicated wetlands protection Act is lacking.

The National Water Act 36 of 1998 makes specific provision for the protection of wetlands. The Conservation of Agricultural Resources Act 43 of 1983 also covers wetlands, but this Act does not apply to land situated in any urban area. It is also arguable that the Sea Shore Act 21 of 1935 is applicable in the case of those wetlands in coastal waters, such as tidal lagoons and estuaries. The Environment Conservation Act 73 of 1989 and Regulations are relevant in the case of ‘reclamation’ of land in wetlands and below the high-water mark in coastal waters. A national policy on wetlands is in preparation.

To date, the following informal guidelines exist on wetland management in South Africa:

- **WETLAND-USE** - a wetland management decision support system exist which assists agricultural and nature conservation extension workers by providing advice for agricultural land-use (cropping, grazing, burning) in wetlands (Kotze *et al*., 1994). The system helps identify what was defined as acceptable land-use for a particular site based mostly on soil characteristics as an indication of wetland zone (open water, marsh, wet meadow and wet grassland). The system is ideally consulted in conjunction with a document on land-use impacts on wetlands (Kotze and Breen, 1994). Recommendations on burning may not be in keeping with a future national policy (see Section 4).

- **WETLAND FIX** – a publication of field guides emerging from four years of the Rennies Wetlands Project, and discussions with farmers and agriculture/conservation extension officers in KwaZulu-Natal, the Eastern Free State and Mpumalanga. Wetland Fix is South Africa's first illustrated set of field guides on the assessment, management and rehabilitation of wetlands. Reports on rehabilitation and wise use of wetlands are also presented (http://www.wetland.org.za/). The series includes:

- Part 1: Introduction and wetland assessment.
- Part 2: Wetland burning and grazing guide.
- Part 3: Streambank stabilization and channel plug development.
- Part 4: Indigenous plants suitable for rehabilitation.
- Part 5: Spring protection guide.
- Part 6: Alien plant control guide.

It should be remembered that the guides mentioned above, as well as these WRC project Guidelines, are merely intended to direct the user towards the appropriate decision for the particular wetland in question. No one guide is a replacement for a multi-faceted, site-specific approach which entails gathering information, using the appropriate guide(s), consulting people involved and applying the results to the local situation.

Although there is no national policy on wetland use as yet, it is clear that any cultivation-use of wetlands should be limited to altered or constructed wetlands, be sustainable, and maintain or restore the functionality, i.e. ecology and hydrology, thereof.

1.5 WISE USE OF WETLANDS: SITE ASSESSMENT AND DESIGN

Wetlands have been used actively for water purification, for the cultivation of aquatic and semi-aquatic plants (medicinal, building and textile materials) and for recreation, including tourism. Wetlands are in any case a source of food (fish, shellfish, crustaceans and plants), water (domestic, agricultural and industrial) and recreation for people.

In these Guidelines, a clear distinction is made between the appropriate uses of altered, pristine and constructed wetlands. The Guidelines help the user to identify the type of wetland in question. From there, practical guidelines are given mostly on cultivation in altered wetlands. Regarding pristine wetlands, this guide recommends non-invasive use. On the rehabilitation of wetlands and construction of wetlands, there is a wealth of detailed literature and the reader is referred to this. While the content of this document is mostly on cultivation in altered wetlands, current opinion and policy on use of pristine wetlands and reference to sources for constructing and rehabilitating wetlands are included for completeness.

Regarding cultivation in altered wetlands, the key to proper wetland site assessment and design is through obtaining the relevant information and making the necessary on-site observations and measurements. Ways of finding this information are given in these guidelines. In addition there is a database of wetland plants with economic potential, `new green`, which is designed to be used together with these guidelines. The `new green` database is available on the world-wide web at the site: www.wrc.org\newgreen.

2
HOW TO USE THIS GUIDE

This guide is to be used together with the new green database on wetland plants with economic potential (see Main Form in Figure 1), and with the flow diagram in Figure 2. Each section of this guide is essentially an explanation of the relevant step shown in the flow diagram. The steps in the flow diagram cross-refer to the relevant section of this guide.

Although details are given for plant cultivation methods, it is stressed again that cultivation is only appropriate in altered wetlands where such cultivation would be rehabilitative, that is by cultivating wetland plant species.

This guide and new green provide decision support when cultivation in a wetland is being contemplated. However, they do not provide the last word, and their use should be accompanied by consultation with local wetland and plant experts, relevant environmental organisations, as well as by consultation with local and national authorities administering land use, environment and water affairs.

3
INTERFACE BETWEEN NEW GREEN AND THESE GUIDELINES

Four options for searching new green are presented in the main form of the database (Figure 1):

1. SITE QUIZ search, which allows the user to characterise the type of wetland and provides a list of the viable species for a wetland with those characteristics;
2. SPECIES search, provides information about a particular species;
3. USE search, provides a list of species which have a particular use (e.g. Medicinal, weaving, etc); OR
4. REGION search, provides a list of species for the region of interest.

Figure 1 Main form of the database `new green`

The four options for starting a search to assess sites and species are explained more fully below in relation to these guidelines:

1 SITE QUIZ

This search option goes hand-in-hand with the Site Assessment step described in these guidelines below at 4.1.1.

The first stage of enquiry involves making a preliminary assessment to determine whether the particular wetland is in a pristine condition, or whether it has been altered. Pristine wetlands must not be altered in any way by cultivation or introduction of additional plant species, and the only option is for non-invasive and sustainable uses of the wetland and the plants occurring there naturally.

- If a potential site is an altered wetland, site assessment based on visual inspection, historical data, digital data, and ground-truthing will provide the data for the site quiz.

Ways to find this information (regional and metropolitan scale) are provided in these Guidelines at 4.1.1. Once a site has been environmentally characterised in this way, the new green Site Quiz search provides a list of plant species appropriate to the site.

2 SPECIES

If the desired plant species is selected first, an appropriate site may be found based on the optimal environment displayed in the database for that plant species.

3 USES

If the potential uses of the plant and the site are known (e.g. growth of medicinal aquatic plants, sustainable harvesting of *Typhus* reeds), the database provides a list of potentially suitable species together with their optimal environmental conditions. This makes it possible to choose a suitable site in which to grow them.

4 REGION

If the user is not sure where to start, the database can provide a list of species which occur naturally in a given region of South Africa.

Whether the user chooses the new green SITE QUIZ initially or has to assess the site after selecting plant species or use, some site assessment will be necessary.

4
CULTIVATION IN WETLANDS

The following definition of the wise use of wetlands was accepted at the third meeting of contracting parties to the Ramsar Convention:

> *"The wise use of wetlands is their sustainable utilization for the benefit of humankind in a way compatible with the maintenance of the natural properties of the ecosystem."*

In accepting this definition of the wise use of wetlands, the Ramsar Convention recommends that all contracting parties prepare national wetland policies. Policy on use of wetlands falls mostly within the spheres of environmental affairs, agriculture, water affairs and nature conservation. The most recent discussion document for agricultural policy in SA (Ministry for Agriculture and Land Affairs, 1998) states the following regarding natural wetlands:

> *"in accordance with the Conservation of Agricultural Resources Act, 1983 (Act No. 43 of 1983), there are control measures governing certain agricultural activities.* ***A land owner may not use the vegetation in a wetland in such a manner that it causes deterioration****;* ***cultivation and drainage of wetlands are not permissible****; the flow pattern of water may not be changed; and permission must be obtained to burn wetland, and this will only be given under special circumstances "*

It is clear that draining, clearing and burning of wetland areas for conventional dryland crop production is inappropriate and not in keeping with the above policy statement. However, there would be a large difference between the impact of conventional crop production on wetlands and that of a more sustainable approach that did not involve drainage or alteration of flow. There have been no statements specifying to what degree wetlands may be cultivated if cultivation maintains the ecological and hydrological functioning of the wetland. The Ministry for Agriculture and Land Affairs should include a clear statement on different modes of cultivation and their acceptance in their national policy on wetlands, which is in preparation.

