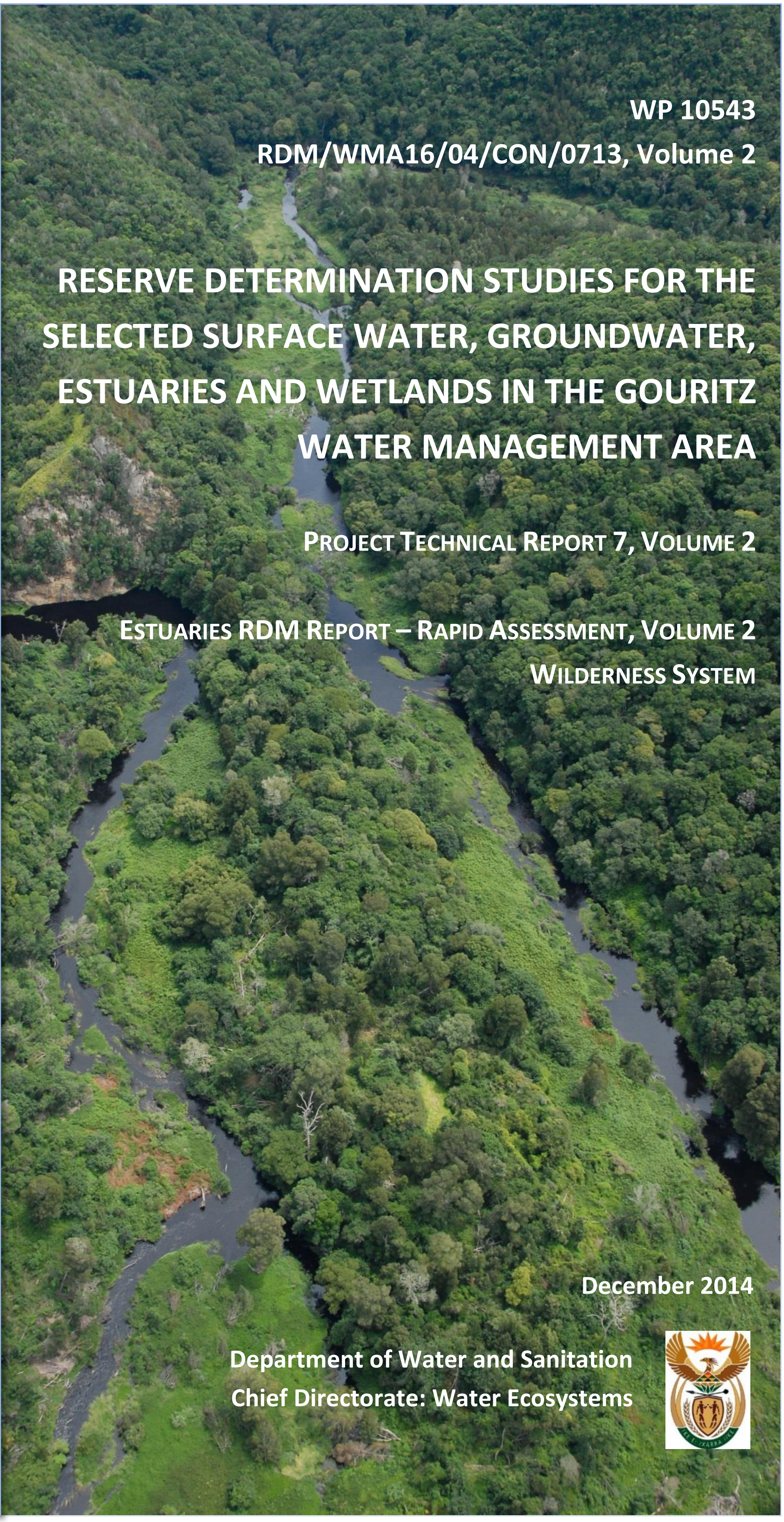

WP 10543
RDM/WMA16/04/CON/0713, Volume 2

RESERVE DETERMINATION STUDIES FOR THE SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE GOURITZ WATER MANAGEMENT AREA

PROJECT TECHNICAL REPORT 7, VOLUME 2

ESTUARIES RDM REPORT – RAPID ASSESSMENT, VOLUME 2
WILDERNESS SYSTEM

December 2014

Department of Water and Sanitation
Chief Directorate: Water Ecosystems

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Private Bag X313
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Tel: +27 (12) 336 7500
Fax: +27 (12) 323 0321

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Compiled by:
Scherman Colloty & Associates cc.
22 Somerset Street
Grahamstown
6139

In association with:
AECOM SA (Pty) Ltd
Waterside Place
South Gate
Tyger Waterfront
Carl Cronje Drive
Bellville
7530

DOCUMENT INDEX

Reports as part of this project:

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Report Number 03, Volume 1	RDM/WMA16/00/CON/0313, Volume 1	Delineation Report, Volume 1 (Groundwater, Estuaries and Wetlands)
Report Number 03, Volume 2	RDM/WMA16/00/CON/0313, Volume 2	Delineation Report, Volume 2 (Rivers)
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Report Number 14	RDM/WMA16/00/CON/1413	Study Closure Report

Bold indicates this report.

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AUTHORS:	Taljaard S; van Niekerk L; Adams J; Snow GC; Wooldridge T; Theron AK; Huizinga P; Lamberth S; Turpie J
EDITOR:	Scherman Colloty and Associates cc.
REVIEWERS:	SAIAB: Angus Paterson; Project Management Team
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Approved for Scherman Colloty & Associates cc.:

Dr Patsy Scherman
Technical Team Leader

Approved for AECOM SA (Pty) Ltd:

Dr Aldu le Grange
Study Leader

Approved for the Department of Water and Sanitation by:

Ms Nancy Motebe
Deputy-Director: Groundwater
Reserve Requirements

Ms Barbara Weston
Deputy-Director: Surface Water
Reserve Requirements

Mr Yakeen Atwaru
Director: Reserve Requirements

Ms Ndileka Mohapi
Chief Director: Water Ecosystems

ACKNOWLEDGEMENTS

The following individuals are thanked for their contributions to this project:

Project Co-ordinators

Yakeen Atwaru	Department of Water and Sanitation	Project Director
Barbara Weston	Department of Water and Sanitation	Project Manager: Surface Water
Nancy Motebe	Department of Water and Sanitation	Project Manager: Groundwater
Thapelo Machaba	Department of Water and Sanitation	Project Co-ordinator

Project Team

Aldu le Grange	AECOM SA (Pty) Ltd	Professional Service Provider Study Leader
Patsy Scherman	Scherman Colloty and Associates	Technical Study Team Leader
Simon von Witt	AECOM SA (Pty) Ltd	Professional Service Provider Study Co-ordinator

Members of Project Steering Committee

Names	**Affiliation**
Ndileka Mohapi	CD: Water Ecosystems (WE)
Yakeen Atwaru	D: Reserve Requirements (RR)
Barbara Weston	D: Surface Water Reserve Requirements (SWRR)
Nancy Motebe	D: Ground Water Reserve Requirements (GWRR)
Thapelo Machaba	D: SWRR
Vuledzani Muthelo	D: RR-SWRR
Gladys Makhado	D: RR
Happy Maleme	D: RR
Wietsche Roets	D: Water Abstraction and Instream Use
Shane Naidoo	D: Water Resources Classification
Vusi Mema	D: Resource Directed Measures Compliance (RDMC)
Boitumelo Sejamoholo	D: RDMC
Manelisi Ndima	D: GWRR
Isa Thompson	DWS: National Planning
Pieter Viljoen	DWS: Water Quality Planning
Mennard Mugumo	DWS: Options Analysis
Fanus Fourie	DWS: Planning Groundwater
Nadene Slabbert	DWS: Resource Quality Services (RQS)
Neels Kleynhans	DWS: RQS
Gerhard CillIers/Nolu Jafta	DWS: RQS
Rashid Khan	DWS Western Cape (WC): Regional Director
Wilna Kloppers	DWS WC: Resource Protection
Andrew Gordon	DWS WC: Resource Protection
Bertrand van Zyl	DWS WC: Operations
John Roberts/Hester Lyons	DWS WC: Gouritz Catchment Manager
Frans Mouski	DWS WC: Hydrology
Mike Smart	DWS WC: Geo-Hydrology
André Roux	Department of Agriculture Western Cape (DAWC)
Danie Swanepoel/ Francois Naude	Department of Environmental Affairs and Development Planning (DEADP)

Names	**Affiliation**
Ian Russell/ Dirk Roux	South African National Parks Board (SANParks)
Greg Palmer/ Andrew Turner/ Pierre de Villiers	CapeNature
Heidi Nieuwoudt	South African National Biodiversity Institute (SANBI)
Jannie van Staden	Breede Overberg Catchment Management Agency (BOCMA)
Vernon Gibbs-Halls	Eden District Municipality
Harold Basson	George Municipality
Alie Killian	Oudtshoorn Municipality
Roy Parry	Knysna Municipality
Johan du Preez	Mossel Bay Municipality
Pikkie Lombard	Bitou Municipality
Reggie Wesso	Hessequa Municipality
Louw Smit/Christopher Wright	Beaufort West Municipality
Richard Fransen/ Heinrich Mettler	Prince Albert Municipality
Jannie Venter	Laingsburg Municipality
Aldu le Grange	AECOM
Simon von Witt	AECOM
Patsy Scherman	SC&A
Cecilia Bester	Agricultural Research Council
Carl Opperman	Agri-Western Cape
Barry Levinrad	Department of Land Affairs
Alwyn Lubbe	Endangered Wildlife Trust
Connie Jonker	Jonkersberg Plantation
Ayanda Matoti	Marine and Coastal Management
Alan Boyd	Marine Protected Area and Estuary Management

AUTHORS

The following persons contributed to this report:

Authors	Company
Adams, Janine	Nelson Mandela Metropolitan University (NMMU)
Huizinga, Piet	Private
Lamberth, Stephen	Department of Agriculture, Fisheries and Forestry (DAFF)
Snow, Gavin	NMMU
Taljaard, Susan	Council for Scientific and Industrial Research (CSIR)
Theron, André	CSIR
Turpie, Jane	Anchor Environmental Consulting
Van Niekerk, Lara	CSIR
Wooldridge, Tris	NMMU

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Second draft	February 2015
Final report	September 2015

EXECUTIVE SUMMARY

GEOGRAPHICAL BOUNDARIES

*For the purposes of the Ecological Water Requirement (EWR) Study, the Wilderness System is subdivided into **two resource units**, namely the **Touw Estuary** and the **Wilderness estuarine lakes (hereafter referred to as the Wilderness Lakes)**.*

The motivation for this is that these two sub-systems function at markedly different spatial and temporal scales. In the case of the Touw Estuary, the system shows strong longitudinal gradients in physico-chemical characteristics (typical of estuaries) while these characteristics are more uniform in the lakes. Also, temporal variability of the hydrodynamics and water quality in the Touw Estuary show stronger intra-annual (e.g. seasonal) variability, while the temporal variability in the lakes shows stronger inter-annual (across years). The geographical boundaries of the system are:

Downstream boundary	*Estuary mouth 33°59'45.56"S, 22°34'51.01"E*
Upstream boundary	*Touw 33°58'26.64"S, 22°36'19.64"* *Rondevlei 33°59'44.69"S, 22°43'7.47"E*
Lateral boundaries	*5 m contour above Mean Sea Level (MSL) along banks*

PRESENT ECOLOGICAL STATUS

*The Estuarine Health Score for the **Touw Estuary** of **68** corresponds to a Present Ecological Status (**PES) of Category C,** while a score of **75** for the **Wilderness Lakes** corresponds to a **PES of Category B/C.** These results suggest that the lakes are under less direct development and fishing pressure and may also be slightly more resilient to the flow reduction and water quality changes affecting this system compared with the estuary:*

Touw Estuary:

Variable	***Weight***	***Score***
Hydrology	*25*	*79*
Hydrodynamics and mouth condition	*25*	*71*
Water quality	*25*	*81*
Physical habitat alteration	*25*	*64*
Habitat health score		***74***
Microalgae	*20*	*53*
Macrophytes	*20*	*70*
Invertebrates	*20*	*55*
Fish	*20*	*60*
Birds	*20*	*70*
Biotic health score		***62***
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		***68***
PRESENT ECOLOGICAL STATUS (PES)		***C***

