Reviewed Methodology Report for SDG 6.6

Report Prepared for

Water Research Commission

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Reviewed Methodology Report SDG 6.6

Water Research Commission

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List of Abbreviations

Abbreviation	Definition
CBD	Convention on Biological Diversity
CSIR	Council for Scientific and Industrial Research
DWS	Department of Water and Sanitation
EI	Ecological Importance
EFZ	Estuarine Functional Zone
ES	Ecological Sensitivity
IHI	Index of Habitat Integrity
LDN	Land Degradation Neutrality
MDG	Millennium Development Goal
NAP	National Action Plan
NBA	National Biodiversity Assessment
NBSAP	National Biodiversity Strategy and Action Plan
NGLMP	National Groundwater Level Monitoring Programme
NPAES	National Protected Area Expansion Strategy
NWM5	National Wetland Map Version 5
NWMP	National Wetland Monitoring Programme
NWRP	National Water Resource Strategy
NW&SMP	National Water and Sanitation Master Plan
PES	Present Ecological State
SA	South Africa
SANBI	South African National Biodiversity Institute
SDG	Sustainable Development Goal
SRK	SRK Consulting South Africa (Pty) Ltd
UNEP	United Nations Environment Programme
UKZN	University of KwaZulu Natal
UN	United Nations
WCWDM	water conservation and water demand management
WRC	Water Research Commission
WSA	Water Service Authority

1 Introduction and Approach

South Africa is one of 193 countries who is a signatory to the Sustainable Development Goal (SDG) 2030 Agenda, which included the commitment to achieve SDG 6: Clean Water and Sanitation. The Department of Water and Sanitation (DWS) is mandated to be responsible for the management of SDG 6 policy, plans and implementation programs. In adopting the goal, the DWS adopted existing indicators (carried over from the United Nations [UN] Millennium Development Goals [MDGs]), domesticated new indicators, and defined additional indicators (where necessary).

South Africa has committed to the achievement of the 17 SDGs by 2030. SDG 6 aims to ensure clean water and sanitation for all by 2030. Some of the SDG 6 targets and indicators are well established (those carried over from the MDGs in 2000), while others are less established (those introduced with the adoption of the SDGs or in the years following adoption). At a global level, specialists in various international agencies developed methodologies for all the SDG targets and their indicators. In May 2017 the UN released the first round of the Step-by-step Methodology Reports for each of the indicators. Revisions of these methods have subsequently been published through updated methodology reports and captured in the 2018 Synthesis Reports for each indicator. At a national level, countries were encouraged to domesticate these methods and to set targets that are relevant to their context and resources, while maintaining consistency with the targets set out in the SDGs.

While South Africa has developed methodologies to domesticate its indicators, some of the indicators are still not being measured in a meaningful way that shows and drives progress against the targets. For some of these indicators, an assessment, and potentially, a revision of these methodologies is required. For others, new methodologies are required to be developed. In addition, several new indicators are required, and a solid founding methodology is required for the new indicators. Research by a multidisciplinary team with a deep understanding of water resources management in the SA context is required to achieve these research outputs.

1.1 SDG 6 Adoption in South Africa

SDG 6 has been divided into 8 targets, which are then divided into indicators. The intent of setting the targets and defining the indicators is to monitor progress towards achieving SDG 6. The DWS, works closely with several other branches of government, as well as other organisations, to measure and report on the indicators. The objective of monitoring and reporting on the indicators is to effect real change in the water and sanitation landscape in South Africa, by informing policy formulation and aiding decision-making.

South Africa's monitoring of, and performance against, the SDG 6 indicators has shown slow uptake of policies and actions developed for water and sanitation. South Africa published a Community Survey in 2016 (StatsSA, 2016), an SDG Baseline Report in 2017 (StatsSA, 2017), an SDG Country Report in 2019 (StatsSA, 2019), and a General Household Survey in 2019 (StatsSA, 2019). In addition, South Africa has established a Goal Tracker website (StatsSA, 2021). These documents show that several indicators are not tracked, that data continuity is poor for some indicators, and that there is a lack of consistency in tracking some indicators.

The Water Research Commission (WRC) has identified complex indicators within SDG 6, resulting in the appointment of an SDG 6 working group, with SRK Consulting South Africa’s (Pty) Ltd (SRK’s) acting as a professional service provider, to evaluate targets, indicators, and methodologies for SDG 6.6, 6.3 and 6.b; and to propose improvements where shortfalls are identified. These gaps / shortfalls will inform the development and definition of new additional indicators, where necessary; using existing data (where available) and investigating new data sources (where data is not available).

2 Scope of Work

Research Task 1: Peer review and assessment of the SDG 6.6 methodology, and development of additional indicators (Task Leader: Erin Haricombe. Team: Giulia Barr, Bjanka Korb, Lindsay Shand, Simon Lorentz, Kershani Chetty and UKZN Student:

1. Review the existing methodology document for SDG 6.6 to determine the adequacy of the current SDG 6.6. indicators for influencing national decision-making and showing progress against SDG 6.6 to ensure restoration and protection of water related ecosystems.
2. An assessment will be carried out to determine whether the SDG 6.6 indicators pertaining to water quality of the water-related ecosystems adequately represent changes in the extent of water-related ecosystems over time in South Africa (Section 5). The content and frequency of reporting (i.e. in the next SDG Voluntary National Review) is to be considered based on the global-level reporting standard to show the sustainability status for water quality and water-related ecosystems in South Africa.
3. The statistical correctness and scientific validity of the methodology for SDG 6.6 will be evaluated by examining available data in relation to the methodology, and analysing the status quo reflected by the data.
4. Recommendations for amendments and improvements will be made, and where appropriate, alternative methodologies will be proposed.
5. The domesticated and proposed additional indicators for SDG 6.6 will be reviewed for the period from 2016 to 2020, and recommendations for meaningful (relevant, pragmatic, indicative of progress) country-level targets and indicators will be made. These indicators will be developed based on availability of data. Also, cognisance will be given to varying local conditions, that can be aggregated into a single country-level indicator without losing impact or meaning.
6. A methodology for at least one of the additional indicators identified for SDG 6.6 will be developed. This methodology will be tested using available data.
7. Data analysis and synthesis will be conducted in collaboration with DWS and StatsSA, taking cognisance of possible linkages with other SDGs relating to water-related ecosystems (e.g. SDG 14) to avoid any duplication of reporting by RSA. Regular virtual meetings will take place with key DWS representatives to facilitate this collaboration.
8. DWS will be assisted with setting management targets for SDG 6.6 and with selecting and developing methods for additional country level indicators where gaps were identified.

3 SDG 6.6 Methodology Background

SDG target 6.6 is a global indicator, which monitors the extent and quality of the water-related ecosystems using global data tools and products. According to the WRC, “the existing methodology for Target 6.6 requires review” where necessary and determination of targets. There is a need to consider developing a methodology for one of the additional indicators identified for SDG 6.6. Where data exist, testing will be crucial.

Due to the data gaps associated with national datasets, long-term monitoring of these ecosystems becomes a difficult task, therefore, the use of global data products has made it possible to bridge these gaps associated with the acquisition of data. Furthermore, this is also beneficial on a national level as countries can incorporate both globally available data and national data to monitor water-related ecosystems.

Part of the review is to determine the value of the current SDG 6.6. indicators for influencing national decision making i.e. will the method proposed be both useful for global reporting and at the same time have a real influence nationally? Where appropriate, the statistical correctness and scientific validity of the methods are to be evaluated. Recommendations for amendments and improvements will be made, and where appropriate, alternative methodologies may be recommended.

In addition to the need for peer review and finalization of the methodology report for SDG 6.6, the DWS need to:

1. Set management targets for SDG 6.6; and
2. Select and develop methods for additional, country level indicators for SDG 6.6.

3.1 SDG 6.6 Methodology and Development of Additional Indicators

According to the UN Water Integrated Monitoring Guide for SDG 6 on Water and Sanitation Targets and Global Indicators, "*Target 6.6 seeks to halt the degradation and destruction of water related ecosystems, and to assist the recovery of those already degraded. The target includes water-related ecosystems such as vegetated wetlands, rivers, lakes, reservoirs and groundwater as well as those occurring in mountains and forests, which play a special role in storing freshwater and maintaining water*".

Table 3-1 summarises the South African SDG 6.6 Target and Indicators and Sub-indicators.

SDG Target 6.6

"By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes" [1]

Table 3-1: SDG 6.6 South African Target, Indicator and Sub-indicators

Target 6.6	Indicator			Sub-Indicators
Ecosystems – protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes	6.6.1	Change in the extent of water-related ecosystems over time	Global	Percentage change in the surface area of wetlands (vegetated and unvegetated/arid), estuaries, reservoirs, and lakes over time from a predefined baseline, expressed as a % of the total land area
	6.6.1D(1)	Change in the spatial extent of water-related ecosystems over time, including wetlands, reservoirs, lakes, and estuaries as a percentage of total land area	Domesticated	Change in Spatial Extent of Rivers
				Change in Spatial Extent of Wetlands, including lakes, vegetated wetlands, and ephemeral wetlands
				Change in Spatial Extent of Estuaries
				Change in the Extent of Estuarine Functional Zones (EFZ)

[1] 2030 Agenda for Sustainable Development

Target 6.6	Indicator			Sub-Indicators
				Change in Spatial Extent of Artificial Systems (Reservoirs)
	6.6.1D(2)	Number of lakes and dams affected by high trophic and turbidity states	Domesticated	Proportion of lakes and dams affected by High Trophic States
				Proportion of lakes and dams affected by High Turbidity States
	6.6.1D(3)	Change in the national discharge of rivers and estuaries over time	Domesticated	Change in the Water Quantity in Rivers
				Change in the Water Quantity in Estuaries
	6.6.1D(4)	Change in groundwater levels over time	Domesticated	Change in Groundwater Levels over time
	6.6.1A(5)	Change in the ecological condition of rivers, estuaries, lakes, and wetlands	Additional	Change in the Ecological Condition of Rivers
				Change in the Ecological Condition of Estuaries
				Change in the Ecological Condition of wetlands

Based on the UN SDG Goal Tracker for South Africa[2] data for Indicator 6.6.1 (2018) and 6.6.1.3 (2010 and 2017) is available at present.

4 SDG 6.6 UN Methodology Review

SDG target 6.6 aims to ensure that all water-related ecosystems are protected and restored to ensure sustainable water availability in the long-term. It is only comprised of one indicator, which monitors quantity and quality changes in the extent of water-related ecosystems over time. These water-related ecosystems include rivers, wetlands, lakes, estuaries, reservoirs, and mangroves. Data acquired for monitoring these ecosystems are based on and related to their spatial extent and water quality and quantity.

The UN methodology documents reviewed in relation to SDG 6.6 include the following documents:

- Step-by-step Monitoring Methodology for SDG Indicator 6.6.1, UN, Version 20, January 2017;
- Monitoring Methodology for SDG Indicator 6.6.1, UNEP, March 2018; and
- Sustainable Development Goal 6 2020 Data Drive: SDG Target 6.6 – Indicator 6.6.1 Change in Extent of Water-Related Ecosystems Over Time, UN, June 2020.

The global methodologies for SDG 6.6.1 have been reviewed as these forms the basis for the SDG reporting against which South Africa is required to report and is assessed globally. A brief overview of the UN monitoring methodologies used for each indicator is summarized below.

Figure 4-1 presents the current UN SDG 6.6 report on spatial extent of water-related ecosystems from earth observation data in South Africa, progress over time. Changes include both increases and decreases in the area covered by surface water, corresponding to flooding and droughts and often associated with climate change. Spatial extent of lakes, rivers, estuaries, and artificial water bodies.

[2] https://south-africa.goaltracker.org/platform/south-africa/data

- Baseline (2001-2005): 3,180 km^2
- Latest five-year period (2011-2015): 3,415 km^2
- Change in extent compared to baseline: gain of 26 %

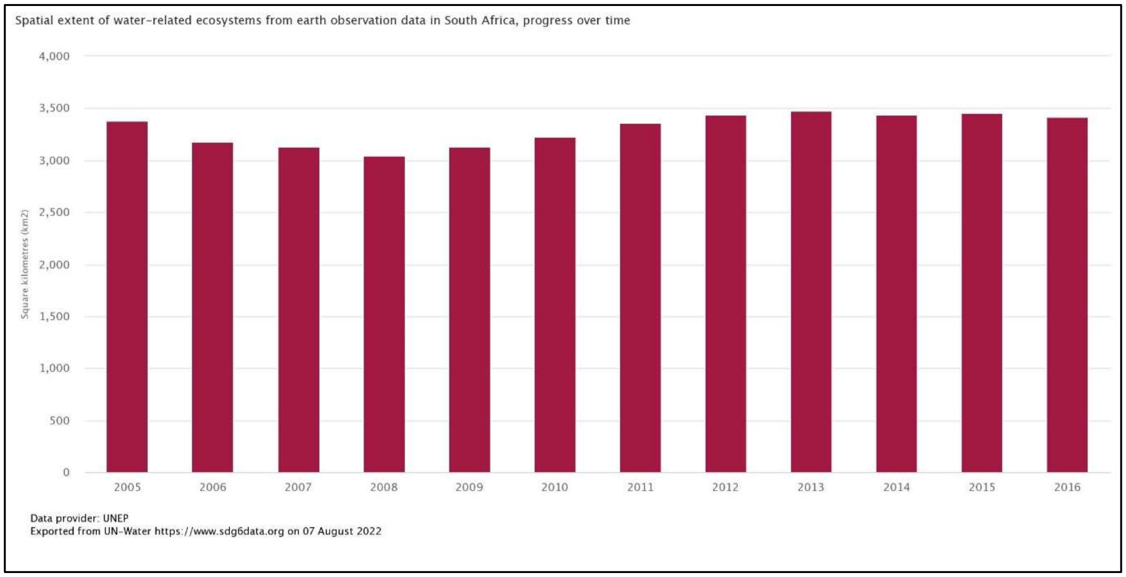


Figure 4-1 Spatial extent of water-related ecosystems from earth observation data in South Africa, progress over time (UNEP, August 2022)[3]

4.1 UNEP SDG 6.6.1. Measuring Change in the Extent of Water-related Ecosystems Over Time, SDG Monitoring Methodology Indicator 6.6.1

The UNEP methodology applies a progressive monitoring approach whereby countries can utilize both globally- and nationally- derived data to report on Indicator 6.6.1. According to the UNEP Monitoring Methodology for Indicator 6.6.1 "Countries should aim to report on all aspects of Indicator 6.6.1 should they have the data and capacity to do so. While it is beneficial to capture data on all aspects of the Indicator, some countries may be able to achieve this, and others may not have all data available."