A project dealing with cultivation in wetlands will pass through two broad stages, planning and implementation (see flow diagram). Both stages can be broken down into a number of steps, as has been done in these Guidelines. The first step of planning requires an assessment as to whether it is an altered wetland or whether it is still in a pristine natural state, since the potential use to which it can be put depends firstly upon this factor. Once this has been established, the planning stage may proceed through further steps culminating in project implementation.

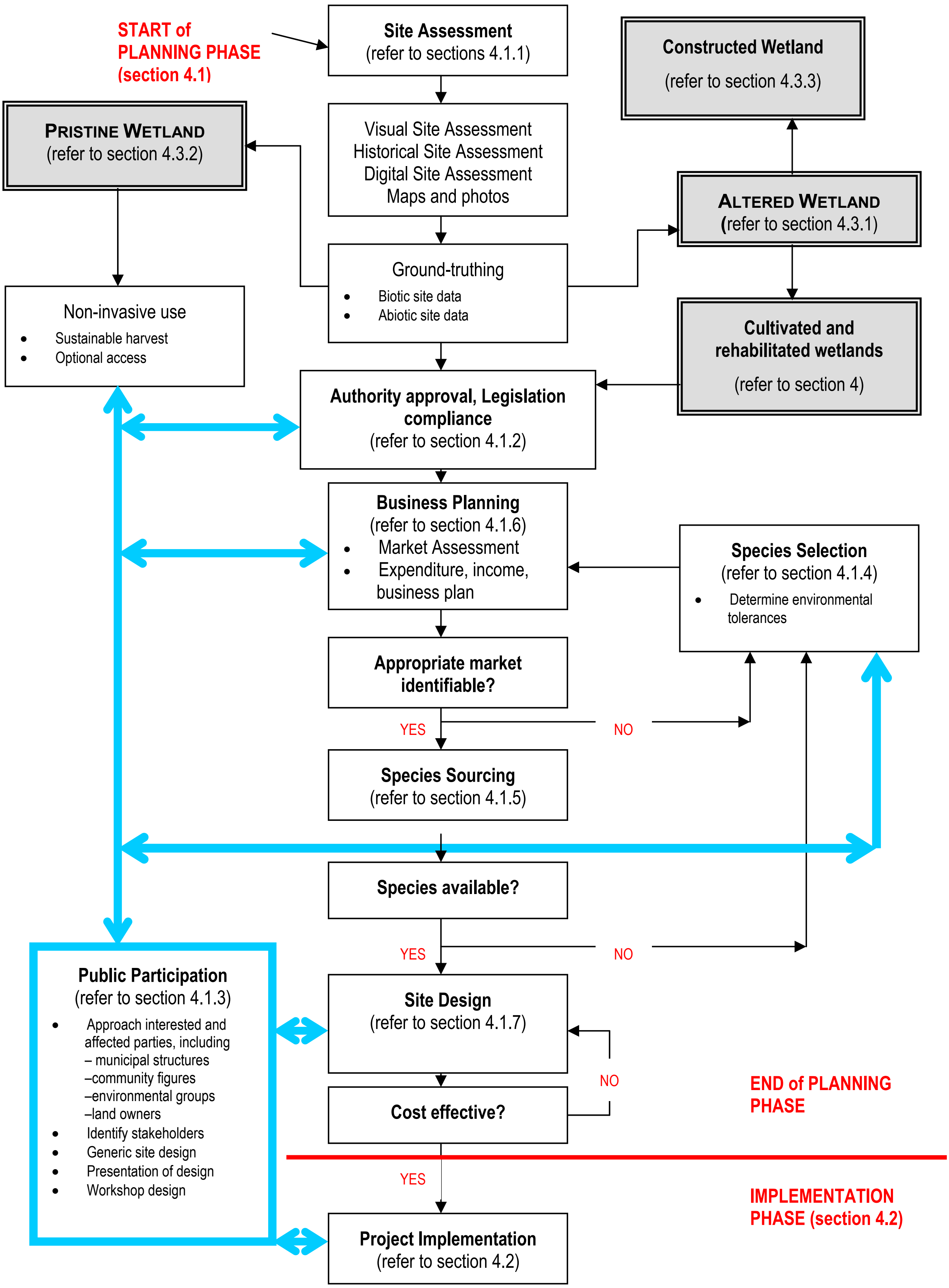


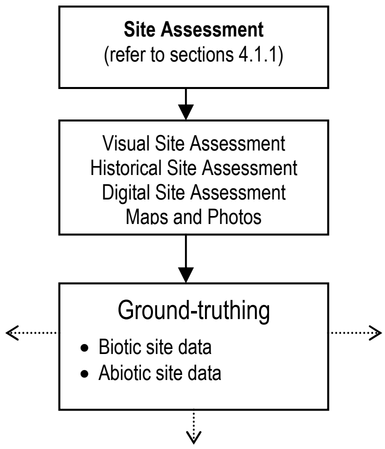
Figure 2 Flowchart outlining generic site assessment and design procedures for sustainable use of wetlands

The steps of planning and implementation are described below at section 4.1 and 4.2.

4.1 PROJECT PLANNING

4.1.1 SITE ASSESSMENT

This step will allow the user to decide whether the wetland site is in pristine condition, or whether it has been altered and is thus suitable for cultivation. Wetland sites can be assessed by one or more of the following routes:



1. By visual inspection;
2. From historical data or existing data-sets on wetlands;
3. Using digital site assessment, maps and photos;
4. By ground-truthing (i.e. measurement on site)

The types of information of relevance to the assessment include the following:

- Topography and geology;
- Climatic data for the site and its catchment area;
- Catchment conditions;
- Soil characteristics;
- Water characteristics;
- Water and soil nutrients;
- Water and soil pollutants;
- Wet and dry cycles, and flooding levels and patterns;
- Vegetation characteristics and species inventory;
- Animals and insects present;
- Prior and present land uses.

The four broad methods of acquiring this type of information are discussed further below. Site assessment using any of these methods will require the help of appropriate environmental experts. Local environmental consultants can be approached. Other expert information is freely available on the Internet, for example at the Wetland Fix site http://www.wetland.org.za/. The site has a series of six field guides including one on site assessment (Part 1: Introduction and wetland assessment). Wetland Fix guides provide a simple method of wetland evaluation for use by an agency extension official and others who are unfamiliar with wetlands and who are not wetland specialists. It is intended to be used for education, simple impact assessments, management or restoration, and wetland inventory purposes.

1. Visual site assessment

This is quite literally a process of walking though the site, and noting the following:

- signs of pollution of the water, litter, industrial waste, human or animal wastes;
- species of plants present;
- species of animals, birds and insects present;
- artificial drainage ditches, pipelines, channel or weir construction;
- signs of overgrazing, trampling, ploughing or other cultivation methods; and
- any other signs of alteration or over-use

2. Historical data and existing data sets on wetlands

Historical environmental data can provide broad and large-scale information on e.g. topography, floodlines and vegetation. This facilitates the site design and planning of the placement or modification of various structures (e.g. weirs, water retention trenches, irrigation and diversion channels) if these are to be used.

There are also inventories of SA wetlands available from the Department of Environmental Affairs and Tourism (South African Wetlands Conservation Programme, 1997). These provide data sets on marine, estuarine, riverine, lacustrine and palustrine wetlands. This can assist those in need of data as an interim substitute for a full wetland survey .

3. Digital site assessment, maps and photographs

Digital information sets can be obtained from the Department of Land Affairs, Maps and Surveying in Mowbray, Cape Town. These are suitable for GIS-based assessment.

