THE RETURNS ON INVESTMENTS IN RESERVE DETERMINATIONS IN THE LAST 20 YEARS

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by

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EXECUTIVE SUMMARY

This short scoping project attempted to address the valuation of the investment in RDM Reserve studies in the past 20 years. The Reserve concept followed from a period of extractive use and wide-ranging impacts prior to the 1960s. The National Water Act (No. 36 of 1998) made provision for determining Resource Directed Measures (RDM), which includes the ecological Reserve and the Basic Human Needs Reserve. The Reserve concept sought to achieve a balance between development (water used by, and impacted on, all sectors) and protection (securing water quantity and quality for basic human needs and sustaining the resource base). Since the method development of the Reserve concept, numerous studies of varying costs, in various catchments were completed. A need was identified to review the returns on investment (ROI) of the different RDM studies.

The objectives of the study were to:

- Develop a methodology for assessing the costs of the Reserve
- Develop a methodology for assessing the benefits of the Reserve
- Collect information on case studies needed to populate the methods at case-specific scale
- Based on representative case studies, assess the costs and benefits, and present ROI in the past and for different future scenarios
- Develop a dashboard with indicators (such as ROI) to support communication and future applications thereof

A reserve assessment framework was informed by the assessments of the methods for determining firstly, the costs and secondly, the benefits of reserve determinations of a particular resource (river, estuary, wetland and aquifer/groundwater). The framework was informed by three major cost components; research component cost, Reserve determination cost and Reserve implementation cost. Implementation costs can include a wide range of strategic actions. It therefore includes both determination and operationalisation of the Reserve. From an operationalisation perspective it would include operational planning such as projecting Reserve requirements for a pre-defined management period, monitoring, measurement, regulation and enforcement. The second component that informs the framework is the benefits (goods and services and value) that are or will be derived from Reserve implementation. The two major benefit components included in this study are direct and indirect benefits. A distinction between, benefits with and without a Reserve was necessary to avoid double counting of benefits, i.e. only the benefits resulting/derived from the costs mentioned above, were counted. We employed a cost-benefit ratio (BCR) to indicate the ROI, in simple terms, this is calculated as **benefit** divided by **cost (BCR)**.

The report presents some relevant underlying theory of non-market valuation, accompanied assumptions/limitations and proposed steps to follow in the valuation process. Some valuation theory including the main methods for the valuation of the value attributes of benefits/costs are presented, discussing the importance of an appropriate discount rate, reflection on the level of detail of valuation required for a ROI assessment as well as a discussion on the merits of a rapid assessment and the merits of ROI as a credible indicator for decision-making is provided.

Study areas selected as case studies included a catchment where the Reserve was implemented and one catchment where the Reserve was determined but not yet implemented. The two study areas selected, in consultation with the reference group and consultants, were the Olifants-Doorn Water Management Area and the Inkomati Water Management Area.

The **most conservative** CBR indicated that R364m has been spent in 20 years on Reserve related research (costs, determination, implementation) in South Africa (R7m for Inkomati and R14m for Olifants-Doorn), which yielded a benefit of R911m. For every R1 spent on Reserve-related research in South Africa as a whole, a benefit of R2.50 was realised. The results were 18:1 and 1.6:1 for Inkomati and Olifants-Doorn respectively.

When adding ecosystem services the ratio was 3.5:1 for South Africa and 23.8:1 for Inkomati and 2:1 for the Olifants-Doorn. These are considered more realistic and should be used to inform decisions as the addition of serviced water (e.g. chlorinated water) to the benefits side of the equation cannot be justified since water in the Reserve is strictly speaking, not serviced.

It should be noted that the data represented 60% of all studies identified. If the remaining data gaps were filled with the average cost of a research project on this topic of R1.23m, the total cost of research increases to R558m. Associated BCR for South Africa for unserviced water and ecosystem services will then be 2:1 for South Africa, 24:1 for Inkomati and 2:1 for Olifants-Doorn. When allowing a 5-year benefit stream the ratios increases to 10:1 for South Africa, 119:1 for Inkomati and 10:1 for Olifants-Doorn.

It should be noted that this was a short project with time and budgetary constraints. No data on EWR or IFR sites were used, hence data from statistical accounting was used. This was due to lack of Reserve monitoring data. A large component of the project was dependent on research completed by consultancies and there were some limitations in obtaining information due to a limited budget with no additional funding to allocate to consultants for sourcing additional information. The data and information should be readily available from DWS every time a Reserve study is completed. In this scoping project most of the objectives have been addressed. A methodology framework was developed for assessing the costs and benefits of the Reserve (based on Excel spreadsheets). Information on case studies were collected via statistical accounting and the methodology framework was populated at a case-specific scale and projected to national scale. The project demonstrated that it is possible to link Reserve studies to economic costs and benefits. The final objective in developing a dashboard with indicators (such as ROI) to support communication and future applications was partly achieved, in that indicators were identified with a higher-level view of costs and benefits associated with the Reserve.

A longer-term project would allow for a more comprehensive data capture exercise and allow for the development of a detailed indicator tool for the determination of costs and benefits of Reserve studies for management purposes. A list of recommendations are included for further study.

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GLOSSARY OF TERMS

Consumer Price Index (CPI): This is a measure that examines the weighted average of prices of a basket of consumer goods and services, e.g. transportation, food, and medical care. It is calculated by taking price changes for each item in the predetermined basket of goods and averaging them.

Contingent valuation method (CVM): A survey-based method where people are asked to state their willingness to pay to receive a hypothetical benefit (e.g. an improvement in air quality) or to avoid a hypothetical loss.

Cost-benefit ratio (CBR/BCR): This is an indicator used in cost-benefit analysis which shows the relationship between the relative costs and benefits of a proposed project expressed in monetary or qualitative terms.

Ecological Water Requirements (EWR): The flow patterns (magnitude, timing, and duration) and water quality and quantity needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.

Internal rate of return (IRR): This is a metric used in capital budgeting to estimate the profitability of potential investments.

Producer Price Index (PPI): This is an economic indicator that measures the average change in the sales prices for the entire domestic market of raw goods and services.

Reserve: The Reserve consists of two parts: The basic human needs Reserve and the ecological Reserve. The basic human needs Reserve provides for the essential needs of individuals served by the water resource in question and includes water for drinking, for food preparation and for personal hygiene. The ecological Reserve relates to the water required to protect the aquatic ecosystems of the water resource. The Reserve refers to both the quantity and quality of the water in the resource and varies depending on the class of the resource.

Resource Directed Measures (RDM): The National Water Act (NWA) makes provision for implementing Resource Directed Measures (RDM) for the protection of water resources. The Resource Directed Measures allow for the establishment of the Reserve, the classification of the water resource and the setting of Resource Quality Objectives.

Resource Quality Objectives (RQOs): These are defined as clear goals (numerical or descriptive statements) relating to the quality of a water resource and are set in accordance to the management class (preliminary class in the absence of the classification system) specified for the resource to ensure the water resource is protected.

Returns on investment (ROI): ROI indicates the performance of an investment enabling the comparison with other investments.

Total Economic Value (TEV): This is a concept in cost-benefit analysis that refers to the value derived by people from a natural resource, a man-made heritage resource or an infrastructure system, compared to not having it.

Water Resource Classification System (WRCS): The classification of water resources is required by the National Water Act (NWA) (No. 36 of 1998), and consists of a set of guidelines and procedures for determining the different classes of water resources (Chapter 3, Part 1, Section 12). Desired characteristics of the resource are represented by a Management Class (MC) which outlines the attributes required of different water resources by the resource custodian (Department: Water and Sanitation (DWS) and by society. The WRCS will be used in a consultative process to classify the water resources (economic, social and ecological implications) within a geographic region in order to facilitate finding a balance between protection and use of the water resources.

Willingness to Accept (WTA): The compensation to forego a benefit or tolerate a loss.

Willingness to Pay (WTP): The willingness to pay for using an area to receive a benefit (e.g. an improvement in air quality) or avoid a loss.

1 INTRODUCTION

1.1 Background and rationale

The concept of the Reserve was introduced as early as the 1980s, following from a period of extractive use and wide-ranging impacts (Le Maitre, 2014). The National Water Act (No. 36 of 1998) makes explicit provision for implementing Resource Directed Measures (RDM) for the protection of water resources in South Africa, which is based on principles guiding the sustainable and equitable use of the resource (Seward, 2010, Pollard and Du Toit, 2008). Resource Directed Measures refers to the establishment of the Reserve (water quantity and quality), the classification of the water resource into management classes and the setting of Resource Quality Objectives (RQOs) (quantitative and qualitative description of the water resource) (DWA, 2011). Before any authorisation of water use can occur, the determination of the Reserve is necessary for the ecological component that will be impacted on by any proposed water use (DWS, 2014). The Reserve consists of two parts, one being the Basic Human Needs Reserve and the other being the Ecological Reserve. The Reserve refers to the quantity, quality and reliability of water required to satisfy the Basic Human Needs (BHN) and to protect aquatic ecosystems, so as to secure ecologically sustainable development and use of the relevant water resource (DWS, 2014). The purpose of the Ecological Reserve is to ensure that the quantity, quality and reliability of water resources are available to maintain the ecological functions in aquatic ecosystems to assure sustainable development in the future. The resource should, therefore, be afforded some level of protection from human use so as to ensure the long-term sustainability of the water resources and associated ecosystems. The Reserve is therefore directly linked to ecosystem services (Le Maitre, 2014, van Wyk et al., 2006). The Reserve concept is implemented at a local scale, through Resource Units within the Water Resource Classification System (WRCS) (DWA, 2011).

Since the RDM method development of the Reserve concept and implementation studies in various catchments, a need was identified to review the returns on investment (ROI) in Reserve determinations to learn from trials and develop different approaches, if needed. In the context of this study, this encompasses all studies relating to the Reserve in Resource Directed Measures and later studies (after 2010) in the Water Resource Classification System. The accepted mainstream definition of ROI indicates the performance of an investment enabling the comparison with other investments. The two main components for reviewing the returns on investment for any investment is a comparison of the incurred costs of the investment with the benefits derived from the investment. Several standard indicators exist to express the comparative merit of return on investment, chiefly, among others, the cost-benefit ratio (BCR) or internal rate of return (IRR). The BCR was applied in the current study. Here performance is presented as a ratio, calculated as the benefit (return) of the investment divided by the cost of the investment yielding a benefit-to-cost ratio (normally expressed as Rx (benefit):R1 (cost).

Three major cost components included in this study were:

1. Research component cost: These costs are not water resource-specific and represent the cost of developing the general method for determining the Reserve.
2. Reserve determination cost: These costs are water resource-specific and refer to the costs of determining the Reserve for a particular water resource.
3. Reserve implementation cost: These costs are water resource-specific and refer to the costs of implementing the recommended Reserve requirement for a particular water resource (Environmental Water Requirement-EWR or Instream Flow Requirement- IFR). Implementation costs can include a wide range of strategic actions, which can include capturing of the Reserve in policy, institutional and strategic realignment and determination of the Reserve. It therefore includes both determination and

operationalisation of the Reserve. From an operationalisation perspective it would include operational planning such as projecting Reserve requirements for a pre-defined management period, monitoring, measurement, regulation, enforcement, reflection and learning (Pollard et al., 2012). Proxies for these costs will be any infrastructural cost or managerial cost associated with the implementation of the Reserve. It would also include any monitoring studies of the Reserve or projects related to its operationalisation.

The two major benefit components included in this study:

1. Direct benefits: These benefits are water resource type-specific and refer to all the direct benefits usually derived from a water resource type (i.e. the same set of benefits (value attributes) are at play), but we are interested in the marginal/additional benefit of the Reserve, for example, the increase in **water supply assurance** and increase in **water quality maintenance** due to having a Reserve. There may be other direct benefits for which the marginal benefit will need to be derived.
2. Indirect benefits: These benefits are water resource type-specific and refer to indirect benefits such as flood risk mitigation, improved human health, recreational value, and cultural values of a specific resource type. Again, we are only interested in the marginal/additional benefit of the Reserve.

Although the cost component is conceptually simple and one can with confidence allocate all costs to the Reserve, the same cannot be said for the benefit component. Here we need to distinguish between benefits with and without a Reserve. Although the same kind/type of benefits comes into play, the extent of these is expected to differ/change depending as to whether or not a Reserve is, or is not, in place. This distinction is important to avoid double counting of benefits, i.e. only the benefits resulting/derived from the costs mentioned above, may be counted, i.e. we are interested in the additional benefit of having a Reserve (called the marginal benefit of having a Reserve).

The ROI can easily be calculated for private goods. However, when it comes to public goods such as water, this mainstream interpretation is broadened to account for the complexities associated with non-excludability and non-rivalry. Here, although the calculation of the BCR ratio itself remains conceptually simple, the underlying valuation of the value attributes for both the benefit- and the cost-side of the ratio becomes more complex (since it involves non-market valuation), and justifies some further explanation. This is especially true for public goods such as the Reserve.

The sections to follow below delves into more detail presenting some relevant underlying theory of non-market valuation, accompanied assumptions/limitations and proposed steps to follow in the valuation process. We will present some valuation theory including the main methods for the valuation of the value attributes of benefits/costs, discussing the importance of an appropriate discount rate, reflect on the level of detail of valuation required for a ROI assessment; discuss the merits of a rapid assessment and discuss the merits of ROI as a credible indicator for decision-making.

Experience has taught the research team that no single valuation method can be used to estimate/derive monetary values for the complete spectrum of non-market value attributes. We will consequently match suitable methods for specific value attributes to each case study. The following serves as a short review of the concept of value, valuation methods, some underlying assumptions and our preferred approach.

2 ON NON-MARKET VALUATION

For the purpose of this project, the definition of the term 'value' is not constrained to chrematistics (the study of market price formation for the purpose of making money (Martinez-Alier, 2005) or exchange value in a market economy (Parks and Gowdy, 2013). Since environmental goods and services do not generally enter markets, or do so only imperfectly, market prices for these goods and services either do not exist or capture their true value inadequately (Dixon and Pagiola, 1998). In such cases, it is necessary to conduct economic valuation using suitable non-market valuation techniques. The process involves a systematic procedure to design or derive a monetary value of costs incurred or benefits derived by society as a result of the environmental or social impacts associated with the service.

Although ecosystem services provide a nearly limitless set of valuable properties, a large proportion of their services remain unpriced through traditional markets (Hanley et al., 2007). Unfortunately, entirely inclusive valuations of ecosystem services have not been particularly successful due to a myriad of methodological challenges, and because it is not always possible to identify marketable value attributes of such services accurately (Barbier et al., 2011, Limburg, 2009, Parks and Gowdy, 2013). Thus, such goods and services are left without a market price; albeit not without value (Ferraro, 2000, Alpizar et al., 2007). Until now, one way of accounting for such goods and services was to present them as intermediate services to 'final' services and then derive the value of the intermediate good from the final services (Pascual et al., 2010). This distinction helps to prevent double-counting (Boyd and Banzhaf, 2007, Fisher et al., 2009).

There are several approaches towards valuing attributes of public goods including market value approaches (which involve the quantification of production), surrogate market or revealed preference approaches (which involve observation of related behaviour), and simulated market or stated preference approaches (which involve direct questioning). There are also numerous ways these values can be expressed and depends on who requires the information and for what purpose the information is required.

The well-known total economic value (TEV) framework (Figure 1) tries to present this spectrum of values and provide an indication as to which method is suitable for which kind of value. The framework disaggregates value into two broad categories (use and non-use) and then five sub-categories as per Figure 1 below. These values can be measured at local to national scales and from social or private perspectives.

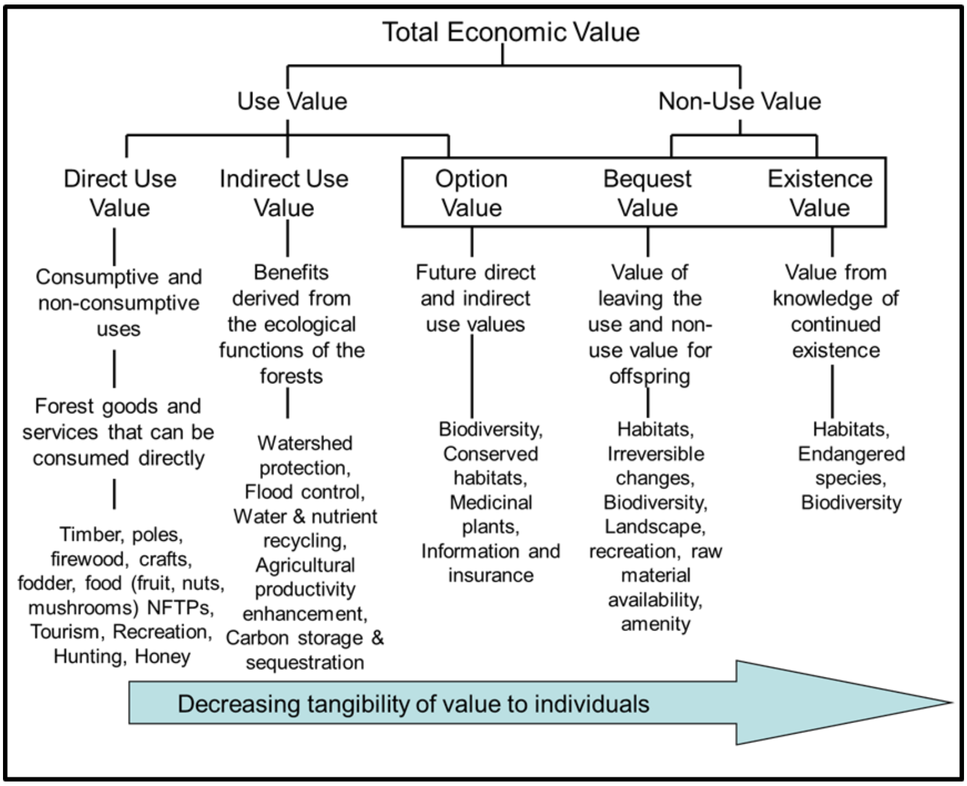

Figure 1: The total economic value of natural resources, modified from Merlo and Croitoru (2005)

Use values are based on the actual physical use of environmental goods and services, whereas non-use values are not associated with actual use, or even the option to use an ecosystem and/or its services (Dziegielewska, 2013, Goodstein, 2011). Direct use values are derived through the consumptive or non-consumptive use of ecosystem services such as hunting, fishing, drinking water or hiking, whereas indirect use values arise when ecosystems produce outputs that create inputs into separate production processes elsewhere (Goodstein, 2011), e.g. flood control.

Option value is the value placed on goods and services for their potential to be available in the future, even though it may currently not be used (Goodstein, 2011). Existence values, reflect benefits from knowing that a particular good or service simply exists and bequest values make up the other non-use value component and specifically refers to the benefits attained from preserving particular goods and services for future generations (Goodstein, 2011). For example, many people are willing to pay to reduce potential future damages because of climate change, which is despite the fact that most of these changes are predicted to occur long after the current generation. Figure 2 illustrates many of the various approaches used to value the value-attributes of public goods. These methods have been separated into preference-based approaches and biophysical approaches alike (Pascual et al., 2010). Table 1 presents many of the commonly used valuation methods and the types of value that they are generally used for.

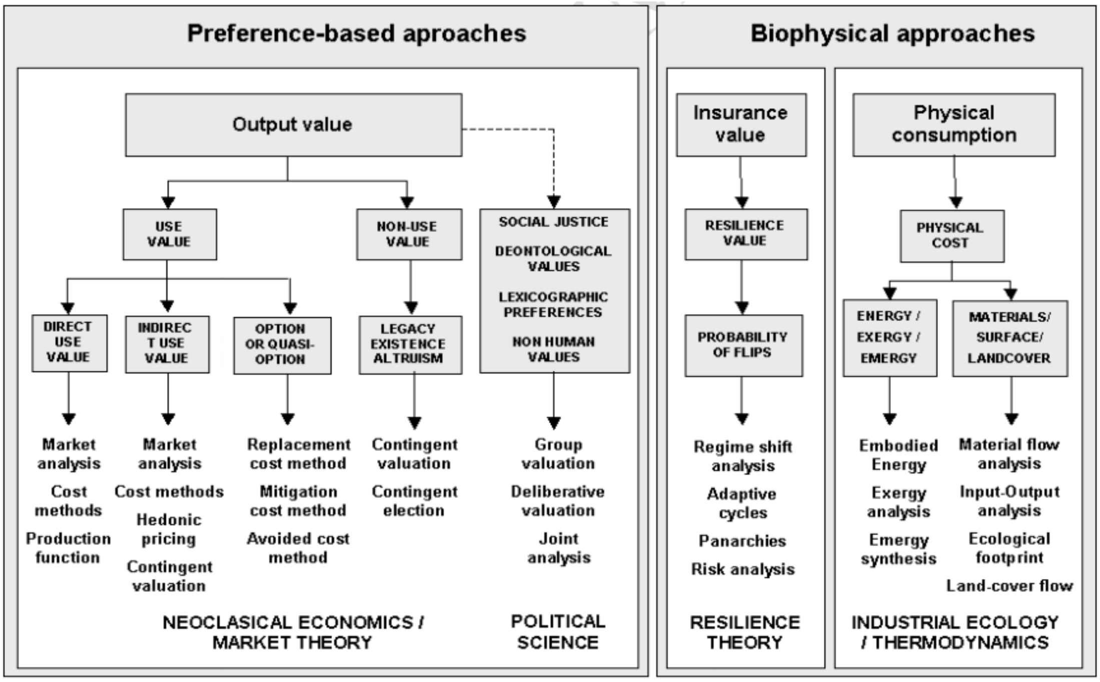

Figure 2: Approaches for the estimation of nature's value (Pascual et al., 2010)

Table 1: Commonly used natural resource valuation methods and the types of value which they are generally used to measure (XX = main use, X = possible use)

		Direct use value		Indirect use value	Option and non-use value
		Consumptive	Non-consumptive		
Market value approaches	Market valuation	XX	X		
	Production function	XX	X		
	Replacement cost/avoided damage	X	X	XX	
Surrogate market/ revealed preference	Travel cost method	X	XX		
	Hedonic pricing	X	XX	XX	
Simulated market/ stated preference	Contingent valuation	XX	XX	X	XX
	Conjoint valuation	X	X	X	X
Benefit transfer		XX	XX	XX	XX

Pascual et al. (2010) distinguish between three main approaches to direct market valuation (or market value approaches): (1) market price-based approaches, (2) cost-based approaches and (3) production function-based approaches. The primary advantage of these approaches are that they use data from existing markets and thus reflect real preferences and costs to individuals (Pascual et al., 2010).

Market valuation applies standard economic methods to value goods or services that are traded in formal markets. The particular types of costs and prices used are dependent on how one aims to express the value (i.e. economic surplus, nett private income, gross economic output or direct value-added). Market price-based approaches are often used to determine the values of provisioning services because these are generally traded on actual existing markets (Pascual et al., 2010). For fisheries as an example it involves estimating a demand curve for fish, calculating the consumer surplus, estimate revenue received by fishermen, and subtracting the variable costs to estimate producer surplus.

Surrogate prices may be used for natural resources where there are no market prices. Barbier et al. (1997) suggest some possible methods for using surrogate prices. If the particular resource is traded or bartered, it should be possible to derive its value from the market price of the commodity for which it is traded (e.g. fish for vegetables). Substitute prices can also be used if a close substitute for the good or service in question can be identified (e.g. chicken for fish). Replacement cost estimates may also be used, i.e. the amount of money people save by using ecosystem services as opposed to purchasing the service. Indirect substitute prices use the opportunity cost of a substitute product as a proxy measure for the value of the good or service in question (Barbier et al., 1997). However it may become necessary to adjust these prices and costs using shadow prices (Parks and Gowdy, 2013), which reflects economic value as opposed to financial value of particular goods or services as they are corrected to account for market distortions; their primary aim is to indicate the 'true', full value of a good or service to society (Parks and Gowdy, 2013). Lastly, social survey methods, which require interviewing users, can be used as a market valuation approach when obtaining the necessary data, prices, and costs (Ryan and Spash, 2011). These interviews can be in the form of focus group discussions, key informant interviews or household questionnaires.

Cost-based approaches are based on estimating the costs that would be incurred if ecosystem service benefits needed to be recreated through artificial means (Garrod and Willis, 1999). The main techniques associated with this approach are the avoided cost method, the replacement cost method and the restoration or mitigation cost method. The avoided cost method involves valuing the costs that would have been incurred in the absence of certain ecosystem services (Farber et al., 2002, Tietenberg and Lewis, 2010). The replacement cost method estimates the costs incurred by substituting specific ecosystem services with artificial technology (Goodstein, 2011). Lastly, the restoration or mitigation cost approach derives the costs of mitigating the impacts of the loss of ecosystem services or the cost of restoring those particular services (Pascual et al., 2010).