As a result, a progressive monitoring approach uses 2 Levels and 5 Sub-Indicators. Level 1 data utilizes data which is already globally available as a "foundation" which provides scope to be strengthened by countries as they develop capacity and ability to report on Level 2 data.

Level 1 includes 2 Sub-Indicators based on globally available data from earth observations which is expected to be validated by countries against their own methodologies and datasets:

- Sub-Indicator 1 (also referred to as: 6.6.1D(1)) – spatial extent of water-related ecosystems.
- Sub-Indicator 2 (also referred to as: 6.6.1D(2)) – water quality of lakes and artificial water bodies.

Level 2 data is additional data informing progress on target 6.6 collected by countries. Countries are encouraged to consolidate this data to better understand the state of their freshwater ecosystems and prioritize actions, where necessary. Level 2 data includes the following 3 Sub-Indicators:

- Sub-Indicator 3 (also referred to as: 6.6.1D(3)) – quantity of water (discharge) in rivers and estuaries.
- Sub-Indicator 4 – water quality imported from SDG Indicator 6.3.2.
- Sub-Indicator 5 (also referred to as: 6.6.1D(4))– quantity of groundwater within aquifers.

[3] https://www.sdg6data.org/country-or-area/South%20Africa#anchor_6.6.1

The National Sub-indicator 6.6.1A(1) State of Ecosystem Health does not form part of the aggregated 6.6.1 index but is kept separate for National level reporting and to assist with restoration activities.

4.2 Sub-Indicator 1 (6.6.1D(1)): Spatial Extent of Water-Related Ecosystems

4.2.1 Measuring Change in Surface Water Area of Lakes and Rivers

To calculate percentage change in river area using a 2000-2019 dataset, a baseline period is first defined against which to measure change. This methodology uses 2000-2004 as the 5-year baseline period. Averaging all earth observations annually and over a five-year period the baseline is then compared a subsequent 5-year target period. From the baseline and target period, the percentage change of spatial extent is calculated using the following formula:

Percentage Change in Spatial Extent=(β-γ)/β×100

Where β = the average national spatial extent from 2000-2004

Where γ = the average national spatial extent of any other subsequent 5-year period

The nature of this formula yields percentage change values as either positive or negative, which helps to indicate how spatial area is changing. On the UN SDG 6.6.1 data portal, statistics are displayed using both positive and negative symbols. For the purpose of interpretation, if the value is positive, the statistics represent an area gain in surface area; while if the value is negative, it represents a loss in surface area.

“The use of ‘positive’ and ‘negative’ terminology does not imply a positive or negative state of the water related ecosystem being monitored. Gain or loss in surface water area can be beneficial or detrimental. The resulting impact of a gain or loss in surface area must be locally contextualized. The percentage change statistic produced represents how the total area of rivers within a given boundary (e.g. nationally) is changing over time. Percentage change statistics aggregated at a national scale should be interpreted with some degree of caution because these statistics reflect the areas of all the lakes and rivers within a country boundary. For this reason, sub-national statistics are also made available including at basin and sub-basin scales. The statistics produced at these smaller scales reflects area changes to a smaller number of lakes and rivers within a basin or sub-section of a basin, allowing for localized, water body specific, decision making to occur.”

4.2.2 Measuring the Change in Reservoir Surface Area

Data on reservoir area dynamics are available for a 36-year period, from 1984-2019. To calculate percentage change in reservoir area using a 2000-2019 dataset, a baseline period is first defined against which to measure change.

“This methodology uses 2000-2004 as the 5-year baseline period. Averaging all earth observations annually and over a five-year period the baseline is then compared a subsequent 5-year target period 2015-2019. From the baseline and target period, percentage change of spatial extent is calculated using the following formula”:

Percentage Change in Spatial Extent=(β-γ)/β×100

Where β = the average national spatial extent from 2000-2004

Where γ = the average national spatial extent of any other subsequent 5-year period

4.2.3 Measuring Wetland Area

This methodology uses a 2017 baseline (based on input imagery data from 2016 to 2018 to even out potential annual biases). Wetland area dataset updates will allow for the calculation of the change of wetland area from the baseline reference period. Percentage change of spatial extent is calculated using the following formula:

Percentage change in wetland extent (β-γ)/β×100

Where β = the spatial wetland extent for the baseline reference period.

Where γ = the spatial extent for the reporting period.

4.2.4 Measuring Change in Mangrove Area

Data on mangroves area is available (for 1996, 2007, 2008, 2009, 2010, 2015 and 2016), with new annual data for the 2017 and 2018 period produced during 2020. For the purpose of producing national statistics, the year 2000 has been used as a proxy based on the 1996 annual dataset to align this baseline with the surface water dataset. National mangrove extent for the year 2000 will be used as the baseline reference period, against which annual mangrove extent is compared. It should be noted that the data provided by the UN over estimated the extent of mangroves in South Africa.

Percentage change of spatial extent is calculated using the following formula:

Percentage Change in Spatial Extent=(β-γ)/β×100

Where β = the national spatial extent from year 2000

Where γ = the national spatial extent of any other subsequent annual period

4.3 Sub-Indicator 1 and 2 (6.6.1D(2)): Quality of Water in Ecosystems

4.3.1 Measuring Lake Turbidity and Trophic State

A baseline reference period has been produced utilizing monthly averages across 5 years of observations (2006-2010). From these five years of data, 12 monthly averages (one for each month of the year) for both trophic state and turbidity, were derived. A further set of observations are then used to calculate change against the baseline data. These monthly data sets comprise years 2017,2018 and 2019. The 12 monthly averages (monthly deviation of the multiannual baseline) for these three years have been calculated using the following equation:

((Month_average - Month_baseline) / Month_baseline) x 100

For each pixel, and for each month, the number of valid observations is counted and the number of months where there are monthly deviations, falling in one of the following range of values: 0-25%, 25-50% (medium), 50-75%, 75-100% (high). An annual deviation synthesis is also produced.

4.4 Sub-Indicator 2 (6.6.1D(3)): Quantity of Water in Ecosystems

4.4.1 Measuring or Modelling River Flow (discharge)

River and estuary discharge, or the volume of water moving downstream per unit of time, is an essential metric for understanding water quantity within an ecosystem and availability for human use. Key considerations for monitoring discharge and provides criteria for discharge data generated to support Indicator 6.6.1 include the following:

- Common in-situ monitoring methods: There are a variety of methods for monitoring discharge in situ and selection should be based on the size and type of the waterbody, terrain and velocity of water flow, the desired accuracy of measurement, as well as finances available. The most common and accessible approaches are gauging stations and current meters. Propeller, pygmy or electromagnetic current meters are often used to measure velocity and can be used in conjunction with cross-sectional area methods to obtain flow rates.

- Location of Monitoring: The chosen monitoring method may dictate where along a river or estuary the discharge is captured. The minimum monitoring effort is to locate one flow measuring site within proximity to each basin's exit (into another basin). Where there is a local impact on discharge due to human influence, then it is recommended to monitor flow upstream and downstream of these areas so that the overall situation can be managed.
- Frequency of Monitoring: The quantity of water in a river or estuary can change rapidly in response to rainfall and weather patterns. Data on discharge should ideally be collected at a given location once a month at minimum (ideally at a daily frequency) and this data can then be used to determine annual and long-term trends. The quantity of water in estuaries may be significantly influenced by tidal inflows, thus this indicator is limited to the freshwater inflows to the estuary from the upstream river.
- Modelling Discharge: In addition to in situ monitoring which always is impacted by all forms of flow moderation, storage or abstractions upstream, discharge may also be modelled from one of the many available models which use climatic and land-use data, amongst other data, to estimate both natural and present-day flows. It is recommended that modelled discharge data is complimented by measured in situ data wherever possible to ensure accuracy.

4.5 Additional National Indicator 6.6.1D(4)

4.5.1 Measuring Quantity of Groundwater within Aquifers

The changes to the quantity of groundwater within aquifers is important information for many countries that rely heavily on groundwater availability. For the purposes of Indicator 6.6.1 monitoring the changes to groundwater levels gives a good indication of changes to the water stored in an aquifer. Furthermore, only significant ground water aquifers, that can be seen as individual freshwater ecosystems will be included in the reporting.

Groundwater level data statistics generate a proxy to the quantity of groundwater in an aquifer over time. To examine this change over time, percentage change in groundwater level will be generated and validated between the custodian agency(s) and the country. Calculating percentage change at a national level requires the establishment of a common reference period for all basins, which can either be based on historical groundwater level data (preferred) or modelled data if available. In cases where these are unavailable, a more recent period can be adopted to represent the 'baseline' or reference period.

5 SDG 6.6 South African Methodology Review

The methodology documents reviewed for South Africa's SDG 6.6 reporting include the following documents:

- Methodology Report: SDG Target 6.6 - Water Related Ecosystems. Edition 01 (Version 08). DWS, 2021; and
- Indicator 6.6.1D(1) Spatial Extent of Water-Related Ecosystems Baseline Data - definition and method of computation, DWS, March 2022.
- Methodology for Measuring Lake Turbidity and Trophic State, DWS, July 2022.

The global methodologies for SDG 6.6.1 have been reviewed and are applicable and relevant to the South African water context. The data utilized for the formulation of the global data sets is required to be reviewed at a local level to determine the validity of the global data sets presented by the UNEP.

The existing domesticated methodologies for SDG 6.6 have also been reviewed and assessed to determine the adequacy of the current SDG 6.6. indicators to influence national decision-making and show progress against SDG 6.6. A brief overview of the methodologies used for each indicator is summarized with a more critical review of the methods, included below.

5.1 SDG6.6 General Methodology Review Feedback

The methodologies are numbered according to the South African reporting nomenclature system, some discrepancies seem to be present when comparing the South African numbering system to the UNEP numbering. Where possible alignment to the UN numbering system should be used to aid cross referencing and verification of data sets.

The methodologies have all been based on the UN SDG 6.6 indicator methodologies, which provides a good baseline off which to work. The domesticated and additional methodologies are recognised to have been developed by different teams with integral knowledge of the subject matter. Despite the variety of authors, it is recommended that the different methodologies be presented in a standardised format, for ease of reference and to ensure that the key content is communicated for future reporting requirements. The primary components identified and recommended to be included in all methodologies include the following:

- Title: Indicator
- Institutional Information
- Concepts and Definitions
  - Definitions
  - Rational
  - Concepts
- Methodology
  - Computation Method
- Data Sources
- Data Availability
- Calendar
- Management Targets
- Data Providers/Compilers
- References
- Related Indicators
- Approval

The methodologies developed should be compiled to ensure that they meet sustainable reporting requirements. Key components to take into consideration in relation to sustainable reporting requirements include:

- Long term consistency, using representative and sustainable data collection practices; and
- Consistency of data sets required for comparison during all consecutive UN reporting years.

5.1.1 Methodology Report SDG Target 6.6 Observations

Acronyms

A suite of acronyms is included in the report on page vi, however many acronyms that appear in the text are not included in the acronym list. The omitted acronyms identified are summarised in Table 5-1.

Table 5-1 Omitted Acronym List

Acronym		Comment
CMAs	Catchment Management Agencies	
DRDLR	Department of Rural Development and Land Reform	DALRRD included in the list, however, differs to the acronym used in the report
FEPA	Freshwater Ecosystem Priority Areas	

Acronym		Comment
GFCS	Global Framework on Climate Services	
GSWE	Global Surface Water Explorer	
GSW	Global Surface Water	
GWLS	Groundwater Level Status	
INDC	Intended nationally determined contribution	
IUCN	International Union for Conservation of Nature	
IWRM	Integrated Water Resource Management	
MAMSL	Meters Above Mean Sea Level	
NBF	National Biodiversity Framework	
NBSAP	National Biodiversity Strategy and Action Plan	
NCA	National Capital Accounts	
NCCAS	National Climate Change Adaptation Strategy	
NDC	Nationally Determined Contributions	
NEMBA	Biodiversity Act (NEMBA, Act 10 of 2004)	
NPAES	National Protected Areas Expansion Strategy	
NRM	Natural Resource Management	
NSoW	National State of Water Report	
NWRS	South African National Water Resource Strategy	
NW&SMP	South African National Water and Sanitation Master Plan	
RDMs	Resource Directed Measures	
REC	Recommended Ecological Category	
REMP	The River Ecostatus Monitoring Programme	RHP in methodology report, does not exist anymore and should be The River Ecostatus Monitoring Programme
RSA	Republic of South Africa	
SAEON	South African Environmental Observation Network	
SAWS	South African Weather Service	
SEEA	System of Environment & Economic Accounting	
SEMA's	Specific Environmental Management Acts	
LDN	Land Degradation Neutrality	
UNCCD	United Nations Convention to Combat Desertification	
UNFCCC	UN Framework Convention on Climate Change	
USGS	United States Geological Survey	
WRC	Water Research Commission	

Typographical Errors

Various typographical errors have been identified in the text and will be compiled in a track change version of the document.

The cross referencing of tables within the text needs to be updated across much of the report.

5.2 Indicator SDG 6.6.1D(1a): Change in Spatial Extent of Rivers (In Development) Methodology Review

The SDG sub-indicator 6.6.1D(1a) is intended to monitor changes in the geographical extent of large rivers over time. This indicator is currently under development. The coverage of such water bodies does not solely comprise the river itself but also includes its surrounding riparian zone. Therefore, monitoring rivers is necessary to be able to identify changes in flow, which may influence water habitats. Currently, there are several gauge networks in South Africa that allow for changes in river flow to be monitored, however, the acquisition of spatial data is crucial to be able to identify the consequences of such changes in flow.

Appendix A of the Methodology Report Target 6.6: Water Related Ecosystems presents the SDG 6.6.1D(1a) indicator methodology, August 2021, was noted to still be under development. Table 5-2 summarises the methodology developed to date.

Table 5-2: SDG 6.6.1D(1a) Indicator Methodology

Indicator		Aim	Methodology
6.6.1	Change in the extent of water-related ecosystems over time: - use the image differencing to identifying spatial changes in surface overtime		
6.6.1.1 (UN - 6.6.1.a)	Change in the spatial extent of water-related ecosystems over time, including wetlands, reservoirs, lakes and estuaries as a percentage of total land area	**Change in Spatial Extent of Rivers (6.6.1D (1a))**	
		To use the image differencing to identifying spatial changes in surface overtime	Developing a continuous spatial boundary for selected main rivers across the country. Next step, investigate the extent of mapped surface water for these rivers per the following: - Identification and selection of the imagery data - Determine the period i.e., same season/period - Selection and deployment of the change detection toolset - Processing of the images - Assessment of processed digital results

Currently the spatial extent of rivers is only mapped up until a 1:50000 km scale, hence, resulting in the provision of partial data records for large river bodies. Therefore, the development of a continuous spatial boundary for large river channels in South Africa is currently in progress. The spatial extent of these water bodies would then be monitored to identify any changes over time. This will be undertaken using image differencing, the same period or season, image processing and finally, an assessment of the processed results. The inclusion of data pertaining to the riparian zones would also be beneficial in providing indications of change. Furthermore, during data analysis and monitoring changes in spatial extent of rivers over time, it is important to be able to distinguish between the different causes of change.

It should be noted that the global methodology makes provision for measuring large rivers, however South African rivers are too narrow to be identified using the current satellite imagery and as such can't be measured. The only parameter that can currently be measured is length, which is unlikely to change. This present a challenge in terms of reporting the spatial extent of rivers.

5.2.1 Indicator SDG 6.6.1D(1a) Methodology Observations

The SDG 6.6 Methodology Report notes the following in relation to the development of SDG 6.6.1 (1a) "the intention of the 6.6.1 method was only to use river extent in special circumstances e.g., large, wide rivers that are not gauged e.g., the Ganges, Amazon etc., South Africa could potentially benefit from further exploration of this indicator as a means of tracking how much inundation there is at a given time and thus how much inundated habitat there is. Although South Arica does have gauges that provide data on flow changes, spatial data provides an indication of what this means in terms of the area of permanent water habitat that is either gained or lost, which impacts the health of freshwater species."

5.2.2 UNEP SDG Target 6.6 (June 2020)

The South African Response to the UNEP SDG Target 6.6 (June 2020) states that, in the context of the global dataset representing less than 10% of South Africa's spatial extent of rivers, "Moving forward South Africa will work towards preparing a baseline river area dataset for priority large rivers, against which the global change datasets could be applied."

According to Stuart Crane of the UNEP (personal coms. 22 November 2022), the UN is utilizing global, consistent, satellite imagery for the calculations of the extent of rivers. The UN is aware of the challenges the current SDG 6.6.1 spatial extent of rivers poses to many countries. As a result, the UN is considering modifying the methodology to utilize rainfall and runoff orientated data to measure the flow in rivers rather than the spatial extent.

5.3 Indicator SDG 6.6.1D(1b) and SDG 6.6.1A(1c): Change in Spatial Extent of Wetlands, including Lakes, Vegetated Wetlands and Ephemeral Wetlands Methodology Review

The SDG sub-indicator SDG 6.6.1D(1b) and SDG 6.6.1A(1c) monitors changes in the spatial extent of wetlands, which comprises of lakes, vegetated wetlands and ephemeral wetlands. Vegetated wetlands include palustrine, peatlands and mangroves. Ephemeral wetlands refer to arid and seasonal wetlands, which only occur during certain periods. Lacustrine wetlands, which refer to open water bodies with fringing vegetation will also be monitored.

The United Nations Environment Programme (UNEP) provided earth observation data, with methodologies developed in South Africa used for the validation and assessment of these datasets. The validation results showed that the full extent of wetlands as represented by the global data underestimated the actual spatial extent of South Africa's wetlands. Therefore, this sub-indicator is monitored using nationally derived datasets to better represent South Africa's wetlands.

Appendix B of the Methodology Report Target 6.6: Water Related Ecosystems presents the SDG 6.6.1D(1b) and SDG 6.6.1A(1c) indicator methodology, Version 2, December 2020. Table 5-3 summarises the methodology developed to date

Table 5-3: SDG 6.6.1D(1b) and SDG 6.6.1A(1c) Indicator Methodology

Indicator		**Aim**	**Methodology**
6.6.1	Change in the extent of water-related ecosystems over time: - use the image differencing to identifying spatial changes in surface overtime		
6.6.1.1 (UN - 6.6.1.a)	Change in the spatial extent of water-related ecosystems over time, including wetlands, reservoirs, lakes and estuaries as a percentage of total land area	**Change in Spatial Extent of Wetlands, including Lakes, Vegetated Wetlands, and Ephemeral Wetlands (6.6.1D (1b))**	
		Two wetland types: Vegetated and Lacustrine (possibly lake). An additional wetland type is proposed as Ephemeral. Areal extent of 75 estuarine lakes included the EFZ has been mapped in 2020. Changes in the areal extent of these lakes can be monitored, including bathymetry validation.	The national percentage (%) change in spatial extent will be calculated using the following formula Percentage change in spatial extent = $100 * (\beta - y)/\beta$ β = the average national spatial extent from determined baseline period y = the average national spatial extent of any other 5-year period
		Change in the Ecological Condition of Wetlands (6.6.1A (1c))	

Indicator		Aim	Methodology
6.6.1.5 (UN - 6.6.1.d)	Change in the ecological condition of rivers, estuaries, lakes and wetlands	Measures the baseline condition that is expressed as the Present Ecological State (PES) the % value of the reach in comparison of the total river length. The baseline input data for the ecological condition of rivers expressed would be the 2011 PES EI and ES study.	The change in ecological conditions can be calculated using the following formula: Percentage Change in Ecological Condition $=100 * (\beta - y)\beta$ Where β = the ecological condition 2014 Where y = the ecological condition for any other period

5.3.1 Indicator SDG 6.6.1D(1b) Methodology Observations

The methodology is well structured, introducing the methodology and including definition and rational for the indicator, followed by the methodology and computational method used.

The methodology appears incomplete in relation to Section B4. Data Sources, Section B7. Management Targets and Section B8. Comments and Limitations. The inclusion of some text stating the relevant or lack of information in these sections would help improved the completeness of the methodology. It is understood that the team is working on setting the management targets, which have been challenging due to the use of different methodologies in the NBA 2011 and 2018 reports. The intention is that the next NBA report will help to set a new baseline data set around which management targets can be developed.

The cross referencing of tables within the text needs to be updated to reflect the Appendix numbering system.

Tables B2 and B3 include a key defining the role of the various data providers, however there is no variety in the indicators presented in the tables. Furthermore, the tables appear to be a repeat of one another when Table B2 is intended to present Data providers (as presented), while Table B3 is intended to present Data compilers, but is presenting Data providers.

Time Frame Proposed Change

A significant change to the global methodology is presented, in relation to the time frame for assessing change in spatial extent of ephemeral wetland systems, with the suggestion of a 10-year timeframe comparted to the global standardised 5-year timeframe. Taking into consideration the nature of the ephemeral wetlands found in over a third for the South African identified wetlands, makes this suggestion appropriate in the South African context, however this variation in timeframe may be confusing or appear to be an omission when comparing to global standardized data sets. South Africa should aim to align the reporting timeframe to the global 5-year reporting period, where possible, to ultimately align to the UN reporting standard in time.

Computation Method Error

The two formulas presented in the methodology under Section B2.1.1. and B 2.1.2. present two different calculations, as follows:

Section B2.1.1. Wetlands

Percentage Change in Spatial Extent=100x(β-γ)β×100

Where β = the average national spatial extent in 2000

Where γ = the average national spatial extent of any other subsequent 5-year period

Section B2.1.2. Lakes

Percentage Change in Spatial Extent=(β-γ)/β×100

Where β = the average national spatial extent from determined baseline period

Where γ = the average national spatial extent of any other subsequent 5-year period

Section 4.2 of this report summarises the method proposed by the UN for calculating the change in surface area of permanent and seasonal surface water. The second formula presented in Section B2.1.2. is aligned to the UN calculation, while the formula presented under Section B2.1.1 differs from the UN calculation. It is assumed that the second formula, being the UN calculation, is the formula that should be used in both calculations.

Data Sources

Data for monitoring the spatial extent of wetlands is acquired from national geodatabases. These datasets are then merged with national level datasets to locate overlapping areas, which are incorporated into mapping exercises to monitor the spatial extent of wetlands. This is undertaken through the National Wetland Map Version 5 (NWM5). However, due to certain limitations and a low confidence level, improvements will be made in an updated NWM i.e. Version 6. Baseline datasets are then derived for vegetated wetlands, ephemeral and lacustrine systems in NWM5. The national percentage change in spatial extent is, thereafter, determined for a five-year period. With regards to ephemeral wetlands, the use of a period that is at least 10 years is recommended to produce reliable results. These wetlands do not occur permanently in the year and need to be monitored for longer periods than vegetated wetlands, which occur throughout the year.

5.3.2 UNEP SDG Target 6.6 (June 2020)

The South African Response to the UNEP SDG Target 6.6 (June 2020) states that, in the context of the global dataset including 75 estuarine lakes which have been included in the Estuarine Functional Zone (EFZ), “will in future need to undertake further studies to validate and identify any other lakes that may exist in the country.”

5.3.3 Methodology Testing

The baseline data set for the extent of water related ecosystems at a point in time, including wetlands, reservoirs, lakes and estuaries as a percentage of total land area is available for 2018 data, see Figure 5-1. No follow up data sets are available, and as a result, no change in spatial extent has as yet been calculated in relation to the baseline.

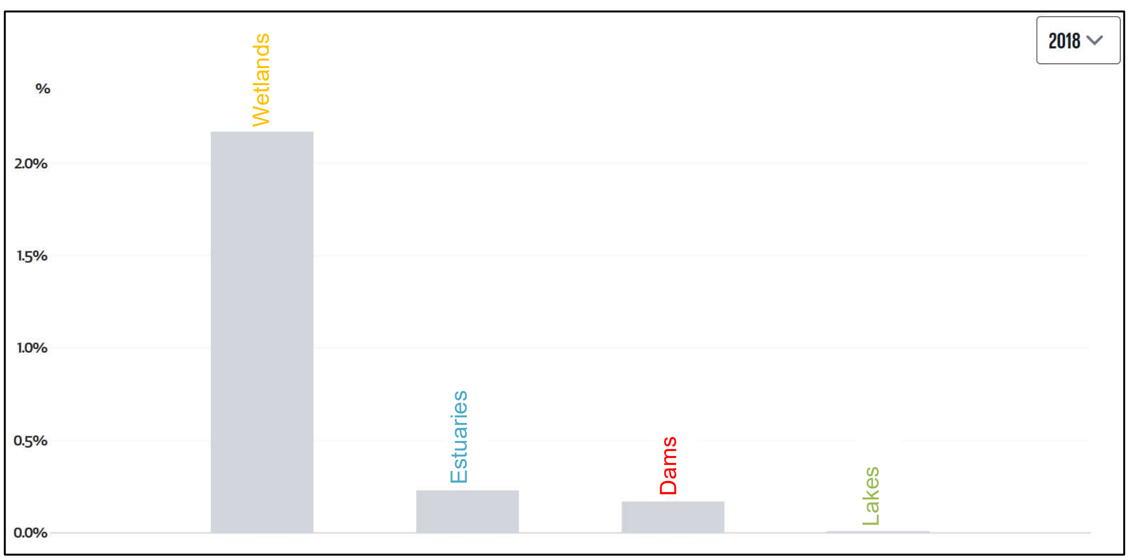


Figure 5-1 UN SDG 6.6/1D (1a) Extent in the spatial extent of water related ecosystems at a point in time, including wetlands, estuaries dams and lakes as a percentage of total land area

5.4 Indicator SDG 6.6.1D(1c), SDG6.6.1A(2) and SDG 6.6.1A(1b): Change in Spatial Extent (Open Water) of Estuaries Methodology Review

The sub-indicator SDG 6.6.1D(1c), SDG 6.6.1A(2) and SDG6.6.1A(1c) monitors changes in the extent of estuaries over time. It is domesticated based on circumstances in South Africa. The primary difference between the global and national (South Africa) indicators is the addition of monitoring changes in the Estuarine Functional Zone (EFZ). This zone is basically an area comprising of the estuary itself as well as additional characteristics, processes and surrounding habitats that allows for the functionality of the estuary. Therefore, while SDG 6.6.1 D (1c) has been domesticated, an additional indicator (6.6.1 A (2)) is also reported on in South Africa. In addition to being used to monitoring EFZ solely, the EFZ datasets can also be used to justify or support changes that occur in the estuary.

Appendix C of the Methodology Report Target 6.6: Water Related Ecosystems presents the SDG 6.6.1D(1c), SDG 6.6.1A(2) and SDG6.6.1A(1c) indicator methodology, Version 2, December 2020. Table 5-4 summarises the methodology developed to date.

Please note the numbering of SDG6.6.1A(1c) is reflected as indicator SDG6.6.1A(1b) elsewhere in the methodology report. Please verify and use a consistent numbering system for this indicator.

Table 5-4: SDG 6.6.1D(1c), SDG6.6.1A(2) and SDG 6.6.1A(1c) Indicator Methodology

Indicator		Aim	Methodology
6.6.1	Change in the extent of water-related ecosystems over time: - use the image differencing to identifying spatial changes in surface overtime		
6.6.1.1 (UN - 6.6.1.a)	Change in the spatial extent of water-related ecosystems over time, including wetlands, reservoirs, lakes and estuaries as a percentage of total land area	**Change in Spatial Extent of Estuaries (6.6.1D (1c))**	
		The surface area of estuaries. It is measured in km^2 or hectares. This includes the entire functional zone and not only the open water area. The percentage change in area of estuaries from a baseline reference. For reporting such change, the previous extent, if known, and the period over which the change has taken place should be specified.	The surface area of estuaries. It is measured in km^2 or hectares. This includes the entire functional zone and not only the open water area. The percentage change in area of estuaries from a baseline reference. For reporting such change, the previous extent, if known, and the period over which the change has taken place should be specified.
		Change in the Extent of Estuarine Functional Zones (EFZ) (6.6.1A (2))	
		The South African estuarine functional zone (EFZ) is seen as the entire area associated with an estuary that ensures its functionality.	The extent of South African estuaries is based on available remote sensing data available through the CSIR and SANBI for the National Biodiversity Assessment, which is a 5 yearly project. Ramsar definition and classification is found in the document "Guidance on information on national wetland extent, to be provided in Target 8 National Wetlands Inventory of the Ramsar National Report for COP13".
		Change in the Ecological Condition of Estuaries (6.6.1A (1b))	

Indicator		Aim	Methodology
6.6.1.5 (UN - 6.6.1.d)	Change in the ecological condition of rivers, estuaries, lakes and wetlands	Measures the percentage change in the ecological condition of estuaries over time, defined from a baseline condition and expressed as the Present Ecological State (PES), the %value of the ecological state in comparison to the baseline ecological condition.	The method/model applies a modified Index of Habitat Integrity (IHI) approach; using existing, field verified data or data from research projects. In areas where no data exists, satellite data (Google Earth) will be used, local knowledge and expert opinion. The approach is based on assessing the degree of modification of the following criteria: - Instream habitat continuity - Riparian area or wetland habitat continuity - Potential instream habitat function, processes, and biota - Riparian or wetland zone structure and composition - Flow and flood regimes; and - Physico-chemical conditions

The disaggregation of data for estuaries is based on their biogeographical region and type of estuary that is being monitored. There are currently four biogeographical regions in South Africa, namely tropical, sub-tropical, warm temperate and cold temperate regions. Furthermore, there are a total of nine estuary types, which each have their respective characteristics that allow for the classification of an estuary. The methodology used to monitor the spatial extent of estuaries includes the acquisition of estuarine data from satellite sources, which is regarded as the baseline. The data sources include SPOT 5 imagery, Google Earth images, 5 m topographical contours and georeferenced 1:10000 ortho-photos. The change in the extent of estuaries is then determined using the baseline estuarine and current estuarine area, after which, the percentage change in the extent of estuaries can be calculated.

5.4.1 Indicator SDG 6.6.1D(1c), SDG6.6.1A(2) and SDG 6.6.1A(1b) Methodology Observations

The methodology is well structured, introducing the methodology and including definition and rational for the indicator, followed by the methodology and computational method used.

The cross referencing of tables within the text needs to be updated to reflect the Appendix numbering system. In addition, Table C3's heading to not reflecting the same caption style as the tabular captains within the methodology.

Tables which are split across pages need to include the header row, for ease of reading.

Table 1C effectively summarises the South African estuaries according to the classification system of van Niekerk et al (2019). The three types of micro-systems identified in van Niekerk et al (2019) should be summarized in a tabular format, like Table 1C, for consistency purposes.

Section 2.3 Concepts presents a summary of the data presented in Table C4. The areas and percentages presented should reference the date of the data being presents, i.e. 2018. The areas and percentages presented in the text do not corelate with the data presented in Table C4.

Computation Method

The computational method presented in Section C3.1 is presented in words, unlike similar methodologies. Utilisation of a formula for the calculation of the methodology would be preferable from a consistency perspective, as follows:

Change in the Extent of Estuaries=(β-γ)

Percentage Change in the Extent of Estuaries=(γ/β)x100

Where β = baseline estuarine area (ha or km^2)

Where γ = current reporting cycle estuarine area (ha or km^2)

The formula presented differs from the UN calculation of ((β-γ)/β)x100. The UN calculation presents a globally consistent data interpretation calculation and is therefore considered applicable for use from a global reporting perspective. Section 4.2 of this report summarises the method proposed by the UN for calculating the change in surface area of permanent and seasonal surface water. In order to maintain a consistent reporting approach for the indicators; inclusion of the UN calculations is pertinent for indicator SDG 6.6.1D(1c).

Data Sources

The data collected for this indicator in 2011 and 2018 is noted to have been collected form "various sources". In order to maintain a consistent and comparable data set, variability in the data sources and information obtained from these data sources could create false data changes, induced as a result of the data source rather than changes in the geographic extent of the surface water feature.

The technological advances in satellite imagery and image processing is resulting in significant advances in the available data and the integrity of that data. Global comparative reporting is therefore challenging and needs to be taken into consideration when comparing data sets.

5.4.2 UNEP SDG Target 6.6 (June 2020)

The South African Response to the UNEP SDG Target 6.6 (June 2020) states that, in the context of the global dataset not separating out the estuarine area from the other natural surface waters. "Should this (estuarine open water area) statistics become available an exercise would need to be undertaken within South Africa in order to verify the statistics as existing datasets within South Africa do not map open water extents for Estuaries but rather changes in the EFZ, which is undertaken in order to sufficiently inform management actions."

5.4.3 Methodology Testing

The baseline data set for the extent of water related ecosystems at a point in time, includes a comparison of the extent of the South African EFZ according to the 2011 and 2018 NBA (van Niekerk et al., 2012 and 2018). Table 5-5 utilizes the date presented in DWS SDG6.6 Methodology Report, Table 4C, and expands upon it based on the prescribed computation method presented in the methodology, with the results depicted in Figure 5-2 and Figure 5-3, respectively.

Table 5-5 A comparison of the extent of the South African Estuarine Functional Zone according to the 2011 and 2018 NBA (van Niekerk et al., 2012 and 2018)

Biogeographical Region	2011 NBA – Proportional EFZ (ha)	2018 NBA – Proportional EFZ (ha)	Change in the Extent of Estuaries (ha) (β-γ)	Percentage Change in Extent of Estuaries (γ/β)x100	UN Percentage Change in Spatial Extent (β-γ)/βx100
Cool Temperate	26,516	37,680	-11,164	142%	-42%
Warm Temperate	41,785	44,500	-2,715	106%	-6%
Sub-tropical	102,746	110,390	-7,644	107%	-7%
Tropical		8,170	-8,170	100%	
Total	171,047	200,740	-29,693	117%	-17%

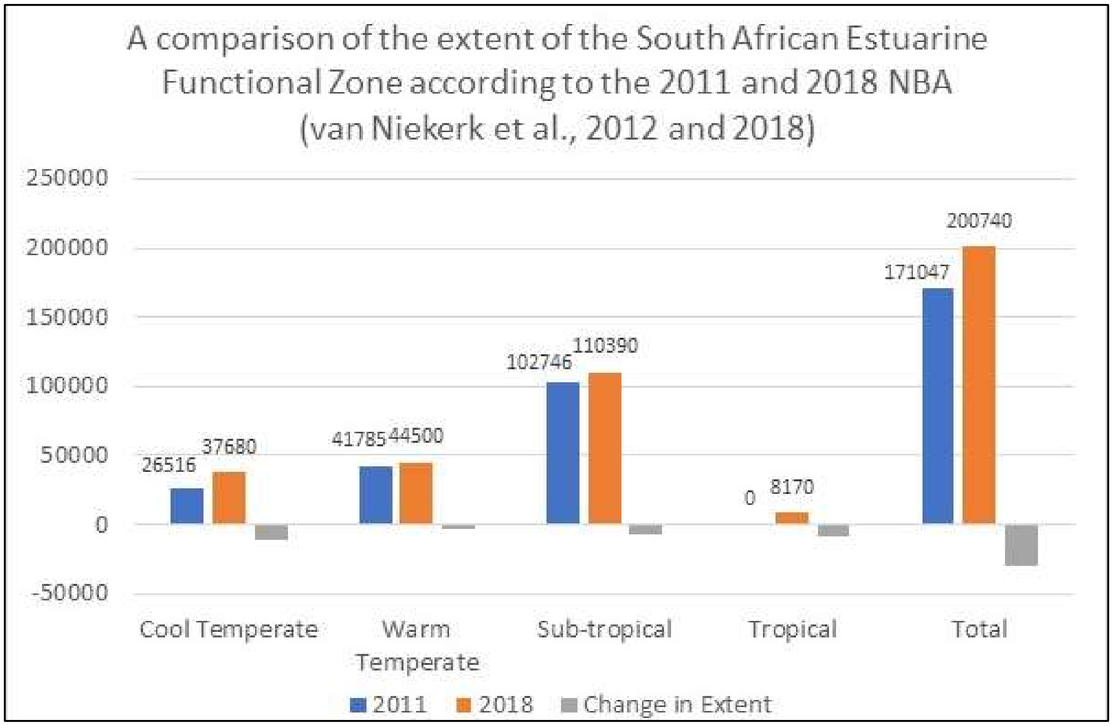


Figure 5-2 A comparison of the extent of the South African Estuarine Functional Zone according to the 2011 and 2018 NBA (van Niekerk et al., 2012 and 2018)

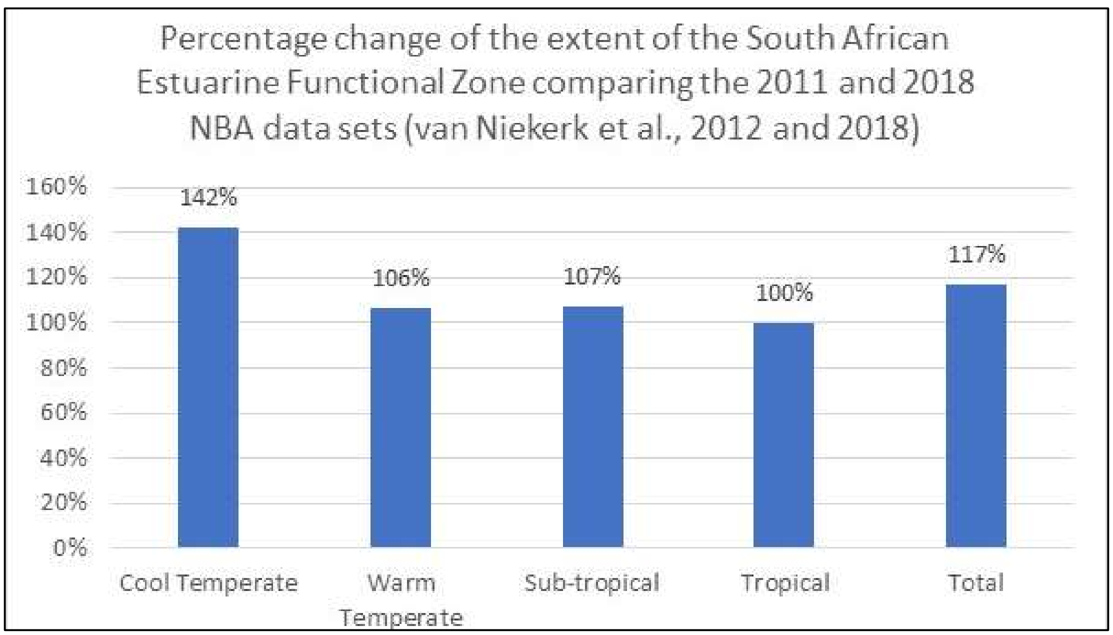


Figure 5-3 Percentage change of the extent of the South African Estuarine Functional Zone comparing the 2011 and 2018 NBA data sets (van Niekerk et al., 2012 and 2018)

The method proposed to calculate the change in spatial extent of the estuarine functional zone is considered to be a well thought through set of formulas, which present a usable data set for interpretation of changes going forward. However, the UN calculation presents a globally consistent data interpretation calculation and should therefore be considered for use, from a global reporting perspective. Figure 5-4 presents a results of the UN calculations when comparing the baseline spatial extent of the South African Estuarine Functional Zone to the subsequent data set (2018).

Please note this formula yields percentage change values as either positive or negative, which helps to indicate how spatial area is changing. According to the UN Water Sustainable Development Goal Monitoring Methodology Indicator 6.6.1 “If the value is shown as positive, the statistics represent an area gain while if the value is shown as negative, it represents a loss in surface area.” Using the UN calculation for this dataset, suggests that the interpretation of the positive and negative figures in this calculation are contrary to the proposed interpretation. The data shows how spatial area changes, where a negative value, represents an area gain, while a positive value presents an area loss.

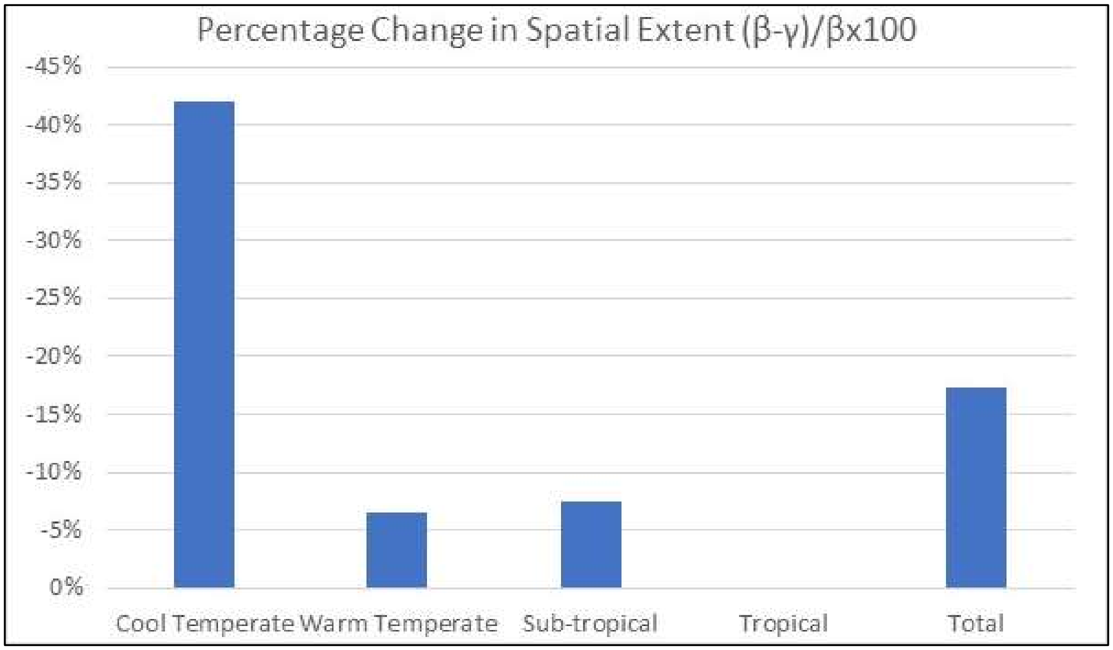


Figure 5-4 Percentage change of spatial extent of the South African Estuarine Functional Zone comparing the 2011 and 2018 NBA data sets

5.5 Indicator SDG 6.6.1D(1d): Change in Spatial Extent of Artificial Systems Methodology Review

SDG 6.6.1 D (1d) measures the change in the spatial extent of reservoirs over time. While these water bodies are man-made, they hold a significant amount of our freshwater resource. Therefore, monitoring the changes in the spatial extent of artificial systems is also crucial as it is representative of changes in water quantity levels. Drastic changes in water quantity will not only impact the availability of freshwater but may also affect ecosystem habitats and its functions.