Maps and aerial photographs of areas in S.A. can be obtained from the Department of Land Affairs, Maps and Surveying in Mowbray, Cape Town. Small-scale aerial photographs (e.g. 1:2000 or 1:5000) with data overlays such as floodlines can be obtained from the survey branch of city administrations or regional service councils. In addition, urban and environmental planners/consultants may be commissioned to survey an area.

Environmental data and maps are also available from government and educational institutions (see below for examples). The following are some of the important environmental parameters and the common sources of this data:

Soil data

Information about soils is available from a number of sources.

A. Environmental Potential Atlas (ENPAT)

ENPAT is a CD-based digital geographic and environmental database for South Africa which utilizes GIS (Geographic Information Systems) technology (Van Riet *et al*., 1997). ENPAT draws together on one CD environmental information for South Africa that was originally spread across a variety of media from many different organizations. It should be noted that ENPAT can only give a very general idea of the soil type of the area, with resolution at the metropolitan scale. Even at better resolution, however, it is important to note that wetland soils may differ from the surrounding soils, and wetland soils should be ground-truthed.

Other data available on ENPAT concerns rainfall, geology, catchment area, vegetation types and land use, amongst others. Maps are also available which combine data sets in a unique way (e.g. a map of areas with potential for environmentally sustainable development was constructed by combining data on environmental resources and population density).

ENPAT provides information at national, provincial and metropolitan scales (Gauteng, Cape Town, Port Elizabeth, Durban Functional Region and Bloemfontein). It is available from the ENPAT Steering Committee, Department of Environmental Affairs and Tourism.

B. University Soil Science Departments

Soil science experts at local university and agricultural colleges should be able to act in an advisory capacity and provide soil maps of the relevant area.

Climatic data

South African Weather Bureau (SAWB)

The SAWB provides monthly and annual rainfall and temperature maps (in millimetres of rainfall, or percentage of normal). Maps are available as hard copies or files of these can be downloaded directly from their Internet site http://www.weathersa.co.za. Data are available regarding temperature, rainfall, humidity and days of sunshine. Data are available for national, regional and metropolitan levels.

Biome and vegetation data

Vegetation maps are available from the Department of Land Affairs, Maps and Surveying, Mowbray, Cape Town, and are also available on ENPAT. In addition, the user should note the biome of the site and the existing vegetation to determine which plant species grow naturally in the area. Consequently, some existing species may be added to the desired species list. Aerial photographs, if of a sufficiently high resolution, and low-level remote sensing technology can also be extremely accurate and informative, but must be ground-truthed.

Animal and insect data

Information about animal distribution can be found in standard reference works. Insect distribution tends to be quite localised, and ground-truthing will be the primary way to ascertain this.

At this stage of the site assessment it should be possible to evaluate the wetland site, and decide whether or not it has been altered. If it is in an unaltered state then the options for its future use are limited to those that are sustainable and non-invasive.

On the other hand, if it has clearly been altered then more options exist regarding its future use. In this case, it will be necessary to ascertain the physical condition of the wetland components, so that plants can be chosen for cultivation which will tolerate the on-site conditions.

4. Physical site assessment and Ground-truthing

Biotic data

A survey of existing plant, animal, bird and insect life should be carried out, noting the presence of any endangered or red data species. Their presence may preclude cultivation on all or part of that site. An assessment of the existing biota will also reveal whether any useful indigenous species are present, as well as the presence of exotic and invader species.

Assessments can be conducted using field guides and/or with the help of botanists, zoologists and environmental consultants. Leaf samples may be taken from plants in order to compile a species list, which can be done by the local herbarium.

If a species present on the site is also a species desired for cultivation, leaf samples can be taken for analyses of macronutrients (Nitrogen, Phosphorus, Magnesium, Calcium, Potassium) in order to assess the fertility of the site for that species. Also, other elements that may be important on that site can be analysed, such as heavy metals, micronutrients or sodium (on saline sites). Results of analyses are only useful if standard or reference values are available for the desired plant species to be cultivated. Certified laboratories for soil, plant and water analyses can be consulted.

Abiotic data

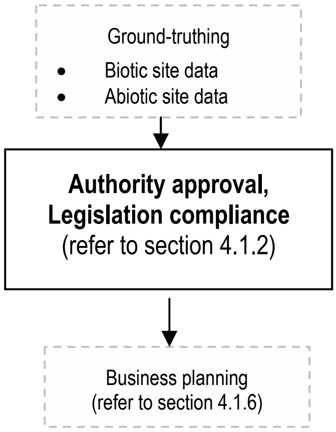
The following baseline measurements should be obtained on-site:

- soil types;
- soil nutrients (carbon, nitrogen, phosphorus, magnesium, calcium, potassium);
- other soil parameters (soil type, texture, pH, electrical conductivity);
- water nutrients (nitrate, nitrite, ammonium, phosphate, magnesium, calcium, potassium);
- other water parameters (pH, temperature, electrical conductivity, chemical oxygen demand, suspended solids, levels of faecal coliform bacteria and *E.coli*);
- daily maximum and minimum air temperatures;
- water availability and seasonality.

This data will provide the user with the actual growing conditions which can be expected on site, and will assist in selection of suitable species for cultivation. For example a site heavily contaminated with faecal coliforms and/or heavy metals would not be suitable for harvesting either medicinal or edible plants, since these would be unsafe for human use and consumption. Certified laboratories for soil, plant and water analyses can be consulted prior to taking samples, and having them analysed.

4.1.2 AUTHORITY APPROVAL AND LEGISLATION COMPLIANCE

This is an integral part of the broader public participation process.



During or immediately after the site assessment process outlined above the user must initiate discussions with the national, provincial and local authorities. Determine the level of support of the authorities for your plans. Look for areas of synergy between your plans and the policy, plans and projects underway already. The national, local and provincial authorities will also be able to advise you as to the relevant legislative instruments with which your plan must comply, and the various authorisations which will be required before the plan can become reality.

At the national level the relevant authorities would be the Departments of Environmental Affairs and Tourism, Water Affairs and Forestry, and Agriculture and Land Affairs. Relevant national legislation would be those laws which are administered by these national departments - National Environment Management Act 107 of 1998 and the Environment Conservation Act 73 of 1989, National Water Act 36 of 1998, Development Facilitation Act 67 of 1995 and various other statutes dealing with agriculture, land reform and development. For further information refer to Environmental Law in South Africa by Glazewski (2000).

Once it has been determined that the plan can be accommodated in principle within national, provincial and local legislative and policy contexts, you must comply with the following two Acts with regard to environmental assessment procedures to be undertaken and the environmental approvals required:

1. The National Environmental Management Act
2. The Environmental Conservation Act

It is only after environmental approval has been obtained that it then becomes possible to apply for any approvals required by national and provincial land-use planning laws and local by-laws. For more information about relevant provincial planning laws see Planning Law by van Wyk (1999).

4.1.3 PUBLIC PARTICIPATION

In addition to consulting with local authorities, the communities surrounding the site, local land-owners, and other stakeholders must be informed and consulted as an integral part of the assessment, and subsequent design of the site. Even if the surrounding communities are not to be directly involved in the wetland cultivation project, they must nevertheless be consulted at least in the initial stages of the project. Stakeholders include land owners, municipalities, community figures and environmental and botanical organisations.

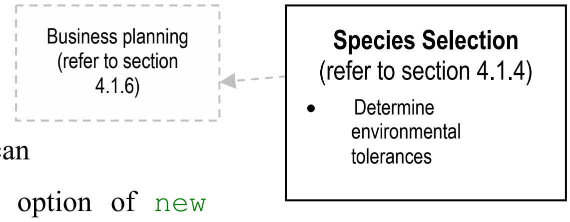
> **Public Participation**
> (refer to section 4.1.3)
> - Approach interested and affected parties, including
>   – municipal structures
>   –community figures
>   –environmental groups
>   –land owners
> - Identify stakeholders
> - Generic site design
> - Presentation of design
> - Workshop design

A process of public participation should inform each stage of the project planning from authority approval to species selection, business planning, site design, and land use. It is highly recommended that the assistance be obtained of someone experienced in public participation processes. Furthermore it is important that the public participation process be carried out in a clearly independent manner, ideally by someone who is not associated with either the project planning, the community or the local authority interests.