Wilderness Lakes:

Variable	***Weight***	***Score***
Hydrology	*25*	*79*
Hydrodynamics and mouth condition	*25*	*73*
Water quality	*25*	*79*
Physical habitat alteration	*25*	*80*
Habitat health score		***78***
Microalgae	*20*	*70*
Macrophytes	*20*	*80*
Invertebrates	*20*	*90*
Fish	*20*	*65*
Birds	*20*	*55*
Biotic health score		***72***
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		***75***
PRESENT ECOLOGICAL STATUS (PES)		***B/C***

ECOLOGICAL IMPORTANCE

The importance score of the Wilderness Estuarine System – a score of ***85*** *– translates into an importance rating of* ***'Highly Important"****. The Wilderness System scores high as it is a very important nursery for collapsed and endangered fish species, e.g. Dusky cob and Elf. The system also plays an important role as a waypoint/refuge area for fish along a coast that is known for extreme upwelling events that can cause fish kills. Further, the Wilderness Estuarine System is part of the Garden Route National Park and contributes significantly towards South Africa's overall estuarine biodiversity targets.*

RECOMMENDED ECOLOGICAL CATEGORY

A highly important estuarine system such as the Wilderness System, also being in a protected area should, ideally be managed in a Category A, or at least the Best Attainable State (BAS). The PES of the Wilderness System resembles a Category C (Touw Estuary) and B/C (Wilderness Lakes). By far the most dominant factor determining the PES of this system is the low water levels at which the system is regularly breached to protect low lying development. Any chance of rehabilitating the system to a Category A mostly likely will require the removal of those developments from the estuarine functional zone. Specialists concluded that it may not be realistic to go back to natural breaching levels (i.e. +3.5 m MSL), but that there were certain other, non-flow related impacts on the system that could be mitigated to at least improve the ***Recommended Ecological Category*** *(REC) of the system, both the estuary and lakes, to a* ***Category B****.*

RECOMMENDED ECOLOGICAL FLOW SCENARIO

In the case of the Wilderness System a ***Category B*** *was proposed as the REC. However, a hydrological scenario, increasing inflow above the Present scenario was not considered realistic, given the agricultural demand from water in the catchment (and that the system still receives 85% of its natural MAR). Also, even by hypothetically returning some of the MAR (15%) it will not be possible to improve a PES Category C (in the case of the Touw Estuary) and Category B/C (in the case of the Wilderness Lakes) to a REC of Category B due to the significant impact of other non-flow related factors. In the case of the Wilderness System, mitigation of other non-flow related factors will therefore be required to improve to the REC.* ***However, the present inflow into the systems remains a critical force to maintain open-mouth conditions and further reduction in inflows to the system will increase the contribution of river flow in modification of conditions in the estuary.***

Present total inflow to the system (i.e. presented as the total present inflow into the Wilderness System from adjacent catchments) *is therefore recommended as the recommended ecological water requirement for the Wilderness System:*

%iles	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*
99.9	6.08	9.94	14.20	7.52	7.10	9.69	7.73	7.66	2.78	4.38	9.90	8.85
99	5.65	8.92	6.92	6.77	6.29	7.07	5.69	7.08	1.98	2.98	8.46	8.43
90	3.85	3.50	1.90	1.76	2.10	3.29	1.97	1.63	0.64	1.45	2.16	2.64
80	1.99	1.97	1.14	1.02	0.83	1.88	1.04	0.83	0.43	0.74	0.86	1.18
70	1.04	1.00	0.60	0.55	0.40	1.16	0.50	0.46	0.33	0.35	0.61	0.75
60	0.70	0.56	0.31	0.27	0.27	0.90	0.36	0.29	0.25	0.24	0.45	0.50
50	0.41	0.16	0.06	0.16	0.06	0.51	0.23	0.21	0.21	0.19	0.31	0.33
40	0.27	0.08	0.00	0.04	0.01	0.25	0.17	0.12	0.14	0.10	0.22	0.28
30	0.15	0.02	0.00	0.00	0.00	0.12	0.09	0.07	0.08	0.08	0.16	0.17
20	0.06	0.00	0.00	0.00	0.00	0.01	0.05	0.04	0.03	0.05	0.09	0.10
10	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.06	0.01
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

However, the REC for the Wilderness System (Category B) can only be realised if some non-flow related factors are also improved. Key factors that should be addressed are:

- *Increase breaching level, at least to +2.9 m MSL (currently the system is breached between 2.1-2.4 m MSL). These higher levels match levels experienced during the 2007 and 2011 floods. If the system can be breached at these higher water levels, more sediment will be removed and the system will remain open to the sea for longer periods.*
- *The practice of artificially closing the system when the inlet becomes constricted should also be terminated.*
- *Alien fish and vegetation in the system should be controlled/eradicated.[e.g. establish fishery for alien invasive fish (e.g. design seine for tilapia) and Working for Water].*
- *Interim management measures should be considered to improved connectivity (interlinking channels) between the estuary and lakes, e.g. harvesting excessive macrophyte growth*
- *Terminate ad hoc riparian protection practices along the banks of the estuary and the lakes and consider developing strategic guidelines for bank protection that will be more appropriate for this system.*

The overall confidence of this study is ***Low,*** *mainly because of the low confidence in the hydrology (especially low flows) and the uncertainty about the Reference Condition (breaching levels, duration of mouth closure and bathymetry in the lower estuary). This, in turn affects the confidence of the definition and characterisation of abiotic states which is the primary mechanism by which modification in health condition from the Reference Condition to Present State is determined, together with simulated river runoff scenarios. Due to limited data on other abiotic and biotic components the confidence of most components ranged between low to medium confidence. Even though specialists drew on experience from their collective research on other, related estuarine systems, the complexity of the lake system, as well as the low confidence in the hydrology resulted in a low overall confidence of this study. However, the recommended monitoring programme should focus on improving confidence for future reviews.*

ECOLOGICAL SPECIFICATIONS

Ecological Specifications (EcoSpecs) and associated Thresholds of Potential Concern (TPCs) for the ***Wilderness System (Category B)*** *are presented below:*

Component	***EcoSpecs***	***Thresholds of Potential Concern***
Hydrology	*Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality*	▪ *River inflow distribution patterns differ by more than 5% from that of present day* ▪ *Monthly river inflow < 0.1 m^3/s persists for longer than 20% of the time*
Hydrodynamics	*Maintain intermittent connectivity with marine environment*	▪ *During the open state average tidal amplitude < 30% of present observed data from the water level recorder in the estuary near the mouth* ▪ *Mouth closure > 60% of the time over a 5-year period*

Component	***EcoSpecs***	***Thresholds of Potential Concern***
Sediment dynamics	▪ *Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) for biota* ▪ *No significant changes in sediment grain size distribution patterns for biota* ▪ *No significant change in average sediment composition and characteristics* ▪ *No significant change in average bathymetry* ▪ *Connecting channel bathymetry to be such that adequate flow connectivity is maintained*	▪ *Average sediment composition in any survey (% fractions) along estuary change from that of the Present State (2014 baseline, to be measured) by 30%* ▪ *Average sediment composition in any survey (% fractions) in each of the lakes change from that of the Present State (2014 baseline, to be measured) by 5%* ▪ *Average bathymetry along main channel change by 30% in any survey along estuary from that of the Present State (2014 baseline, to be measured) (system expected to significantly fluctuate in terms of bathymetry between flood and extended closed periods)* ▪ *Average bathymetry change by 2 to 5% in any survey in each of the lakes from that of the Present State (2014 baseline, to be measured)* ▪ *Average bathymetry along connecting channels to be maintained (average depth threshold to be determined following a baseline monitoring survey)*
Water quality	*Salinity*	*Estuary in the closed state:* ▪ *Average salinity in Zone A < 12* ▪ *Average salinity in Zone B: < 10* ▪ *Average salinity in Zone C < 5* *Lakes average salinity +2 from baseline (2013) and variability do not increase as below:* ▪ *Serpentine: 12 ± 10* ▪ *Eilandvlei: 8 ± 5* ▪ *Langvlei: 10 ±4* ▪ *Rondevlei: 10 ±5*
	System variables (pH, dissolved oxygen and turbidity) not to cause exceedance of TPCs for biota (see below)	*River inflow:* ▪ *6.0 < pH > 7.0 (Touw)* ▪ *7.0 < pH > 8.0 (Duiwe)* ▪ *Dissolved oxyxgen (DO) < 5 mg/ℓ* ▪ *Suspended solids > 5 mg/ ℓ (low flow)* *Estuary:* ▪ *Average turbidity > 5 NTU (low flow)* ▪ *Average 6.0 < pH > 8.5 (increasing with increase in salinity)* ▪ *Average DO < 5 mg/ℓ* *Lakes:* ▪ *Average turbidity > 5 NTU* ▪ *Average 7.0 < pH > 8.5* ▪ *Average DO < 5 mg/ℓ*

Component	EcoSpecs	Thresholds of Potential Concern
	Inorganic nutrient concentrations (NO_3-N, NH_3-N and PO_4-P) not to cause an exceedance of TPCs for macrophytes and microalgae (see below)	*River inflow:* ▪ *NO_x-N > 50 µg/ℓ over two consecutive months* ▪ *NH_3-N > 10 µg/ℓ over two consecutive months* ▪ *PO_4-P > 10 µg/ℓ over two consecutive months* *Estuary (except during upwelling or floods):* ▪ *Average NO_x-N > 50 µg/ℓ single concentration > 100 µg/ℓ* ▪ *Average NH_3-N > 10 µg/ℓ during survey, single concentration > 100 µg/ℓ* ▪ *Average PO_4-P > 10 µg/ℓ during survey, single concentration > 50 µg/ℓ* *Lakes:* ▪ *Average NO_x-N > 50 µg/ℓ during survey, single concentration > 100 µg/ℓ* ▪ *Average NH_3-N > 20 µg/ℓ during survey (to be confirmed)* ▪ *Average PO_4-P > 20 µg/ℓ during survey (to be confirmed)*
	Presence of toxic substances (e.g. trace metals and pesticides/herbicides) not to cause exceedance of TPCs for biota (see below)	*River inflow:* • *Trace metals (to be confirmed)* • *Pesticides/herbicides (to be confirmed)* *Estuary:* ▪ *Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995)* ▪ *Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)*
Microalgae	▪ *Maintain low median phytoplankton biomass* ▪ *Maintain medium median benthic microalgal biomass* ▪ *Prevent formation of phytoplankton blooms* ▪ *Prevent dramatic shift of phytoplankton community structure*	▪ *Median phytoplankton chlorophyll a (minimum five sites) exceeds 3.5 µg/ℓ during any survey* ▪ *Median intertidal benthic chlorophyll a (minimum five sites) exceeds 23 mg/m^2 during any survey* ▪ *Site specific chlorophyll a concentration exceeds 20 µg/ℓ and/or cell density exceeds 10 000 cells/ml during any survey* ▪ *Dinoflagellates, cyanobacteria and/or chlorophytes > 10% of relative abundance during any survey*
Macrophytes	▪ *Maintain the distribution of sensitive macrophyte habitats (e.g. salt marsh, submerged macrophytes)* ▪ *No invasive plants* ▪ *Prevent the spread of reeds into open water*	▪ *Greater than 20% change in the area covered by submerged macrophytes and salt marsh due to disturbance, freshening of the system and changes in turbidity* ▪ *Presence of invasive floating aquatic macrophytes* ▪ *Invasive plants cover > 5% of total floodplain area.* ▪ *Increase in reeds & sedges and encroachment into main water channel due to infilling and drop in water level*