The production function approach facilitates the estimation of marginal values (change in value that would occur with a change in quality or quantity of ecosystem good or service) (Barbier, 1994). The approach estimates the amount a given ecosystem service contributes to the provision of another service or product that is traded through an existing market. The quantity of a good or service provided by an ecosystem is dependent on the attributes of the system itself and the inputs involved in the production of the good or service. For example, the value of harvesting fish from a river is a function of the flow rate, water quality, availability of food, the structure of the river, etc. as well as of the labour inputs of fishermen. Therefore, any resulting improvements in the resource base or environmental quality derived from enriched ecosystem services could lead to lower prices and costs as well as increases in the quantities of marketed goods, thus ultimately increasing consumer and producer surplus (Pascual et al., 2010).

Revealed preference or surrogate market approaches include two main methods, namely, the travel cost method and the hedonic pricing method. Revealed preference approaches observe individuals' choices in existing, active markets that are directly related to the ecosystem service (Pascual et al., 2010) while the travel cost method observe direct expenses and opportunity cost of time relating to recreational activities, such as visiting a game reserve by determining the willingness to pay (WTP) for using an area (Farber et al., 2002, Pascual et al., 2010).

The travel cost method assumes that the costs of a trip to a recreational site in terms of travel, entry fees, on-site expenditures and time can be used as a proxy for the use-value of the site and for changes in its quality.

The hedonic pricing method uses information about implicit demands for a particular environmental good or attribute of marketed commodities such as property (Farber et al., 2002; Pascual et al., 2010). It attempts to derive the contribution of environmental variables towards the value of certain properties using linear modelling of the various variables that make up property value (such as availability of water or a beautiful view). The value of ecosystem services is reflected in property prices.

Stated preference approaches attempt to mimic a market and demand for a suite of ecosystem services by conducting surveys that address hypothetical, policy-induced changes in providing the specified services (Limburg, 2009, Pascual et al., 2010). These types of methods have been used to estimate the use and non-use values of ecosystem services, even in the absence of surrogate markets (Kontoleon and Pascual, 2007, Pascual et al., 2010).Turpie and Malan (2009) argue that stated preference approaches should not be used to determine the value of ecosystem services as most people do not understand the complexity of ecosystem services and their linkages to economic activity. The main stated preference methods are a contingent valuation, choice modelling or conjoint valuation, and benefits transfer.

The contingent valuation method (CVM) is a survey-based method where people are asked to state their WTP to receive a hypothetical benefit (e.g. an improvement in air quality), or to avoid a hypothetical loss. Or, conversely, their willingness to accept (WTA) compensation to forego a benefit or tolerate a loss. It is intuitive in principle, seemingly easy to apply and widely applicable to a range of different situations (since it is based on hypothetical scenarios such as hypothetical improvements or deterioration of the environment). However, the method is challenging to apply in practice, and the accuracy of the results is subject to debate. In particular, conducting a proper survey that meets best-practice requirements is data-intensive, costly, and time-consuming. Nevertheless, the CVM method is one of the few methods capable of estimating non-use values (Goodstein, 2011).

The choice modelling or conjoint valuation method is a broad term for a variety of survey methods (e.g. choice experiments, contingent ranking/rating, paired comparisons, etc.) that request respondents to rank/rate/choose alternatives rather than explicitly express a WTP or WTA. It was developed originally in the field of marketing but is increasingly used to value ecosystem services. The most common approach attempts to model the decision-making processes of an individual within a specific context with the aim of estimating non-market values of ecosystem goods or services (Pascual et al., 2010). Each individual is faced with two or more alternatives to the good or service being valued, each with shared characteristics. However, each alternative has different amounts of each attribute, and one attribute is always the amount people would have to pay for said good or service (Pascual et al., 2010). Thus, from the choices that people make between the alternative goods and services, a value for the chosen ecosystem good or service can be estimated. A monetary value is therefore obtained based on the trade-offs that respondents make between the monetary and non-monetary attributes. A baseline status quo alternative is usually included to help establish other alternatives in relation to the respondent's actual experience (Goodstein et al., 2011).

Benefits transfer is an econometric tool for transferring existing estimates of non-market values (benefit and/or damage) from one study context to another, and making appropriate adjustments to account for differences in the two contexts (e.g. socioeconomic, demographic, geographic and climatic differences) (Barbier et al., 1997). Benefit transfer is not a valuation method in a true sense, but rather a method for transferring existing estimates of non-market values from one study site to another. The method requires appropriate adjustments to accommodate contextual differences between study sites (Eshet et al., 2005). The value estimates used in the method are obtained via any non-market valuation method (Eshet et al., 2005, Nahman et al., 2009, Vo et al., 2012, Parks and Gowdy, 2013). Benefit transfer methods are subdivided into two broad categories. The first being ‘unit value transfer’, which involves the direct transfer of value estimates from source studies to the study area with limited or no adjustment. Secondly, ‘function transfers’ involve the transfer of parameterized benefit function which is adjusted with independent variables from the study area (Johnston and Rosenberger, 2010, Rolfe, 2006).

An obvious limitation of the benefit transfer method lies within the accuracy of the adjustment process (Bergstrom and Taylor, 2006, Wilson and Hoehn, 2006, Moeltner et al., 2007). Here it becomes necessary that the methods being followed for the adjustment process are made explicit and that the process is done in a transparent way (Moeltner et al., 2007, Bergstrom and De Civita, 1999, Bergstrom and Taylor, 2006, Rosenberger and Loomis, 2000, Smith and Pattanayak, 2002, Shrestha and Loomis, 2001, Shrestha and Loomis, 2003, Wilson and Hoehn, 2006, Johnston et al., 2015). Furthermore, the method has been subject to many applications that sacrifice scientific rigor in ways that provide inaccurate information on ecosystem values (Johnston and Wainger, 2015) that misinform policies which could reduce human welfare in the long term. One particular area of concern relates to the choice of transferring unit values or the underlying function of such value (Loomis and Rosenberger, 2006). Although, function transfers allow for adjustments to be made according to a variety of factors that can influence values and although the literature suggests that function transfers outperform unit value transfers in terms of representivity and inclusiveness (Kaul et al., 2013), actual evidence for this preference in practice is mixed (Johnston and Rosenberger, 2010). Indeed, Bateman et al. (2011) argue that unit value transfers are appropriate when source studies are within the same socio-economic context as target sites, but that function transfer becomes more appropriate as contextual differences increase. Context similarity is therefore important, but the exact point as to when to use unit value transfer as opposed to functional transfer remains somewhat obscure. It is, however, clear that unit value transfers are simpler to use and often the only approach available when source studies are limited or when benefit functions are not reported in source studies (Rolfe et al., 2015).

The academic literature has highlighted the problem of divergence between transfer practices recommended in the literature and those applied in practice. Unit value transfer is often the preferred practice (it is simpler) although it could be less accurate than functional transfer. However, although benefit transfer is subject to these conceptual and empirical limitations, the method is still widely applied (especially by government agencies) in policy design and implementation (Bergstrom and De Civita, 1999).

Not disregarding its limitations, we employed the benefit transfer method where appropriate because of an increasing need for utilizing more cost-effective valuation methods in South Africa and because several studies have been done on describing, mapping, physical quantification and monetary valuation of estuary ecosystem services in southern Africa. This has allowed the confident use of the method, but with special attention to adjust values to serve as estimates for the study site. We considered unit value transfer since we considered it acceptable to use as a preliminary value estimate within similar socio-economic contexts.

The above-mentioned theoretical introduction underlies the study. However, each river is unique, which therefore requires a systematic account of the value attributes found in the study site. Each value attribute is matched (data pending) to a suitable valuation method (as described above) in order to derive the associated monetary value for the relevant attribute.

3 THE CHOICE OF DISCOUNT RATE

It is worth noting that costs and benefits occur at different times and also for different time periods and consequently, the timeframe and time value of money of such a comparison becomes extremely important. Costs are typically incurred upfront (i.e. before the impact/result) while benefits are derived afterward (for the case of ecosystem services benefits could be over significant time periods and often into perpetuity). These costs and benefits need to be at the same moment in time to allow direct comparison. This implies that we need to account for the time value of money in order to compare. For example, some costs may have been incurred ten years ago, which implies that those costs will need to be inflated (at a suitable rate) to the present day. On the other hand, some benefits may incur only within 15 years which need to be discounted (again at a suitable rate) to the present day. The inflation and discounting rates do not necessarily need to be the same and the choice of rate is still subject to many theoretical studies and can be quite complex. In a nutshell, the rate of discount reflects the investor's or society's rate of time preference. For a private owner or investor, this is influenced by the rate of interest that they could obtain on their investments. For example, if capital grows at a real interest rate of 10%, then in theory, the investor should be indifferent between receiving an amount of R100 in the present or R110 in a year's time. Similarly, the present value of next year's earnings of R110 will be R100, calculated by applying a discount rate of 10%. The discount rate can thus be based on the real rate of earning interest on investment accounts or the interest on borrowed capital. Discount rates based on these interest rates can be considered to be 'private' discount rates in that they reflect individual rates of time preference.

In reality, private discount rates will be higher than this when the risk of poverty, starvation or death is high. However, in the case of publicly-owned goods such as rivers, it is more appropriate to use a social rate of discount. Indeed, the conservationist argument is that a low social discount rate should be applied when valuing environmental costs and benefits associated with rivers. Social discount rates are usually lower than private rates because society as a whole places greater value to benefits and costs to future generations than individuals do (a lower rate will depreciate future values less). While there is no interest rate proxy for a social discount rate, we propose to apply the Ramsey rule which argues that the discount rate should be the sum of the rate of time preference and the income growth rate, multiplied by the elasticity of the marginal utility for money (Johansson-Stenman and Sterner, 2015). The first component implies discounting of future utility per se, while the second implies discounting the value of future consumption goods based on the notion that we will be richer in the future and that the rich gain proportionally less welfare than the poor from a given quantity of money, i.e. serving equity principles.

4 DETERMINING THE LEVEL OF DETAIL REQUIRED FOR A VALUATION STUDY

Methods for the comprehensive and rigorous valuation of value attributes have become increasingly refined. However, there is also growing pressure for the rapid estimation of these values, especially when large scale assessments are required or resources (money and skills) are limited. Rapid methods are increasingly being tested and applied, both for assessments in non-monetary terms (Kotze et al., 2008) and for those in monetary terms (Van Zyl and Leiman, 2002), although usually at the expense of the confidence of the study results. Because of the correlation between the quality of data and statistical analysis and accuracy of the output, there is an inevitable trade-off between minimizing resources allocated to the problem and confidence in the results. It is therefore important to determine the level of confidence or certainty required for the decision-making process that the valuation study informs, as well as to ascertain the potential impact of the more rapid methods on the reliability of those results.

We argue that the comprehensiveness of a study can be described in terms of its scope (coverage of different values, i.e. how many value attributes it includes), the extent of valuation (how beneficiaries are defined and value expressed) and methodological rigor. These concepts are explained in more detail below.

4.1 Scope (coverage of values)

The scope of a valuation study is defined as its completeness in terms of the extent of its coverage (how many attributes of value it includes) and may range from a partial to a comprehensive valuation. A comprehensive valuation study will consider all provisioning, regulating and cultural services, and all the components of TEV yielded by those services, and will also consider the opportunity costs involved in maintaining those outputs – i.e. a fully inclusive study. At the other end of the scale, a partial valuation study may only concentrate on a single value attribute. It is generally accepted that some types of value are easier to estimate than others, with the level of difficulty generally increasing from the direct use values (such as grazing, fishing, tourism) to indirect use values (such as water purification) and non-use values (such as existence value).

4.2 The way in which values are expressed, and to whom

For market values, a comprehensive study might estimate the extent to which an attribute contributes to Gross Domestic Product (GDP) or Gross Geographic Product (GGP), by estimating the direct and indirect contributions to national or regional income using macro-economic models. It might also investigate what proportion of the national or regional income accrues to lower-income sectors of the population, by using a social accounting matrix and how a river contributes to people's livelihoods (e.g. using the Wetland Livelihood Value Index) (Turpie and Egoh, 2003).

At their simplest, partial valuation studies might only estimate the direct gross income generated, such as the total revenue generated from river/wetland fish sales (Table 2). The difference between gross private value and net private value is the cost of offering the services; it will exclude depreciation, interest, and taxes. This can be important if looking at a resource which is being harvested at an unsustainable rate, in which case the unsustainable part of the harvest should be treated as "depreciation".

Table 2: Different ways in which monetary values can be expressed

<table>
<tr><th></th><th>Simple, local</th><th>>></th><th>>></th><th>Comprehensive, national, global</th></tr>
<tr><td>Direct consumptive use (e.g. harvesting of resources)</td><td>Gross private value (income from sales + value of subsistence use)</td><td>Net private value (total income less input costs, i.e. producer surplus, + buyers' consumer surplus)</td><td rowspan="2">Direct value added to GDP/GGP (total revenue less intermediate expenditure)</td><td rowspan="2">Gross (direct + indirect) value added to GDP/GGP (Previous + modelled estimate of multiplier effects)</td></tr>
<tr><td>Direct non-consumptive use (e.g. tourism)</td><td>Gross private value (tourist expenditure / gross income generated by tourism businesses)</td><td>Net private value (turnover less input costs, i.e. producer surplus, plus tourists' consumers' surplus)</td></tr>
<tr><td>Indirect use (e.g. refuge service)</td><td>Gross turnover generated in surrounding area</td><td>Net income generated in surrounding area</td><td>Direct value added at regional / national scale</td><td>Gross value added at regional / national scale</td></tr>
<tr><td>Indirect use (e.g. water purification service)</td><td colspan="4">Cost savings in terms of damage or replacement costs avoided</td></tr>
<tr><td>Non-use (existence value of biodiversity)</td><td>Willingness to Pay (local)</td><td colspan="2">Willingness to Pay (regional)</td><td>Willingness to Pay (national)</td></tr>
</table>

Non-consumptive uses are challenging because one has to estimate how much value should be attributed to the resource in question. In the case of non-market values of intangible benefits (such as the feeling of well-being gained from knowing that a river is in good condition), most studies are bound to estimates of Willingness to Pay derived from stated preference methods. Here it is also important to distinguish between the geographic extent of the study area and the extent to which beneficiaries beyond the study area are considered. Beneficiaries can be considered up to a global level, even if the study is considering a single river. Nevertheless, there tends to be a positive relationship between the geographic scale of the study area and the scale at which beneficiaries need to be considered. It may be unnecessary to estimate the impact of a small river system on GDP and employment, but this becomes increasingly relevant as the size of the study area increases. For any particular river, direct use values (such as resource use and property values) are normally considered at the local level, indirect use values (such as flood attenuation) at a regional scale, and non-use values (e.g. society's willingness to pay to conserve the river) at the national level. The Okavango Delta is a good example of a single wetland that yields resource use benefits at a local scale, flow regulation services at a regional scale, tourism value at a national scale and existence value at a global scale (Turpie et al., 2006). Here it becomes important to keep in mind that local scale benefits may incur regional scale costs and vice versa. Thus, the extent to which opportunity costs are investigated also has to be carefully considered.

4.3 Methodological rigor

Data quality and depth of analysis are the most important determinants of the level of comprehensiveness of a study, in that they affect the level of certainty or confidence in the results. The most comprehensive study will be based on statistically robust data that can cope with spatial and temporal variability in most parameters that influence value. At the other end of the scale, estimates may be used that have been derived from expert knowledge based on findings from other systems. The data quality aspect is the main determinant of the confidence level of the study.

The depth of analysis determines the predictive ability of the outputs. The outputs of a comprehensive study will be in the form of a robust dynamic model which allows the computation of marginal values and is able to predict the consequences of changes in ecosystem condition or socio-economic circumstances. At the other end of the scale, a valuation study may only provide an estimate of the current average value. The latter has less reliability for extrapolation in time or place.

5 EFFECTS OF SCOPE, EXTENT AND METHODOLOGICAL RIGOR ON CONFIDENCE

It is important to note that the level of confidence of rough or intermediate studies which involve some element of extrapolation or expert opinion is strongly related to the extent to which assessments have been carried out on similar systems elsewhere. Where few or no comparable data are available, rough assessments can have unacceptably low levels of confidence. The scope and extent of the valuation affect confidence in as much as there is a danger of omitting important values or beneficiaries, or an important way of expressing value. For example, a study might produce a very accurate estimate of income derived from a river system (which could be small), but fail to express how important that income is in the livelihoods of the surrounding community. Such omissions can lead to distorted decision-making.

6 TRADE-OFFS BETWEEN SCOPE, EXTENT AND METHODOLOGICAL RIGOR

Since resources for valuation studies are generally limited, increasing the scope of the study to include all types of value may come at the cost of the methodological rigor or extent of the valuation for one or more types of value. It may be necessary to put more effort into values that are considered more important, or in other cases, it might be better to spread the research effort amongst all values. There may also be a trade-off between data quality and depth of analysis. In other words, it is possible to develop simple predictive models with relatively few data and low confidence, but with the ability to produce rough predictions of the consequences of change. The choice involved in these types of trade-offs will be dictated by the needs of the study. The level of confidence and the scope of the analysis limit the way in which the valuation results can be applied.

7 EFFECT OF THE GEOGRAPHICAL SCALE OF STUDY AREA ON COMPREHENSIVENESS

Valuation might be required for an individual river, rivers within a small area, or at a catchment scale, regional scale or even national scale. The scale of the study limits the approach that can be taken, with larger-scale studies having to adopt a more extrapolative or rapid approach. At a local level, all available resources can be concentrated, whereas at a broad scale, resources are stretched more thinly, data have to be collected at a broad scale (i.e. simple data) and the analysis will rely more heavily on assumptions and extrapolation.

Nevertheless, analysis at a single river level is potentially limiting in terms of the depth of analysis possible. For example, if a good understanding of the relationship between resource use and community characteristics is required, then this will be better achieved by studying many river systems at a catchment or regional scale. Again, there will be a trade-off when the number of rivers increases to a point where it is no longer possible to sample comprehensively. To achieve the same level of confidence, the level of effort has to increase with the scale of study.

8 IS RAPID ASSESSMENT A VIABLE ALTERNATIVE?

At the same time as methods have become increasingly refined, there has also been pressure to develop rapid, or cheaper, means of assessing the value of river systems. Many of the methods described above are extremely data- and labour-intensive. Estimation of direct consumptive and non-consumptive use of natural resources requires surveys of users, and estimation of non-use values also relies on extensive surveys, preferably with sample sizes of over 1000 respondents. The design, execution, and analysis of these surveys are specialized activities and costly. Hedonic pricing methods to estimate property values are fraught with difficulty in obtaining property value data. The level of difficulty varies between countries but is fairly high in South Africa. Finally, the estimation of the indirect use values, which are important values of many rivers, has proved to be extremely difficult for some types of value because of the detailed hydrological and other biophysical data required. One of the ways that researchers have tried to circumvent these problems is through "benefit transfer" or using values from one system to estimate those of another. The difficulties with this approach have been discussed.

9 WHAT CONSTITUTES A CREDIBLE VALUE FOR DECISION-MAKING?

Up to now, policy- and decision-makers have had to welcome and use numerical estimates of the value of river services almost irrespective of the quality or confidence of the estimation, since these estimates have been fairly hard to obtain. Rough estimates such as those extrapolated from Costanza et al. (1997) estimates of global average values have certainly played a role in swaying South African policymakers towards more environmentally conscious thinking. Broad-scale decision-making can be based on rough estimates, but project level or resource allocation decisions need more reliable estimates. More important is that the confidence of the estimates is known to the decision-makers. The confidence of an estimate can be described in words (e.g. low or high), using ranges of estimates, or by means of statistical confidence intervals. A more sophisticated analysis might involve the use of software such as Excel's @RISK, which calculates a probability distribution for a change in value. Such an analysis would integrate the uncertainties in the valuation exercise, to give a more realistic idea of the certainty of the result.

10 APPROACH TO THE VALUATION OF VALUE ATTRIBUTES OF BENEFITS FROM THE RESERVE

With the above-mentioned theoretical background, it is necessary to align the methodology with the objectives of the study and to define the scale and comprehensiveness of the study accordingly. All of these aspects are primarily determined by the terms of reference for the study and is subject to budgetary constraints. Above-mentioned methodological context and constraints in terms of detail, budget and time have led to the following approach to derive values for the benefits side of the equation for each case-study:

- Provide some socio-economic context of the study site;
- Identify and select the value attributes to be included;
- Employ benefit transfer to identify representative unit prices for each attribute;
- Reconcile value estimates (could be value per unit or total value) on a temporal scale (preferably annual figures) by means of comparing functional substitutability;
- Determine the quantity of the attribute over a year.
- Present the value in a suitable unit (e.g. R/ha/yr or R/m^3/yr)
- Aggregation and extrapolation (if required)
- Sensitivity analysis under different scenarios (if required).

11 APPROACH TO ACCOUNTING THE COSTS FROM THE RESERVE

There were three major cost components included on the cost-side of the BCR ratio as determined for rivers, wetlands, estuaries, and groundwater:

1. Research/Method development costs
2. Reserve determination cost
3. Reserve implementation cost (e.g. infrastructural cost or managerial costs, monitoring, measurement, regulation, enforcement, reflection and learning)

These are considered in more detail below.

11.1 Research component/Method development costs

These are the costs of developing an appropriate method for determining the Reserve for a water resource type. These costs are not water resource type-specific and represent the cost of developing the general method for determining the Reserve. It should be remembered that investment in research was necessary to design an appropriate method of determining Reserves in a scientifically rigorous way that will enable the comparison of systems. The aggregated cost of these projects and consultancies on the development of the Reserve determination methods, as funded by the main research funding agencies (DWS, WRC), were used as proxies for the cost of developing the method for determining the Reserve. Research budgets were constructed and inflated at the Consumer Price Index (CPI) for the relevant time-period to obtain present values if the actual costs of projects were not available.

11.2 Reserve determination costs

These are water resource-specific costs resulting from following the method for determining the Reserve for a particular water resource type or catchment. Proxies for these costs were research projects and consultancies that were completed for the determination of the Reserve for a specific water resource type. Again, the WRC and DWS were requested to provide the necessary costing of past projects and consultancies. Research budgets were constructed and inflated at the CPI for the relevant time-period to obtain present values if the actual costs of projects were not available.

11.3 Reserve implementation costs

These costs are also water resource type-specific and refer to the costs of implementing the recommended Reserve requirement for a particular water resource type. Suitable case-studies were identified and proxies were assumed for implementation costs as any infrastructural cost or managerial cost associated with the implementation or operationalisation of the Reserve. Information on these costs was obtained from WUA of case water resource types as well as from the national RDM office at DWS. Again, where the actual costs of projects were not available implementation budgets were constructed and inflated at the CPI for the relevant time-period to obtain present values.

Relevant databases were searched to compile a comprehensive list of projects relating to the full suite of RDM tools, with regard to Reserve method development, determination, and implementation. The projects identified were relevant to all water resource types, which included rivers, estuaries, wetlands and groundwater. A list of relevant organisations or individuals were compiled that managed or part took in any projects linked to RDM. The project budgets for the 3 components listed above, were relatively easily obtainable from the WRC where costs were extracted from Knowledge Review documents for the relevant period. The more recent budgets (after 2010) were readily available from DWS, however, project costs from earlier years were more difficult to source as the records were not stored in a central database/location. Individual project leaders/consultancies were approached to source the remaining data gaps. However, of the consultancies and individuals contacted some were unable to assist. Project budgets were not always timeously received from organisations or individuals, which to an extent, hampered analysis of the results. Most of the project budgets obtained were linked to research component/method development and Reserve determination costs rather than on Reserve implementation costs. Most project budgets obtained were also linked to the Ecological Reserve rather than the Basic Human Needs Reserve. Although the final list of costs that were analysed was extensive, there were still costs that were omitted in the analysis as the data could not be sourced timeously due to the short project time frame.

11.4 Criteria for site selection to determine ROI

The ROI was based on representative case studies. The following criteria were identified for case study selection:

- A maximum of two study areas to be selected. It will be difficult to extrapolate the results to all areas of the country since the river systems/catchments are so diverse. While some of the benefits (ecosystem services) can be generalised, it will depend on the various catchment characteristics.
- Study areas must have sufficient and relevant data that is readily available or can be readily obtained.
- The study area scale will be determined by the scale of the RDM study completed (e.g. whether it was on a WMA scale or a catchment scale).
- Study areas will be selected that include a catchment where the Reserve was implemented and a catchment where the Reserve was determined but not yet implemented.

There were several case study area suggestions made by the reference group and consultants which fit the above criteria for study area selection. From these, the following were selected;

- Inkomati Water Management Area (WMA): Upper Komati (industry, power generation, agriculture, conservation importance and Crocodile River (Agriculture, Industry, Tourism) (Reserve determined in 2010 (DWA, 2010a) and gazetted 2019 (DWS, 2019)).
- Olifants-Doorn WMA (Reserve completed 2006, WRCS was completed in 2012)

The study team decided to use the Olifants-Doorn as one of the case studies, although there were some concerns that the Reserve determination was based on the older tools/methods. However, the use of this catchment provided an opportunity for the comparison between ROI of these methods and more recent RDM tools/methods used in the later studies. It also provided the opportunity to determine the benefits resulting after implementation of a Reserve, in comparison with studies where the Reserve was determined, but yet to be implemented. The Olifants-Doorn WMA has also been the focus of scientific study due to the length of time since the Reserve was determined in 2006 and signed off in 2008. It would likely be easier to determine the benefits with increased data availability.

11.5 Background to study areas

Olifants-Doorn WMA

The Olifants-Doorn WMA is situated on the West Coast of South Africa, approximately 100 km to 450 km north of Cape Town (Figure 3). Most of the south-western part occurs within the Western Cape Province and the north-eastern part occurring in the Northern Cape Province. The drainage area covers an area of 56 446 km^2 (Belcher et al., 2011b). The major rivers are the Olifants River and the Doorn River which both rise in the Agter Witzenberg Mountains. The Olifants River drains to the north of Ceres and the Doorn River drains the opposite side of the Cederberg Mountains (Kouebokkeveld and Doorn area) (Brown et al., 2010). The Sout River is another major tributary that drains the Knersvlakte.

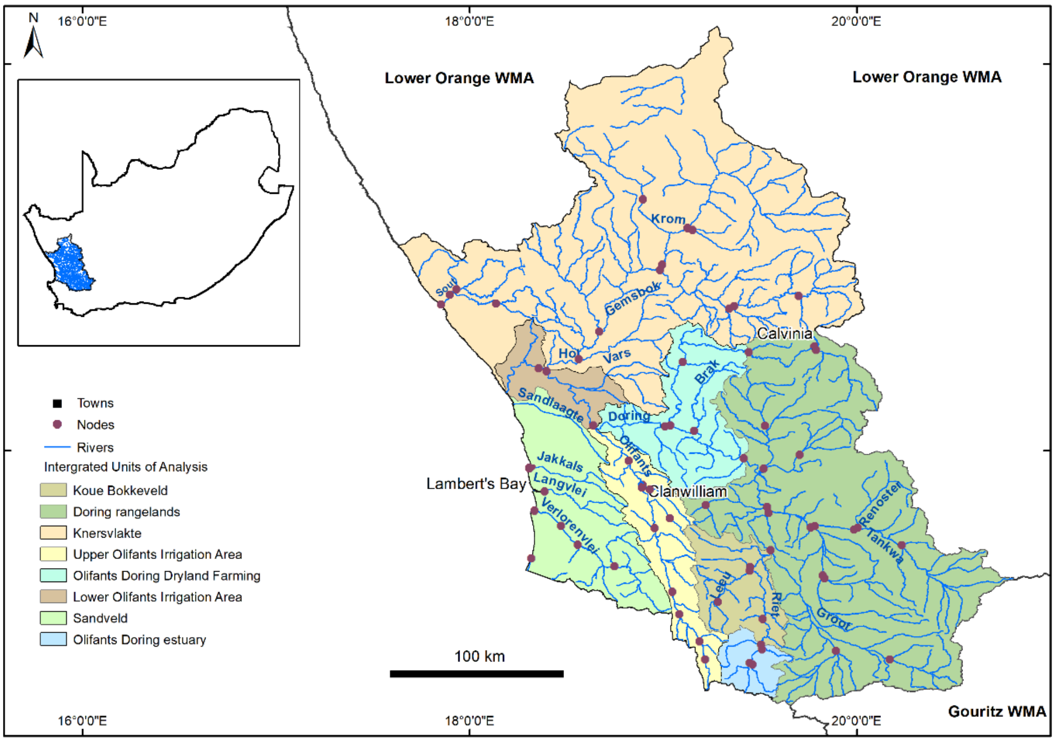

Figure 3: Olifants-Doorn WMA with biophysical modelling nodes (gave consideration to a suite of characteristics that dictate the ecological nature of rivers at different scales) established for the quantification of EWRs. The map illustrates the Integrated Units of Analysis established for the classification procedure for the WMA

Water resources are unevenly distributed in the WMA as precipitation varies. In the Cederberg Mountains in the southwest precipitation reaches 1500 mm per annum whereas in the northern coastal areas precipitation decreases to 100 mm per annum. Evaporation potential in the area is an order of magnitude higher than rainfall for much of the area. The Olifants River is naturally a perennial river but flow changes occurred due to abstractions for irrigation. The Doorn River is a seasonal river and its tributaries are more natural and unspoilt by human impact, being considered as rivers with high ecological importance and sensitivity (Brown et al., 2010).

The geology has a strong influence on the physical and chemical water quality that occurs. Part of the Olifants River flows through the Greater Cederberg Biodiversity Corridor and the water quality in the upper and middle reaches is good and both the Olifants and Doorn Rivers are hotspots for endemic fish species. The upper Doorn River water quality is considered good for agriculture and domestic purposes but deteriorates by the end of the summer season. The lower reaches, below the confluence with the Doorn River, are however impacted by increasing nitrification and salinities due to the Tankwa Karoo tributaries influence. The agricultural activities on the Malmesbury Shales also increase the salinities in the upper reaches of the Sandveld sub-area (DEA&DP, 2011). The Olifants River estuary is considered to be an important estuary due to its size, zonal-type, habitat, rarity and biodiversity and one of only three permanently open estuaries on the west coast (DEA&DP, 2011, Brown et al., 2010).

The main economic activity in the Olifants-Doorn WMA is agriculture, mainly citrus farming, and winemaking, and it contributes 45% of the economic output. Tourism and eco-tourism is also an important economic factor in the area. There is approximately 500 km^2 area under irrigation with almost 50% occurring in the Olifants river catchment. There is also a significant amount of irrigation that occurs in the Koue Bokkeveld area along the rivers and from groundwater in the Sandveld sub-area (DEA&DP, 2011). Figure 3 shows the Environmental Water

Requirement (EWR) biophysical node sites identified in the catchment. The full explanation of methods can be found in Belcher et al. (2011a). The EWR per Reserve was reported in (DWS, 2018).

Inkomati WMA

The Inkomati WMA is situated in the north-eastern part of South Africa, in the Mpumalanga Province, but also crosses international borders to include a part of Mozambique on the east and Swaziland in the southeast (Figure 4). The WMA covers an area of 28 757 km^2. This WMA also contains one District Management Area, which is the Southern Kruger National Park, which makes up 35% of the WMA. The main rivers of the WMA include the Sabie, the Crocodile (East) and Komati Rivers, which form the sub-catchments Sabie-Sand, Crocodile (East) and the Komati. The confluence of these rivers forms the Inkomati River within Mozambique (DWAF, 2004, de Lange et al., 2010). Figure 4 shows the Environmental Water Requirement (EWR) sites identified in the catchment, priority areas and the water requirements as per the Reserve was reported in DWA (2010a).

The Drakensberg Mountains creates a divide between the plateau area at about 2000 m above sea level and the marginal lands, the Lowveld, toward the east at about 140 m above sea level. The climate is subtropical with hot summers and mild to cool winters. The WMA occurs in the summer rainfall region and the average rainfall per annum is 767 mm. In the mountains, the mean annual rainfall range is 400-1000 mm and up to 1500 mm per annum. The maximum mean annual rainfall in the central parts is 1200 mm, 600 mm in the west and 400 mm in the east. Most rainfall occurs from December to January (de Lange et al., 2010). The mean potential evaporation is 1600 mm in the south-west and up to 2000 mm in the eastern parts. The north-eastern part, mostly the Kruger National Park, of the WMA (downstream part, closest to Mozambique border) receives the least amount of rainfall and downstream users are dependent on river flow (DWAF, 2004).

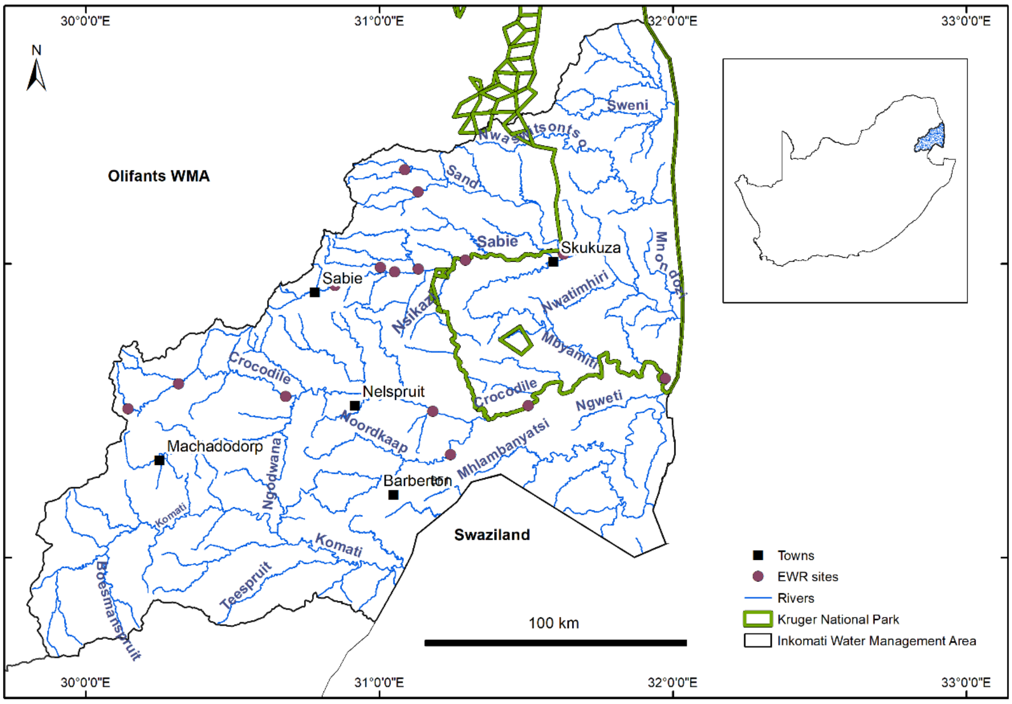

Figure 4: The location of the Inkomati Water Management Area (WMA) with EWR sites

The topography of the Sabie, Crocodile and Komati catchments are steep and together with high rainfall generates the most surface runoff. There are extensive rain-fed agricultural commercial plantations, which reduces runoff by 480 million m^3 and alien vegetation infested areas, which results in reducing surface runoff by 240 million m^3 (DWAF, 2004).

Wetlands in the Inkomati WMA are of importance to communities and are harvested for farming, grazing and thatch. These activities, however, renders them vulnerable to ecological degradation due to unsustainable human pressures. The wetlands in the Kruger Park are in a good ecological condition as they occur in a protected area. Endhoreic pans also occur in the Highveld sedimentary formations and in the Lebombo Mountains, which function independently of groundwater flows. Palustrine wetlands, which are in contact with groundwater, occur in the Komati River system (DWAF, 2004).

The main economic activity in the WMA is manufacturing (25%), agriculture (19%), government (16%), and trade (13%). The sub-tropical climate is ideal for the cultivation of tropical fruits and frost-sensitive crops including bananas, avocados, pawpaws, and mangoes. The Komati and Crocodile River valleys support irrigated sugar cane crops. The mountainous areas support forestry, large plantations of pine and eucalyptus supply the wood, pulp and paper industries. The town of Nelspruit also supports industrial and manufacturing such as steel, chemicals, food, wood products, paper, and pulp. The Kruger National Park and the natural beauty of scenic areas in the WMA supports a large tourism industry (DWAF, 2004; de Lange, 2010).

12 RESULTS AND DISCUSSION

12.1 The costs of research

The costs of research studies were obtained by approaching relevant private consultants, the Department of Water and Sanitation (Water Ecosystems: Reserve Determination and Water Resource Classification national office) and the Water Research Commission (WRC). An initial spreadsheet list of RDM studies for rivers (1991-2018) and estuaries (1989-2015), (including environmental flows, instream flow requirement (IFR) and water resource classification, etc.), were obtained from Southern Waters Ecological Research & Consulting as a point of departure. The list was distributed to private consultants, CSIR, DWS and WRC to include project costs as well as identify relevant project costs not included in the original list. The DWS National RDM and Water Resource Classification office also contributed to the costs of all the more recent Resource Quality Objectives (RQOs) and Water Resource Classification studies (2010-2016). A search was completed on the WRC's knowledge hub website for all studies related to the RDM process, which included the studies related to the river, estuary, wetland and groundwater Reserve. Once these studies were compiled, the WRC supplied the study team with the knowledge review reports (1995-2018), from which the costs related to each of the studies were extracted. In addition, if the project team came across applicable studies not listed, these were also included in the initial spreadsheet to create a new updated spreadsheet.

Research costs were obtained from:

- The original list of RDM studies that included estuaries and rivers
- WRC studies (including study costs for rivers, wetlands, groundwater, and estuaries)

The research costs were derived from project budgets and captured in an Excel spreadsheet. All cost data were inflated against the CPI to current 2019 prices. The final year of the multi-year project was taken as the basis for inflating costs. Relevant research projects attributable to the cost-side of the Inkomati and the Olifants-Doorn BCRs were identified by means of a simple keyword search in the data. The results were aggregated in a spreadsheet (see Table 3).

Table 3: Summary of RDM research cost

	Time frame included	Number of studies identified (number of studies for which cost data was obtained in brackets)	Present value of aggregated research cost (South Africa)	Inkomati (number of studies for which cost data was obtained in brackets)	Olifants-Doorn (number of studies for which cost data was obtained in brackets)
Estuaries	1989-2015	74 (38)	R35m	-	R1.7m (1)
Rivers	1991-2018	105 (29)	R181m	R7m (9)	R12m (4)
WRC studies (rivers, wetlands, groundwater, and estuaries)	1998-2018	115 (102)	R147m	-	-
Total		**294 (169)**	**R364m**	**R7m (9)**	**R14m (5)**

We managed to identify a total of 294 studies from 1989 until 2019. We had financial data for 169 of these studies, which were obtained from the various sources mentioned in section 11. A total of R364m has been spent on Reserve related research in South Africa (R7m for Inkomati and R14m for Olifants-Doorn). These figures will be representing the cost side of benefit-cost ratios.

12.2 Value attributes for the benefit side of the equation

We employed the direct value of water and associated ecosystem services in rivers as the two main categories of value attributes on the benefit-side of the BCR.

12.3 Identifying a proxy for the value of water

South Africa's water use profile (STATSSA, 2010) indicates that 61% of the total water demand in South Africa is un-serviced[1] water whereas 34.6% for serviced water (see Table 4). This is based on the previous 19 WMAs as in the new 9 WMAs the Olifants-Doorn is incorporated in the Berg-Olifants WMA (DWS, 2016).

[1] Several services can be added to raw water (i.e. water in a river) depending on user requirements. For example, domestic users require water that needs to be supplied under pressure and of which the quality complies with human health standards (chlorinated and stabilised, etc.). These services costs money and consequently increase the price of water. However, other

Table 4: South African water use profile (STATSSA, 2010)

WMA	MAR (Mm^3)	Reserve (Mm^3)	Total yield (Mm^3)	Serviced water(Mm^3)	Un-serviced water(Mm^3)
Limpopo	1006	156	281	78	243
Luvuvhu and Letaba	1209	224	310	43	253
Crocodile (West) and Marico	872	164	716	725	454
Olifants	2081	460	609	413	568
Inkomati	3610	1008	897	116	605
Usutu to Mhlatuze	4876	1192	1110	185	441
Thukela	3875	859	737	132	208
Upper Vaal	2471	299	1130	950	116
Middle Vaal	906	109	50	215	162
Lower Vaal	185	49	126	120	536
*Mvoti to Umzimkulu	4894	1160	523	536	211
Mzimvubu to Keiskamma	7386	1122	854	140	194
Upper Orange	7121	1349	4447	192	796
Lower Orange	512	69	-962	52	997
Fish to Tsitsikamma	2197	243	418	131	780
Gouritz	1713	325	275	70	259
Olifants/Doorn	1130	156	335	16	363
Breede	2521	384	866	51	588
Berg	1458	217	508	411	307
Total	**50021**	**9545**	**13230**	**4575**	**8079**
				34.6%	**61.1%**

* Inter basis transfers

The associated cost structure and derived value from these two use categories of water differ significantly. It was therefore decided to use two scenarios where the first employed a weighted average between the serviced and un-serviced water when indicating the estimated value for water in the Reserve, as well as a scenario where serviced water is excluded. It was argued that the Reserve should be regarded as un-serviced water and it would, therefore, be an over-estimation to use serviced water as a value proxy for the Reserve (i.e. the Reserve has no associated built-in services and could therefore not be used as value attribute for serviced water).

A previous study (De Lange, 2018) on the South African bulk water supply infrastructure and associated costs indicated an estimated value of R0.14 and R5.39 per cubic meter for un-serviced and serviced water respectively (2019 values). Each of these values was weighted according to serviced and un-serviced use profile of each WMA (Table 4) and then aggregated to present a representative value for that particular WMA and an average of R1.89 per cube of water for South Africa (Table 5). The second scenario was calculated with un-serviced water prices for each WMA (average R0.10 per cube for South Africa) (see Table 5).

users such as irrigators do not require all these built-in services. Consequently, such "raw" water costs significantly less compared to water for domestic use.

Table 5: Cost of serviced and un-serviced water per WMA (own calculations)

WMA	Cost of serviced water (R)	Cost of un-serviced water (R)	Total (R/m^3)
Limpopo	1.31	0.11	1.41
Luvuvhu and Letaba	0.78	0.12	0.90
Crocodile (West) and Marico	3.32	0.06	3.37
Olifants	2.27	0.08	2.35
Inkomati	0.87	0.12	0.99
Usutu to Mhlatuze	1.59	0.10	1.69
Thukela	2.09	0.09	2.18
Upper Vaal	4.81	0.02	4.82
Middle Vaal	3.08	0.06	3.14
Lower Vaal	0.99	0.12	1.11
Mvoti to Umzimkulu	3.87	0.04	3.91
Mzimvubu to Keiskamma	2.26	0.08	2.34
Upper Orange	1.05	0.12	1.16
Lower Orange	0.27	0.14	0.40
Fish to Tsitsikamma	0.77	0.12	0.90
Gouritz	1.15	0.11	1.27
Olifants/Doorn	0.23	0.14	0.37
Breede	0.43	0.13	0.56
Berg	3.09	0.06	3.15
Average	**1.80**	**0.10**	**1.897**

12.4 Identifying representative unit values for ecosystem services

Rivers and wetlands are complex hydro-ecological systems, which provide ecosystem services that are a function of the direct or indirect use of the biophysical characteristics of its landscapes. The Millennium Ecosystem Assessment (2005) (MEA, 2005) classifies these services into provisioning, regulating and cultural services with intermediate supporting services. A vast amount of literature is available on wetland and river valuation from all over the world. However, given the challenges associated with benefit transfer studies mentioned earlier, we focused on studies from southern Africa where these water bodies are recognised as being valuable ecosystems as they play an important role in ecosystem functioning and sustaining peoples' livelihoods.

We now present those studies (grouped according to the MEA, 2005 categorisation) used in the benefit transfer for this study. Several studies have been carried out on the provisioning values of wetlands in southern Africa (Table 6).

Table 6: Examples of provisioning value of wetlands from Southern Africa

Study area	Reference	Type or service	Rand (2019) per hectare per year
Olifants River, Mpumalanga	Palmer et al. (2002)	Riparian wetlands	R174
		Seepage wetlands	R6 496
		Pans	R9 685
		Artificial wetlands	R5 441
	DWA (2010)	Livestock grazing	R4 717
		Food and firewood	R4 858
Rufiji floodplain and delta, Tanzania	Turpie (2000)	Rivers and lakes	R828
		Flood plain	R1 321
		Mangroves	R335
Knysna estuary	Napier et al. (2009)		R508
Okavango Delta, Botswana	Turpie et al. (2006)		R33
Barotse flood plain, Zambia	Turpie et al. (1999)		R288
Chobe-Caprivi, Namibia	Turpie et al. (1999)		R287
Lower Shire, Malawi	Turpie et al. (1999)		R1 497
Zambezi Delta, Mozambique	Turpie et al. (2000)		R130
Lake Chilwa wetland, Malawi	Schuyt (2005)		R1 209

We found a number of South African studies on the recreational and tourism values of rivers and wetlands (Table 7). Recreational values are often reflected in changes in the value of property due to its proximity to a waterbody, i.e. the same/similar property has a different value due to proximity. Alternatively, these values can be reflected in terms of actual expenditure (or stated willingness to pay) of people visiting water bodies.

Table 7: Studies on the recreational and tourism value of rivers, wetlands and estuaries from southern Africa

Study area	Reference	Rand (2019) per hectare per year
Cape Town metro	Turpie et al. (2001)	R8 297
Sandvlei, Cape Town	Van Zyl and Leiman (2002)	R12 100
Knysna estuary	Turpie and Joubert (2004)	R597 700
Linyati-Chobe, Zambezi basin	Seyam et al. (2001)	R15
Okavango Delta, Botswana	Turpie et al. (2006)	R2 282
Olifants WMA	DWA (2010)	R200

Regulating values are often indirect and refer to those benefits that people receive indirectly from water bodies. Beneficiaries are often unaware of the benefits derived from regulating services. We present studies on the indirect use value of rivers, wetlands and estuaries from southern Africa in Table 8.

Table 8: Examples of regulating values of rivers, wetlands and estuaries in southern Africa

Study area	Reference	Service	Rand per hectare per year
Cape Town metro	Turpie et al. (2001)	Water storage and purification	R50 994
Knysna estuary	Turpie and Clark (2007)	Fish nursery areas (refugia)	R75 696
Barotse flood plain, Zambia	Turpie et al. (1999)	Groundwater recharge, carbon sequestration, and water purification	R1 462
Chobe-Caprivi, Namibia	Turpie et al. (1999)	Groundwater recharge, carbon sequestration, and water purification	R1 323
Lower Shire, Malawi	Turpie et al. (1999)	Groundwater recharge, carbon sequestration, and water purification	R2 759
Zambezi Delta, Mozambique	Turpie et al. (1999)	Groundwater recharge, carbon sequestration and water purification	R818
Olifants WMA	DWA (2010b)	Groundwater recharge	R255
		Carbon sequestration	R156
		Flow regulation	R485
		Water purification	R362
Okavango Delta, Botswana	Turpie et al. (2006)	Groundwater recharge	R34
		Carbon sequestration	R184
		Wildlife refuge	R164
		Water purification	R5
		Education and scientific value	R38

Considerably fewer studies were found focusing on non-use value (e.g. existence and bequest value) of rivers and wetlands. Turpie and Clark (2007) and Turpie and Joubert (2004) assessed a number of South African wetlands and calculated an average value of US$ 185 per hectare per year. Turpie and Barnes (1999) assessed the non-use values of the Barotse flood plain in Zambia and estimated the average value for this area on US$ 8 per hectare per year. We are aware that all of the above-mentioned studies have different underlying assumptions and that these measures should be considered as partial.

12.5 Deriving values for river and wetland services

Table 9 was compiled by applying the Millennium Ecosystem Assessment, (2005) (MEA, 2005) categorisation and was consequently taken as a basic point of departure to identify relevant services to be included in the benefit transfer.

Table 9: Relevant services for the study areas

Ecosystem Service		Description
Provisioning	Food	Ability to facilitate the production of fish, wild game, fruits and grains.
	Freshwater	Ability to provide storage and retention of water for domestic, industrial and agricultural use.
	Fibre and Fuel	Ability to produce logs, fuelwood, peat, and fodder.
	Biochemical	Extent to which medicines and other biochemical materials from biota can be extracted.
	Genetic material	Ability to provide genetic material for selection for resistance to plant pathogens, ornamental species, etc.
Regulating	Climate regulation	Extent to which the body acts as a source and sink for greenhouse gases; influences local and regional temperature, precipitation and other climate processes.
	Water regulation	Extent to which the system recharges/discharges groundwater.
	Erosion regulation	Extent to which the system facilitates the retention of soils and sediments.
	Natural hazard regulation/flood control/attenuation	Extent to which the system facilitates flood control and storm protection.
	Water purification and waste treatment	Extent to which the system facilitates retention, recover, and removal of excess nutrients and other pollutants.
Supporting	Refugia	Extent to which the system provides habitat, breeding and feeding habitat for plants and animals.
Cultural	Spiritual and inspiration/ aesthetic	Extent to which the system serves as a source of inspiration; spiritual and religious values and aesthetic beauty.
	Recreational	Extent to which the system facilitates recreational activities (e.g. angling, sport, and tourism).
	Educational	Extent to which the system provides opportunities for education and training.

A value for each service as per Table 9 was derived via a benefit transfer exercise based on several studies as presented in Tables 6-8. The focus was exclusively on southern African studies, albeit at different times and different base years. The main reason for selecting only studies from southern Africa (study sites were located in Namibia, South Africa, Botswana, Zambia, Mozambique, and Malawi) was to draw from studies from a comparable socio-economic and biophysical context.

Values were, where necessary, inflated against the consumer price index up to 2019 values and foreign currency values were exchanged against prevailing annual exchange rates. Unit valuations of ecosystem services are limited and show wide variance. Consequently, we have used median value estimates and not mean values as per Rolfe et al. (2015) as representative unit reference values.

Table 10: Median representative values drawn from southern Africa studies (2019 Rand values).

Ecosystem Services		Description	Rand per hectare per year
Provisioning	Food	Ability to facilitate the production of fish, wild game, fruits, and grains.	3071 (Letseng-la-Letsie, Turpie et al., 1999) 24639 (Mfuleni, Turpie et al.,1999) 508 (Knysna, (Napier et al., 2009)) 4717 (Olifants WMA, (DWA, 2010b)) median: 3894
	Freshwater	Ability to provide storage and retention of water for domestic, industrial and agricultural use.	25479 (Cape Town Metro, Turpie et al., 2001) 174 (Olifants river, (Palmer et al., 2002)) 6496 (Upper Olifants WMA, Palmer et al., 2002) 9685 (Middle Olifants WMA, Palmer et al,, 2002) 5441 (Lower Olifants WMA, Palmer et al., 2002) median: 6496
	Fibre and Fuel	Ability to produce logs, fuelwood, peat, and fodder.	33 (Okavango delta, Turpie et al., 2006) 288 (Barotse floodplain, Turpie et al., 1999) 287 (Chobe National Park, Turpie et al., 1999) 1497 (LowerShire, Turpie, et al., 1999) 130 (Zambezi river, Turpie et al., 1999) 1209 (Lake Chilwa, (Schuyt, 2005)) 828; 1321 and 335 (Rufiji floodplain, (Turpie, 2000)) 4858 (Olifants WMA, DWA, 2010) median: 582
	Biochemical	Extent to which medicines and other biochemical materials from biota can be extracted.	1 (no data)
	Genetic material	Ability to provide genetic material for selection for resistance to plant pathogens, ornamental species, etc.	1 (no data)
Regulating	Climate regulation	Extent to which the body acts as a source and sink for greenhouse gases; influences local and regional temperature, precipitation and other climate processes.	184 (Okavango delta, Turpie et al., 2006) 487 (Barotse floodplain, Turpie et al., 1999) 441 (Caprivi, Turpie, et al., 1999) 920 (Lower Shire, Turpie et al., 1999) 273 (Zambezi delta, Tuprie et al., 1999) 156 (Olifants WMA, DWA, 2010) median: 357
	Water regulation	Extent to which the system recharges/discharges groundwater.	184 (Okavango delta, Turpie et al., 2006) 487 (Barotse floodplain, Turpie et al., 1999) 441 (Caprivi, Turpie, et al., 1999) 920 (Lower Shire, Turpie et al., 1999) 273 (Zambezi delta, Turpie et al., 1999) 156 (Olifants WMA, DWA, 2010) median: 357
	Erosion regulation	Extent to which the system facilitates the retention of soils and sediments.	1 (no data)
	Natural hazard regulation/flood control/attenuation	Extent to which the system facilitates flood control and storm protection.	12271 (Nylsvlei, Turpie et al., 1999) 485 (Olifants WMA, DWA, 2010) median: 6378
	Water purification and waste treatment	Extent to which the system facilitates retention, recover, and removal of excess nutrients and other pollutants.	23796 (Cape Town, Turpie et al., 1999) 5 (Okavango, Turpie et al., 2006) 25497 (Turpie et al., 2001)) 487 (Barotse floodplain, Turpie et al., 1999) 441 (Caprivi, Turpie et al., 1999) 920 (Lower Shire, Turpie et al., 1999) 273 (Zambezi delta, Tuprie et al., 1999) 67090 (Zaalklap wetland, (Harris and Crafford, 2014)) 362 (Olifants WMA, DWA, 2010) median: 487
	Refugia	Extent to which the system provides habitat, breeding and feeding habitat for plants and animals.	18924 (Knysna, (Turpie and Clark, 2007)) 164 (Okavango delta, Turpie et al., 2006) median: 9544
Cultural	Spiritual and inspiration/ aesthetic	Extent to which the system serves as a source of inspiration; spiritual and religious values and aesthetic beauty.	2564 (South Africa, Turpie and Clark, 2007) 140 (Barotse floodplain, Turpie et al.,1999) median: 1352
	Recreational (e.g. angling and tourism)	Extent to which the system facilitates recreational activities (e.g. angling, sport and tourism).	8297 (Cape Town metro, Turpie et al., 2001) 12100 (Sandvlei, Van Zyl and Leiman, 2002) 149425 (Knysna, (Turpie and Joubert, 2004))

Ecosystem Services		Description	Rand per hectare per year
Provisioning	Food	Ability to facilitate the production of fish, wild game, fruits, and grains.	3071 (Letseng-la-Letsie, Turpie et al., 1999) 24639 (Mfuleni, Turpie et al.,1999) 508 (Knysna, (Napier et al., 2009)) 4717 (Olifants WMA, (DWA, 2010b)) median: 3894
	Freshwater	Ability to provide storage and retention of water for domestic, industrial and agricultural use.	25479 (Cape Town Metro, Turpie et al., 2001) 174 (Olifants river, (Palmer et al., 2002)) 6496 (Upper Olifants WMA, Palmer et al., 2002) 9685 (Middle Olifants WMA, Palmer et al,, 2002) 5441 (Lower Olifants WMA, Palmer et al., 2002) median: 6496
	Fibre and Fuel	Ability to produce logs, fuelwood, peat, and fodder.	33 (Okavango delta, Turpie et al., 2006) 288 (Barotse floodplain, Turpie et al., 1999) 287 (Chobe National Park, Turpie et al., 1999) 1497 (LowerShire, Turpie, et al., 1999) 130 (Zambezi river, Turpie et al., 1999) 1209 (Lake Chilwa, (Schuyt, 2005)) 828; 1321 and 335 (Rufiji floodplain, (Turpie, 2000)) 4858 (Olifants WMA, DWA, 2010) median: 582
	Biochemical	Extent to which medicines and other biochemical materials from biota can be extracted.	1 (no data)
	Genetic material	Ability to provide genetic material for selection for resistance to plant pathogens, ornamental species, etc.	1 (no data)
Regulating	Climate regulation	Extent to which the body acts as a source and sink for greenhouse gases; influences local and regional temperature, precipitation and other climate processes.	184 (Okavango delta, Turpie et al., 2006) 487 (Barotse floodplain, Turpie et al., 1999) 441 (Caprivi, Turpie, et al., 1999) 920 (Lower Shire, Turpie et al., 1999) 273 (Zambezi delta, Tuprie et al., 1999) 156 (Olifants WMA, DWA, 2010) median: 357
			15 (Linyati, (Seyam et al., 2001)) 2282 (Okavango delta, (Turpie et al., 2006)) 10364 (Nylsvlei, Turpie et al., 1999) 200 (Olifants WMA, DWA, 2010) median: 8297
	Educational	Extent to which the system provide opportunities for education and training.	38 (Okavango delta, Turpie et al., 2006)
Total			**37785**

Table 10 indicates an estimated aggregated value of R37 785 per hectare per year. The results of the estimates show that more than 80 percent of this value is explained by four services namely: water provisioning (17%) for which there were five unit values ranging between R174 and R25 497; flood control (17%) with two unit values (R485 and R12 271); recreational services (22%) for which there were 7 unit values between R200 and R149 000; and refugia (25%) which had two unit values (R164 and R18 924).

Table 11: Ecosystem service value (R) per WMA (own calculations)

	Provisioning (R/yr)					Regulating (R/yr)						Cultural (R/yr)			Total
	Food	Fresh-water	Fibre and Fuel	Bio-chemical	Genetic material	Climate regulation	Water regulation	Erosion regulation	Natural hazard regulation/ flood control/atte-nuation	Water purification and waste treatment	Refugia	Spiritual and inspiration/ aesthetic	Recreation	Education	
Unit price (R/ha)	3 93.8	6 495.4	581.8	1.0	1.0	356.8	356.8	1.0	6 377.8	487.4	9 544.0	1 352.1	8 297.2	38.4	
Unit price (R/m³)	0.00527	0.00880	0.00079	0.000	0.000	0.00048	0.00048	0.00000	0.00864	0.00066	0.01293	0.00183	0.01124	0.00005	
Limpopo	R822 635	R1 372 267	R122 917	R211	R211	R75 375	R75 375	R211	R1347 428	R102 969	R2 016 337	R285 651	R1 752 931	R8 123	R7 982 642
Luvuvhu and Letaba	R1 181 219	R1 970 435	R76 497	R303	R303	R108 231	R108 231	R303	R1 934 768	R147 853	R2 895 253	R410 166	R2 517 029	R11 664	R11 462 255
Crocodile (West) and Marico	R864 821	R1 442 640	R129 221	R2 222	R222	R79 241	R79 241	R222	R1 416 527	R108 249	R2 119 739	R300 300	R1 842 825	R8 539	R8 392 008
Olifants	R2 425 719	R4 046 428	R362 448	R623	R623	R222 261	R222 261	R623	R3 973 184	R303 626	R5 945 608	R842 305	R5 168 899	R23 952	R23 538 559
Inkomati	R5 315 488	R8 866 956	R794 234	R1 365	R1 365	R487 041	R487 041	R1 365	R706 456	R665 337	R1 302 837	R1 845 746	R11 326 630	R52 486	R51 580 147
Usutu to Mhlatuze	R6 285 775	R10 485 527	R939 214	R1 614	R1 614	R575 946	R575 946	R1 614	R1 0295 729	R786 787	R15 406 880	R2 182 668	R13 394 190	R62 067	R60 995 571
Thukela	R4 529 766	R7 556 265	R676 833	R1 163	R1 163	R415 048	R415 048	R1 163	R7 419 489	R566 988	R1 110 277	R1 572 913	R9 652 357	R44 728	R43 955 701
Upper Vaal	R1 576 717	R2 630 178	R235 591	R405	R405	R144 470	R144 470	R405	R2 582 570	R197 357	R3 864 645	R547 498	R3 359 784	R15 569	R15 300 064
Middle Vaal	R574 790	R958 828	R85 884	R148	R148	R52 666	R52 666	R148	R941 472	R71 946	R1 408 851	R199 590	R1 224 804	R5 676	R5 577 615
Lower Vaal	R258 392	R431 033	R38 609	R66	R66	R23 676	R23 676	R66	R423 230	R32 343	R633 337	R89 724	R550 600	R2 551	R2 507 368
Mvoti to Umzimkulu	R6 117 029	R10 204 036	R914 000	R1 571	R1 571	R560 484	R560 484	R1 571	R10 019 334	R765 665	R14 993 273	R2 124 073	R13 034 614	R60 401	R59 358 106
Mzimvubu to Keiskamma	R5 916 644	R9 869 766	R884 058	R1 519	R1 519	R542 123	R542 123	R1 519	R9 691 114	R740 583	R14 502 114	R2 054 491	R12 607 618	R58 422	R57 413 616
Upper Orange	R7 113 683	R11 866 591	R1 062 919	R1 827	R1 827	R651 804	R651 804	R1 827	R1 165 194	R890 416	R1 743 642	R2 470 150	R15 158 358	R70 242	R69 029 384
Lower Orange	R363 858	R606 964	R54 367	R93	R93	R33 339	R33 339	R93	R595 978	R45 544	R891 841	R126 346	R775 335	R3 593	R3 530 784
Fish to Tsitsikamma	R1 281 412	R2 137 570	R91 467	R329	R329	R117 412	R117 412	R329	R2 098 878	R160 394	R3 140 832	R444 957	R2 730 527	R12 653	R12 434 500
Gouritz	R1 713 823	R2 858 889	R256 078	R440	R440	R157 032	R157 032	R440	R2 807 141	R214 518	R4 200 701	R595 107	R3 651 939	R16 923	R16 630 504
Olifants/ Doon	R822 635	R1 372 267	R122 917	R211	R211	R75 375	R75 375	R211	R1 347 428	R102 969	R2 016 337	R285 651	R1 752 931	R8 123	R7 982 642
Breede	R2 024 948	R3 377 888	R302 565	R520	R520	R185 540	R185 540	R520	R3 316 745	R253 462	R4 963 290	R703 141	R4 314 907	R19 995	R19 649 580
Berg	R1 144 306	R1 908 859	R170 981	R294	R294	R104 849	R104 849	R294	R1 874 306	R143 232	R2 804 776	R397 348	R2 438 372	R11 299	R11 104 060
Total	R50 333 659	R83 963 385	R7 520 800	R1 227	R12 927	R411 913	R4 611 913	R12 927	R8 244 370	R6 300 238	R123 371 368	R1 747 723	R107 254 650	R497 007	R488 425 106

Furthermore, one particular study (Anderson et al., 2017) drawing on (Costanza et al., 2014)) presented an aggregated value for ecosystem services of R19 928 per hectare year for South African water bodies. The claimed value could not be verified but compared reasonably with our estimated R37 785 per hectare per year. We consequently decided to take the average between these two estimates of R28 857 per hectare per year for further calculations.

Table 12 presents a summary of the unit reference values of each value attribute multiplied with the volume of the Reserve for each WMA. These figures were then used to derive the BCR ratios while Table 13 represents the benefit-cost ratios (BCR) for different combinations of benefits.

Table 12: Summarised total value estimates for the Reserve per WMA (own calculations)

WMA	**Value of serviced and un-serviced water in Reserve (R/yr)**	**Value of un-serviced water (R/yr)**	**Ecosystem service of water for Reserve (R/yr)**
Limpopo	220 670 400	16 956 108	6 096 468
Luvuvhu and Letaba	202 499 738	27 469 829	8 753 902
Crocodile (West) and Marico	553 265 734	9 053 162	6 409 107
Olifants	1 083 036 024	38 193 742	17 976 763
Inkomati	998 159 037	121 241 157	39 392 560
Usutu to Mhlatuze	2 019 385 843	120 463 031	46 583 265
Thukela	1 870 823 090	75 462 877	33 569 652
Upper Vaal	1 441 878 582	4 677 502	11 684 896
Middle Vaal	342 083 904	6 717 013	4 259 711
Lower Vaal	54 252 633	5 737 183	1 914 916
Mvoti to Umzimkulu	4 535 725 851	47 040 455	45 332 708
Mzimvubu to Keiskamma	2 629 658 930	93 487 375	43 847 671
Upper Orange	1 569 415 931	155 878 226	52 718 812
Lower Orange	27 872 649	9 403 831	2 696 515
Fish to Tsitsikamma	217 773 849	29 851 799	9 496 421
Gouritz	411 228 098	36 649 564	12 700 974
Olifants/Doorn	57 608 986	21 408 484	6 096 468
Breede	216 145 828	50 667 985	15 006 689
Berg	683 505 792	13 304 784	8 480 343
Total	**18 106 057 913**	**911 759 022**	**373 017 839**

Table 13: Output table for selected BCRs (own calculations)

	South Africa	**Inkomati**	**Olifants-Doorn**
MAR (Mm^3)	50021	3610	1130
Reserve (Mm^3)	9545	1008	156
Total local yield (Mm^3)	13230	897	335
Un-serviced water (Mm^3)	8079	605	363
Serviced water (Mm^3)	4575	116	16
Estimated current value of total cost of research associated with specific area	R390 098 625	R6 745 910	R13 801 778
Value of un-serviced water in Reserve(R/yr)	R911 759 022	R121 241 157	R21 408 484
BCR ratio (un-serviced water only)	2.3	18.0	1.6
Value of serviced and un-serviced water in Reserve(R/yr)	R18 106 057 913	R998 159 037	R57 608 986
BCR ratio (water)	46.4	148.0	4.2
ES value of water for reserve (R/yr)	R373 017 839	R39 392 560	R6 096 468
BCR ratio (ES only)	1.0	5.8	0.4
Value of un-serviced water and ES (R/yr)	R1 284 776 861	R160 633 716	R27 504 952
BCR ratio (un-serviced water and ES)	3.3	23.8	2.0
SENSITIVITIES:			
Value of 5-year benefits stream (un-serviced water and ES) (R/yr)	R5 557 932 187	R803 165 973	R137 524 354
BCR for 5-year benefit stream for un-serviced water and ES	14	119	10
Estimated current value of total cost of research associated with specific area (gaps in data filled with average)	R558 294 286	R6 745 910	R13 801 778
BCR ratio for un-serviced water and ES	2	24	2
BCR for 5-year benefit stream for un-serviced water and ES	10	119	10

The most conservative BCR is based on un-serviced water only. Here the results indicated that R364m has been spent on research in South Africa which yielded a benefit of R911m. For every R1 being spent on Reserve related research in South Africa as a whole a benefit of R2.50 was realised. The results were 18:1 and 1.6:1 for Inkomati and Olifants-Doorn respectively.

The ratios changed dramatically when serviced water is added to the benefit side, i.e. 49.7:1 for South Africa as a whole and 148:1 for Inkomati and 4.2:1 for Olifants-Doorn.

Ecosystem services yielded ratios of 1:1 for South Africa as a whole and 5.8:1 for Inkomati and 0.4:1 for Olifants-Doorn respectively.

When adding un-serviced water and ecosystem services the benefit-cost ratio was 3.5:1 for South Africa and 23.8:1 for Inkomati and 2:1 for the Olifants-Doorn (shaded in **Table 13**). These are considered the most realistic set of ratios that should be used to inform decisions, since the addition of serviced water to the benefits side of the equation cannot be justified since water in the Reserve is strictly speaking, not serviced.

The results of the study were used to identify a set of indicators that could be applied in a dashboard with a higher-level view of costs and benefits associated with the Reserve. The economic monetary and non-monetary indicators used in the study were included. The dashboard can also be altered to exclude or include indicators to affect a change in the results, for example, additional ecosystem service indicators can be included. The indicators identified can be used to:

- add and subtract additional project costs
- the values attached to water and ecosystem services can be changed
- the CPI can be changed to PPI (Producer Price Index)
- serviced water can be included in the final estimates

13 LIMITATIONS ANS SENSITIVITIES

The conversion of area-specific unit reference values (R/ha/yr) to volume-based unit reference values (R/m^3/yr) in Table 11 was achieved by multiplying the surface area of the water body (not the surface area of the WMA) with the relevant area-specific unit reference values (R/ha/yr), then divided by the MAR for the specific WMA, and then multiplying with the Instream Flow Requirement of the specific WMA. The accuracy of this conversion is debatable.

The values as per Table 11 was aggregated for each WMA because no scientific evidence exists to base a consistent selection of WMA-specific ecosystem services to be used for the calculation of BCR ratios. Therefore no consistent argument can be put forward to extract representative ecosystem services for specific WMAs. Consequently it was assumed that the entire spectrum of ecosystem services are more or less present in all WMAs and the aggregate value was used to calculate the BCR for ecosystem services for any particular WMA. Furthermore, no consistent argument can be put forward to argue differences in the unit-values of specific ecosystems services across WMAs. For example it cannot be argued that water quality regulation is considered more valuable per cubic meter of water in the Berg WMA as compared to the Limpopo WMA.

It should be noted that only two value attributes (water and ecosystem services) were included in the study. By adding additional value attributes not covered under ecosystem services as per Table 10 (such as the human health impacts), will increase the benefit-side of the ratio and will therefore not change the findings as the cost side will remain unaffected.

It should be noted that the benefit side of the BCR represents annual values thereby representing only one year's worth of benefits. In reality these benefits are repeatedly realised each year. Assuming present value of a five-year benefit stream of R5.5bn (see **Table 13**) a BCR of 14:1 is realised for South Africa with 119:1 and 10:1 for Inkomati and Olifants/Doorn respectively.

Furthermore, Table 3 presented the research cost associated with the Reserve. However, the data represented 60% of all studies identified. If the remaining data gaps were filled with the average cost of a research project on this topic of R1.23m the total cost of research increases to R558m (see **Table 13**). Associated BCR for South Africa for unserviced water and ecosystem services will then be 2:1 for South Africa, 24:1 for Inkomati and 2:1 for Olifants/Doorn. When allowing a 5-year benefit stream the ratios increases to 10:1 for South Africa, 119:1 for Inkomati and 10:1 for Olifants/Doorn.

14 CONCLUSIONS

The Reserve concept is entrenched into water law in South Africa and there was a need to determine whether the costs allocated to the Reserve over the past 20 years were positively correlated with the benefits derived from the Reserve in terms of ecosystem services provided to society. In the current study, a methodology framework was developed that could be applied in future cost-benefit studies regarding the Reserve. There was a direct economic impact and outcome as the study showed that the Reserve, despite a number of complexities, can be linked to economic costs and economic benefits. The two study areas used as case studies provided credible evidence of this and trends and Benefit-Cost Ratios could be derived.

With reference to the two case studies used, the Inkomati and Olifants-Doorn WMAs, the cost estimates derived should be regarded as conservative due to cross-pollination effects from other studies. Many research projects were done on a national scale which implies that such results could benefit the Inkomati and Olifants-Doorn WMAs while being excluded on the cost side of the ratio for these two areas. Likewise, the results from many area-specific studies could be relevant or could be extrapolated to the Inkomati and/or Olifants-Doorn WMAs subject to contextual similarities. The focus on the Inkomati and Olifants-Doorn WMAs and resulting arbitrary distinction and identification of research costs specifically for the Inkomati and the Olifants-Doorn, is contested. The same argument goes for the benefit side of these two WMAs.

From the methodology framework, it was possible to identify a set of indicators that could be applied in a dashboard with a higher-level view of costs and benefits associated with the Reserve. The economic monetary and non-monetary indicators used in the study were included. The dashboard can also be altered to exclude or include indicators to affect a change in the results as it pertains to different studies.

The current study had a high level and broad overview which provides Departments such as DWS with the information necessary to validate past expenditure on the Reserve and to ensure that budget is made available for future investments. If higher confidence is to be attained in whether the Reserve is ensuring that ecosystem services are provided, DWS should ensure that the appropriate monitoring is occurring to provide the necessary data. This again, can be used as a justification to ensure the provision of sufficient budget for future investments. Monitoring will provide the data to identify appropriate surrogates/proxies to use when determining the benefits of Reserve implementation. Improved monitoring of water resources will aid in the identification of priority areas for protection such as the Strategic Water Source Areas (SWSA) where the transboundary SWSA-surface water cover only 10% of the country's land surface area but produce 50% of its surface runoff and most of its groundwater recharge, which sustains most of the perennial rivers (Le Maitre et al., 2018). Monitoring will further illustrate the importance and benefits of completing the full cycle of the Reserve process.

15 RECOMMENDATIONS FOR FURTHER STUDY

- The Basic Human Needs (BHN) Reserve was initially to be included in the study, however, when collating the costs data very few of these were related to the BHN Reserve and therefore the focus shifted to the Ecological Reserve. A more inclusive project would allow for a more comprehensive data capture and allocation exercise.
- Most of the budget for the Reserve related projects came from DWS and therefore Department was listed as the custrodian of the data. However, historical project costs (as early as 1990) were not available from DWS. It is recommended that CD: RDM develop a database management system where all Reserve data generated in the last 20 years can be collated and stored for future studies and for accurate record keeping.
- An indicator dashboard tool was not developed in this project due to time/budget constraints but comprehensive Excel spreadsheets were compiled with input and output tables. The spreadsheets developed provides a good compilation of the indicators and methods to follow to produce a tool for ROI calculations for future applications where more value attributes could be included.
- The 2 study areas included were used as a means to illustrate the benefits versus the costs (ROI) of the Ecological Reserve in terms of a broad overview in comparison to the country as a whole. As the study was a scoping exercise it was based on desktop analysis of existing water accounts per WMA for SA provided by Statistics SA. The study did not determine if the Ecological Reserve was being implemented on the ground in the two study areas or whether ecosystem services (whether to benefit ecosystems or society), were realised. This would require a much higher resolution study which would also increase the level of confidence in the ROI results. It is recommended that such a study becomes a dedicated funded project in order to determine the costs and benefits (ecosystem services) of the Reserve in terms of whether the ecosystem services are apparent after Reserve implementation. In other words one would need to compare value attributes to the particular Reserve volumes.
- It is recommended that Reserve determinations are implemented by DWS as a matter of urgency in order to generate the data required, based on observations, to determine whether environmental water requirements are met or not.

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