If any of the surrounding communities are to be directly involved in the wetland cultivation project as stakeholders, then the following should be ascertained:

- What is the extent of community interest in the project?
- Are there any conflicts in land use by the community?
- Will the project affect living conditions of the community, e.g. in terms of water quantity or quality?
- Will the community benefit from the project, e.g. in terms of income generation
- Is the community cohesive enough to contribute to or manage the project?
- Does the community provide a secure environment?
- Does some social structure already exist that could be used as a platform for the project (e.g. some existing environmental or self-help group)?
- Can interest and/or financial support from other community organisations and the regional council be obtained?
- Who will be the direct beneficiaries of the project?

4.1.4 SPECIES SELECTION

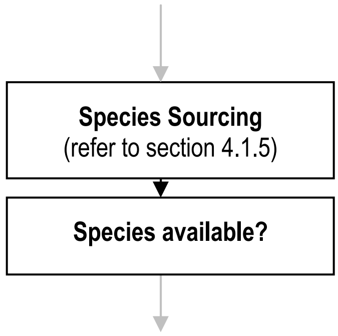


Once a site has been environmentally characterised, the new green database provides a means of selecting plant species appropriate to the site. These can be accessed via the SITE QUIZ search option of new green.

Alternatively, as mentioned in Section 3, the potentially suitable plant species may be selected first via the new green SPECIES search option, or by narrowing the search by using the REGION option. After this selection, an appropriate altered wetland site may be found based on the optimal environment displayed in the database for the desired plant species. Similarly if the user knows what products are to be marketed, the database provides a USES search which will select the species which have the relevant use, and give the optimal environmental conditions of the species so that a site may be chosen or evaluated based on this. In all cases, the database provides information on the range of environmental tolerance of the species, which should correspond to the site chosen.

The selection of species for cultivation is simultaneous with the market assessment stage, and in the early stages of planning a range of species may be assessed for marketability, before narrowing them down to the best or most promising candidate/s.

4.1.5 SPECIES SOURCING



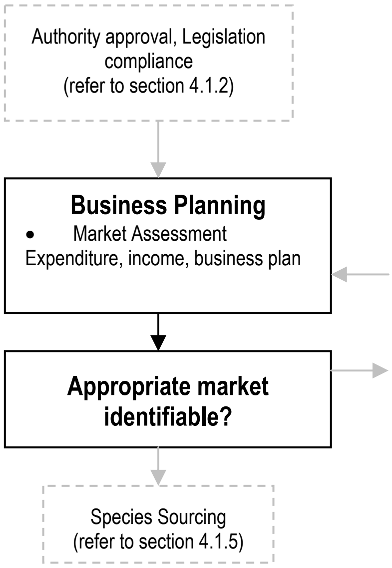
The following factors should be considered in sourcing suitable plant material for the project:

- Search and rescue of plants from new development sites is a low-cost alternative to purchasing plants from nurseries, but this can only take place if the necessary legal collection permits have been obtained first, usually from the provincial nature conservation department;
- Growers and suppliers of the plant species selected should be located;
- new green has some information on plant sources (see below);
- Choose a supplier who is close to the site to reduce transport costs;
- Ensure that the most suitable and marketable varieties of the chosen species have been identified;
- Make sure adequate plant supplies are available before planting begins.

The new green database provides plant species' availability where possible. Another database, NURSERY, was used to obtain some of this information. Both NURSERY and a similar database, INDPLANT, were designed for use with Microsoft Access. NURSERY provides propagation and plant availability information for all species that might be of interest to nurserymen, i.e. not only indigenous SA plants are listed. INDPLANT has a similar structure but provides information on only desirable indigenous plants for the garden (i.e. poisonous indigenous plants are excluded). Both NURSERY and INDPLANT can be obtained from Prof. JF de Wet, PO Box 13145, Humewood, 6013, Port Elizabeth. It is recommended that only indigenous SA plants be used for cultivation in natural wetlands, while other species could be used in constructed wetlands (see Section 6).

4.1.6 BUSINESS PLANNING

Business planning requires the assessment of the potential market for the product, and estimation of the income stream once the project is up and running. It is also necessary to plan in detail the expenditure required in setting up and operating the project. Successful planning also requires identifying potential pitfalls and risks, and building in contingency measures to the budgeting and planning process, in order to deal with these eventualities in ways that will allow the business to remain operational.



Market assessment is an important factor which can influence project sustainability. Market assessment should be carried out in parallel with species selection, site assessment and public participation.

new green provides a USES search option, allowing the user to search for plants which have a particular use, for example medicinal or craft use. In this way various markets can be assessed, based on the various uses to which plants or parts of plants can be put. Alternatively, plants species can be selected to supply material for a particular market which is known to exist, and about which there is reliable information available.

Provided that the plant species under consideration are marketable, the calculated revenue per hectare must be greater than the costs incurred per hectare in order for the cultivation project to be financially viable.

1. Market assessment

Local and foreign markets should be investigated and buying prices obtained for the potential product, and for similar products. Amongst the factors which must be taken into account are the following:

- Market demand and size of the market;
- Fluctuations in the market, due to seasonality, competition, and changes in consumer preferences;
- The need to establish a market or to educate consumers about the product;

- Quality level required in order to enter the market;
- Marketing costs and barriers to entry.

2. *Expenditure, Income and Business Planning*

Once the existence of an attractive market for the proposed product has been identified, a generic business plan should be drawn up to determine whether the scheme is broadly viable. This involves estimating the expenditure and income of the proposed project, and identifying potential problems so that contingency plans can be made for dealing with these.

Expenditure

The following factors must be considered in determining expenditure:

<u>Set-up costs and capital expenditure:</u>

- Site assessment (experts' and consultants' fees, laboratory analyses);
- Site preparation (earthworks, soil preparation);
- Plant material purchase;
- Materials (fencing, walls, pipes, hosing, pumps);
- Tools;
- Structures (sheds, offices);
- Transport, labour, and training costs involved in site establishment;
- Community liaison costs;

<u>Running costs:</u>

- Cost of project finance (interest charges);
- Depreciation of capital items;
- Site lease or purchase costs;
- Site management and office and administration running costs;
- Site services such as electricity and water charges;
- Transport (also for delivery of produce);
- Labour (permanent and casual);

- Training of staff;
- Site maintenance (compost, fertilizer, plants);
- Seasonal costs of production (packaging, storage of produce).

Income

The predicted running expenses are offset against the gross income from sale of the produce. Gross income will depend on the market value of the product, yield per hectare of the plant product, and total area under cultivation. Information on plant yield per hectare for some plants is available from the `new green` database. However, for most species this is highly site-dependent. Some market prices are available from `new green` as well, but in general market prices for produce at local and foreign markets will have to be determined for each specific situation. This information may be found through the local Chamber of Commerce, farmers' co-operatives, and on the Internet.

Cash flows can be calculated for a number of years after planting (depending on plant life-cycle and seasonality). The business plan should allow for initial lags in production, and increasing production with plant maturity. For instance production costs may exceed income in the first few years of cultivation but as yield and income increases the project may become self-sustaining in subsequent years. This scenario must be included in the business plan.

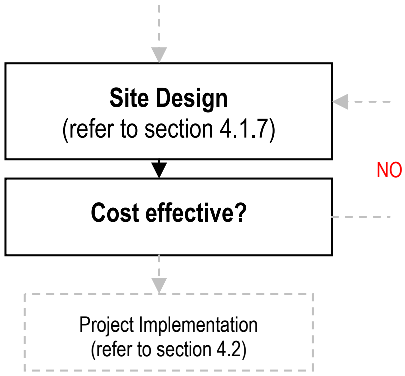
Business planning

Once the market has been assessed and the cash flow spreadsheet prepared, the planning should identify the critical risks and potential problems that the project will face. Contingency plans, together with a contingency budget, must be made in order to handle these situations and delays which inevitably arise. The business plan must also make allowance for inflation, and for the effects of exchange rate fluctuation in the case of an export project.

It is also advisable to develop business plans for sites of different sizes, since a project that is not financially viable on a small site may turn out to become so on a larger one. In general it is best to choose a site size that is manageable but which can be extended as finance allows, i.e. start small, but plan for expansion.

4.1.7 SITE DESIGN

Site design will depend on various criteria listed below:



1. *Biophysical criteria*

1. The size of area available for cultivation. Site establishment costs may be such that a site less than a given size will not be financially viable straight away. However, a smaller site could be financially viable after a number of years and is less risky than investing large amounts in cultivating a large area, particularly in a market that is not completely known.

2. Physical characteristics of the site: climate, water availability, water quality, soil types.

3. Site topography and flood risk. Depending on the nature of the plant species, this may have more or less significance for the project design.

4. Wind exposure.

5. Local wild fauna and domesticated animals.

6. Provision for setting aside fallows. Extensive weed invasion can be typical of cultivated wetlands after a few years (Nebel, 2001).

2. *Economic criteria*

1. Distance from roads and airport, if relevant.

2. Investment in security measures on site.

3. *Social criteria*

1. Current land use, including informal uses. Significant conflicts may arise if this is not correctly assessed from the very beginning of the project.

2. Zoning and proposed future land use. Included here is the existence of any Land Development Objectives (in terms of the Development Facilitation Act) and Integrated Development Plans (in terms of the Local Government Transition Act 209 of 1993). In urban areas in particular, it is important to determine if such long-term master plans exist for the area, which may involve new or redesigned stormwater flows, transportation networks, housing settlements, or specific economic development objectives.

3. Land ownership. Cultivation projects may be established on municipal land, private land, or other (e.g. communal) land, and in each case the nature of the negotiation with the stakeholders and the relationship with the community will be different.

4. Community stability. Where a community is recently established, or significant social conflict exists, this type of long-term cultivation project may not be appropriate. Stable communities and strong community structures will tend to promote the project's long-term viability.

5. Distance from potential labour force. It will be socio-economically more beneficial if jobs can be made available close to communities which have high unemployment levels.

Criteria such as those listed above can be used to evaluate several competing cultivation sites. Each site is assessed for how well it meets the various criteria, and by assigning a final numerical value to each of the sites they can then be ranked in order of suitability for a particular cultivation proposal.

An example of an evaluation carried out specifically for the cultivation of arum lilies is given in Table 1. **Please note** that characteristics of a site that have been allocated a negative ranking for the cultivation of arum lilies may not be relevant in the case of cultivating a different plant. For example arum lilies do not tolerate heat well, therefore sites with a hot climate receive a negative ranking. Also note that some of the criteria of relevance in one project may not be relevant in the case of a different project.

Table 1 Site ranking for arum lily cultivation project in Cape Town wetlands.
Primary and secondary criteria are listed along with explanation of what would be considered positive, acceptable and negative attributes of each for purposes of arum lily cultivation.

Characteristic	Positive (+)	Acceptable (0)	Negative (-)
Primary criteria			
Available area	>15 000 m^2	10 000–15 000 m^2	<10 000 m^2
Current land use	Unused/ Public open space	Informal recreation	Used: housing, formal recreation, farming, industry, or nature conservation
Zoning and availability (Proposed land use)	Public open space Available immediately	May be rezoned within the next 5 years/ Not available immediately	Zoned for other purposes/ Zoning contested
Land ownership	Local, provincial or national government	Communal	Private
Flood risk	Low flood risk	Moderate flood risk	High flood risk
Topography	Flat floodplain	Not flat	Significantly higher than channel
Climate	Cool, no frost	Warm/ Cool with frost	Hot
Water availability	Suitable wetland/ Infrastructure for irrigation in place	Infrastructure for irrigation and flow control required	Water not available
Water quality in terms of plant requirements	Unpolluted	Pollution levels within tolerance limits	Pollutants a risk to plant health
Water quality in terms of human requirements	Unpolluted	High faecal coliform counts- worker protection required	Unacceptably hazardous to human health
Ecosystem condition	Moderately disturbed (1)	Highly disturbed (2)	Severely polluted/ Undisturbed (3)
Community stability	Stable community organizations exist with some environmental capacity	Stable community organizations exist	Unstable due to community divisions or conflicts
Secondary criteria			
Distance from road	Direct vehicular access	Access could be inexpensively provided	No vehicular access
Distance from work force	<2 km	2 km	>2 km
Distance from airport	<20 km	20–50 km	>50 km
Security	Protected/ Already fenced in	Could be protected	Difficult to protect

(1) Litter, human waste; (2) industrial waste, heavy metal contamination; (3) undisturbed sites qualify as pristine, therefore cultivation inappropriate.

4. *Ecological design criteria for altered and constructed wetlands*

The most effective way to develop and manage such wetlands is so as to mimic the functional ecological components of a natural wetland (Williams, 1994).

It is imperative therefore that wetland cultivation projects strive to maintain the nature and function of a wetland, and that they do so in a sustainable manner.

Sustainability

In natural systems, the components of a wetland are multifunctional and many functions are therefore also served by several components (Mollison, 1988). This contributes to system stability and reduces the management requirements of the site. The following generic procedures can be adopted when designing a site:

- Make a list of site components and intended site components (crop, existing vegetation, river, dunes, reeds, workers, etc.);
- Assemble and choose these components in such a way that each component is multifunctional and each function (e.g. water purification, floriculture) is served by several components;
- Try to establish the requirements (including energy input) and products (including pollutants) of each component;
- Try to arrange each component in such a way that each serves the requirements and accepts the products of other components.

An example of this approach is given in Table 2 below.

Table 2 Requirements and products of components in a hypothetical wetland site that is cultivated and producing cut flowers

Component	Requires	Produces
Flower crop	Water, nutrients, shelter from sun and wind	Flowers (income), bio-filtration, compost
Vetiver grass	Water, nutrients	Erosion control, water infiltration, root pest control, weed/invasive grass control
Reeds	Water, nutrients	Bio-filter, thatch, wind shelter, compost
Trees	Water, nutrients	Shade, retards run-off, litter
River	Possible filtration	Water, nutrients, floods
Structures :		
Rain tank	Money, labour, available space	Water storage and supply
Swales	Labour	Flood/drought protection, water infiltration
People	Wages	Labour, money, maintenance
Animals :		
Waterfowl	Water, nutrients, shelter from sun, wind, and predators	Manure, weeding behaviour

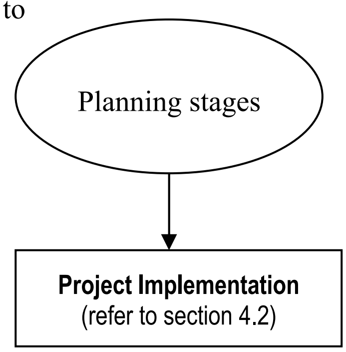
Examination of Table 2 shows that some of the products of one component are required by another component. For example, both vetiver grass and waterfowl may prevent weed invasion for the flower crop. In turn, the flower crop provides wages for the people and can act as a bio-filter for the river. The river in turn provides water and nutrients for the plant crops.

The actual site layout should position those components that are inter-linked through resource and product close to one another, e.g. swales for flood/drought protection should be along the river, protecting the field. Trees should surround the flower crop to provide shade and reduce run-off, vetiver grass or reeds could provide windbreaks and reinforcement to the swales, and the vetiver grass could be grown in between the flower crop to control root pests and reduce weed occurrence.

Maintenance of the wetland nature of the site

Maintaining the wetland nature of a site means maintaining the ecological and hydrological functioning of the site or restoring these functions to a site. Care should be taken in selecting wetland plants so that the water budget of the area is not exceeded. The ground-water levels on the site should be monitored, if the site is not always inundated. Some form of water storage and an irrigation system may need to be planned accordingly.

4.2 PROJECT IMPLEMENTATION



Once authorisation has been given by the relevant authorities to proceed with a particular project design, and following site assessment and the preparation of a business plan, the following steps are recommended for project implementation on a specific site:

1. Earthworks and any construction necessary may then proceed, with appropriate supervision to ensure that all development is environmentally responsible and within the limits set by the authorities.

2. The manager appointed to oversee the project will take responsibility for planting, cultivation, harvesting and marketing of the produce. Should several sites be involved, a centralized marketing organization may be formed to reduce competition between sites, to facilitate marketing of produce and to reduce costs in areas associated with produce transport, packing and shipping.

3. The organizational structure and ownership of the project should be formalized. The full range of options should be considered, for instance:

- a community-driven organization (a co-operative, community trust or section 21 company);
- a local authority-driven organization;
- a partnership (between some of the role-players, e.g. local authorities, the workers and local communities, community organisations, private investor).
- a private sector organization/entrepreneur.

In any case, it is important that the roles of the various players be defined carefully, that the nature of rights of ownership or use be clearly understood.

4. Following project implementation there must be ongoing monitoring and evaluation of the environmental (ecological, social and economic) impact of the cultivation and harvesting project. The following are amongst the factors which should be monitored:

- Ecological indicators such as water quality, soil nutrient levels, levels of organic matter, invasiveness of wetland plants, any signs of soil erosion;
- Social indicators of the impact of the cultivation project;
- Economic indicators of the financial sustainability of the project.

4.3 WETLAND TYPES

4.3.1 ALTERED WETLANDS

Example of use of an altered wetland for water purification

Wetlands have properties that make them especially suitable for wastewater purification and have been used for this purpose since the 1950's (Verhoeven *et al*., 1999). Natural altered wetland systems used for wastewater purification include marginal lake wetlands, fens and floodplain marshes. *Phragmites* species grow especially on margins of tidal salt marshes, brackish marshes of river deltas, alkaline or saline inland wetlands and river banks (Gessner, 2001). It is recommended that only slightly polluted water be used (i.e. >500 mg l^{-1} COD). Sometimes wetlands are used to polish the effluent from a conventional water purification plant (Verhoeven *et al*., 1999).

Characteristics that make wetlands suitable for wastewater purification are:

- Wetlands support very productive vegetation capable of taking up large nutrient loads;
- Wetlands are semi-aquatic and the flooding that would occur with wastewater supply is a normal feature of such a system;
- Organic matter breakdown also takes place via anaerobic pathways (in the anaerobic parts of the soil) and so alternative electron acceptors to oxygen are used (nitrate, sulphate, iron).

A negative characteristic of using wetlands to purify effluent or to discharge treated effluent into is that a year-round inflow of effluent water disrupts any natural seasonality of the wetland water regime. For example, the water level can remain higher than normal and the wetland can become permanently inundated rather than drying out in the dry season as it would have done naturally. This can lead to other negative impacts on the surrounding environment. For an example of this see the case of Wildevoëlvlei in the Noordhoek Catchment, Cape Town (Noordhoek Catchment Forum, 2001).

<u>Design criteria for water purification</u>

Some of the important criteria are the following:

1. Physical characteristics of the site: suitability of plant species for water purification; climate; water availability; water quality; and soil types.

2. The size of available area relative to the area being supplied with water and the quantity of water to be purified.

3. Zoning and proposed future land use: in urban areas in particular, it is important to determine if long-term master plans exist for the area, which may involve new or redesigned storm water flows, transportation networks, housing settlements etc.

4. Land ownership.

5. Opportunity to employ workers from surrounding communities.

6. Funding availability for monitoring water quality upstream and downstream of the wetland.

Site implementation

Site implementation for using a wetland for water purification would be similar to that described in section 4.2.

Examples of wetland cultivation and rehabilitation

Spekboomspruit wetland (1 ha) is a small restored wetland that will now supply clean water to the local community – rehabilitation was planned by Mpumalanga Parks Board (Lindley, 2001).

Zoar wetland (300 ha in extent, > 500 ha planned) was rehabilitated by a landowner near Piet Retief, Mpumalanga (Lindley, 2001).

Upper Mokolo River was rehabilitated by a landowner near Nylstroom, Northern Province – funded by Working for Water (Lindley, 2001).

4.3.2 Pristine wetlands

1. Direct-use and non-use functions of wetlands

Wetlands are essential for certain ecological and hydrological functions (e.g. habitat for many animal species, and purification/storage of water). However, wetland loss rates remain high as people are unaware of the full value served by wetlands (Breen *et al*., 1994) and may not care because wetlands are not marketable assets.

Wetlands have some obvious direct uses appreciated by most people:

- Water storage, also in terms of being integral to other ecosystems;
- Water provision;
- Supporting the food chain of the fisheries industry (Bell, 1997);
- Option to have access to the wetlands;
- Food supply (fish, shellfish, crustaceans);
- Building materials (reeds).

Besides these uses, the public may be encouraged to see the non-use benefits of wetlands, such as:

- Existence of wetlands (having the satisfaction of knowing that a wetlands is vital to their environment, without needing to directly access the wetland);
- Bequest value of wetlands (benefit of the existence of wetlands for future generations).

2. Economic valuation of pristine wetlands

Some benefits of preserving wetlands (optional access, existence and bequest value) are intangible to many people because wetlands are not assets traded on markets and it is therefore difficult to price them (Breen *et al*., 1994). Nevertheless, the desire and preference of people to preserve wetlands can be converted into monetary terms. This was done in the Wakkerstroom vlei in Kwazulu/Natal, using the so-called Contingent Valuation Method (Breen *et al*., 1994). This method takes the form of a questionnaire where people are asked to visualise hypothetical markets (e.g. how much would one be willing to pay into an exclusive fund to have exclusive access to a particular wetland).

This would seem a very useful educational tool, especially for people in an income bracket able to allocate surplus funds to such a hypothetical fund. For example, the study of Breen and colleagues (1994) found that a median household (gross annual income R 80 000 – R90 000) was willing to pay R17.51 – R20.00 per month for the option of visiting a wetland.

3. Recommendations for using pristine wetlands

Any use of these environments will have to comply with legislative requirements applicable to such areas, and will have to be preceded by obtaining the necessary authorisations. Any use must comply with any conditions imposed by the authorities.

What degree of land-use is permissible, given that pristine wetlands must firstly be conserved as an integral life support system?

Little information is available on the impact of land-use on the ecological value of pristine wetlands in South Africa (Kotze *et al*., 1994). An assessment of the wetlands of the Lake Victoria basin in Tanzania showed that land-use for agriculture and settlement was irrational, creating problems of sedimentation, hydrological changes and subsidence of land due to the excessive water extraction (Kassenga, 1997). Since an excess of water is the dominant feature determining biota in a wetland, it can be assumed that the greater the disruption of the hydrological regime, the greater the loss of the ecological value (Kotze *et al*., 1994) as well as the hydrological value.

Therefore, for pristine wetlands, this guide recommends wise use to be the minimal- or non-invasive use of pristine wetlands, such as the following uses:

1. Water storage;
2. Sustainable harvesting of reeds or other plants (with appropriate studies on plant re-growth and nutrient depletion rates of the soil);
3. Recreation and associated controlled and limited building of structures:
   - bird watching trails and structures;
   - hiking trails and structures;
4. Low-impact water sports that do not disturb wetland birds, mammals etc., particularly the breeding areas of these wetland inhabitants.

In keeping with a wise-use policy for wetlands, and in the absence of any official national policy, the following should be considered by individual land owners and land-use decision makers:

- More research is required on the impacts of land-use on ecological function of wetlands;
- Education is required - where people are encouraged to understand that :
  - only pristine wetlands naturally supply clean drinking water;
  - wetlands provide not only vital ecological and hydrological services , but also benefits of a personal and general nature;
- Compensation should be negotiated for land-owners who are willing to maintain or rehabilitate wetlands rather than cultivate them (planting of crops is tempting because crop yields on wetlands can be higher than on surrounding veld (Breen *et al*., 1994)).

4. Example of the wise use of pristine wetlands

Kosi Bay Nature Reserve – approximately 10 ha of incema (*Juncus kraussii*) sedge is sustainably harvested by local women. In 1992, there was a ban on the use of sickles and this has made collecting less commercially viable and curbed the large number of people that used to over-exploit the sedge resource (Kyle, 1995).

4.3.3 CONSTRUCTED WETLANDS

Constructed wetlands have been used extensively for water purification and growing economically important aquatic plants. The site chosen need only be near a source of water or wastewater. Common plant species that act as bio-filters are *Phragmites spp.*, *Typha spp.* and *Scirpus spp.* and these have all been used for wastewater purification (Verhoeven *et al*., 1999). These reed species have a high biomass production rate of 1-4 kg/year dry mass per m^2 of stand (Gessner, 2001). *Phragmites* spp. in particular have a high nutrient loading capacity (Ostendorp *et al*., 2001). Hence constructed wetlands are often referred to as reedbeds. The sedges, *Juncus spp*., could also be used.

1. Efficiency of constructed wetlands

From a practical standpoint, constructed wetlands offer better opportunities for wastewater treatment than natural wetlands, since they can be designed for optimal removal of BOD, COD and nutrients with simultaneous control over the hydrological and vegetative components of the wetland (Verhoeven and Meuleman, 1999). Constructed wetlands have been used successfully for treating domestic wastewater (Mandi *et al*., 1998; Kern and Idler, 1999), agricultural wastewater (Kern and Idler, 1999) and industrial wastewater (Vrhovšek *et al*., 1996).

Constructed wetlands can be not only efficient but also low-cost solutions for rural areas in third world countries (Denny, 1997) and there have been successful examples, e.g. in Uganda (Okurut *et al*., 1999). Constructed wetlands may be further optimised by integration into agricultural and fish production systems where the products of the latter are re-cycled or re-used (Denny, 1997).

2. Nutrient and pathogen removal

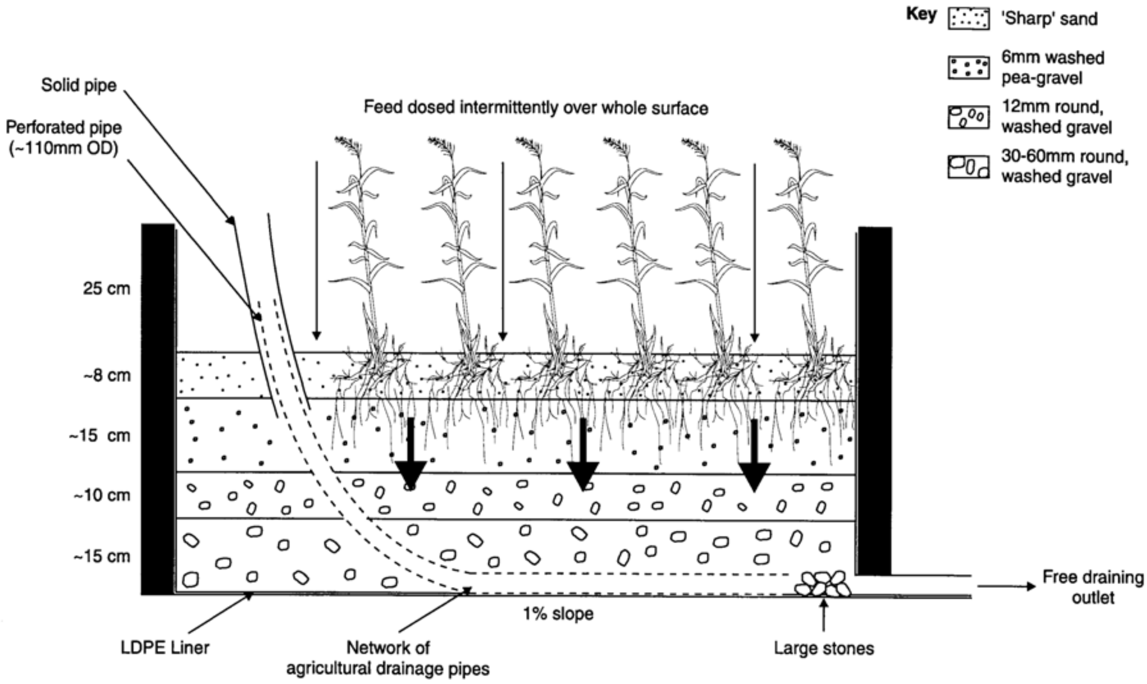
In general, constructed wetlands can be designed to remove more than 90% BOD, COD, suspended solids and bacteriological pollution from the through-flowing wastewater, while the removal of N and P is only around 50% (Verhoeven and Meuleman, 1999). According to Kern and Idler (1999), the conditions in constructed wetlands need to be improved to favour both denitrifying and nitrifying bacteria to enhance the removal of N.

3. Types of constructed wetlands

There are two main types of constructed wetlands:

- Infiltration or vertical flow wetlands (water flows vertically through highly permeable sediment and is collected in drains);
- Surface or horizontal flow wetlands (water flows horizontally over wetland sediment).

Vertical Flow Reed Beds (VFRBs)

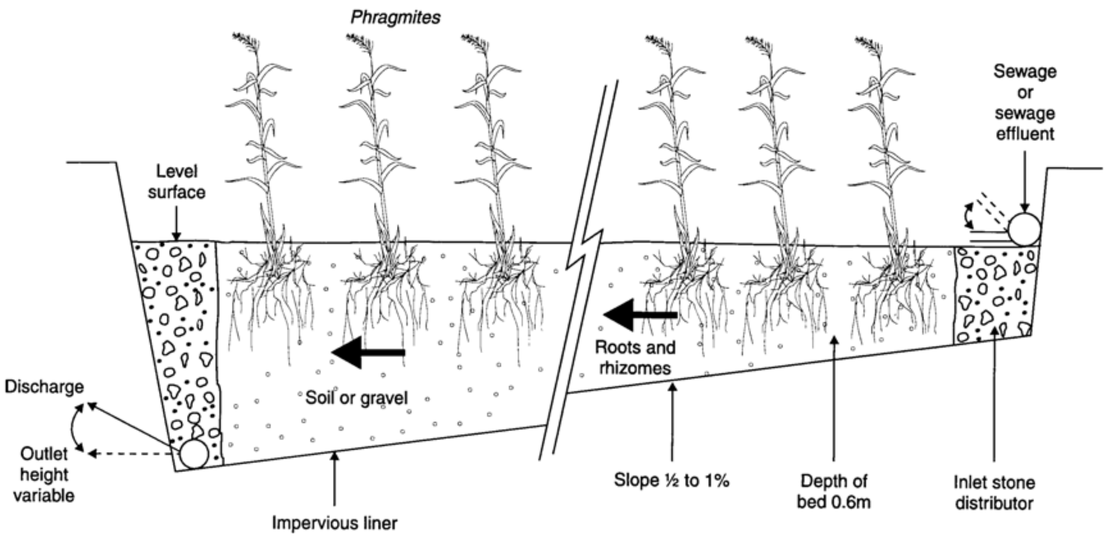


Typical arrangement of a vertical-flow reed bed system

(Cooper et al., 1996)

VFRBs can process a high load of wastewater, but can only be used intermittently. The liquid floods the surface and then percolates downwards and out. The bed then drains completely, allowing air to refill the bed. The next batch of liquid traps these air spaces, thus oxygenating the water. This in turn increases the efficiency of the bed. More than one VFRB bed is necessary so that one bed can drain free while another is in use. VFRBs are less good at removing suspended solids than soluble loading, and therefore in most cases need to be followed by a HFRB as part of a multi-stage treatment system.

Horizontal Flow Reed Beds (HFRBs)



Typical arrangement for a horizontal-flow reed bed treatment system

(Cooper et al., 1996)

HFRBs process a lower load of wastewater, but are good at removing suspended solids. The liquid flows through the bed horizontally, beneath the surface of the gravel. Because the wastewater fills all the spaces between the gravel, HFRBs are generally oxygen limited and consequently less efficient then VFRBs. They can, however, be used continuously, so only one is required and they are simpler to operate.

4. How do constructed wetlands work?

First, the wastewater passes through a settling tank (or septic tank) to remove any solid material. Then it flows into the reed beds for cleansing. Organic material and fine particles are removed from the water as they are filtered out by the soil.

From here, micro-organisms (fungi and bacteria) which develop in the planted soil are responsible for most of the treatment. The root and rhizome systems of the reeds bring air into the soil immediately surrounding them, providing ideal growth conditions for aerobic bacteria, which form very high populations on the plant roots and rhizomes. Further away from the roots, the environment is anaerobic. Thus there is a mosaic of treatment spheres, allowing the reed bed to act as a self-contained aerobic/anaerobic digester. This facilitates the impressive ability of reed beds to remove complex and refractory pollutants and reduce them to environmentally neutral outputs. The majority of treatment is by soil microbes, but certain contaminants (such as heavy metals, sulphur and phosphorus) are removed via soil processes.

The plants are also extremely important in the functioning of the reed bed. As well as providing oxygen and taking up certain nutrients from the water, the plants ensure that water can continually flow through the soil. Soils subjected to COD (Chemical Oxygen Demand) loading tend to degrade either through ion exchange or by neutralisation of the charges on the clay structure, which maintain the particulate nature of the soil. Without plants becoming established, the reed bed would soon block.

Table 3 lists the most important removal mechanisms in reed bed treatment systems.

Table 3 Predominant removal mechanisms in reed bed treatment systems
(taken from Cooper *et al.*, 1996)

Wastewater constituent	**Removal mechanism**
Suspended solids	Sedimentation Filtration
Soluble organics	Aerobic microbial degradation Anaerobic microbial degradation
Nitrogen	Ammonification followed by microbial nitrification and denitrification Plant uptake Matrix adsorption Ammonia volatilisation
Phosphorus	Matrix sorption Plant Uptake
Metals	Adsorption and cation exchange Complexation Precipitation Plant uptake Microbial oxidation/reduction
Pathogens	Sedimentation Filtration Natural die-off Predation UV irradiation Excretion of antibiotics from roots of macrophytes

It takes up to 18 months for establishment of the correct biological matrix. Within this period there is a possibility of partial load removal. After approximately 18 months, the system should be up and running.

5. Maintenance

It has been found that remarkably little maintenance is required by HFRBs. The system should be checked regularly to ensure the water is flowing properly and there are no blockages. Once or twice a year, the plants should be harvested and the surface organic material removed. Periodically, solids should be cleared out from the settling tank and composted. In a VFRB, the flow needs to be switched between the parallel beds each week, to allow for drainage.

6. Effectiveness of constructed wetlands

Primary settled sewage: Richmond, Australia

Table 4 Summary of performance of pilot plant at Water Research Laboratory, Richmond Australia.
All values are mg/l averages. (taken from Cooper *et al*., 1996)

Parameter	influent	effluent	% removal
Biological oxygen demand (BOD)	110	1.6	99
Total suspended solids (TSS)	43	4.8	89
Ammoniacal-nitrogen (NH_4-N)	43	3.2	93
Total Nitrogen	54	43.7	19
Total Phosphorus	8.8	0.06	99

Stormwater treatment

Table 5 Summary of performance of storm sewage overflow treatment plant, Lightmore Heath, Warwickshire.
All values are kg averages. (taken from Cooper *et al*., 1996)

Parameter	influent	effluent	% removal
Biological oxygen demand (BOD)	14	3.1	78
Total suspended solids (TSS)	34.6	6.2	82
Ammoniacal-nitrogen (NH_4-N)	1.5	0.7	51
Total Oxidised Nitrogen (TON)	1.7	1.1	38

Urban runoff

Table 6 Summary of performance of urban runoff treatment beds.
Data combined from Europe, Australia, US, Canada and laboratory experiments (taken from Cooper *et al*., 1996)

Parameter	% removal
Biological oxygen demand (BOD)	89.5
Chemical oxygen demand (COD)	83.1
Faecal coliforms	99.9
Total extractable Hydrocarbons	96
Lead	27 to 98
Total Nitrogen	27 to 90
Total Phosphorus	0 to 90

Chemical effluent treatment

Table 7 Summary of performance from a reed bed constructed to treat effluent from a chemical plant, UK
(data taken from Rootzone Soil Filters Website)

Parameter	Average Inlet Load (kg)	Average Reduction (%)
Phenol	35	95
COD	624	80
Methanol	118	> 99
Ethanol	270	85
MMA	13	97
DMA	17	> 96
TMA	27	95

Agricultural effluent treatment

Table 8 Summary of performance from a reed bed constructed to treat effluent from a pig farm, Nordhausen, Germany
(data taken from Rootzone Soil Filters Website)

Parameter	Inlet	Outlet	Current Elimination (%)
Total Nitrogen	1574	173.8	88.9
Ammoniacal-nitrogen (NH_4-N)	1364	92.70	93.2
Nitrates (NO_3)	34.10	2.300	93.2
Phosphates (PO_4^{3-})	133.5	0.490	99.6
Potassium (K^+)	884.6	116.5	86.8
Copper (Cu^{2+})	1.140	0.080	93.0

7. Useful guides for constructing wetlands

The following are useful guides for constructing wetlands:

Centre for Alternative Technology Website. http://www.cat.org.uk

Cooper, P.F., Job, G.D., Green, M.B. and Shutes, R.B.E. (1996) Reed beds and constructed wetlands for wastewater treatment. WRc, Wiltshire. pp 186.

Kadlec and Knight (1996) give a review on the current state of the art in constructing wetlands. This review explains not only principles of water purification but also detailed engineering guidelines for the construction and management of constructed wetlands.

North American Data Base with data from over 100 wastewater wetlands compiled by Knight *et al*. (1992).

Rootzone Soil Filters Website. http://www.wetlands.com.au/industrialwaste.htm.

5
CONCLUDING REMARKS

In these guidelines, a clear distinction has been made between the use of pristine and altered wetlands. In brief, pristine wetlands should be conserved as a valuable resource, with limited access and use of the wetland that is largely non-invasive and allows the wetland to maintain ecological and hydrological functions. Altered wetlands can be preserved from further degradation or destruction, and rehabilitated at the same time, through providing income from cultivation of economically valuable wetland plants. The wetland will simultaneously provide the local communities with clean water, flood attenuation, and a certain level of biodiversity.

Wetlands are inter-linked and dependent on their catchment areas for their continued health. Polluted water entering a wetland can destroy its functioning over time. Therefore, for the maintenance of pristine wetlands or the rehabilitation of wetlands, it is essential that the catchments upstream of the wetlands are also properly managed.

The new green database of wetland plants with economic potential should be used in conjunction with the Guidelines to select suitable potential wetland cultivation plants and sites.

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