Component	***EcoSpecs***	***Thresholds of Potential Concern***
Invertebrates	▪ *Maintain presence of sand prawn Callichirus kraussi on sand banks in lower Touw Estuary* ▪ *Maintain rich populations of the benthic amphipod Grandidierella lignorum throughout the lakes and estuary*	*Populations should not deviate from average baseline values (as determined in first three visits) by more 30%*
Fish	*Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the Reference (see 2015 EWR report). Relative proportions should be roughly similar to that currently in the Touw Estuary and Wilderness Lakes. Numerically, assemblage should comprise:* ▪ *Ia estuarine residents (20-60% of total abundance)* ▪ *Ib marine and estuarine breeders (20-60%)* ▪ *IIa obligate estuarine-dependent (5-10%)* ▪ *IIb estuarine associated species (1-10%),* ▪ *IIc marine opportunists (5-20%)* ▪ *III marine vagrants (not more than 5%)* ▪ *IV indigenous fish (1-5%)* ▪ *V catadromous species (1-5%)* *Category Ia species should contain viable populations of at least 4 species (including G.aestuaria, Hyporamphus capensis, Omobranchus woodii).* *Category IIa obligate dependents should be well represented by large exploited species especially A. japonicus, L. lithognathus, P. commersonii, Lichia amia.* *REI species dominated by both Myxus capensis and G. aestuaria.*	▪ *Ia estuarine residents < 20%* ▪ *Ib marine and estuarine breeders < 20%* ▪ *IIa obligate estuarine-dependent < 5%* ▪ *IIb estuarine associated species < 1%* ▪ *IIc marine opportunists < 5%* ▪ *III marine vagrants > 5%* ▪ *IV indigenous fish < 1%* ▪ *V catadromous species < 1%* ▪ *Ia represented only by G. aestuaria.* ▪ *IIa exploited species in very low numbers or absent* ▪ *REI species represented only by G. aestuaria, Myxus capensis absent*

Component	*EcoSpecs*	*Thresholds of Potential Concern*
Birds	*The estuarine lake system should contain a diverse avifaunal community that includes representatives of all the original groups, and that sustains the populations for which the system has acquired Ramsar status*	*Numbers of waterbirds on the entire system, other than those that have or are increasing regionally such as Egyptian Goose, drops below 40 species or below 1500 birds for three consecutive counts*

BASELINE AND LONG-TERM MONITORING PROGRAMMES

The following additional baseline surveys are required to improve the confidence of the Ecological Water Requirement (EWR) study (priority components are highlighted):

Component	*Action*	*Temporal scale (frequency and when)*	*Spatial scale (Stations)*
Sediment dynamics	*Monitoring berm height using appropriate technologies*	*Quarterly*	*Mouth*
	Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 300 m intervals, but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm	*Once-off*	*Entire estuary* *All three connecting channels*
	Bathymetric survey lines extending from the entrance of the western connecting channel to the entrance of the eastern connecting channel (or eastern bank), as well as a survey line from the southern to northern banks through the approximate centre of each lake	*Once-off*	*Each of the three lakes (exact position of survey lines to be confirmed during baseline survey)*
	Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations)	*Once-off*	*Entire estuary and each of the three lakes*
Water quality	*Collect samples for herbicides and pesticides in river inflow*	*Once-off*	*Near head of estuary in:* *Touw River (station K3H5)* *Duiwe River (station K3H11)* *Langspruit River*

Component	**Action**	**Temporal scale (frequency and when)**	**Spatial scale (Stations)**
	Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – see Newman and Watling, 2007)	*Once-off*	*Entire estuary and lakes, including depositional areas (i.e. muddy areas)*
	Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, dissolved oxygen and turbidity profiles	*Quarterly, preferably over two years*	*Entire estuary (nine stations)* *All lakes and connecting channels (including stations in deeper middle, and shallower peripheral areas of lakes)*
Microalgae	▪ *Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae.* ▪ *Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC, fluoroprobe.* ▪ *Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.*	*Quarterly, preferably over two years*	*Entire estuary (minimum three stations)* *All lakes, including stations in deeper middle, and shallower peripheral areas of lakes (minimum five stations each)*
Macrophytes	▪ *Ground-truthed maps to update changes over time in emergent vegetation after the SANParks 1997 assessment (Russell 2003).* ▪ *Measurement of area covered by submerged macrophytes, SANParks annual field assessment to be included in vegetation map.* ▪ *Assess and map extent of invasive plants within the 5 m contour line*	*Once-off*	*Entire estuary and lakes*

Component	Action	Temporal scale (frequency and when)	Spatial scale (Stations)
Invertebrates	- *Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 um mesh) along estuary* - *Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 um).* - *Collect sled samples (day) at same zooplankton sites for hyper benthos (190 um)* - *Intertidal invertebrate hole counts using 0.25 m^2 grid (5 replicates per site). Establish the species concerned using a prawn pump. Check for the presence of mudprawn in muddy intertidal substrate in thye lower estuary* - *Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton)*	*Quarterly, preferable over two years*	*Minimum of three sites along length of entire estuary and one site in each of the lakes* *For hole counts – three sites in Touw Estuary near the N2 bridge.*

The recommended monitoring programme, to test for compliance with TPCs is as follows (priority components are highlighted):

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (Stations)
Hydrodynamics	*Record water levels*	*Continuous*	*Touw Estuary (station K3T006)* *Eilandvlei (station K3R005)* *Langvlei (station K3R004)* *Rondevlei (station K3R003)*
	Measure freshwater inflow into the estuary	*Continuous*	*Near head of estuary in:* *Touw River (station K3H005)* *Duiwe River (station K3H011)* *Langspruit River*
	Aerial photographs or high resolution satellite imagery (5 x 5 m) of estuary	*Every three years*	*Entire estuary*
Sediment dynamics	*Monitoring berm height using appropriate technologies*	*Quarterly*	*Mouth*

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (Stations)
	Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 300 m intervals, but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm	*Every three years (and after large resetting event)*	*Entire estuary* *All three connecting channels*
	Bathymetric survey lines extending from the entrance of the western connecting channel to the entrance of the eastern connecting channel (or eastern bank), as well as a survey line from the southern to northern banks through the approximate centre of each lake	*Every three years (and after large resetting event)*	*Each of the three lakes (exact position of survey lines to be confirmed during baseline survey)*
	Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations)	*Every three years*	*Entire estuary and each of the three lakes*
Water quality	*Collect data on conductivity, temperature, suspended matter/turbidity, dissolved oxygen, pH, inorganic nutrients and organic content in river inflow*	*Monthly, continuous*	*Near head of estuary in:* *Touw River (K3H5)* *Duiwe River (K3H11)* *Langspruit River* *Also in Lakes:* *Eilandvlei (K3R005)* *Langvlei (K3R004)* *Rondevlei (K3R003)*
	Collect in situ continuous salinity data with mini CTD probe at a depth of about 1 m	*Continuous*	*Six sites - at the mouth, ebb and flow, head of the estuary, Eilandvlei, Langvlei and Rondevle*
	Collect samples for herbicides and pesticides in river inflow	*Every 3 – 6 years*	*Near head of estuary in:* *Touw River (K3H5)* *Duiwe River (K3H11)* *Langspruit River*
	Record in situ salinity, temperature, pH, DO, turbidity profiles	*Seasonally, every year*	*Entire estuary (nine stations)* *All lakes and connecting channels (including stations in deeper middle, and shallower peripheral areas of lakes)*

Component	**Monitoring action**	**Temporal scale (frequency and when)**	**Spatial scale (Stations)**
	Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, dissolved oxygen and turbidity profiles	*Every three years (high flow and low flow) or when significant change in WQ expected*	*Entire estuary (nine stations)* *All lakes and connecting channels (including stations in deeper middle, and shallower peripheral areas of lakes)*
	Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – see Newman and Walting, 2007)	*Every 3 – 6 years*	*Entire estuary, including depositional areas (i.e. muddy areas)*
Microalgae	▪ *Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae.* ▪ *Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC, fluoroprobe.* ▪ *Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe*.	*Every three years during low flow*	*Entire estuary (minimum three stations)* *All lakes, including stations in deeper middle, and shallower peripheral areas of lakes (minimum five stations each)*
Macrophytes	*Map the area covered by the different macrophyte habitats. Compile a species list and check for expansion of invasive plants, reed, sedge and grass areas.*	*Summer surveys every three years*	*Entire estuary and lakes*
	SANParks to continue their monitoring including that of submerged macrophytes which includes four littoral transects around each lake and five transects in the Touw Estuary for biomass measurements. At the same time assessments of area covered should be made.	*Bi-annually*	*Entire estuary and lakes*

Component	***Monitoring action***	***Temporal scale (frequency and when)***	***Spatial scale (Stations)***
Invertebrates	▪ *Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 um mesh) along estuary* ▪ *Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 um).* ▪ *Collect sled samples (day) at same zooplankton sites for hyper benthos (190 um)* ▪ *Intertidal invertebrate hole counts using 0.25* m^2 *grid (five replicates per site). Establish the species concerned using a prawn pump. Check for the presence of mudprawn in muddy intertidal substrate in thye lower estuary* ▪ *Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton)*	*Every two years mid-summer*	*Minimum of three sites along length of entire estuary and one site in each of the lakes* *For hole counts – three sites in Touw Estuary near the N2 bridge.*
Fish	*As per SANParks detailed monitoring programme*		
Birds	*Undertake counts of all water associated birds, identified to species level.*	*Continued winter and summer counts.* *A series of monthly counts carried out for two years each decade*	*Entire system, divided into its component sections (estuary, serpentine, three lakes)*

The recommended interventions, as well as the implementation of the monitoring programme should be undertaken in collaboration with various responsible departments in Department of Water And Sanitation (DWS), as well as other national and provincial departments and institutions responsible for estuarine resource management such as Department of Agriculture Forestry and Fisheries (DAFF), Department of Environmental Affairs (DEA: Oceans and Coasts) and South African National Parks (SANParks) authorities. It is recommended that the estuarine management planning process and the associated institutional structures (as required under the Integrated Coastal Management Act, 2008) be used as a mechanisms through which to facilitate the implementation these interventions.

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ACRONYMS AND ABBREVIATIONS

BAS	Best Attainable State
CSIR	Centre of Scientific and Industrial Research
CTD	Conductivity-Temperature-Depth
CWAC	Coordinated Waterbird Counts
DAFF	Department of Agrculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphate
DO	Dissolved Oxygen
DRS	Dissolved Reactive Silicate
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EcoSpecs	Ecological Specifications
EHI	Estuarine Health Index
EIS	Estuarine Importance Score
EWR	Ecological Water Requirement
GPS	Global Positioning System
GRDS	Gouritz Reserve Determination Study
H	High
L	Low
M	Medium
MAR	Mean Annual Runoff
MPB	Microphytobenthos
MSL	Mean Sea Level
NMMU	Nelson Mandela Metropolitan University
NBA	National Biodiversity Assessment
NTU	Nephelometric Turbidity Units
NWA	National Water Act (1998)
PES	Present Ecological Status
RDM	Resource Directed Measures
REC	Recommended Ecological Category
REI	River Estuary Interface
SA	South Africa
SC&A	Scherman Colloty & Associates cc
SANBI	South African National Biodiversity Institute
TPC	Threshold of Potential Concern
UNEP	United Nations Environmental Programme
VL	Very Low
WIO	Western Indian Ocean
WMA	Water Management Area
WQ	Water Quality
WRC	Water Research Commission
%ILE	Percentile

1 INTRODUCTION

1.1 ECOLOGICAL WATER REQUIREMENT METHOD FOR ESTUARIES

Methods to determine the Environmental Water Requirement (EWR) of estuaries were established soon after the promulgation of the National Water Act (No. 36 of 1998) (NWA). The so-called "Preliminary Reserve Method" involves setting a Recommended Ecological Category (REC) (i.e. desired state), recommended Ecological Reserve (i.e. flow allocation to achieve the desired state) and Ecological Specifications (EcoSpecs) for a resource on the basis of its present health status and its ecological importance. The method follows a generic methodology which can be carried out at different levels (e.g. Rapid, Intermediate or Comprehensive). The official method for estuaries (Version 2) is documented in DWAF (2008). Currently a Version 3 of the method is in preparation as part of a Water Research Commission (WRC) study (Turpie *et al*., in prep.). Pending the official approval of Version 3 by the Department of Water and Sanitation (DWS), Version 2 is still applied in this study (DWAF, 2008), but considers obvious improvements proposed in Version 3. Currently, the official suite of "Preliminary Reserve Methods" for estuaries does not include a Desktop assessment method. However, a Desktop approach for assessing estuary health in data-poor environments was recently applied successfully in the National Biodiversity Assessment 2011 (NBA 2011) (Van Niekerk and Turpie, 2012). This method has since been refined in a WRC study (Van Niekerk *et al.*, 2014) and was also applied in this Gouritz Reserve Determination Study (GRDS), where considered appropriate.

For management and improved governance reasons, South Africa's 19 water management areas have been consolidated into nine (9) WMAs. The Gouritz WMA (previously WMA16) now forms part of the Breede WMA (WMA8) and is known as the Breede-Gouritz WMA. It will be governed by the Breede-Gouritz Catchment Management Agency (CMA).

Within the time and budgetary constraints it was not possible to conduct the preliminary Reserve determination studies on the estuaries of the Gouritz Water Management Area (WMA) at a high confidence. Instead a "best attainable" approach was adopted to assess as many estuaries as possible within the available budgetary framework. In selecting the level of Reserve (i.e. Intermediate, Rapid or Desktop) for various estuaries, systems were prioritised in terms of the degree to which they were already water stressed or had major future abstraction pressures. Also, their protected status or desired protected status (NBA 2011) was taken into account. Using this rating system, the Goukou, Gouritz and Duiwenhoks estuaries showed highest priority (best attainable: Intermediate level) followed by the Klein Brak and Wilderness estuaries (best attainable: Rapid level). The Hartenbos, Blinde, Piesang, Groot (Wes) and Bloukrans estuaries clustered as the lowest rated systems (best attainable: Desktop assessment). This report presents the **Rapid level assessment on the Touw Estuary and Wilderness Lakes (Wilderness System),** including a field measurement programme and data summary reports.

The generic steps of the official "Ecological Reserve Method" for estuaries were applied as follows:

Step 1: Initiate study defining the study area, project team and level of study (confirmed in the GRDS **Inception Report**; DWA, 2013).

Step 2: Delineate the geographical boundaries of the resource units (confirmed in the GRDS **Delineation Report**; DWA, 2013).

Step 3a: Determine the **Present Ecological Status** (PES) of resource health (water quantity, water quality, habitat and biota) assessed in terms of the degree of similarity to the Reference Condition (referring to natural, unimpacted characteristics of a water resource, and must represent a stable baseline based on expert judgement in conjunction with local knowledge and historical data). An Estuarine Health Index (EHI) is used (see **Section 5**).

The Estuary Health Index (EHI) score, in turn, corresponds to an Ecological Category that describes the health using six categories, ranging from natural (A) to critically modified (F) (**Table 1.1**). The A to F scale represents a continuum, where the boundaries between categories are conceptual points along the continuum. To reflect this, straddling categories (+/- 3 from the category scoring range) were therefore introduced in this study, denoted by A/B, B/C, C/D, and so on.

Table 1.1 Translation of EHI scores into ecological categories

EHI Score	PES	General description
91 – 100	A	**Unmodified**, or approximates natural condition; the natural abiotic template should not be modified. The characteristics of the resource should be determined by unmodified natural disturbance regimes. There should be no human induced risks to the abiotic and biotic maintenance of the resource. The supply capacity of the resource will not be used.
76 – 90	B	**Largely natural with few modifications.** A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged. Only a small risk of modifying the natural abiotic template and exceeding the resource base should not be allowed. Although the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a very limited number of localities may be slightly higher than expected under natural conditions, the resilience and adaptability of biota must not be compromised. The impact of acute disturbances must be totally mitigated by the presence of sufficient refuge areas.
61 – 75	C	**Moderately modified.** A loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. A moderate risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the wellbeing and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities. However, the impact of local and acute disturbances must at least be partly mitigated by the presence of sufficient refuge areas.

EHI Score	PES	General description
41 – 60	D	**Largely modified**. A large loss of natural habitat, biota and basic ecosystem functions has occurred. Large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risk to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may be allowed to generally increase substantially with resulting low abundances and frequency of occurrence, and a reduction of resilience and adaptability at a large number of localities. However, the associated increase in the abundance of tolerant species must not be allowed to assume pest proportions. The impact of local and acute disturbances must at least to some extent be mitigated by refuge areas.
21 – 40	E	**Seriously modified.** The loss of natural habitat, biota and basic ecosystem functions is extensive.
0 – 20	F	**Critically modified.** Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

Step 3b: Determine the **Estuary Importance Score (EIS)** that takes into account the size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary (see **Section 6**).

Step 3c: Set the **Recommended Ecological Category (REC)** which is derived from the PES and EIS (or the protection status allocated to a specific estuary) (see **Section 6**).

An estuary cannot be allocated an REC below a category “D”. Therefore systems with a PES in categories ‘E’ or ‘F’ needs to be managed towards achieving at least a REC of “D”.

Step 4: **Quantify the Ecological Consequences of various runoff scenarios** (including proposed operational scenarios) where the predicted future condition of the estuary is assessed under each scenario. As with the determination of the PES, the EHI is used to assess the predicted condition in terms of the degree of similarity to the Reference Condition.

Step 5: Quantify the (recommended) **Ecological Water Requirements** which represent the lowest flow scenario that will maintain the resource in the REC.

Step 6: **EcoSpecs** for the recommended REC, as well as **additional baseline and long-term monitoring requirements** to improve the confidence of the EWR and to test compliance with EcoSpecs.

1.2 DEFINITION OF CONFIDENCE LEVELS

The level of available historical data in combination with the level of effort expended during the assessment determines the level of confidence of the study. Criteria for the confidence limits attached to statements in this study are:

Confidence level	Situation	Expressed as percentage
Very Low	No data available for the estuary or similar estuaries	(i.e. < 40% certain)
Low	Limited data available	40 – 60% certainty
Medium	Reasonable data available	60 – 80% certainty
High	Good data available	> 80% certainty

In the case of a Desktop assessment study the confidence levels generally falls in the “very low” to “low” categories.

1.3 SPECIALIST TEAM

The following specialists comprised the core Wilderness Lakes System study team:

Specialist	Affiliation	Area of responsibility
Dr S Taljaard	CSIR, Stellenbosch	Project co-ordinator/Water quality
Ms L van Niekerk	CSIR, Stellenbosch	Hydrodynamics
Mr A K Theron	CSIR, Stellenbosch	Sediment dynamics, abiotic morphology
Mr P Huizinga	Private Consultant	Hydrodynamics (advisory role)
Dr G Snow	Nelson Mandela Metropolitan University	Microalgae
Prof J Adams	Nelson Mandela Metropolitan University	Macrophytes
Prof T Wooldridge	Nelson Mandela Metropolitan University	Invertebrates
Dr S Lamberth	DAFF	Fish
Dr J Turpie	Anchor Environmental Consultants	Birds

Contributions were also received from:

- Chantel Peterson (CSIR) – hydrodynamic component;
- Nuette Gordon (NMMU) – macrophyte component;
- Nompumelelo Thwala (NMMU/National Research Foundation) – invertebrate component;
- Kyle Smith (SANParks) – fish component; and
- Alexis Olds (CapeNature) – fish component.

1.4 ASSUMPTIONS AND LIMITATIONS FOR THIS STUDY

The following assumptions and limitations should be taken into account:

- The Wilderness is a very complex system compared with others estuaries in this WMA. It requires long-term detailed data sets to even meet requirements of an Intermediate confidence.

It was therefore proposed that for the present study a Rapid assessment be undertaken (including one field survey) and that this new data be consolidated with historical data on the system to provide a first, best estimate of the present ecological status, but that the monitoring plan specifically addresses the long-term monitoring requirements necessary to improve the confidence.

- The accuracy and confidence of an Estuarine Ecological Water Requirements study is strongly dependant on the **quality of the simulated hydrology**. The overall confidence in the hydrology supplied is of a very low level (< 40).
- A detailed flood analysis was not conducted as it is not a requirement for a Rapid level assessment. The simulated runoff data were used to estimate flood conditions.
- A Rapid level assessment is typically undertaken with available data. However, for this study a field survey was included to provide additional understanding on this complex system. The reader is referred to the Specialist summary reports for a summary of available data.
- For the purposes of the EWR study, the Wilderness System is subdivided into two resource units, namely the Touw Estuary and the Wilderness estuarine lakes (hereafter referred to as the Wilderness Lakes). The motivation for this is that these two sub-systems function at markedly different spatial and temporal scales. In the case of the Touw Estuary, the system shows strong longitudinal gradients in physico-chemical characteristics (typical of estuaries) while these characteristics are more uniform in the lakes. Also, temporal variability of the hydrodynamics and water quality in the Touw Estuary show stronger intra-annual (e.g. seasonal) variability, while the temporal variability in the lakes shows stronger inter-annual (across years).
- A Rapid level assessment can only be used for individual licensing for small impacts in unstressed catchments of low importance and sensitivity. For individual licensing in important, unstressed systems an Intermediate level assessment is required, while a comprehensive level assessment is required for individual licensing for large impacts in any catchment (e.g. dams), as well as small or large impacts in very important and/or sensitive catchments (DWAF, 2008).

1.5 STRUCTURE OF THIS REPORT

The report is structured as follows:

Section 1	provides an overview of EWR methods, confidence of the study and study team.
Section 2	provides important background information related to the hydrological characteristics, catchment characteristics and land-use, as well as human pressures affecting the estuary.
Section 3	defines the geographical boundaries of the study area, as well as the zoning and typical abiotic states adopted for this estuary.
Section 4	provides a baseline ecological and health assessment of the estuary. It describes each of the abiotic and biotic aspects of the estuary – from hydrology to birds – describing understanding of the present situation and estimation of the Reference Condition. The health state of each component is computed using the EHI.
Section 5	describes the overall state of health (or present ecological status) of the estuary. It also summarises the overall confidence of the study and the degree to which non-flow factors have contributed to the degradation of the system.

Section 6	combines the EHI score with the Estuarine Importance Score (EIS) for the system to determine the REC.
Section 7	describes the ecological consequences of various future flow scenarios, and determines the Ecological Category for each of these using the EHI.
Section 8	concludes with recommendations on the ecological water requirements for the estuary, as well as EcoSpecs. Finally, additional baseline and long-term monitoring requirements to improve the confidence of the EWR assessment and to test compliance with EcoSpecs are provided.

Appendices include:

A:	Data summary report: Bathymetry and Hudrodynamics
B:	Data summary report: Sediment dynamics
C:	Data summary report: Water quality
D:	Data summary report: Microalgae
E:	Data summary report: Macropghytes
F:	Data summary report: Invertebrates
G:	Data summary report: Fish
H	Data summary report: Birds
I:	Comments and response register.

2 BACKGROUND INFORMATION

2.1 CATCHMENT CHARACTERISTICS AND LAND-USE

The Wilderness System is fed by three catchments, namely the Touw, Duiwe and Langvlei Spruit catchments. The Touw River catchment is the largest (approximately 89 km^2), followed by the Duiwe River catchment (33 km^2) and Langvlei Spruit catchment (approximately 18 km^2). All three rivers flow predominantly over Table Mountain Sandstones, with a substantial part of the Duiwe catchment also comprising. The dominant land-use types in combined catchment area include (**Figure 2.1):**

- 38% (light brown) scrubland and low fynbos;
- 22% (beige) thicket, bush clumps and high fynbos;
- 10% (pink) forest plantation (Pine);
- 5% (dark green) Forest (indigenous);
- 5% Planted grassland;
- 4% (bright green) cultivated, temporarily commercial dryland.

2.2 HUMAN ACTIVITIES AFFECTING THE WILDERNESS SYSTEM (PRESSURES)

Human activities affecting the estuary is summarised in **Tables 2.1** and **2.2** for pressures relating to flow modification and non-flow related pressures, respectively.

Table 2.1 Pressures related to flow modification

Activity	Present	Description of impact
Water abstraction and dams (including farm dams)	✓	Water abstraction affects mainly base flow to these systems
Augmentation/Inter-basin transfer schemes		
Infestation by invasive alien plants	✓	These infestation affects base flow and threatens natural fauna and flora
Forestation	✓	Forestation has high water demand that affects mainly base flow

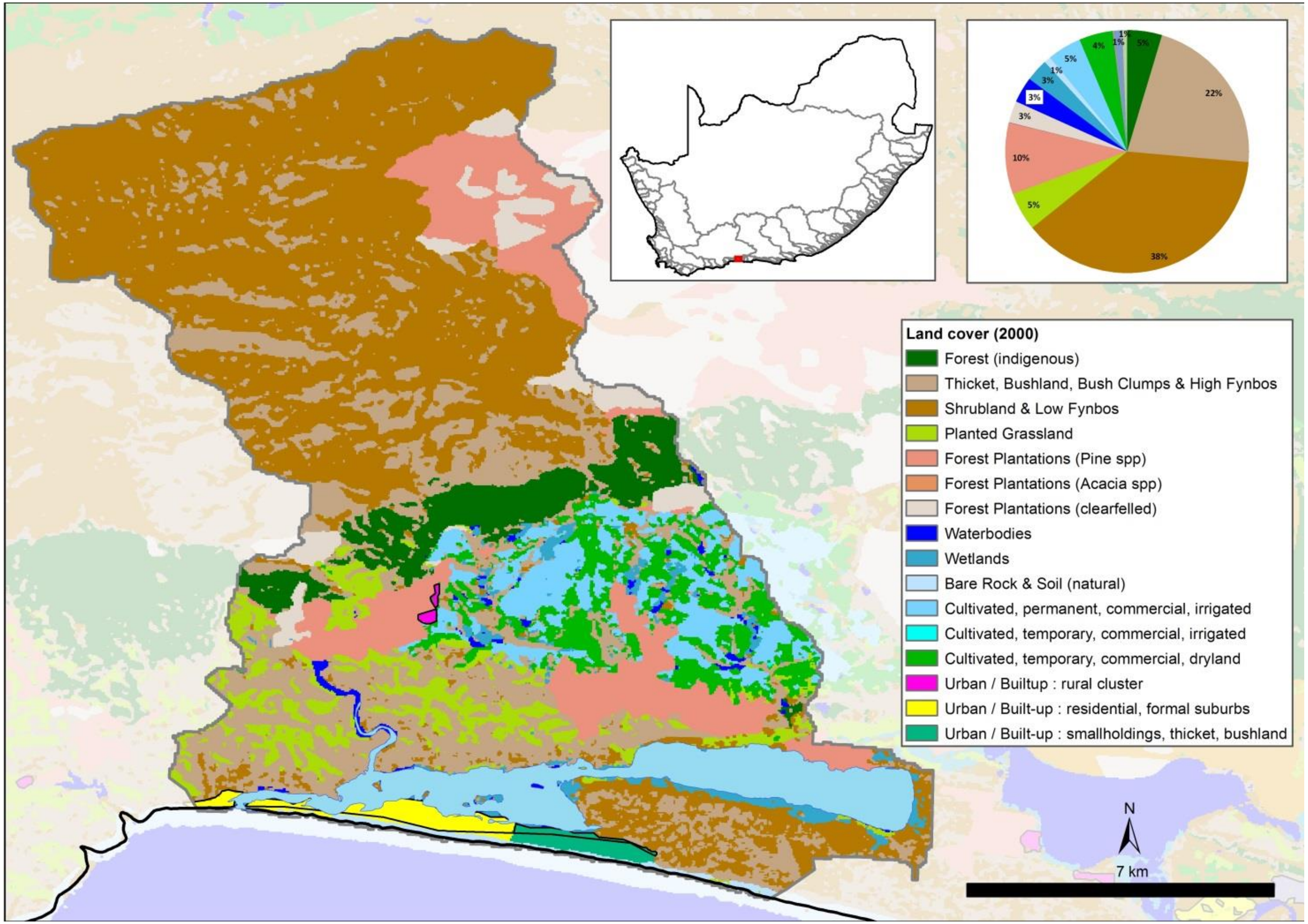


Figure 2.1 Catchment of the Wilderness System, as well as dominant land-use distribution

Table 2.2 Pressures, other than modification of river inflow presently affecting estuary

Activity	Present	Description of impact
Agricultural and pastoral run-off containing fertilisers, pesticides and herbicides	✓	The Duiwe catchment extensive agricultural activities that affect water quality and sedimentation
Municipal waste (including sewage disposal)/infrastructure problems		
Bridge(s) and culverts	✓	There are a number of bridges and culverts in the system, including the N2 bridge at the mouth
Artificial mouth manipulation	✓	The Touw Estuary currently breaches at levels between 2.1 and 2.4 m MSL to prevent flooding. The estuary mouth is also artificially closed when it becomes constricted to reduce sedimentation.
Bank stabilisation and destabilisation	✓	
Jetties	✓	Limited number
Low-lying developments	✓	Low lying developments around Touw Estuary the major driver for breaching
Migration barrier in river		
Recreational fishing		
Commercial/Subsistence fishing (e.g. gillnet fishery)		
Illegal fishing (Poaching)		
Bait collection		
Grazing and trampling of salt mashes		
Translocated or alien fauna and flora		
Recreational disturbance of waterbirds		

3 DELINEATION OF SYSTEM

3.1 GEOGRAPHICAL BOUNDARIES

The Wilderness System is subdivided into **two resource units**, namely the **Touw Estuary** and the **Wilderness estuarine lakes (hereafter referred to as the Wilderness Lakes)** (**Figure 3.1**). The motivation for this is that these two sub-systems function at markedly different spatial and temporal scales. In the case of the Touw Estuary, the system shows strong longitudinal gradients in physico-chemical characteristics (typical of estuaries) while these characteristics are more uniform in the lakes. Also, temporal variability of the hydrodynamics and water quality in the Touw Estuary show stronger intra-annual (e.g. seasonal) variability, while the temporal variability in the lakes shows stronger inter-annual (across years).

Figure 3.1 The two resource units for the Wilderness System, i.e. Touw Estuary and Wilderness Lakes

The geographical boundaries for the system are as follows:

Downstream boundary	Estuary mouth 33°59'45.56"S, 22°34'51.01"E
Upstream boundary	Touw 33°58'26.64"S, 22°36'19.64" Rondevlei 33°59'44.69"S, 22°43'7.47"E
Lateral boundaries	5 m contour above Mean Sea Level (MSL) along banks

3.2 ZONING OF THE WILDERNESS SYSTEM

Touw Estuary

For the purposes of this study, the Touw Estuary is sub-divided into three distinct zones, primarily based on geomorphology (**Figure 3.2**).

Figure 3.2 Zonation in the Touw Estuary

Table 3.1 below lists some of the key features of the Touw Estuary zonation that is used to determine the weighting of scores.

Table 3.1 Key features of the Touw Estuary zones

Feature	Zone		
	A (lower)	B (middle)	C (upper)
Area (ha)	18.8	10.75	7.1
Depth (m)	1.0	1.5 - 2.0	1.0
Relative percentage	40	45	15

Wilderness Lakes

For the purposes of this study, the Wilderness Lakes is sub-divided into four distinct zones, primarily based on geomorphology (**Figure 3.3**).

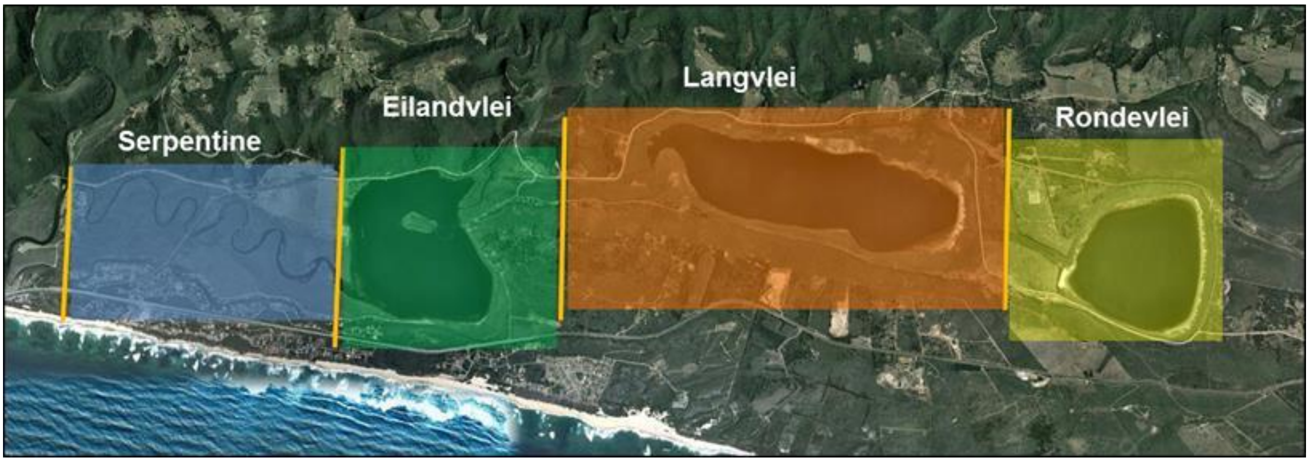


Figure 3.3 Zonation in the Wilderness Lakes

Table 3.2 lists key features of the Wilderness Lakes zonation that is used to determine the weighting of scores.

Table 3.2 Key features of the Wilderness Lakes zones

Feature	Zone			
	Serpentine	Eilandvlei	Langvlei	Rondevlei
Area (ha)	~20	137	203	106
Depth (m)	1.5	Max=6.5 Ave=3.0	Max=4.0 Ave=2.0	Max=6.0 Ave=3.0
Relative percentage	5	35	35	25

3.3 TYPICAL ABIOTIC STATES IN THE WILDERNESS SYSTEM

Based on current understanding, a number of characteristic 'abiotic states' was identified for the Wilderness System, associated with specific flow ranges, also taking into account the variability in characteristics such as tidal exchange, salinity distribution, estuary mouth manipulations (breaching and closures) and water quality. The different states are for the Touw Estuary and Wilderness Lakes in **Tables 3.3** and **3.4**, respectively.

Table 3.3 Summary of the abiotic states in the Touw Estuary

State	Flow range (m^3/s)	Description
State 1	<0.3 (Reference); <0.5 (Present)	Closed state
State 2	0.1 – 1	Open with full salinity gradient
State 3	>20	Open, freshwater dominated

Characterisation of abiotic states for the Wilderness Lakes was primarily based on water level in the lakes. Water levels in the lakes, in turn, are primarily influenced by the state of mouth in the Touw Estuary, or high flow events. For example, when the Touw mouth is closed there is no outflow from the Wilderness System and water levels become high. When the mouth is open, water drains from the Wilderness System resulting in low lake levels. During periods of high flows, the lakes fill for short periods resulting in very high water levels. The simulated data from the Touw River, therefore, could be applied as proxy to estimate the distribution of states in the Lakes as illustrated in **Table 3.4**.

Table 3.4 Summary of the abiotic states in the Wilderness Lakes

State	Water level in lakes	Corresponding flow in Touw River (m^3/s)	Description
State 1	High	<0.3 (Reference)/ <0.5 (Present)	Touw mouth closed
State 2	Low	0.1 – 1	Touw mouth open or recently open
State 3	Very high	>20	High flows into the systems

The transition between the different states will not be instantaneous, but will take place gradually. To assess the occurrence and duration of the different abiotic states selected for the estuary during the different scenarios, a number of techniques were used:

- Colour coding (indicated above) was used to visually highlight the occurrence of the various abiotic states between different scenarios.
- Summary tables of the occurrence of different flows at increments of the 10%ile are listed separately to provide a quick comprehensive overview.

A summary of the typical physical and water quality characteristics of different abiotic states is provided in **Section 4**. For a more detailed account on the underlying data and assumptions, refer to the data summary reports (**Appendix C**).

4 ECOLOGICAL BASELINE AND HEALTH ASSESSMENT

4.1 HYDROLOGY

4.1.1 General

The present day total MAR into the Wilderness Estuarine Lake system is 25.15 million m^3. This is a decrease of 15% compared to the natural MAR of 29.66 million m^3. The net seepage and evaporation losses from the Wilderness System are estimated at 6.2 million m^3 per year (Fijen, 1995). This is equivalent to a monthly volume of 0.516 million m^3. An evaluation of the simulated flow data indicate that the combined inflow to the system exceeded this monthly volume for only 55 % of the time under the Present State, while it exceeded this value for about 69% of the time under the Reference Condition.

To provide a general indication of the change in flood regime from the Reference Condition to the Present State in the Wilderness System the ten highest simulated monthly flow volumes (combined flow from Touwe, Duiwe and Langspruit) were compared for the 75-year period (summarised **Table 4.1**). The analysis of the simulated monthly flow data indicate that under Reference Conditions floods were about 5% higher than at present, depending on the size class.

Table 4.1 Summary of the ten highest simulated monthly volumes to the Wilderness Estuary System under Reference Condition and Present State

Date	Monthly volume (million m^3/month)		% remaining
	Natural	Present	
Dec 1931	41.4	40.2	97.0
Mar 1963	28.8	26.7	92.7
Nov 1996	27.9	26.1	93.3
Aug 1954	27.9	27.0	96.5
Nov 1928	24.3	22.6	92.9
Sep 1925	23.8	23.1	96.8
Aug 1962	22.6	21.8	96.5
Sep 1932	22.3	21.6	96.8
Apr 1967	22.0	20.6	93.7
Sep 1993	21.5	20.8	96.8
% Similarity in floods			**95.3**

Confidence: Low

4.1.2 Hydrology for the Touw River (only)

The Touw River is the primary abiotic driver of the Touw Estuary, and the Wilderness Lakes as it strongly influences mouth condition of the estuary. The Touw River feeds directly into the Touw

Estuary and provides about 60% of the total runoff to the Wilderness System under the Present State. Under Reference Condition it contributed 58% but the relative percentage increased under the Present State as a result of flow reduction from the Duiwe River.

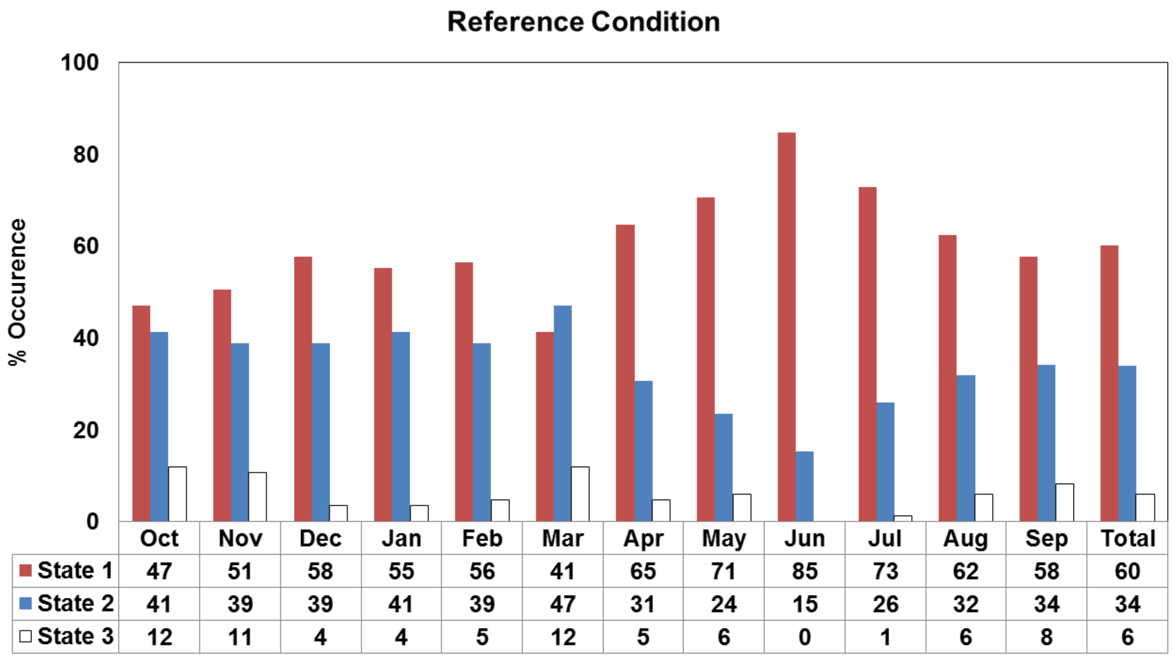
The present MAR of the Touw River is estimated at 15.34 million m^3. This is a decrease of 11% compared to Natural MAR (17.2 million m^3). The occurrences of flow distributions (mean monthly flows in m^3/s) for the Reference Condition and Present State, derived from the 85-year simulated data set, are provided in **Tables 4.2** and **4.3**. A graphic representation of the occurrence of the various abiotic states is presented in **Figures 4.1** and **4.2**. The full 85-year series of simulated monthly runoff data for the Present State and Reference Condition is provided in **Tables 4.4** and **4.5.**

Table 4.2 Summary of the monthly flow distribution (in m^3/s) from the Touw River for the Reference Condition (refer to Table 3.3 for colour coding of abiotic states)

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	3.53	6.18	8.49	4.45	4.36	6.07	4.79	4.57	1.67	2.60	5.95	5.30
99	3.28	5.56	4.19	4.01	3.86	4.52	3.60	4.23	1.19	1.76	5.09	5.05
90	2.25	2.18	1.23	1.13	1.40	2.07	1.22	0.97	0.39	0.86	1.30	1.58
80	1.21	1.26	0.83	0.75	0.66	1.27	0.63	0.51	0.28	0.45	0.53	0.73
70	0.68	0.70	0.51	0.50	0.43	0.80	0.41	0.28	0.21	0.22	0.43	0.46
60	0.48	0.44	0.36	0.34	0.35	0.66	0.26	0.18	0.18	0.16	0.29	0.33
50	0.32	0.22	0.18	0.27	0.20	0.52	0.19	0.15	0.15	0.13	0.22	0.25
40	0.26	0.18	0.12	0.15	0.16	0.27	0.15	0.10	0.11	0.09	0.17	0.21
30	0.20	0.13	0.09	0.11	0.10	0.19	0.11	0.08	0.07	0.07	0.13	0.16
20	0.15	0.08	0.06	0.06	0.08	0.11	0.09	0.05	0.04	0.06	0.08	0.12
10	0.09	0.06	0.04	0.04	0.05	0.06	0.06	0.04	0.03	0.04	0.07	0.06
1	0.04	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.04
0.1	0.04	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.04

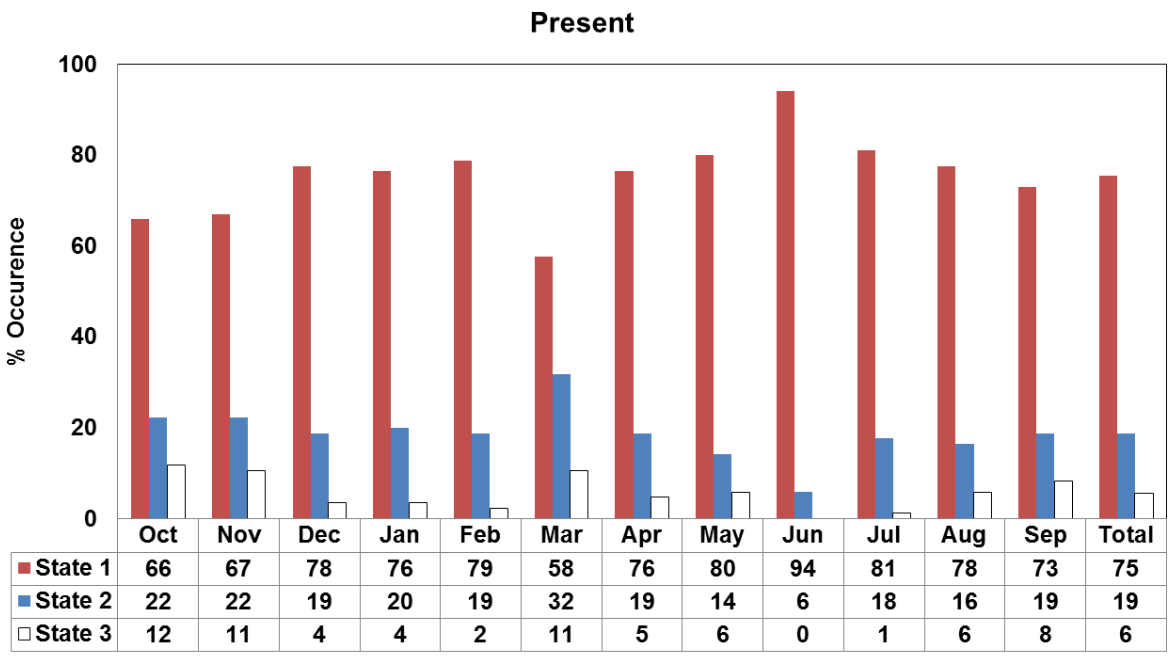
Table 4.3 Summary of the monthly flow distribution (in m^3/s) from the Touw River for the Present State (refer to Table 3.3 for colour coding of abiotic states)

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	3.71	6.06	8.66	4.59	4.33	5.91	4.72	4.68	1.70	2.67	6.04	5.40
99	3.45	5.44	4.22	4.13	3.84	4.32	3.47	4.32	1.21	1.82	5.16	5.14
90	2.35	2.13	1.16	1.07	1.28	2.01	1.20	0.99	0.39	0.89	1.32	1.61
80	1.21	1.20	0.69	0.62	0.50	1.15	0.63	0.51	0.26	0.45	0.52	0.72
70	0.64	0.61	0.37	0.34	0.25	0.71	0.31	0.28	0.20	0.22	0.37	0.46
60	0.43	0.34	0.19	0.16	0.16	0.55	0.22	0.18	0.15	0.15	0.27	0.31
50	0.25	0.10	0.03	0.10	0.04	0.31	0.14	0.13	0.13	0.12	0.19	0.20
40	0.17	0.05	0.00	0.02	0.00	0.15	0.10	0.07	0.08	0.06	0.14	0.17
30	0.09	0.01	0.00	0.00	0.00	0.07	0.05	0.04	0.05	0.05	0.10	0.10
20	0.04	0.00	0.00	0.00	0.00	0.01	0.03	0.03	0.02	0.03	0.06	0.06
10	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.02	0.03	0.01
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
🟥 State 1	47	51	58	55	56	41	65	71	85	73	62	58	60
🟦 State 2	41	39	39	41	39	47	31	24	15	26	32	34	34
☐ State 3	12	11	4	4	5	12	5	6	0	1	6	8	6

Figure 4.1 Occurrence of the abiotic states in the Touw Estuary under the Reference Condition (refer to Table 3.3 for colour coding of abiotic states)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
🟥 State 1	66	67	78	76	79	58	76	80	94	81	78	73	75
🟦 State 2	22	22	19	20	19	32	19	14	6	18	16	19	19
☐ State 3	12	11	4	4	2	11	5	6	0	1	6	8	6

Figure 4.2 Occurrence of the abiotic states in the Touw Estuary under the Present State (refer to Table 3.3 for colour coding of abiotic states)

Table 4.4 Simulated monthly flows (in m^3/s) from the Touw River for the Reference Condition (refer to Table 3.3 for colour coding of abiotic states)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.06	0.13	1.13	0.03	1.96	0.64	1.18	0.18	0.22	0.13	0.20	0.25
1921	0.10	0.18	1.16	1.02	0.34	1.35	0.17	0.39	0.13	1.05	0.25	0.24
1922	0.28	2.35	0.10	0.12	0.07	0.11	0.97	0.15	0.37	0.13	0.09	0.05
1923	0.20	0.35	0.07	0.13	0.16	0.06	0.11	0.05	0.07	0.06	0.44	0.24
1924	0.26	0.21	0.61	0.20	0.04	1.17	0.31	0.10	0.21	0.10	0.45	5.33
1925	0.49	0.18	0.78	0.10	0.05	0.25	0.08	0.05	0.23	0.21	0.15	0.13
1926	0.96	1.37	0.08	0.29	0.82	0.25	0.04	0.35	0.07	0.04	0.13	0.06
1927	0.09	0.15	0.03	0.03	0.07	2.44	0.23	0.06	0.08	0.04	0.29	0.48
1928	0.13	5.43	1.27	0.06	0.26	0.36	0.09	0.18	0.15	0.81	0.61	1.10
1929	0.29	0.12	1.02	0.22	1.59	0.52	0.27	0.69	0.28	0.19	0.61	0.42
1930	0.39	0.07	0.06	1.13	0.09	0.21	0.91	0.11	0.05	0.45	0.18	0.21
1931	0.80	0.09	8.97	0.42	1.12	0.22	0.04	0.11	0.30	0.13	0.09	5.00
1932	0.48	0.49	0.08	0.01	0.45	0.36	0.18	0.30	0.11	0.07	1.93	0.24
1933	0.04	1.04	0.05	0.58	0.42	1.09	0.11	0.02	0.02	0.65	0.37	0.24
1934	1.88	1.50	0.08	0.13	0.16	0.04	0.49	4.16	0.40	0.22	0.19	1.33
1935	0.32	0.64	0.51	0.11	0.42	0.28	0.04	0.43	0.07	0.75	0.17	0.62
1936	0.49	2.84	0.42	0.15	0.20	2.10	0.09	0.02	0.03	0.17	0.05	0.51
1937	0.42	0.31	1.07	0.51	0.02	0.52	0.32	0.08	0.04	0.04	0.07	0.19
1938	0.39	0.39	0.53	0.02	2.12	2.67	0.17	0.03	0.02	1.27	1.67	0.61
1939	0.25	0.45	0.07	0.46	4.41	0.80	0.12	0.06	0.04	0.04	0.03	0.28
1940	0.12	0.48	0.02	0.51	0.11	0.19	3.35	0.18	0.21	0.08	0.09	0.20
1941	1.04	0.21	0.53	1.93	0.09	0.80	0.17	0.54	0.16	0.06	0.08	0.09
1942	0.29	0.15	0.86	1.08	0.17	0.68	0.20	0.04	0.04	0.03	0.27	1.51
1943	0.47	1.66	0.51	0.04	0.06	0.84	0.08	1.56	0.25	0.99	0.26	1.42
1944	0.32	0.08	0.02	0.07	0.06	0.06	0.02	1.23	0.49	0.19	0.52	0.19
1945	1.57	0.12	0.05	0.15	0.50	2.77	0.09	0.02	0.03	0.06	0.07	0.12
1946	0.18	0.05	0.02	0.05	0.32	2.90	0.15	0.25	0.18	0.60	0.17	0.51
1947	0.52	0.44	0.03	1.40	0.09	0.68	0.67	0.11	0.04	0.05	0.03	0.41
1948	1.73	0.22	0.12	0.61	0.15	0.02	0.31	0.63	0.11	0.03	0.06	0.33
1949	0.10	4.22	0.09	0.05	0.09	0.03	0.04	0.05	0.02	1.21	0.22	0.26
1950	1.40	3.94	0.97	3.92	0.14	0.22	0.04	0.09	0.18	1.09	0.46	1.02
1951	0.16	0.02	0.03	0.99	0.39	0.08	0.27	0.09	0.06	0.06	0.56	2.20
1952	0.30	0.51	0.16	0.21	0.43	0.11	0.71	0.09	1.09	0.66	1.29	0.85
1953	3.56	1.71	0.13	0.01	0.04	0.56	0.47	2.29	0.30	0.40	6.05	0.37
1954	0.17	2.37	0.09	2.33	3.75	0.21	0.16	0.16	0.20	0.13	0.11	0.34
1955	0.69	1.05	0.06	0.28	0.37	1.06	0.24	1.03	0.18	0.08	0.07	0.13
1956	1.37	0.18	1.00	0.08	0.73	0.65	0.09	0.17	0.47	0.19	0.38	1.80
1957	0.26	0.03	0.09	0.04	0.03	1.31	0.23	1.94	0.24	0.05	0.50	0.14
1958	0.27	0.07	0.41	1.51	0.37	1.73	1.24	0.23	0.06	0.52	0.85	0.21
1959	2.78	0.18	0.54	1.12	0.05	2.35	0.48	0.35	0.17	0.13	0.06	0.70
1960	0.15	0.77	1.08	0.27	0.50	2.03	1.13	0.32	0.10	0.14	0.17	0.23
1961	0.42	0.20	0.12	0.35	0.18	1.26	0.42	0.10	0.04	0.08	4.90	0.27
1962	2.22	1.20	0.06	0.79	0.10	6.24	0.17	0.13	0.06	0.18	0.08	0.04
1963	0.29	0.16	0.83	1.03	0.17	0.30	0.15	0.04	0.94	0.16	0.58	4.53
1964	0.24	0.22	0.04	0.06	0.18	0.77	0.19	0.77	0.20	0.14	0.08	0.06
1965	2.27	2.70	0.36	1.08	0.19	0.02	0.19	0.26	0.06	0.04	1.31	0.41
1966	0.08	0.02	0.42	0.02	1.71	1.79	4.93	2.19	0.30	0.40	0.21	0.64
1967	0.16	0.41	0.04	0.01	0.01	0.56	0.16	0.15	1.72	0.22	0.33	0.25
1968	0.22	1.40	0.08	0.12	0.13	0.63	0.12	0.03	0.61	0.12	0.13	0.13
1969	0.32	0.04	0.01	0.39	0.86	0.06	0.02	0.03	0.03	0.05	0.74	0.15
1970	0.85	0.09	1.76	0.09	1.04	0.52	1.17	0.68	0.21	2.69	2.12	0.26
1971	0.14	1.23	0.05	0.15	1.90	0.76	0.14	0.18	0.15	0.16	0.34	0.13
1972	0.05	0.09	0.10	0.34	0.08	0.13	0.52	0.10	0.30	0.15	0.15	0.15
1973	0.06	0.32	0.13	1.04	0.95	0.80	0.09	0.60	0.11	0.04	0.29	0.21
1974	0.08	0.17	0.01	0.70	0.06	0.25	0.09	0.07	0.21	0.24	0.50	1.64
1975	0.20	0.58	0.48	0.18	0.36	0.68	0.08	0.26	0.14	0.33	0.16	0.19
1976	2.32	0.71	0.15	0.02	2.10	0.41	0.09	3.37	0.26	0.06	0.32	0.54
1977	0.21	0.73	0.23	0.19	0.02	0.16	0.21	0.05	0.16	0.08	0.22	0.13
1978	0.74	1.04	0.42	0.26	0.20	0.06	0.12	0.38	0.15	1.20	0.59	1.06
1979	0.19	0.05	0.17	0.30	0.03	0.02	0.24	0.04	0.34	0.07	0.18	0.43
1980	1.07	0.99	0.37	4.50	0.76	1.89	2.30	4.61	0.35	0.20	4.63	0.35
1981	0.56	0.09	0.49	0.32	0.58	0.42	3.13	0.17	0.45	0.26	0.14	2.33
1982	0.53	0.07	0.14	0.02	0.13	0.04	0.11	0.19	0.91	1.59	0.28	0.46
1983	1.27	0.48	0.28	0.11	0.10	0.75	0.09	0.05	0.05	0.90	0.17	0.12
1984	0.57	0.17	0.23	0.71	0.70	0.11	0.62	0.10	0.14	0.45	0.17	0.05
1985	2.91	0.68	1.41	0.27	0.15	0.11	0.05	0.02	0.03	0.06	2.73	0.24
1986	1.79	0.18	0.22	0.15	0.28	0.13	1.73	0.10	0.12	0.04	0.24	2.23
1987	0.20	0.03	0.49	0.05	0.14	0.11	0.44	0.22	0.15	0.09	0.51	0.19
1988	0.13	0.07	0.20	0.11	0.07	0.11	1.04	0.05	0.03	0.05	0.05	0.07
1989	2.61	1.93	0.08	0.05	1.89	0.32	0.62	0.20	0.28	0.11	0.10	0.06
1990	0.51	0.21	0.06	0.29	0.25	0.11	0.13	0.05	0.13	0.10	0.08	0.06
1991	2.33	0.13	0.57	0.37	0.42	0.52	0.11	0.18	0.14	0.73	0.29	0.12
1992	3.23	0.37	0.03	0.59	0.07	0.15	1.76	0.50	0.16	0.08	0.10	4.80
1993	0.22	0.33	1.68	0.29	0.66	1.04	0.51	0.12	0.09	0.34	1.71	0.29
1994	0.65	0.08	3.27	0.63	0.65	1.37	1.72	0.29	0.20	0.10	0.08	0.06
1995	0.06	2.87	1.36	0.35	0.09	0.04	0.11	0.03	0.02	0.07	0.06	0.31
1996	2.98	6.25	0.31	0.07	0.65	0.76	0.25	0.88	0.26	0.14	0.32	0.15
1997	0.41	0.07	0.06	0.38	0.10	1.77	0.05	0.06	0.03	0.06	0.11	0.04
1998	0.03	0.13	0.25	0.44	0.20	0.89	0.30	0.07	0.03	0.07	0.07	0.47
1999	1.20	0.11	0.12	1.78	0.31	2.60	0.14	0.05	0.03	0.02	0.02	0.05
2000	0.08	1.80	1.54	0.10	0.39	0.39	1.36	0.16	0.04	0.06	0.47	0.20
2001	0.23	1.50	0.12	1.41	0.08	0.02	0.07	0.08	0.11	0.39	0.48	0.88
2002	0.14	0.05	0.18	0.05	0.21	4.19	0.13	0.88	0.20	0.08	0.14	0.07
2003	0.23	0.05	0.11	0.32	0.44	0.23	0.29	0.06	0.07	0.05	0.23	0.23
2004	0.82	0.08	2.59	0.74	0.07	0.10	0.38	0.11	0.09	0.04	0.03	0.05

Table 4.5 Simulated monthly flows (in m^3/s) from the Touw River for the Present State (refer to Table 3.3 for colour coding of abiotic states)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.00	0.02	0.96	0.00	1.75	0.58	1.16	0.18	0.21	0.12	0.17	0.22
1921	0.02	0.05	1.05	1.01	0.17	1.35	0.14	0.39	0.12	1.08	0.22	0.22
1922	0.20	2.30	0.00	0.00	0.00	0.01	0.79	0.15	0.38	0.10	0.06	0.00
1923	0.10	0.20	0.00	0.00	0.01	0.00	0.05	0.03	0.04	0.03	0.31	0.19
1924	0.17	0.07	0.49	0.04	0.00	1.03	0.31	0.10	0.20	0.06	0.45	5.43
1925	0.43	0.04	0.61	0.00	0.00	0.13	0.03	0.02	0.16	0.16	0.14	0.09
1926	0.96	1.33	0.00	0.13	0.66	0.14	0.00	0.32	0.06	0.02	0.12	0.00
1927	0.02	0.03	0.00	0.00	0.00	2.25	0.23	0.02	0.07	0.01	0.28	0.48
1928	0.03	5.31	1.23	0.00	0.09	0.21	0.04	0.16	0.14	0.83	0.61	1.11
1929	0.23	0.01	0.93	0.08	1.57	0.48	0.26	0.70	0.28	0.19	0.62	0.42
1930	0.35	0.00	0.00	0.97	0.00	0.09	0.84	0.07	0.05	0.45	0.17	0.18
1931	0.79	0.00	9.16	0.35	1.00	0.14	0.00	0.08	0.31	0.12	0.05	5.09
1932	0.43	0.37	0.00	0.00	0.24	0.21	0.14	0.30	0.10	0.06	1.96	0.18
1933	0.00	0.94	0.00	0.41	0.28	1.07	0.03	0.00	0.00	0.63	0.37	0.20
1934	1.96	1.46	0.00	0.01	0.02	0.00	0.34	4.24	0.40	0.22	0.18	1.35
1935	0.24	0.54	0.39	0.00	0.21	0.14	0.00	0.40	0.04	0.77	0.11	0.62
1936	0.42	2.79	0.26	0.02	0.04	2.00	0.02	0.00	0.02	0.14	0.01	0.47
1937	0.33	0.22	1.02	0.41	0.00	0.30	0.29	0.04	0.02	0.02	0.05	0.14
1938	0.28	0.28	0.38	0.00	1.93	2.64	0.11	0.00	0.00	1.27	1.70	0.61
1939	0.17	0.36	0.00	0.27	4.39	0.74	0.05	0.04	0.02	0.02	0.00	0.26
1940	0.02	0.35	0.00	0.30	0.00	0.07	3.20	0.15	0.20	0.05	0.06	0.17
1941	1.03	0.09	0.42	1.97	0.00	0.69	0.15	0.54	0.15	0.04	0.06	0.03
1942	0.20	0.05	0.77	1.06	0.00	0.60	0.19	0.00	0.03	0.01	0.26	1.53
1943	0.44	1.61	0.38	0.00	0.00	0.65	0.03	1.59	0.25	1.02	0.24	1.44
1944	0.25	0.00	0.00	0.00	0.00	0.00	0.00	1.10	0.50	0.17	0.52	0.13
1945	1.61	0.00	0.00	0.03	0.29	2.65	0.02	0.00	0.01	0.04	0.04	0.06
1946	0.07	0.00	0.00	0.00	0.13	2.71	0.11	0.25	0.18	0.62	0.10	0.51
1947	0.43	0.34	0.00	1.30	0.00	0.52	0.67	0.07	0.03	0.04	0.00	0.38
1948	1.78	0.10	0.00	0.47	0.00	0.00	0.22	0.58	0.05	0.01	0.03	0.31
1949	0.00	4.10	0.00	0.00	0.00	0.00	0.00	0.02	0.00	1.09	0.21	0.22
1950	1.42	3.87	0.89	4.03	0.01	0.11	0.00	0.06	0.14	1.12	0.46	1.03
1951	0.03	0.00	0.00	0.81	0.23	0.00	0.22	0.09	0.05	0.05	0.56	2.25
1952	0.27	0.49	0.03	0.08	0.29	0.01	0.68	0.06	1.10	0.68	1.31	0.84
1953	3.74	1.68	0.01	0.00	0.00	0.36	0.45	2.34	0.30	0.41	6.14	0.37
1954	0.08	2.32	0.00	2.32	3.74	0.15	0.15	0.16	0.19	0.13	0.09	0.31
1955	0.64	0.99	0.00	0.11	0.18	0.94	0.20	1.06	0.14	0.06	0.04	0.08
1956	1.38	0.06	0.91	0.00	0.49	0.60	0.03	0.16	0.48	0.17	0.37	1.83
1957	0.16	0.00	0.00	0.00	0.00	1.14	0.21	1.99	0.23	0.01	0.48	0.07
1958	0.18	0.00	0.21	1.45	0.19	1.71	1.22	0.23	0.02	0.52	0.86	0.13
1959	2.93	0.05	0.37	1.08	0.00	2.21	0.48	0.34	0.16	0.12	0.01	0.69
1960	0.04	0.67	1.01	0.10	0.31	2.01	1.12	0.32	0.07	0.13	0.16	0.18
1961	0.34	0.06	0.00	0.17	0.02	1.17	0.42	0.07	0.01	0.05	4.97	0.18
1962	2.33	1.15	0.00	0.64	0.00	6.09	0.12	0.12	0.04	0.18	0.04	0.00
1963	0.19	0.03	0.67	0.95	0.02	0.17	0.13	0.01	0.94	0.12	0.58	4.61
1964	0.13	0.07	0.00	0.00	0.01	0.55	0.14	0.78	0.20	0.13	0.04	0.00
1965	2.36	2.65	0.17	1.01	0.03	0.00	0.12	0.19	0.03	0.01	1.33	0.40
1966	0.00	0.00	0.23	0.00	1.47	1.78	4.86	2.24	0.30	0.40	0.19	0.63
1967	0.05	0.27	0.00	0.00	0.00	0.34	0.09	0.14	1.75	0.17	0.33	0.23
1968	0.12	1.34	0.00	0.00	0.00	0.41	0.06	0.00	0.61	0.10	0.12	0.06
1969	0.23	0.00	0.00	0.20	0.61	0.00	0.00	0.00	0.01	0.03	0.65	0.08
1970	0.82	0.00	1.66	0.00	0.84	0.47	1.15	0.69	0.20	2.77	2.15	0.18
1971	0.04	1.17	0.00	0.00	1.67	0.68	0.09	0.17	0.14	0.16	0.33	0.04
1972	0.00	0.00	0.00	0.16	0.00	0.03	0.36	0.07	0.30	0.13	0.14	0.10
1973	0.00	0.16	0.00	0.88	0.82	0.75	0.01	0.59	0.08	0.00	0.27	0.17
1974	0.00	0.04	0.00	0.46	0.00	0.14	0.03	0.04	0.15	0.24	0.50	1.67
1975	0.06	0.43	0.35	0.03	0.16	0.57	0.02	0.24	0.13	0.34	0.13	0.15
1976	2.44	0.62	0.01	0.00	1.87	0.31	0.03	3.44	0.24	0.02	0.31	0.54
1977	0.09	0.63	0.06	0.03	0.00	0.04	0.13	0.03	0.11	0.05	0.15	0.06
1978	0.69	0.93	0.25	0.10	0.03	0.00	0.07	0.29	0.14	1.23	0.59	1.07
1979	0.06	0.00	0.03	0.13	0.00	0.00	0.14	0.01	0.24	0.03	0.14	0.43
1980	1.06	0.91	0.31	4.64	0.63	1.87	2.27	4.72	0.36	0.20	4.69	0.31
1981	0.51	0.00	0.30	0.12	0.41	0.31	3.08	0.11	0.46	0.27	0.10	2.37
1982	0.48	0.00	0.00	0.00	0.00	0.00	0.04	0.14	0.82	1.63	0.23	0.44
1983	1.27	0.39	0.12	0.00	0.00	0.56	0.03	0.03	0.02	0.92	0.11	0.06
1984	0.52	0.04	0.07	0.57	0.57	0.01	0.58	0.07	0.13	0.46	0.11	0.00
1985	3.04	0.58	1.36	0.10	0.00	0.00	0.00	0.00	0.02	0.03	2.64	0.16
1986	1.86	0.06	0.07	0.00	0.07	0.02	1.56	0.04	0.11	0.01	0.23	2.27
1987	0.07	0.00	0.25	0.00	0.00	0.01	0.31	0.18	0.15	0.07	0.51	0.14
1988	0.04	0.00	0.06	0.00	0.00	0.01	0.86	0.01	0.01	0.03	0.02	0.01
1989	2.72	1.89	0.00	0.00	1.65	0.21	0.62	0.20	0.28	0.06	0.09	0.01
1990	0.45	0.07	0.00	0.12	0.07	0.00	0.07	0.02	0.09	0.06	0.04	0.01
1991	2.37	0.00	0.38	0.22	0.25	0.43	0.06	0.18	0.13	0.75	0.28	0.04
1992	3.39	0.24	0.00	0.38	0.00	0.04	1.62	0.50	0.15	0.07	0.09	4.89
1993	0.09	0.20	1.67	0.11	0.51	1.02	0.51	0.10	0.08	0.34	1.73	0.24
1994	0.61	0.00	3.28	0.53	0.50	1.36	1.69	0.29	0.19	0.07	0.06	0.00
1995	0.00	2.75	1.32	0.20	0.00	0.00	0.05	0.00	0.00	0.05	0.03	0.21
1996	3.08	6.13	0.14	0.00	0.41	0.71	0.24	0.90	0.25	0.14	0.31	0.09
1997	0.34	0.00	0.00	0.20	0.00	1.60	0.00	0.04	0.00	0.04	0.09	0.00
1998	0.00	0.01	0.09	0.25	0.04	0.73	0.29	0.03	0.00	0.05	0.05	0.46
1999	1.20	0.00	0.00	1.66	0.12	2.56	0.05	0.02	0.00	0.00	0.00	0.00
2000	0.00	1.67	1.53	0.00	0.18	0.24	1.35	0.13	0.01	0.05	0.46	0.16
2001	0.13	1.45	0.00	1.33	0.00	0.00	0.02	0.05	0.07	0.28	0.47	0.88
2002	0.00	0.00	0.03	0.00	0.04	3.98	0.08	0.90	0.20	0.06	0.13	0.01
2003	0.12	0.00	0.00	0.14	0.23	0.10	0.21	0.03	0.06	0.03	0.22	0.19
2004	0.80	0.00	2.46	0.62	0.00	0.02	0.29	0.11	0.08	0.04	0.03	0.02

4.1.3 Hydrological health

Table 4.6 provides a summary of the hydrological health of the Wilderness System based on an assessment of the general hydrology of the system.

Table 4.6 Present hydrological health scores (based on total hydrology, not only Touw River inflow)

Variable	Summary of change	Weight	Score	Confidence
a. % Similarity in period of low flows	Significant increase in the low flow period and reduction in flow rate.	60	68	L
b. % Similarity in mean annual frequency of floods	The simulated monthly flow data indicate that under Reference Condition floods was about 4-7% higher than at present, depending on the size class.	40	95	L
Hydrology score: weighted mean (a,b)			**79**	**L**

4.2 PHYSICAL HABITAT

4.2.1 Baseline description

Over the past 700 years the rate of segmentation of the Wilderness System (and infilling of the lakes) has been increased through anthropogenic actions.

In the **Touw Estuary** the impact of the frequent interventions in mouth dynamics and berm morphology, is less flushing out of sediment from the lower estuary and probably more ingress of marine sediment into the lower estuary. Catchment changes are considered to result in slightly increased riverine fine sediment load to the estuary, with slightly reduced coarser load (sand and gravel) to the estuary. The small reduction in large floods would tend to result in slightly less flushing of sediments from all parts of the estuary, also enabling marine sediment to ingress slightly further into the estuary on average. An additional effect would be slightly longer retention of riverine sediment deposits, enabling more consolidation and more plant growth, all contributing to slightly less dynamic estuarine geomorphology.

There are road and rail bridges crossing the estuary in all three zones. Although the bridge openings are relatively large, the bridges and especially their embankments all have slight constricting effects and tend to fix the estuary channel and banks in the direct vicinity (up- & down-stream) of the bridges. The banks of the middle and especially the lower estuary have been heavily impacted by development (houses, bank stabilisation structures/revetments, slipways & jetties, etc.).

In the Reference Condition the middle reaches of the estuary would have been more directly connected to the coastal dynamics, probably occasionally breaching to the sea at the big bend in the middle reaches during extreme flood events. There would also have been significant aeolian sediment input into the estuary at this location, especially over the spring to autumn period. With the construction of the highway, such breaching is no longer possible, and no aeolian sediment transport can reach the middle estuary from the adjacent beach. The road construction also involved some infilling of the seaward side of the channel at this location, narrowing the channel slightly from the southern (road) side.

Very little information or data regarding Reference Condition versus Present State of the morphology and sediment dynamics of the **Wilderness Lakes** exist. The catchment of the lakes' tributaries (i.e. Duiwe and Langspruit) is less pristine than that of the Touw catchment. Agriculture and forestry occur in patches, also exotic species in some areas, otherwise indigenous. There are significant resort settlements around the lakes. Hotels, camping, picnicking, boat launching are concentrated around and west of Eilandvlei. Thus expected increased sediment inputs into the lakes from catchments and surrounding areas.

The lakes are naturally a virtually total sediment sink (trap) for sediments from the catchments and surrounding areas. Only a small amount of fine sediments could be exported through the lakes to the Touw Estuary during high flows.

A "sluice" gate was constructed on the serpentine channel. The channel between Eilandvlei and Langvlei is severely overgrown; the consequent siltation of the channel has created an effective block to lake interflow when levels fall below +1.2 m MSL.

4.2.2 Physical habitat health

Tables 4.7 and **4.8** provide the present physical habitat health scores of the Touw Estuary and Wilderness Lakes, respectively.

Table 4.7 Touw Estuary: Present physical habitat scores, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable		Summary of change	Score	Confidence
a	% similarity in supratidal area	1. Large floods which flush out sediments from the estuary and deposits new sediments on the floodplain are slightly reduced (~5%). