C.A.P.E. ESTUARIES PROGRAMME

Preliminary zoning of human use of Cape Estuaries based on sensitivity mapping and carrying capacity

G.4

C.A.P.E. Estuarine Management Guideline

Version 1
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Our strategic vision for the estuaries in the Cape Floristic Region is:

*Our estuaries are beautiful, rich in plants
and animals, they attract visitors,
sustain our livelihoods and
uplift our spirits.*

C.A.P.E. Estuaries Guideline 4: Preliminary zoning of human use of C.A.P.E. Estuaries based on sensitivity mapping and carrying capacity

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This Guideline document constitutes a part of a suite of documents for determining an "Estuarine Zonation Plan and Operational Objectives" as discussed in a Framework for a generic Estuarine Management Plan. It should also be read in conjunction with "C.A.P.E. Estuaries Guideline 2: Sustainable Tourism in Estuaries of the Cape Floristic Region" by Dr Anna Spenceley.

1. Background

For the purpose of this document the carrying capacity of an estuary will be loosely defined as *the optimum utilisation of an estuary, taking into account seasonal and random changes, without degradation of the estuarine environment and without compromising the capability of future utilisation of the estuary* (Clark, 1977). The recreational carrying capacity of an estuary has been defined in various ways by researchers, for example, McConnon (1981) has given a general definition of the recreational carrying capacity as:

"The character of use that can be supported over a specified time by an area developed at a certain level without causing excessive damage to either the physical or biological environment or the experience of the visitor."

Increasing development and utilization result in the resource and the related facilities deteriorating and usually lead to conflicts between stakeholders (users) of that particular estuary. It is therefore important for the carrying capacity of an estuary to be researched and guidelines to be determined in order to help manage and maintain the natural well-being of the estuary.

It is acknowledged however that, given the geophysical characteristics of a particular estuary, it is likely to have its own unique carrying capacity. Thus, a "one size fits all" approach can only provide broad guidelines and should not be used to address detail issues. Optimally each estuary should have its own detailed study with specific recommendations to aid management in ensuring that its carrying capacity is optimally utilised.

The conflict of interests amongst users is ongoing, with an increased level of conflict resulting from issues such as overfishing, pollution, overcrowding, and perhaps more seriously, infrastructural development (e.g., ports/harbours & marinas, residential property, recreational facilities, industrial, mariculture and agricultural activities) around the estuary. More and more of our estuaries experience extensive pressures from man's activities; and the curbing of detrimental/harmfull activities need proper estuary management which will ensure the well-being of the estuary. Unfortunately this often causes further conflicts between some of the users and the managers in terms of maintaining the carrying capacity of an estuary at an adequate level, or conserving its pristine nature (as far as still possible).

Estuary managers have a difficult task and responsibility of ensuring that the carrying capacity of a particular estuary is not exceeded, but inadequate information on "what the carrying capacity of a particular estuary is" acts as a hindrance in terms of applying guidelines that prevent over-utilisation of the resource. However, the available literature does provide some guidance, e.g., Saunders, *et al* (2000) provide a thorough review of the effects of recreational interactions within marine sites, including estuaries.

Concerns about environmental impacts of the recreational activities on many CAPE estuaries seem to be a recurring management theme. At present these concerns are addressed on an ad hoc basis without stringent adherence to scientific guidelines that provide principles for implementation. Earlier investigations of the socio-economic factors affecting estuarine degradation in a few estuaries, conducted by Sowman *et al* during the late 1980's (e.g. Sowman, *et al*, 1988), provide much useful information. However, this work is thought to be relatively outdated in terms of changed local and regional socio-economic factors. In addition, significant work is still necessary on the bio-physical aspects. For example, the relationship between shoreline erosion and certain recreational activities have not been investigated adequately. As a result, further studies are required to optimally determine the recreational carrying capacity of our estuaries taking into consideration the unique physical characteristics of each particular estuary. Furthermore, there is growing pressure for more developments in some catchments, especially impoundments and increased water abstraction. In certain instances, this has led to a serious reduction of river inflow, particularly of the low flow periods, leading to an increase in salinity penetration, which in turn, for example, could have caused changes in riparian vegetation, such as a reduction in reed beds, ultimately leading to an increase in bank erosion.