Appendix D of the Methodology Report Target 6.6: Water Related Ecosystems presents the SDG 6.6.1D(1d) indicator methodology, Version 2, June 2021.

Table 5-6 summarises the methodology developed to date.

Table 5-6: SDG 6.6.1D(1d) Indicator Methodology

Indicator		Aim	Methodology
6.6.1	Change in the extent of water-related ecosystems over time: - use the image differencing to identifying spatial changes in surface overtime		
6.6.1.1 (UN - 6.6.1.a)	Change in the spatial extent of water-related ecosystems over time, including wetlands, reservoirs, lakes and estuaries as a percentage of total land area	**Change in Spatial Extent of Artificial Systems (Reservoirs) (6.6.1D (1d))**	
		Measurement of the percentage change in the surface area of reservoirs over time from a predefined baseline, expressed as a % of the total land area	The baseline for artificial water bodies or Dams was captured using the aerial photography but the updating will be done using High Resolution Satellite Imagery such as: • SPOT 67, • Sentinel, • Landsat 8 and • Physical Measurements. Advanced computing technology can be programmed to summarise all of these images and split the earth into land cover type pixels, one of which is open water. Limitations include various versions of datasets. The other limitation is that not all artificial systems are accounted for.

The methodology currently used to monitor changes in the spatial extent of artificial systems incorporates the use of Landsat 8 satellite imagery. Initially, aerial photography was used to capture these images, however, this is currently in the process of being updated and will involve aerial photography being replaced by high resolution satellite data such as Sentinel and Landsat and SPOT 6 imagery. When monitoring one location, several satellite images may be required, however, this has become more applicable due to advanced computing technology. After the acquisition of data for each dam, these records will then be integrated to produce one dataset representing dams on a national level. The accuracy of this dataset is expected to be high due to the integration of different high-resolution imagery. This dataset will ultimately be used to derive the percentage change of the spatial extent of artificial systems over time using a predefined baseline.

5.5.1 Indicator SDG 6.6.1D(1d) Methodology Observations

The methodology is well structured, introducing the indicator including definition and rational for the indicator, followed by the methodology and computational method used as well as data sources etc.

The figure and table numbering and titles need to be updated to reflect the Appendix numbering system. Many of the tables and figures did not have headings or numbered headings.

Computation Method

The computational method presented in Section D2.1 is present, as follows:

Percentage Change in Spatial Extent=(β-γ)βx100

“Where β = the average national spatial extent from 2013-2017”

“Where γ = the average national spatial”

The formula presented differs from the UN calculation of ((β-γ)/β)x100. The UN calculation is assumed to be the formula that this indicator intended to follow. Section 4.2 of this report summarises the method proposed by the UN for calculating the change in surface area of permanent and seasonal surface water. The formula presented in Section D2.1. differs from the UN calculation and is recommended to be amended accordingly.

The dataset will be reported as one national value as well as being segregated into tertiary catchment boundaries with associated attribute tables. The segregation of the data will be more meaningful as a dataset to inform decision making going forward.

Data Sources

The data collected for this indicator in 2011 and 2018 is noted to have been collected form "various sources". In order to maintain a consistent and comparable data set, variability in the data sources and information obtained from these data sources could create false data changes, induced as a result of the data source rather than changes in the geographic extent of the surface water feature.

The technological advances in satellite imagery and image processing is resulting in significant advances in the available data and the integrity of that data. Global comparative reporting is therefore challenging and needs to be taken into consideration when comparing data sets.

Management Targets

The following target has been set for the SDG 6.6.1D(1d) with the aim being to "maintain / improve spatial extent when compared to average over time".

The computational methods presented in Section D8 for the calculation of target and indictor spatial extant, respectively, are present, as follows:

Target Spatial Extent (T)=E/N

Where "E = Σ(spatial extent of 1st dataset + ... + Spatial extent of 2017 dataset)"

Where "N = Number of data sets from 1st dataset to 2017"

Indicator Spatial Extent(I)=C-T

Where "C = Current Spatial Extent" of Reporting Year

Where "T = Target Spatial Extent"

Comments and Limitations

As mentioned above under "Data Sources", the authors of the SDG 6.6.1D(1d) methodology have noted the challenges being experienced associated with "having different versions of dam datasets in the Department of Water Sanitation". Further challenges are identified are listed below:

- Not all dams are accounted for making reporting difficult on all dams in the country.
- Accuracy also differs per dataset, limiting the compilation of comprehensive national dam reporting.

The 2017 baseline data will reportedly be replaced when the integrating of different dam datasets has been completed. According to the SDG 6.6.1D(1d) methodology a new baseline was to be determined by February 2020, to accurately compare future updates.

5.5.2 UNEP SDG Target 6.6 (June 2020)

The South African Response to the UNEP SDG Target 6.6 (June 2020) states that, in the context of the extent of artificial systems (reservoirs) "the number and aerial extents are significantly underrepresented".

Furthermore, in relation to the baseline data set, which reportedly included a drought year affecting 26% of the summer rainfall extent of South Africa, a recommendation "that changes be reported for South Africa against a mean value derived from 36 years of data (Pekel et al., 2016)". Reportedly "The DWS has recently initiated a project to produce an integrated Dam layer", expected to be available in early 2021.

5.5.3 Methodology Testing

The baseline and follow up data set for the extent of artificial systems (reservoirs) were not included in the SDG Target 6.6 Methodology Report. As a result, no calculation testing could be undertaken to verify the computational methods presented.

5.6 Indicator SDG 6.6.1D(2a) and 6.6.1D(2b): Lakes and Dams Affected by High Trophic and Turbidity States Methodology Review

This sub indicator for SDG 6.6.1D(2a) and SDG 6.6.1D(2b) aims to monitor the change in the number of lakes and dams affected by high trophic states and turbidity. Trophic states refer to the productivity of water-related ecosystems in terms of the amount of available nutrients. Turbidity is the measure of relative clarity of a liquid, being a measurement of the amount of light that is scattered by material in the water when a light is shined through a water sample. Therefore, this indictor is a measure of water quality.

The aim of this sub indicator is to monitor changes in the number of lakes and dams affected by high turbidity states. Turbidity states is also a measure of water quality. It refers to the cloudiness of water bodies, which is based on the number of particles or sediments present. Therefore, high turbidity levels are an indication of large amounts of sedimentation, which will ultimately result in poor water quality. The poor water quality is since accumulated sediments can impact water-related ecosystems by contaminating the water, thus affecting aquatic organisms, and also by preventing light from reaching aquatic plants.

Appendix E of the Methodology Report Target 6.6: Water Related Ecosystems presents the SDG 6.6.1D(2a) and SDG 6.6.1D(2b) indicator methodology, Version 1, September 2021, with an updated version provided in July 2022. Table 5-7 summarises the methodology developed to date.

Table 5-7: SDG 6.6.1D(2a) and SDG 6.6.1D(2b) Indicator Methodology

Indicator		Aim	Methodology
6.6.1	Change in the extent of water-related ecosystems over time: - use the image differencing to identifying spatial changes in surface overtime		
6.6.1.2 (UN - 6.6.1.c)	Number of lakes and dams affected by high trophic and turbidity states	**Change in the number of lakes and dams affected by High Trophic States (6.6.1D (2a))**	
		To use in-situ measurements, supplemented by satellite imagery to identify spatial changes overtime	Trophic state is assigned using the SA criterion for the calendar year and the dam is classified (median annual Chl *a*) as either oligotrophic (0< x <10), mesotrophic (10< x <20), eutrophic (20< x <30) or hypertrophic (>30). Monthly deviation of the multiannual baseline is computed using the following equation: (Month_average-Month_baseline) / Month_baseline x 100
		Change in the number of lakes and dams affected by High Turbidity States (6.6.1D (2b))	
		Measurements of the water clarity of lakes and reservoirs/dams	The data represent the number of lakes impacted by a degradation of their environmental conditions (i.e. showing a deviation in turbidity and trophic state from the baseline) compared to the total number of lakes within a country. The values produced account for different sized lakes.

Indicator		Aim	Methodology
			Annual deviation of the multiannual baseline is computed using the following equation: (Annual_average - Baseline) / Baseline x 100

5.6.1 Indicator SDG 6.6.1D(2a) and SDG 6.6.1D(2b) Methodology Observations

The methodology is reasonably structured, introducing rational for the indicator, followed by the methodology and computational method used.

The methodology appears incomplete in relation to Section 3. Disaggregation of Data for Management Purposes, Section 10. Comments and Limitations, Section 12. Additional Information and Section 5. Approval. The inclusion of some text stating the relevant or lack of information in these sections would help improved the completeness of the methodology.

The labelling of tables and figures as well as the cross referencing of tables and figures within the text needs to be updated to reflect the Appendix numbering system.

Computation Method

The computational method presented for SDG 6.6.1D(2a) and SDG 6.6.1D(2b) is presented in words, in accordance with the UN SDG Monitoring Methodology (Section 4.3). The computational methods presented in Section 2.2 for the calculation of trophic state and turbidity, respectively, are present, as follows:

(Month_average - Month_baseline) / Month_Baseline x 100

(Annual_average - Baseline) / Baseline x 100

The first formula proposed for use is consistent with the UN calculation presented a globally consistent data interpretation calculation. The second formula is a domesticated calculation that is likely to align with the local data sets to be used for reporting and data interpretation.

Data Sources

The data collected for this indicator in 2011 and 2018 is noted to have been collected form 3 spatial tiers, namely national, regional and local are perspectives. The technological advances in satellite imagery and image processing is resulting in significant advances in the available data and the integrity of that data. Global comparative reporting is therefore challenging and needs to be taken into consideration when comparing data sets.

5.6.2 UNEP SDG Target 6.6 (June 2020)

The South African National Department of Water and Sanitation (DWS) have a number of monitoring systems that are used to provide information for water resource management.

For the water quality, the UNEP SDG Target 6.6 (June 2020) report lists 21 reservoirs. The UNEP EO data does not correlate with the ground-truth monitoring networks NEMP and EONEMP, suggesting that the country does not have issues related to nutrient enrichment of lakes/dams during the period 2017-2019. “The data generated through EONEMP is based on sound rigorous ground-truth validation method/satellite data/algorithm procedures suitable to SA conditions.”

5.6.3 Methodology Testing

The baseline and follow up data set for the tropic state and turbidity were not included in the SDG Target SDG 6.6 Methodology Report. As a result, no calculation testing could be undertaken to verify the computational methods presented.

5.7 Indicator SDG 6.6.1D(3a) and 6.6.1D(3b): Change in the Quantity of Water (discharge in Rivers and entering Estuaries) Methodology Review

Appendix F of the Methodology Report Target 6.6: Water Related Ecosystems presents the SDG 6.6.1D(3a) and SDG 6.6.1D(3b) indicator methodology, Version 1, September 2021. Table 5-8 summarises the methodology developed to date.

Table 5-8: SDG 6.6.1D(3a) and SDG 6.6.1D(3b) Indicator Methodology

Indicator		Aim	Methodology
6.6.1	Change in the extent of water-related ecosystems over time: - use the image differencing to identifying spatial changes in surface overtime		
6.6.1.3 (UN - 6.6.1.b)	Change in the national discharge of rivers and estuaries over time	**Change in the water Quantity in Rivers (6.6.1D (3a))**	
		Measure and observe cumulative flow volume data	The percentage change of Total cumulative flow volume will be calculated using the following formula Percentage Change of Total cumulative flow volume = $(TC_{7\ present} – TC_{7\ normal\ years})/TC_{7\ normal\ years}$ x 100 Baseline data will be captured using data in Hydstra database
		Change in the water Quantity entering Estuaries (6.6.1D (3b))	
		Measure change in flow into estuaries for change in water quality	This methodology describes how change in Total Volume of the water occurs due to variation in Rainfall, Evaporation and abstraction. DWS has identified gauging stations which includes dams from which to select representative monitoring sites for a chosen period of seven years. Baseline data will be captured using data in Hydstra database

5.7.1 Indicator SDG 6.6.1D(3a) and SDG 6.6.1D(3b) Methodology Observations

The methodology is well structured, introducing the indicator with the associated definitions, rational and concepts, followed by the methodology including the computational method used.

The methodology appears incomplete in relation to Section F9. Management Targets, Section F10. Display of Results, Section F11. Comments and Limitations and Section F13. Additional Information. The inclusion of some text stating the relevant or lack of information in these sections would help improved the completeness of the methodology.

Section F12. Implementation Calendar appears incomplete, stating “The table below describes how reporting on this sub-indicator will be improved over time”. No table of further information is provided in the methodology.

Some minor terminology improvements could be made to this methodology, for example “some groundwater ooze” should be rephrased to be more scientifically correct i.e. ’some groundwater is daylighting at’.

Time Frame Proposed Change

A change to the methodology is proposed, in relation to the baseline calculation by, “The baseline dataset will be determined as total cumulative flow volume over an identified period of seven ‘normal’ years.” The use of this methodology is contrary to scientific norms. The selection of “normal” years would have been based on a prior determined average. It would therefore be more scientifically correct to rather extend the baseline monitoring period over a longer period of time, to accommodate a sufficient time period to allow for periodic highs and lows to be normalized.

Typical time frames used in the UN global standardised are monitored over a 5 year time-frame. The proposed variation in time-frame may be confusing or appear to be an omission when comparing to global standardized data sets.

Computation Method

The computational method presented for SDG 6.6.1D(3a) and SDG 6.6.1D(3b) is presented in words. There is no computational method prescribed in the UN SDG Monitoring Methodology (Section 4.3). The computational methods presented in Section F3.1 of the SDG Target 6.6 Methodology Report for the calculation of total cumulative flow volume is present, as follows:

Percentage Change of Total cumulative flow volume=

(TC7 present −TC7 normal years) / TC7 normal years ×100

Where “TC7 normal years = total cumulative flow volume of seven normal years”

Where “TC7 present = total cumulative flow volume of seven present years”

Despite the lack of a UN calculation, provides an improved calculation of the percentage change of the “present” in comparison to the “baseline”, correcting the UN formula and making it more usable. Section 4.2 of this report summarises the method proposed by the UN for calculating the change in surface area of permanent and seasonal surface water.

Data Sources

The data to be used is reportedly available and collected from monitoring sites from the eight Hydro Regional Offices, where selected gauging stations have been selected to provide representative monitoring sites. The reliance on existing gauging stations will provide a valuable baseline data set, however the location and as a result the regional distribution of these sites may not provide a nationally representative dataset for the country.

5.7.2 UNEP SDG Target 6.6 (June 2020)

The UNEP SDG Target 6.6 (June 2020) report does not contain any data or review of water quantity or volumes in relation to SDG 6.6.1D(3a(or SDG 6.6.1D (3b).

5.7.3 Methodology Testing

The baseline and follow up data set for the change in the quantity of water (discharge in rivers and entering estuaries) were not included in the SDG Target SDG 6.6 Methodology Report. As a result, no calculation testing could be undertaken to verify the computational methods presented.

5.8 Indicator SDG 6.6.1D(4): Change in Groundwater Level Status Methodology Review

The aim of sub-indicator SDG 6.6.1D(4) is to monitor the change in groundwater level status (GwLS), DWS has domesticated this sub indicator based on the diversity and complexity of the South African aquifer system as well as ongoing seasonal fluctuations due to climate change. The changes to the quantity of groundwater within aquifers is important information for many countries that rely heavily on groundwater availability. For the purposes of Indicator 6.6.1 monitoring the changes to groundwater levels gives a good indication of changes to the water stored in an aquifer.

Appendix G of the Methodology Report Target 6.6: Water Related Ecosystems presents the SDG 6.6.1D(4) indicator methodology, Version 2, June 2021. Table 5-9 summarises the methodology developed to date.

Table 5-9: SDG 6.6.1D(4) Indicator Methodology

Indicator		**Aim**	**Methodology**
6.6.1	Change in the extent of water-related ecosystems over time: - use the image differencing to identifying spatial changes in surface overtime		
6.6.1.4 (UN – None)	Change in groundwater levels over time	**Change in Groundwater Levels over time (6.6.1D (4))**	
		Three tier steps process for data collection of which the Department of Water and Sanitation (DWS) are the custodians of the National Groundwater Level Monitoring Programme (NGLMP)	Monthly, quarterly or bi-annually data is collected and uploaded onto the DWS HYDSTRA database. Various formulas have been derived to calculate different aspects of the methodology. For change in quantity the following formula was used: Percentage Change in Quantity = $\frac{\beta-\gamma}{\beta} * 100$ Where β = historical 15-year reference groundwater level and γ = the average groundwater level of 5-year period of interest. For change in groundwater levels the above formula has been adjusted to be negative: Percentage Change in Groundwater Levels = - $\frac{\beta-\gamma}{\beta} * 100$ The Groundwater Levels Status percentage is shown below: Status = $[-1 * Dgw - Cgw/Dgw - Sgw]\%$

5.8.1 Indicator SDG 6.6.1D(4) and Methodology Observations

The methodology is well structured and well compiled with a thorough explanation and cross referencing to the methodology used as well as explanation of the thinking behind the methodology used.

The labelling of some tables and section cross referencing within the text needs to be updated.

The section and figure relating the biodiversity act, is understood to be included to help shape the connection between groundwater and sensitive floral areas. The paragraph does not clearly make this connection known, making this section seem incongruent with the methodology.

Computation Method

The computational method presented for SDG 6.6.1D(4) is presented in comparison to the UN methodology, with the reason for the proposed domestication of the indicator presented. Furthermore, the methodology has been tested which has highlighted the negative values potentially reported using the UN methodology, with the appropriate corrections made to the domesticated indicators. The computational methods presented in Section 3.7 of the UN SDG6.6.1 Indicator Methodology for the calculation of groundwater percentage change in quantity and groundwater level status, are present, as follows:

Percentage Change in Quantity = −(β-γ)/βx100

Where "β = historical 15-year reference groundwater level"

Where "γ = average groundwater level of 5 year period of interest"

Groundwater Level Status Percentage Change = [−1 x (Dgw−Cgw)/(Dgw−Sgw)]x100

Where Sgw = “Shallowest groundwater level”

Where Dgw = “Deepest groundwater level”

Where Cgw = “Current groundwater level”

The frequency of monitoring the GwLS in South Africa is collected monthly, quarterly or bi-annually and uploaded within 30 days of collection whereas our global counterparts the UN collects data during seasonal and wet/dry cycle influences however the UN recommends that monthly monitoring would provide optimal data to assess change within the aquifer more adequately.

Data Sources

The data collected for this indicator is sourced from the National Groundwater Level Monitoring Programme. Data is collected monthly, quarterly or bi-annually and uploaded to the DWS HYDSTRA database, which dates back to the 1940’s covering South Africa’s 65 geohydrological regions.

The methodology for monitoring the change in GwLS incorporates the use of HYDSTRA which is a database owned and maintained by DWS to eliminate an influx of information not verified and approved by professionals. Many challenges arise due to insufficient and untrained staff collecting data as well as issues in travel and procurement. Measuring the level of groundwater within an aquifer is done through the use of boreholes. DWS has selected certain geosites earmarked for monitoring, and these sites extend across the four hydrogeological systems, similarly the UN also had trouble choosing boreholes which adequately represent the total groundwater situation for an aquifer.

5.8.2 UNEP SDG Target 6.6 (June 2020)

For the groundwater levels, the UNEP SDG Target 6.6 (June 2020) report lists the discrepancies that develop through elevation differences while using the groundwater level status. The use of the individual borehole water level range used as a percentage will guide the DWS to re-evaluate the regional aquifer delineation and focus on sub aquifer scale.

5.8.3 Methodology Testing

The baseline data set for the groundwater levels, includes baseline calculated over a 15 year period (2000 to 2015) and groundwater level status calculated on a 5 year period thereafter. utilizes the date presented in UN Indicator 6.6.1 Methodology, Table 5A, and expands upon it based on the prescribed computation method presented in the methodology, with the results summarised for the aquifer regions presented in the UN Indicator 6.6.1 Methodology in Figure 5-5 and Figure 5-6, respectively.

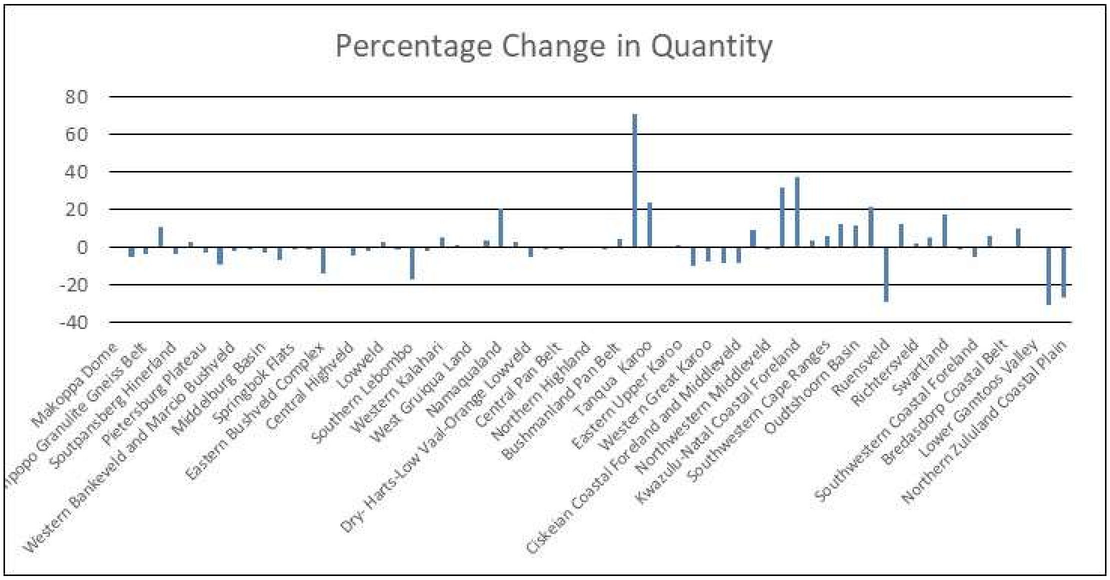


Figure 5-5 Percentage Change in Quantity (baseline (2000-2014) vs 5 yrs (2015-2019)

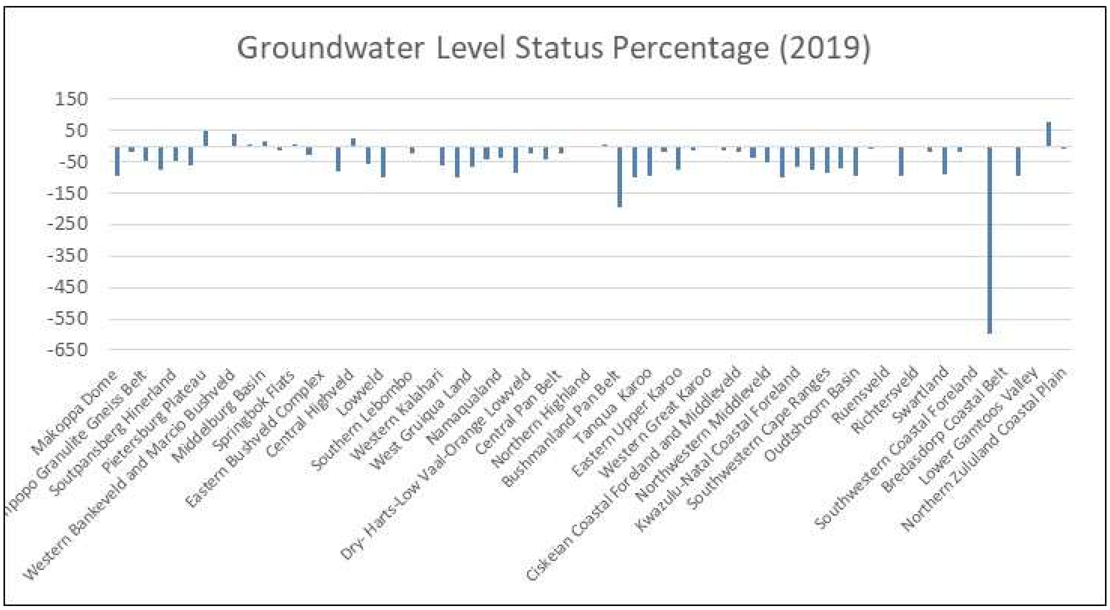


Figure 5-6 Groundwater Level Status Percentage Change

Management Targets

Management targets are dependent on the location of the hydrogeological system therefore the targets vary for regions along the coast as opposed to regions inland. The GwLS target is set at the 25th percentile and all regions should not drop below this set target.

5.9 Indicator SDG 6.6.1A(1a): Change in the Ecological Condition of Rivers Methodology Review

The sub-indicator SDG 6.6.1A(1a) is the only addition indicator identified within the South African context. This sub-indicator aims to monitor changes in the ecological conditions of extent of estuaries over time. It has been domesticated based on conditions in South Africa.

Appendix H of the Methodology Report Target 6.6: Water Related Ecosystems presents the SDG 6.6.1A(1a) indicator methodology, Version 2, November 2020. Table 5-10 summarises the methodology developed to date.

Table 5-10: SDG 6.6.1A(1a) Indicator Methodology

Indicator		Aim	Methodology
6.6.1	Change in the extent of water-related ecosystems over time: - use the image differencing to identifying spatial changes in surface overtime		
6.6.1.5 (UN - 6.6.1.d)	Change in the ecological condition of rivers, estuaries, lakes and wetlands	**Change in the Ecological Condition of Rivers (6.6.1A (1a))**	
		Measures the baseline condition that is expressed as the Present Ecological State (PES) the % value of the reach in comparison of the total river length. The baseline input data for the ecological condition of rivers expressed would be the 2011 PES EI and ES study.	The method/model applies a modified Index of Habitat Integrity (IHI) approach; using existing, field verified data or data from research projects. In areas where no data exists, satellite data (Google Earth) will be used, local knowledge and expert opinion. The approach is based on assessing the degree of modification of the following criteria: - Instream habitat continuity - Riparian area or wetland habitat continuity - Potential instream habitat function, processes, and biota - Riparian or wetland zone structure and composition - Flow and flood regimes; and - Physico-chemical conditions

The disaggregation of data for estuaries are based on their biogeographical region and type of estuary that is being monitored. There are currently four biogeographical regions in South Africa, namely tropical, sub-tropical, warm temperate and cold temperate regions. Furthermore, there are a total of nine estuary types, which each have their respective characteristics that allow for the classification of an estuary. The methodology used to monitor the spatial extent of estuaries includes the acquisition of estuarine data from satellite sources, which is regarded as the baseline. The data sources include SPOT 5 imagery, Google Earth images, 5 m topographical contours and georeferenced 1:10000 ortho-photos. The change in the extent of estuaries is then determined using the baseline estuarine and current estuarine area, after which, the percentage change in the extent of estuaries can be calculated.

5.9.1 Indicator SDG 6.6.1A(1a) and Methodology Observations

The methodology is well structured, introducing rational for the indicator, followed by the methodology and computational method used.

The indicator claims to include the change in the ecological condition of rivers, estuaries, lakes and wetlands, however the aim and methodology only refer to these calculation for rivers.

Computation Method

The computational method presented for SDG 6.6.1A(1a) is presented in words. The computational methods presented in Section H2.2 for the calculation of Ecological Condition Index (written in words) and the change in ecological condition, respectively, are present, as follows:

(Ecological Condition)x(Percentage River Length for ecological condition)=(Length-weighted score for rivers in each ecological condition) + (Ecological Condition Index)

Percentage Change in Ecological Condition=(β−γ) β×100

“Where β = the ecological condition 2014”

“Where γ = the ecological condition for any other period”

The results are recommended to be displayed on maps for the various assessment scales or as simple pie charts.

The formula presented differs from the UN calculation of ((β-γ)/β)x100, commonly used for SDG6.6. Targets. The UN calculation is assumed to be the formula that this indicator intended to follow. Section 4.2 of this report summarises the method proposed by the UN for calculating the change in spatial extent. The formula presented in Section H2.2. differs from the UN calculation and is recommended to be amended accordingly.

Data Sources

The data collected for this indicator will be based on Google Earth images and regional knowledge of the study team. It will be based on assessing land use in the targeted catchments and its impact on various, pre-defined, attributes of river ecosystems.

These tools include Google Earth, local knowledge, specialist opinion, previous high confidence Resource Directed Measures (RDM) studies (Reserves, Classification, RQO studies and/or tertiary studies), research conducted via recognised institutions (i.e., WRC, CSIR, Universities etc.). If these resources are used interchangeably, it will ensure that the model output is continuously updated and will make sure that the layers are not disaggregated. Continuity is key in this study as it will help identifying data gaps. The reporting on this indicator will follow a 10-year cycle.

5.9.2 Methodology Testing

The baseline and follow up data set for the change in ecological condition in rivers was not included in the SDG Target SDG 6.6 Methodology Report. The baseline data for this additional indicator is available in the 2011 WRC led study, where the ecological status of the rivers was determined.

Management Targets

The following target has been set for the SDG 6.6.1A(1a) with the aim being to “Maintain and or Improve the Ecological Condition of the priority water resources”.

The computational methods presented in Section D8 for the calculation of target and indictor spatial extant, respectively, are present, as follows:

Target Ecological Condition (T)= Gazetted TEC (preliminary recommended ecological category)

Indicator Spatial Extent(I)=C-T

Where “C = Ecological Condition of Reporting Year

Where “T = Target Ecological Condition”

It is stated that “It is not feasible to have one target for the whole country due to the diversity of river types in South Africa; based on geomorphological zones (Rowntree et al, 2000), ecoregions (Kleynhans et al. 2005), climate, flow regimes, etc. Thus, the management targets for the ecological condition of rivers will be based on the recommend condition for the river reaches/segments of the country’s network.”

Since this is an additional indictor there are no UN methods to comply with rather a baseline assessment conducted by DWS (2014) using the PES/EIS method.

5.10 Indicator SDG 6.6.1D(1): Change in the Spatial Extent of Water Related Ecosystems including Wetlands, Reservoirs, Lake and Estuaries as a Percentage of Land Area Methodology Review

The SDG 6.6.1D(1) indicator methodology is a stand-alone methodology issued in March 2022. Table 5-11 summarises the methodology developed to date.

Table 5-11: SDG 6.6.1D(1) Indicator Methodology

Indicator		Aim	Methodology
6.6.1.D(1) (UN - 6.6.1.a)	Change in the extent of water-related ecosystems including Wetlands, Reservoirs, Lake and Estuaries as a Percentage of Land Area	To protect and restore water related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.	Percentage change in the surface area of wetlands (vegetated and unvegetated/arid), estuaries, reservoirs and lakes over time from a predefined baseline, expressed as a % of the total land area Percentage of Total Land Area = (Spatial extent of Reservoirs, Estuaries, Wetlands and Lakes/Total Land Area) x 100

5.10.1 Indicator SDG 6.6.1D(1) and Methodology Observations

The methodology follows a different format to most of the indicators compiled. A consistent approach to the indicator methodology development is recommended.

Computation Method

The computational method presented for SDG 6.6.1D(1) provides the computational method proposed to be used for the calculation of spatial extent of water related ecosystems including wetlands, reservoirs, lake and estuaries as a percentage of land area is present, as follows:

Percentage of Total Land Area = (Spatial extent of Reservoirs, Estuaries, Wetlands and Lakes / Total Land Area) x 100

The formula presented differs from the UN calculation of $((\beta-\gamma)/\beta)x100$, commonly used for SDG6.6. Targets. The UN calculation is assumed to be the formula that this indicator intended to follow. Section 4.2 of this report summarises the method proposed by the UN for calculating the change in spatial extent. The formula presented in SDG 6.6.1D(1) differs from the UN calculation and may provide a more representative method for presenting the data, however it is recommended that the UN formula also be included to accommodate the global reporting requirements.

Data Sources

The content of this methodology is limited, and therefore the ability to review the data sources and defensibility of the data collection in relation to the computational method is similarly limited. The information provided in relation to the data sources for this indicator is summarised below/

Surface area is determined based on data from various databases and inventories which have collected data between 2006 -2016. Change is noted to be monitored, in relation to 2016, which is regarded as the set baseline.

The spatial extent of reservoirs is determined based on monitored areas for reservoirs during 2014, 2015 and 2016, representing 4% of the dams in South Africa that have a storage capacity of more than 50 000 cubic metres and a wall height of more than five metres.

5.10.2 Methodology Testing

The baseline and follow up data set for the change in spatial extent of water related ecosystems over time was not included in the methodology. As a result, no calculation testing could be undertaken to verify the computational methods presented.

Management Targets

The following target has been set for the SDG 6.6.1D(1) with the aim stated as follows "By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes".

This target it commendable while being challenging to quantify and therefore achieve. Perhaps this was the intention of the target, and therefore it is recommended that the target be defined as being a progress monitoring target rather than an achievable and quantifiable target. For example how would protection and restoration be quantified, i.e. some work in an area (alien clearing or litter collection?), defining areas as protected areas or nature reserves or observed changes in status of areas, through works undertaken?

5.11 SDG 6.6 Development of Additional Indicator

Domestication of the indicators has allowed South Africa to identify one possible additional indicator based on existing country monitoring programmes.

Additional South African indicators identified during this review process were to be highlighted and would require a process of testing with available data. Based on the review of the methodologies developed to date for South Africa, one possible additional sub-indicator has been identified during this review, for consideration, summarised in Table 5-12.

Table 5-12 Additional SDG 6.6 Methodologies for Consideration

Indicator		Features	UN Global Reporting
6.6.1.(1b) (UN - 6.6.1.a)	Change in spatial extent of water related ecosystems – vegetated wetlands (mangroves)	Surface area Annual and multi-annual changes in mangrove area (2000-2016) Statistics aggregated at national, sub-national & basin scales	In 2020, global data on mangrove extent per country, as a subset of wetlands (coastal wetlands) was also available within the sdg661 data portal and consequently, mangrove data was presented separately. In the coming years as a result of advancing satellite and data production technologies, it is foreseen that disaggregated datasets for other wetland typologies will become available (UN-Water, 2020).

The spatial extent of mangroves is currently incorporated into the SDG 6.6.1D(1b) methodology, however the available data and UN methodologies would appear to provide an opportunity to separate this indicator out from the groupie wetland indicator reporting. There is no particular need to create a separate mangrove methodology, unless this is considered necessary by the particular team involved in the data collection, collation, aggregation and reporting.

6 South African SDG 6.6 Methodology Challenges and Limitations

SDG target 6.6 is a global indicator, which monitors the extent and quality of the water-related ecosystems using global data tools and products. Data gaps associated with national datasets developed through long-term monitoring poses challenges at times. Furthermore, changes in monitoring methodologies of these ecosystems presents challenges for comparing data sets. The use of global data products has made it possible to bridge these gaps associated with the acquisition of data. This duel data gathering system is also beneficial on a national level as countries can incorporate both globally available data and national data to monitor water-related ecosystems.

Indicator SDG6.6.1D (1a)

The UN global methodology for Indicator SDG6.6.1D (1a) (Change in Spatial Extent of Rivers) makes provision for measuring large rivers, however South African rivers are too narrow to be identified using the current satellite imagery and as such can't be measured. The only parameter that can currently be measured is length, which is unlikely to change. This presents a challenge in terms of reporting the spatial extent of rivers. According to Stuart Crane of the UNEP (personal coms. 22 November 2022), the UN is aware of the challenges the current SDG 6.6.1 spatial extent of rivers poses to many countries. As a result, the UN is considering modifying the methodology to utilize rainfall and runoff orientated data to measure the flow in rivers rather than the spatial extent.

Indicator SDG 6.6.1D (1d)

Indicator SDG 6.6.1D (1d) (Change in Spatial Extent of Artificial Systems) presents challenges associated with different versions of dam datasets, including:

- Not all dams are accounted for in the country.
- Dataset accuracy differs, limiting comprehensive national dam reporting.

To assist with addressing these challenges a new baseline has been proposed to be determined by February 2020, to- allow for consistent reporting and accurate comparisons going forward.

A further challenge in relation of target setting for this Indicator SDG 6.6.1D (1d) is associated with the purpose of dams. Dams are designed as storage facilities to be used during dry periods; therefore, dam levels are expected to fluctuate with seasonal use. Setting a target to accommodate change in extent is therefore contrary to their purpose and use.

Indicator SDG 6.6.1D (4)

The data collected for the Indicator SDG 6.6.1D (4) (Change in Groundwater Level Status) presents many challenges due to insufficient and untrained staff collecting data as well as issues in travel and procurement. Furthermore the selection of boreholes to adequately represent the total groundwater situation for an aquifer provides further challenges in order to develop a representative dataset.

Indicator SDG 6.6.1D(3a) and SDG 6.6.1D(3b)

A change to the methodology is proposed, in relation to the baseline calculation whereby, the baseline dataset will be determined as total cumulative flow volume over an identified period of seven 'normal' years. The selection of "normal" years would have been based on a prior determined average. It would therefore be more scientifically correct to rather extend the baseline monitoring period over a longer period, to accommodate a sufficient time period to allow for periodic highs and lows to be normalized.

Typical time frames used in the UN global standardised are monitored over a 5 year time-frame. The proposed variation in time-frame may be confusing or appear to be an omission when comparing to global standardized data sets.

Indicator SDG 6.6.1D(1)

The following target has been set for the SDG 6.6.1D(1) with the aim stated as follows "By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes".

This target it commendable while being challenging to quantify and therefore achieve. Perhaps this was the intention of the target, and therefore it is recommended that the target be defined as being a progress monitoring target rather than an achievable and quantifiable target. For example how would protection and restoration be quantified, i.e. some work in an area (alien clearing or litter collection?), defining areas as protected areas or nature reserves or observed changes in status of areas, through works undertaken?

Calculation Challenges

The UN method of computation, against which many of the indicators are compared provides a calculation of the percentage change of spatial extent, using the following formula:

Percentage change in wetland extent $(\beta-\gamma)/\beta \times 100$

Where β = the spatial wetland extent for the baseline reference period.

Where γ = the spatial extent for the reporting period.

Please note this formula yields percentage change values as either positive or negative, which helps to indicate how spatial area is changing. According to the UN Water Sustainable Development Goal Monitoring Methodology Indicator 6.6.1 “If the value is shown as positive, the statistics represent an area gain while if the value is shown as negative, it represents a loss in surface area.” Using the UN calculation, suggests that the interpretation of the positive and negative figures in this calculation are contrary to the proposed interpretation i.e. a negative value, represents an area gain, while a positive value presents an area loss.

The UN calculation however presents a globally consistent data interpretation calculation and is therefore considered applicable for use from a global reporting perspective. In order to maintain a consistent reporting approach for the indicators; inclusion of the UN calculations is considered pertinent.

The following SDG6.6.1. methodologies contain errors in the UN calculation used or omitted the UN calculation from the methodology:

- Indicator SDG 6.6.1D(1b);
- Indicator SDG 6.6.1D(1c);
- Indicator SDG 6.6.1D(3a) and SDG 6.6.1D(3b);
- Indicator SDG 6.6.1A(1a); and
- Indicator SDG 6.6.1D(1).

Overall Challenges

The overall challenge faced in reporting against the UN SDG 6.6. methodologies is that the historical data sets were largely not compiled for the particular purpose prescribed by the UN. However, the UN SDG 6.6. global reporting provides a platform for the amalgamation of the locally generated data sets into a standardised reporting system. The UN reporting requirements are intended to benchmark countries in the global context, while not necessarily providing data that is immediately useful at a local level.

The domestication of indicators in the South African context allows for the development of useful standardized reporting criteria to provide country wide statistics against which national changes can be assessed, to allow for appropriate responses to be actioned if necessary. The domestication of indicators in South Africa is well advanced, however it is necessary to be selective of the number of indicators developed, to ensure that good quality reporting is possible for all indicators.

7 Target Setting for SDG 6.6 Indicators

According to the UN Integrated Monitoring Guide for SDG 6, Step-by-step monitoring methodology for indicator 6.6.1 on water related ecosystems “The 2030 Agenda for Sustainable Development specifies that all SDG targets “are defined as aspirational and global, with each Government setting its own national targets guided by the global level of ambition but considering national circumstances.”

The global ambition of the Target 6.6 is to “protect and restore” ecosystems (without any numeric specification), and it is up to each country to set their own targets in this regard, i.e., to determine what is an acceptable change in ecosystem extent, quantity and health, and when and how management intervention should be introduced. The Aichi Target for 2020 was to have information from monitoring the indicators for 6.6.1 that could guide countries to manage, protect and restore these ecosystems, in keeping with the Aichi Biodiversity Targets of the Convention of Biological Diversity, which set out a number of objectives for ecosystem management. The three primary Aichi Biodiversity Targets that are of relevance to SDG 6.6.1:

Aichi Target 5

The rate of loss of all natural habitats, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced. Two of the recommended and possible indicators are:

- Sub-indicators UN 6.6.1.a: “Trends in extent of selected biomes, ecosystems and habitats”, and
- Sub-indicators UN 6.6.1.d: “Trends in condition and vulnerability of ecosystems”.

Aichi Target 14

Ecosystems that provide essential services (including services related to water), and contribute to health, livelihoods, and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable. One of the recommended and possible indicators is:

- Sub-indicator UN 6.6.1.b: “Trends in proportion of total freshwater resources used”
  (Also aligns with Indicator SDG 6.4.1 and 6.4.2).

Aichi Target 15

Ecosystem resilience and the contribution of biodiversity to carbon stocks have been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification. One of the recommended and possible indicators is:

- Sub-indicators UN 6.6.1.a and 6.6.1.d: “Status and trends in extent and condition of habitats that provide carbon storage”.

The setting of management targets or objectives for water-related ecosystems extent has become a global priority. While the SDG process sets out to monitor the percentage change in water-related ecosystems extent over time, it will be incumbent on countries to set Targets for this change, to determine what an acceptable change is and when and how management intervention should be introduced.

To assist countries to set targets and objectives for management, Table 7-1 provides a way of considering all ecosystem data relative to the “natural” or reference condition. The method for each sub-indicator and overall 6.6.1 indicator, can be considered in terms of an Ecological Class, which describes the extent of deviation from the natural or reference condition and which in turn can be considered in terms of the implications for the sustainable use of that ecosystem. These categories and the divisions between them are purely subjective but can be used to support management conditions.

Table 7-1 Ecological Classes that show the relation of the ecosystem to its natural condition (UN Step by step monitoring methodology for SDG Indicator 6.6.1, 2017)

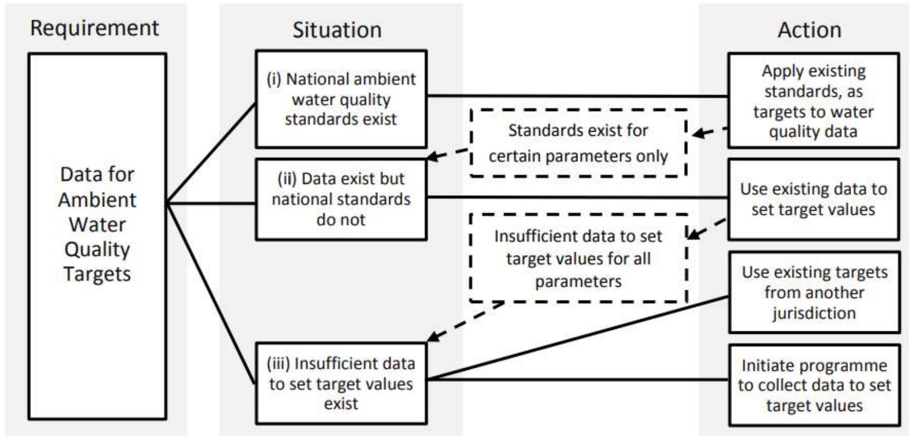
Ecological Class	Description	Deviation from natural	Sustainability
A	Unmodified natural	<10%	Highly sustainable
B	Largely natural with insignificant changes to the ecosystem	>10-20%	Highly sustainable
C	Moderately modified. Loss and change of natural habitat and biota have occurred but the basic ecosystem functions are unchanged	>20-40%	Locally sustainable but threatens global stability
D	Largely modified. A large change to habitat, biota and ecosystem functions has occurred. The ecosystem continues to provide services of value but is no longer representative of the natural situation	>40-60%	Border-line sustainable. Corrective actions are strongly recommended
E	Seriously modified. The loss of habitat, biota and ecosystem function is extensive, and most services are lost to society	>60%	Undesirable Urgent renewal is required

NOTE: The Ecological classes specified in this table do not completely match the DWS system. What is defined at Ecological Class E in this table actually represents Ecological categories E and F in the DWS system.

Table 7-2 summarizes the sub-indicator targets for each of the UN SDG 6.6.1 indicators reflecting possible global and national targets. These targets are purely suggestions to consider while the development of properly derived targets should be part of the global and national agenda.

Table 7-2 Target recommendations for each SDG 6.6.1 Sub-indicator (UN Step by step monitoring methodology for SDG Indicator 6.6.1, 2017)

UN Indicator	Global Target	Proposed National Target
6.6.1	The global aspiration of Target 6.6 is to protect and restore ecosystems (in agreement with Aichi Biodiversity Targets 5,14,15) i.e., there should be no further degradation of water-related ecosystems from the 2017 baseline.	Countries may set their own targets. Two options are available: - Ideally there should be no further degradation of water-related ecosystems from the 2017 baseline. - As in the Aichi Biodiversity Target 5, where countries have economic needs then degradation rates should be at least halved.
6.6.1.A – Spatial Extent	No-net-loss as promoted by the Ramsar Convention. Aichi Biodiversity Target 5 aims to reduce rate of loss almost to zero.	Many countries have set a no-net-loss policy as promoted by Ramsar. Countries may set an alternative target, but this must be justified, and as described by Aichi Biodiversity Target 5, the rate of loss should at least be halved but ideally approach zero. Aichi Biodiversity Target 15 aims to restore 15% of degraded ecosystems that store carbon (wetlands, peat).
6.6.1.B – Quantity of Water	The global ambition is to protect and restore ecosystems, i.e., water withdrawals should not damage the integrity of ecosystems. Aichi Biodiversity Target 5 promotes that habitat loss is reduced to zero (or at least to half), and Target 14 requires that essential ecosystems are restored and safeguarded.	Targets for quantities of water ideally should be established for each river and tributary, for lakes and groundwater, based on priorities in the basin and sub-basin. These should aim to protect the integrity of water-related ecosystems based on their environmental flow requirements. Aichi Biodiversity Targets also apply (5, 14)

UN Indicator	Global Target	Proposed National Target
6.6.1.C – Water Quality		
6.6.1.D – Ecosystem Health	The global ambition is to protect and restore ecosystems. Thus, there should be no reduction of the 2017 baseline. Aichi Biodiversity Target 5 promotes that habitat loss is reduced to almost zero, and Target 14 requires that essential ecosystems are restored and safeguarded.	Targets for the health or state of ecosystems ideally should be established for key river, lakes and for priority wetlands based on priorities in the basin and sub-basin. The guideline presented in Section 5.2 may be used. Aichi Biodiversity Targets also apply (5, 14).

8 Methodology Considerations

From the review of current methodologies that have been implemented for monitoring changes in the extent of water-related ecosystems, it is evident that there are certain limitations that need to be addressed to produce more representative datasets and ensure that these ecosystems are well monitored to sustain them in the long term. To identify possible solutions to these limitations, the methodologies currently in place for indicator 6.6.1 in the United Nations (UN) and United Kingdom (UK) were reviewed. From the review of the methodologies across these different nations, it is evident that the methods involved in monitoring changes in the extent of water-related ecosystems are similar. The basis of these methods involves the derivation of the percentage change in relation to the baseline and current situation of the water bodies. However, while the methodologies are practically the same, differences between the acquisition of the datasets in the UN, UK and SA occur.

8.1 Data Sets

South Africa has domesticated several of the sub-indicators to monitor SDG 6.6.1, however, there is a need for more continuous datasets rather than the provision of statistics at a point in time, to be able to make more representative comparisons with the global datasets. The country can achieve this by collaborating with the UNEP to improve upon the datasets that are produced at a global scale.

In 2020, an innovative platform was launched by UNEP. This platform (Freshwater Ecosystems Explorer) is freely accessible and includes high resolution geospatial datasets for monitoring water-related ecosystems. The platform also provides access to existing national datasets pertaining to these ecosystems. The data can be viewed using geospatial maps; however, the availability of these datasets is dependent on the type of water-related ecosystem that is being analysed. Together with the FEE platform, the Global Surface Water Explorer (GSWE) is also being used in the UN and UK for the acquisition of data for monitoring water-related ecosystems. It was developed by the Joint Research Centre (JRC), UNEP and Google. This platform is similar to the FEE platform, however, the GSWE platform constrains data to official high-water mark boundaries to exclude coastal water estimates and eliminate concerns associated with persistent cloud cover.

While these platforms are useful for the provision of data to monitor changes in the extent of water-related ecosystems, these global datasets are not suitable for South African water bodies. For example, the validation results obtained for the wetlands global dataset showed that the full extent of wetlands, as represented by the global data, underestimated the actual spatial extent of South Africa's wetlands by 87 %. Therefore, this sub-indicator is currently being monitored using nationally derived datasets to represent the country's wetlands more accurately. However, from the UN 2021 progress report, it is expected that improvements will be made in the next two years due to the current concerns with the resolutions of the datasets being used.

8.1.1 Satellite Imagery

Landsat imagery at a 30 m spatial resolution is currently being used to derive data for water-related ecosystems. These images are able to classify large areas of surface water, however, are too coarse to identify smaller water bodies.

The UK carried out an assessment using SPOT imagery with a high resolution of 6 m to evaluate the influence of different resolutions in identifying differently sized water-related ecosystems. In order to assess this, SPOT 6 m imagery was upscaled to 10 m, 20 m and 30 m. It was deduced that the 30 m resolution is too coarse to identify small water bodies. For the 10 m resolution, it was expected that smaller water features will also be identified, which was the case, however, due to the finer resolution detail, other features that have similar reflectance properties such as road networks were being misclassified as water features. The 20 m resolution was the best option as the imagery was able to identify smaller water features than the 30 m resolution and the extent of misclassification is not as much as the 10 m resolution.

Therefore, the 30 m Landsat imagery may have been one of the reasons attributing to the poor representation of South African wetlands when using the global datasets. However, developments are currently taking place to ensure the use of higher resolution Sentinel data together with Landsat imagery for future datasets to produce more accurate outcomes. This may result in more representative and continuous globally available datasets for South Africa's water-related ecosystems.

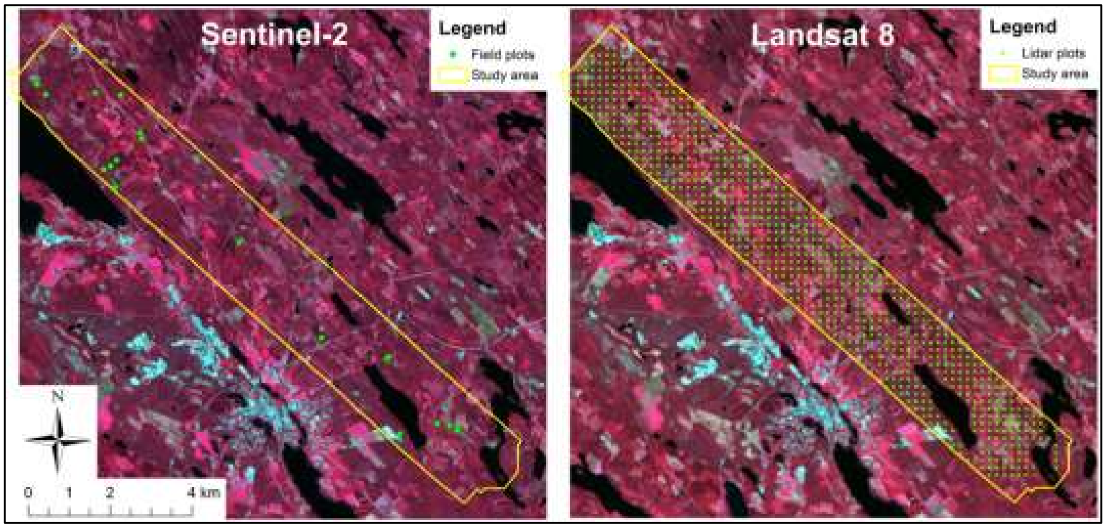


Figure 8-1 Sentinel-2 compared to Landsat 8 Imagery

8.2 Water Quality

With regards to the water quality of these water-related ecosystems, methodologies for monitoring changes in the number of lakes and dams affected by high trophic and turbidity states are still in progress. Currently, the secchi disc depth is being used to obtain measurements for monitoring turbidity of water bodies, however, these measurements will only be available for the areas that have been sampled. For monitoring the trophic status, data is currently generated using the NEMP.

An alternative field method of collecting turbidity date is through the use of telemetry systems. Telemetry is the in situ collection of measurements or other data at remote points and their automatic transmission to receiving equipment for monitoring. This has limitations in relation to the installation and maintenance of the devices, while providing direct field data.

Therefore, the use of satellite-based earth observations acquired from both Landsat and Sentinel imagery is highly recommended. This imagery can be used to derive chlorophyll α (Chl) and total suspended solids (TSS) data. Chl can provide an indication of the extent of eutrophication in water bodies. TSS can be used to determine the extent of sedimentation.

Should a change in methodology be considered appropriate in the future, it is essential to correlate the old and new methodologies through the overlapping sets of observations i.e. Secchi to Satellite imagery, to ensure an ongoing consistent reporting approach.

8.3 Data Efficiency

The use of data platforms that can be used to process and acquire data at a more efficient rate is recommended. The GSWE platform uses Google Earth Engine (GEE) to process datasets. This platform can process large amounts of data within a short space of time and several functions are available to process the data for a desired outcome. For example, the GSWE data is processed using a mask function on GEE to remove pixels that did not produce data due to cloud cover.

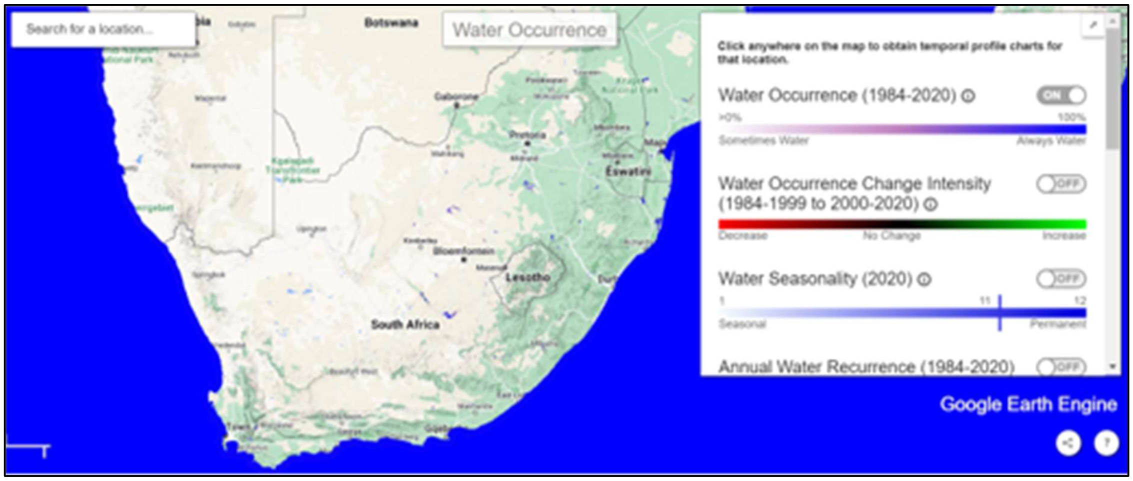


Figure 8-2 GSWE platform

9 Conclusions and Recommendations

The SDG Target 6.6. – Water Related Ecosystems Methodology Report is a well compiled report, incorporating extensive material from both a global and national perspective.

South Africa has extensive datasets developed over many years of work, in relation to water related ecosystems. The challenge faced in reporting against the UN SDG 6.6. methodologies is that the historical data sets were largely not compiled for the particular purpose prescribed by the UN. However, the UN SDG 6.6. global reporting provides a platform for the amalgamation of the locally generated data sets into a standardised reporting system. The combined data sets are therefore comparable in relation to other global data sets, which helps to benchmarking South Africa in the global context.

The South African methodologies generated in relation to SDG 6.6. water related ecosystems, have largely been created based on historical data sets to develop the baseline data set, against which future monitoring updates are compared. These methodologies may require updating as further data is compiled, and should be robust enough to accommodate technological advances, to improve on the reporting efficiencies to supplement historical date reporting systems.

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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