Popular recreational activities such as boating, angling, swimming and sailing are major attractions to many estuaries. This is compounded by the extremely high number of visitors to the coast during summer seasons. It is therefore considered that much of the degradation and environmental impacts that occur as a result of recreational activities happened mainly during peak summer holidays. This gives an indication of how the carrying capacity of an estuary can be severely exceeded during a short space of time. The combination of physical estuarine characteristics, watercraft and various water-based activities determine the type of environmental impact whilst the intensity of impact is determined by the frequency of use.

Ultimately, it can be said that, the ideal is to measure and anticipate the likely environmental impacts of the various uses of an estuary and eventually put in place scientific guidelines that will prevent any excessive use of a resource.

2. Focus of this document & the need for zoning

Although there are various kinds of carrying capacities that can and should ultimately be studied, such as physical, biological, economical and social carrying capacity, which all have to be considered and addressed to ensure that the resource (the estuary) utilization is optimally balanced, this document seeks to address mainly components of the physical carrying capacity of the estuary. (For a broader discussion of guidelines for the sustainable use of some SA estuaries, reference is made to Wood, *et al* 2003, who provide useful and relevant protocols and guidelines for Eastern Cape estuaries.)

Physical characteristics such as depth, width and length play a roll in the selection preference of estuary users. Other characteristics which also play a major role in attracting users include: water quality, aesthetic characteristics and biological component (presence & abundance of bait, fish, birds species, etc.). The geographical location and setting of an estuary can also attract recreational users because they are usually more protected from the harsh wind and wave conditions of the sea and the estuary could thus provide various attractive recreational opportunities for its users.

A major concern that often needs to be addressed, are the impacts emanating from recreational boating activities, which is therefore a major consideration in determining carrying capacity. Recreational boating is a primary means of participating in other activities such as waterskiing and fishing, whilst it is also a recreational activity in its own right (Falk *et al*, 1992). Although these activities bring enjoyment to the participants, they are usually an irritant to other estuary users as they usually lead to various impacts causing estuary degradation. There are a number of notable environmental impacts emanating from boating activities that occur in an estuary. Such concerns are, in no particular order, turbidity, noise, damage to aquatic vegetation, boat engine emissions, decreased human safety, water quality deterioration, shoreline erosion, disturbance of bird and wildlife and other significant environmental impacts (some of which could be unique to a particular estuary); as well as user conflicts (Clark, 1963, McConnon, 1981; FTWRC,2001; Falk *et al*., 1992; Sowman, 1984).

Recreational boating is a major activity in some CAPE estuaries, with potential disturbance compounded by some boating enthusiasts ignoring rules regarding speed limits and zoning. Typical questions that arise are: “How many boats is too much for a particular estuary”, “How much impact can be or is solely caused as a result of boating activities?”, etc.

Some estuaries are more vulnerable than others and have a lesser ability to withstand human impacts without long-term degradation. Hence the need to properly assess “estuary-unique” impacts and individual estuarine characteristics, prior to recommending recreational carrying capacities. This is basically what the intention is of the methodology proposed in the following section.

3. Proposed methodology

The foregoing discussions indicate that *for the long-term sustainable use of a particular estuary, significant investigations of specific components would ideally have to be conducted.* However, such investigations will be time consuming and relatively costly. Thus, *an interim measure is proposed here, which is considered to be more viable in the short-term.* To make this practical, many socio-economic and some biological issues will at this stage be largely excluded from consideration. However, it is believed that, by focussing on mainly physical aspects in conjunction with available biological information, a workable compromise can be achieved. It is considered that despite lacking many inputs, the end product will still go a long way in conserving the wider goods and services provided by the estuary. With ongoing degradation and far reaching decisions about some estuaries on the cards, it is also imperative to initiate as much wise governance as soon as possible, rather than delay until perhaps much damage has been done. *The first practical step is to get a zoning of estuary use in place, which considers as many bio-physical aspects as possible.*

An efficient way of determining such a zoning, is to conduct an *in situ* investigation with the main role players and key experts present. Based on such a site investigation and taking into consideration any previous work (such as e.g. Van Riet, Sowman *et al* 1988.) a draft zoning map can be drawn up. This draft can then be disseminated to all the relevant authorities and other interested and affected parties for comment, followed by possible editing/adaptations if found necessary.

Before this can be done a sensitivity map of the estuary needs to be developed. This data can be included in the development of a more encompassing management plan for the whole of the river and estuary.

A potential set of parameters (as amended & expanded from a list drawn up for the Breede Estuary by CapeNature), to help determine such estuarine sensitivity maps, is as follows:

Physical parameters

- Main channel width and depth vs. present human usage/activities;
- Presence or absence of sandbanks (and approximate spatial extent);
- Salinity distribution (and typical position of River-Estuarine-Interface(< 10ppt);
- Geomorphology & Siol erodability:
  1. Steep banks;
  2. Terraces;
  3. Flood plains;
  4. Mud flats;
  5. Nature of banks (sandy/rocky/cohesive/vegetated); and
  6. % sand/silt/clay/organic content; sediment grain size distribution.
- Structures: Jetties, slipways, bridges, causeways, culverts, marinas/"harbours", gabions, (timber) bank stabilization, etc.

Ecological parameters

- Alien vegetation;
- Intact riparian vegetation (e.g. trampling by cattle);
- Reed beds absence /presence;
- Bank disturbance;
- Submerged macrophyte beds (e.g. zostra);
- Mud/sand prawns habitat;
- Birds (breeding cycles, waders on mudflats);
- Fish (sensitive fish nursery areas); and
- Mammals, e.g. otter sightings

Other characteristics that can be used are habitat vulnerability, geographical layout, etc. The identification of relevant parameters is believed to be an initial step towards this task. The Nelson Mandela Metropole University is currently conducting a mapping exercise of the important C.A.P.E. Estuaries as part of the C.A.P.E. Estuaries Conservation Plan. Included herein are vegetation sensitivity maps for more than 15 C.A.P.E. estuaries (as drawn up under Dr Tom Bornman). These base maps of the estuarine vegetation of these specific estuaries should be available for consideration in drawing up zoning maps for human use of the estuaries.

Besides the nature and characteristics of an estuary, another critical aspect is the present and foreseen future types of human use of the estuary. Although certain forms of use or activity might be banned in total from a particular estuary, it is usually best to be as inclusive as possible, at least initially, until preliminary zoning planning gives an unbiased indication of constraints and possibilities. The list of potential use is long, and for most estuaries should include at least present subsistence and recreational use. Recreational use, including the many types of water sports and water craft, is a major consideration in typical zoning plans. This is because, from a human safety perspective, *it is usually wise not to* *mix different activities within zones*. Thus, for example, while bathing/swimming and snorkelling might still allow rowing craft in the same area (zone) and even perhaps include angling, any form of power boating within the same area is undesirable. Similarly, all types of sailing activities can be allowed together, but should not be mixed with any form of power boating. Some types of water craft are relatively "demanding" in terms of their spatial and other "needs". Key aspects for watercraft include: access, launching & landing needs, water depth and water area. Some requirements for typical activities are listed in the following tables.

Estimated water depth requirements for some recreational activities:

Activity	***Minimum Depth (m)***	***Preferred Depth (m)***
Skiing, power boating	*1*	*at least 1.5*
Sailing – no keel	*0.5*	*at least 1*
Sailing – with keel (retracting?)	*1.5*	*at least 2*
Angling, rowing, bathing/swimming, snorkelling	*0.5*	*at least 1*

Estimated water area requirements for some recreational activities:

Activity	***Minimum Area (m x m)***	***Preferred Area (m x m)***
Sailing – no keel	*50 x 50*	*at least 250 x 100*
Sailing – with keel (retracting)	*200 x 100*	*at least 500 x 150*
Angling, rowing, bathing/swimming, snorkelling	*25 x 25*	*at least 50 x 25*
Slalom skiing, power boating – single lane	*40 x 200*	*at least 70 x 500*
Slalom skiing, power boating – double lane	*80 x 200*	*at least 100 x 500*
Skiing, power boating – turning circle diameter	*60*	*at least 80*

The above estimates should be revised in conjunction with the NSIR and responsible boating/skiing authorities. The above minimum areas are per activity; in addition, the number of simultaneous users also need to be taken into account. For example, 10 swimmers could easily be accommodated within the minimum 25 m x 25 m area, and do not need 10 times the minimum area required, while say 100 people within the minimum area would be too crowded. The spatial requirements for skiing are determined by the length of the skiing rope, the maximum angle between boat & skier position and the safety margin (amongst others). Thus, *the number of skiers that can safely be accommodated simultaneously within a specific estuarine area/zone can be theoretically calculated*. However, with multiple simultaneous users and complex estuarine geometry, the calculations become onerous. Thus, *for practical purposes of preliminary zoning, less complex methods are recommended, for example based simply on area (ha) required per boat*. Bosley (2005) presents a good literature review on techniques for estimating boating carrying capacity. In this review, a wide range of boating densities is reported depending on circumstances, but it seems that a general recommendation is around 4 to 8 ha/boat for water skiing. (This implies that for many small South African estuaries, very few boats or no skiing at all should in fact be allowed, besides any other ecological or social aspects. This may initially appear relatively conservative or stringent, but is never-the-less an objective and widely applied norm.) Other references, eg. Vogel, *et al* (2004) present similar values for open water areas.

The Department of Water Affairs and Forestry has published a very useful document relevant to this Chapter: "Recreational Water Use Manual" (RWU GP2.2, as appended to the end of this chapter). It provides a "Guideline Methodology for Determining Carrying Capacity" of a water resource, to assist water resource planners and managers to determine the carrying capacity of a water resource in respect of water-based recreational visitor use and related infrastructure. A relatively encompassing methodology is described and a detailed case study is presented: determining recreational water use carrying capacity for the Pongolapoort dam. In terms of estuaries, this guideline and methodology should generally be applicable to the estuaries that have relatively large water areas such as, e.g., the Berg, Breede, Mngazana and St Lucia, and especially to the estuarine lakes such as the Bot and Klein, etc. *Thus, it is recommended that this DWAF guideline and methodology should be applied as far as possible to these larger estuaries.*

Where the above mentioned DWAF guideline cannot be well applied (i.e. mostly the smaller estuaries), the following tasks summarize the steps recommended to determine the zoning of human use of the C.A.P.E. Estuaries (according to the proposed initial methodology, eventually to be followed up more holistically and in depth):

Task 1
Summarise the key findings from the Auditing phase (Step: Situation Assessment and Evaluation) and Objective setting phase (Step: Vision and Strategic Objectives and Step: Management strategies) that needs to feed into an Estuarine Zonation Plan. To ensure alignment with the regional and local requirements.

Task 2
Conduct a site inspection by boat during spring high tide with the main management authorities and most significant stakeholders (e.g. DEAT (MCM), Cape Nature, DWAF, Agriculture, Local municipality, boating/skiing, angling, local forums, etc.) and key experts (e.g. estuarine hydro & sediment dynamics and estuarine biota (e.g. estuarine vegetation and fish) present. This should preferably be augmented by a road trip along the banks during low tide.

Task 3
The field visit will be followed by: (2a) a focussed workshop during which the issues will be discussed and (2b) estuarine sensitivity and (2c) zoning usage maps drafted. (To aid rapid progress, it would be useful to include a GIS specialist or competent person in the project team.) It is proposed that such workshops be facilitated by the Provincial Nature Conservation Authority or Marine and Coastal Management. To focus the effort and keep costs to the minimum, it is thought that Task 1 and 2 can mostly be completed within 2 to 3 days.

Task 4
Finalise the spatial mapping of the estuarine sensitivity and zoning usage maps. Summarise scientific findings of the site visit and workshop. Identify issues of concern that might need further investigation. Provide final recommendations to the relevant authorities regarding zoning of human use and aspects relating to carrying capacity of the estuary.

Task 4
Disseminate the zoning plan and recommendations to the wider stakeholder community for comment. It may be advisable for DEAT to take official responsibility for this task.

Task 5
Where possible address stakeholders concerns and finalise documentation. A provisional list of participating bodies includes:

- Marine and Coastal Management, DEAT (inputs on fisheries and proposed Marine Protected Area, etc.);
- CapeNature;
- Local Municipality;
- Local Environmental Committee;
- Dept Agriculture (inputs on agriculture adjacent to estuary, embankment erosion potential, etc.);
- DWAF (inputs on DWAF recreational policy);
- Specialists on estuarine hydro-and sediment dynamics, biota, governance, etc.;
- Local angling& boating associations;
- GIS specialist.

It would be an advantage to have a GIS specialist attending such workshops, so that findings can be mapped as the workshop progresses. Such a person could be provided by CapeNature, MCM, CSIR, etc.

4. References

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Sowman, M.R. (Ed), Brownlie, S., Butcher, S., Glazewski, J, Henderson, C. and Stauth, R. (1988). Socio-economic factors affecting estuarine degradation: a case study of the Kafferskuils estuary. EEU Report 4/88/27; ECRU - CSW 24. Stellenbosch - Documentation Centre.

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Wood A, Cowley P and Paterson A (2003). Protocols Contributing to the Management of Estuaries in South Africa, with a Particular Emphasis on the Eastern Cape Province. Volume II, Report C: A Classification System for Eastern Cape Estuaries, with Management Guidelines for the Sustainable use of their Living Resources.

RWU GP2.2

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
Recreational Water Use Manual
Guideline

Subject: Methodology for Determining Carrying Capacity.

Purposes: To assist water resource planners and managers to determine the carrying capacity of a water resource in respect of water-based recreational visitor use and related infrastructure.

Authority: Operational Policy for Recreational Water Use, August 2004

Approval: Director: Water Abstraction and Instream Use, October 2006.

Contact: Department of Water Affairs and Forestry, Sub-directorate Environment and Recreation, Private Bag X 313, PRETORIA, 0001, Republic of South Africa, Tel: (012) 336 8224; Fax: (012) 336 6608; E-mail: deb@dwaf.gov.za.

CONTENTS

1. INTRODUCTION

Sustainability, whether it is ecological, social or economic, is regarded as an objective of most human activities. The need to balance environmental concerns through utilisation on appropriate levels has resulted as a result of awareness created by publications such as Caring for the Earth (IUCN/UNEP/WWF; 1991), the Brundtland Report (1987) and the adoption of Agenda 21 at the Earth Summit in 1992.

For recreational water utilisation, in particular, to be sustainable, it is imperative that the activity should continue to provide benefits indefinitely. According to Munro (1995): "this means that there must be nothing inherent in the process or activity concerned, or in the circumstances in which it takes place, that would limit the time it can endure." Additionally, it is important that the activity remains worthwhile, meeting both social and economic objectives.

Sustainable utilisation of water resources is thus the development of a complex of activities that can be expected to improve the human and environmental condition in such a manner that the improvement can be maintained. Applying the concept of sustainable utilisation requires attention being focused on development within the carrying capacity of the supporting ecosystems, resulting biophysical, socio-cultural and economic sustainability.

Carrying capacity can be defined as the capacity of a system to support healthy organisms while maintaining its productivity, adaptability and capacity of renewal, effectively representing a threshold level of human activity which if exceeded will result in the deterioration of the resource base.

The carrying capacity of a water resource represents the maximum level of visitor use and related infrastructure that the water resource and surrounding area can accommodate, without diminishing user satisfaction or adverse impacts upon the local or host community, the economy and culture of the area.

Four basic components form part of the carrying capacity of a water resource, namely:

- Biophysical;
- Socio-cultural;
- Psychological; and
- Managerial.

It is not difficult to theoretically understand the concept of carrying capacity, however it is difficult to quantify since the capacity will vary depending on the water use or combination thereof, as well as the environment.

The carrying capacity will vary depending upon place, season and time, user behaviour, facility and infrastructure design, patterns and levels of management and the changing dynamics of the environment. When determining carrying capacity for a specific water resource it is essential to have a clear knowledge and understanding of the impacts that activities have on water resources, and that the relationships between the environmental resources, local community expectations and visitor expectations are managed in a harmonious and balanced way.

2. BASIC COMPONENTS OF CARRYING CAPACITY

The biophysical component relates primarily to the natural resources, and recognises that no biophysical system can withstand unlimited utilisation. Assessing the biophysical carrying capacity of a resource is often used as a management tool in protected area management and relies on the identification of thresholds beyond which irreversible and detrimental changes in the biophysical environment could occur, such as habitat degradation or loss and elimination of species or populations.

The socio-cultural component of carrying capacity recognises that detrimental impacts on the local or host community will occur if the water use or users exceed a certain level. However, since it is very difficult to assess and evaluate socio-cultural carrying capacity it is essential that experts such as anthropologists, and archaeologists be included in the assessment and evaluation phase. Perceptions regarding acceptable impacts and effects will vary both between the host community and visitors, as well as within each group.

The psychological component of carrying capacity refers to the maximum number of users for whom a water resource area is able to provide a quality experience at any one time. The psychological capacity varies according to the area, type of activity and resource, and the specific characteristics of each user or group of users. Due to the difficulty of establishing evaluative standards the psychological carrying capacity must be measured in terms of the area's objective and the limits of acceptable change.

The managerial component of carrying capacity refers to the maximum level of use that can be managed adequately in a given area, linked to the type of physical facilities and staff to manage users.

3. MEASURING CARRYING CAPACITY

In order to define carrying capacity of a water resource it is important that information is obtained regarding the resource itself, infrastructure and objectives for the area. The carrying capacity for each water resource will thus be specific based on environmental, social and economic objectives.

Key parameters that can be used to determine carrying capacity include:

- Type of activity;
- Season;
- Time of day;
- Existing facilities; and
- Satisfaction level of users

Indicator parameters can be used to ascertain success regarding carrying capacity levels, and can include:

- Species;
- Water quality;
- Visible damage; and
- Satisfaction levels of communities and users

Two types of descriptive data can be used to measure and describe carrying capacity, namely:

- Management parameters – any action that can directly manipulate the source of the impact such as limiting the number of visitors or users, type of use and duration of use; and
- Impact parameters – measurable description of impact of impacts directly as result of use pattern and management actions such as percentage loss of ground cover, frequency of encounters with other users, changes in quality, species diversity and density.

Based on the measurement and description it is essential that the results be evaluated, in order to produce a set of objectives or standards specifying the type of experience to be provided in terms of appropriate impact parameters, as well as the limits of change acceptable to management.

4. LIMITS OF ACCEPTABLE CHANGE

The difficulties associated with setting and measuring carrying capacity can be overcome by shifting the focus from an appropriate use level to the desired condition, thereby clarifying the relationship between use and impact. The question shifts thus from “How much use is too much?” to “What conditions are desired here?”.

To set limits of acceptable change it is important to establish measurable limits to human-induced changes in the natural and social environments, and to identify appropriate management strategies to maintain or restore desired conditions.

The use of Carrying Capacity Assessments (CCA) and the setting of Limits of Acceptable Change (LAC) is not aimed at ecological management, but rather at more effective management regarding the impacts of activities on resources. Various understandings of the terms exist, of which Cifuentes (1992) and Ceballos-Lascurain (1996) provide some practical guidelines regarding the use of these as manage tools.

5. THE PROCESS

The process of estimating carrying capacity consists of six steps, namely:

- Analysis of recreation and water resource management policies;
- Analysis of objectives of the water resource;
- Analysis of current recreational water use;
- Definition, strengthening or modification of policies regarding recreational water use management;
- Identification of factors influencing recreational water use; and
- Determination of the recreational water use carrying capacity.

Each of these steps is important and constitutes an interrelated and sequential whole.

Step 1: Analysis of Recreation and Water Resource Management Policies

Policies regarding recreational development and water resource management address the needs and expectations of each separately, and are often contradictory and non-complementary, which hinders sound and sustainable development.

It is imperative that before setting levels of usage through carrying capacity assessment the gaps, potential and contradictions between recreation and water resource management be identified and contextualised.

Step 2: Analysis of Water Resource Objectives

It is essential to determine whether the recreational water use activity is suitable and appropriate with the water resource and the objectives set for the water resource. Questions that must be answered include:

- Are the current activities acceptable, compatible and appropriate?
- Are the current levels and patterns of use appropriate?

Step 3: Analysis of Current Recreational Water Use

An analysis of the current utilisation patterns must be undertaken based on aspects such as the objectives of a water resource contained in the management plan, which should include the management zones.

Questions that must be asked during this analysis include:

- Are the management objectives being met?
- Is the zonation plan adequate for the accomplishment of the recreational water resource objectives?

- Are the zones appropriate for the utilisation and have they been identified correctly?
- Do conflicts exist, and if so how can they be eliminated or attenuated?
- Are changes to the zonation plan and management plan necessary to address both current and projected circumstances?

Step 4: Definition, Strengthening or Modification of Policies Regarding Recreational Water Use Management

Steps 1 – 3 allow for a synthesis of the potentialities and conflicts, both present and future, that have been identified in respect to the management of water resources for recreational purposes. This synthesis will contribute to defining and proposing new objectives, policies, strategies and operational guidelines, as well as strengthen or modify existing measures.

Step 5: Identification of Factors Influencing Recreational Water Use

It is critically important that detailed knowledge of the specific characteristics of each recreational water resource be available. Each resource will have different biophysical and socio-cultural characteristics, with natural and cultural attractions. An understanding of the quantitative and qualitative aspects is essential, as is an assessment of the resource's fragility and vulnerability.

Sustainability will only be achievable if a harmonious balance can be attained between the biophysical, ecological, social and management factors that modify the conditions and supply of water resources.

Step 6: Determination of Recreational Water Use Carrying Capacity

Three levels of recreational water use carrying capacity can be established:

- Physical Carrying Capacity (PCC);
- Real Carrying Capacity (RCC); and
- Effective or Permissible Carrying Capacity (ECC).

Each level constitutes a corrected capacity level of the preceding level.

The PCC is always greater than the RCC, and the RCC is greater than the ECC, thus:

PCC > RCC and RCC ≥ ECC

Physical Carrying Capacity (PCC)

Definition: The maximum number of users that can physically fit into or onto a defined water resource, over a particular time.

Formula: PCC = A x U/a x Rf

Where:

A	=	available area for public use
U/a	=	area required per user
Rf	=	rotation factor (number of visits/day)

Assumptions: To measure the PCC, the following assumptions must be clarified:

- U/a - the area required by recreational water users to undertake activities;
- A - that the available area (A) is determined by the particular conditions of the water resources, and by limitations imposed due to fragility or as a result of the need for safety precautions; and
- Rf – the rotation factor is the number of permissible daily visits to a water resource, determined by:

Rf = Open period / [Average time of utilisation/visit]

Real Carrying Capacity (RCC)

Definition: The maximum permissible number of users to the water resource, once the corrective factors (Cf) derived from the particular characteristics of the site have been applied to the PCC.

Formula: RCC = PCC – Cf1 – Cf2 – Cfn

Where:

Cf = a corrective factor expressed as a percentage

RCC = PCC x (100 – Cf1)% x (100 – Cf2)% x (100 – Cfn)%

Assumptions: To measure the RCC, the following assumptions must be clarified:

- Cf - the corrective factors are obtained by considering the biophysical, environmental, ecological, social and management variables;
- That a group of corrective factors is not necessarily the same for each site in a water resource;
- Corrective factors are closely linked to the specific conditions and characteristics of each site or activity;
- That the carrying capacity of a water resource must be measured site by site; and
- Corrective factors are expressed in percentage terms using the following formula:

Cf = [M1 / Mt] x 100

Where:

Cf = corrective factor
M1 = limiting magnitude of variable
Mt = total magnitude of variable

Corrective factors:

- E.g. Pongola – Excessive sunshine; wind; water quality; temporary closing; mud; and wildlife (crocodiles, birds, hippopotamus)
- E.g Verlorenkloof – Habits (am/pm); and habitat characteristics

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Effective or Permissible Carrying Capacity (ECC)

Definition: The maximum number of visitors that a site can sustain, given the management capacity (MC) available.

Formula: ECC = [Infrastructure Capacity x MC] / RCC

Where:

ECC = effective carrying capacity
MC = management capacity based on staff and budget
RCC = real carrying capacity

Assumptions: To determine the ECC, the following assumptions must be clarified:

- MC – defined as the sum of conditions that the water resource management requires if it is to carry out its functions and objectives;
- Measuring MC is not easy, involving many variables, including inter alia policy measures, legislation, infrastructure, facilities, amenities and equipment, staff (both number and competency), funding, available budget, motivation and commitment;
- Limitations in management capacity constitute one of the most serious problems confronting recreational water resource management;
- As the capacity to manage recreational water resources increases, the ECC will increase, yet never be greater than the RCC, even in the most favourable conditions; and
- MC is determined by using the following formula:

MC = Current staff and budget capacity / required staff and budget

6. A CASE STUDY: DETERMINING RECREATIONAL WATER USE CARRYING CAPACITY FOR THE PONGOLAPOORT DAM

Determine PCC

PCC = A x U/a x Rf

Where:

A = 15 000 ha (mean surface area of the dam) – 4 000 ha (area in Swaziland)
= 11 000 ha
U/a = 1 boat/5 ha
Rf = 1 (weekends on average)

Thus: PCC = 11 000 x (1 boat/5 ha) x 1 = 2 200 boats

Determine RCC

RCC = PCC – Cf1 – Cf2 - Cfn and Cf = [M1 / Mt] x 100

Determine Cf

Excessive sunshine (Cfs)

12 hrs = 06:00 – 18:00 Summer Oct – Feb
10:00 – 15:00 sunshine is excessive = 5 excessive sunshine hours per day

Thus: 5 months = 150 days

M1 = 150 days per year x 5 excessive sunshine hours per day
= 750 hours of excessive sunshine per year

Mt = 365 days x 12 hours = 4 380

Then Cfs = excessive sunshine corrective factor
= [M1 x 100] / Mt
= [750 x 100] / 4 380
= 17% corrective factor for sunshine

Wind (Cfw)

12 weeks excessive wind (6 weeks from Feb – Mar; 6 weeks from Aug – Sept)
6 hours per day (pm)

M1 = [12 x 7 windy days] x 6 hours of limiting wind
= 504 hours of wind per year

Mt = Total number of use hours per day x 365 days
= 12 x 365
= 4 380 use hours per year

Then Cfw = excessive wind corrective factor
= [M1 x 100] / Mt
= [504 x 100] / 4 380
= 11.5% corrective factor for wind

Water Quality (Cfwq)

6 months of the year – water quality is ideal for fishing – clear & warm
(Ideal: Aug – Nov; Apr – May)

M1 = 6 months ideal water quality

Mt = Total number of use months
= 12 months

Then Cfwq = water quality corrective factor
= [M1 x 100] / Mt
= [6 x 100] / 12
= 50% corrective factor for water quality

Mud (Cfm)

1 month of the year (Oct – Nov) – excessive mud as result of releases

M1 = 1 month excessive mud

Mt = Total number of use months
= 12 months

Then Cfm = mud corrective factor
= [M1 x 100] / Mt
= [1 x 100] / 12
= 8% corrective factor for mud

Temporary Closure (Cfc)

During the winter months the reserve is temporarily closed for maintenance, for a period of 2 weeks.

M1 = 2 weeks closure

Mt = Total number of use weeks
= 52 weeks

Then Cfc = closure corrective factor
= [M1 x 100] / Mt
= [2 x 100] / 52
= 3.8% corrective factor for temporary closure

Disturbance to Wildlife (Cfwt)

Three target species – water birds, crocodile and hippopotamus. Water birds are sensitive to disturbance during the breeding season, with some birds breeding in reeds on floating nests. Crocodile and Hippopotamus breed in an area of 750 ha.

Cfw = corrective factor for disturbance of birds

M1 = 3 months per year

Mt = Total number of months per year
= 12 months

Then Cfw1 = disturbance of birds corrective factor
= [M1 x 100] / Mt
= [3 x 100] / 12
= 25% corrective factor for temporary closure

Cfw2 = corrective factor for disturbance of crocodile & hippopotamus

M1 = Breeding area occupied by crocodile & hippopotamus
= 750 ha

Mt = Total number of available area
= 15 000 ha

Then Cfc = closure corrective factor
= [M1 x 100] / Mt

	=	[750 x 100] / 15 000
	=	5% corrective factor for disturbance to crocodile & hippopotamus

Thus Cfwt	=	total corrective factor for disturbance of wildlife
	=	25% + 5%
	=	30% corrective factor for disturbance of wildlife

Thus: RCC = PCC – Cfs – Cfw – Cfwq – Cfm – Cfc – Cfwt

RCC = 2200 x [100 - Cfs]/100 x [100 - Cfw]/100 x [100 - Cfwq]/100 x [100 - Cfm]/100 x [100 - Cfc]/100 x [100 - Cfwt]/100

RCC	=	2200 x (0.83 x 0.885 x 0.5 x 0.92 x 0.962 x 0.7)
	=	2200 x 0.227
	=	499

Determine ECC

ECC = [Infrastructure Capacity x MC] / RCC

It takes approximately 20 minutes to launch or retrieve a boat during the day, and there are 3 slipways (1 at Golela; 2 at Poort). There are 3 existing lawful users namely, KZN Wildlife (1 boat allowed); DWAF (1 boat allowed) and 3 adjacent landowners (2 boats allowed each). Currently there are 5 concessions, each with 2 boats allowed. Management function is carried out by a team of 12 staff, however a management team of 18 is required for affective management.

Determine Infrastructure capacity

Infrastructure capacity	=	[12 hours available per day/20 min] x 3 slipways + Existing lawful Users + Concessionaires
	=	[720/20] x 3 + [1 + 1 + 6] + 10
	=	126

Determine Management capacity as expressed in percentage

MC	=	Current staff and budget capacity / Required staff and budget capacity x 100
	=	12 / 18 x 100
	=	66%

And ECC = [Infrastructure Capacity x MC] x 100 / RCC

ECC	=	[Infrastructure Capacity x MC] x 100/ RCC
	=	[124 x 0.66] x100 / 499
	=	16%

Thus ECC is 16% of the RCC given the current management and infrastructural development, which represents 80 boats allowed on the Pongolapoort Dam currently.

These 80 boats consist of:

10 concession boats, 8 existing lawful user boats and 62 day visitor as well as overnight camping boats. This represents the amount of boats that site management may allow.

7. REFERENCES

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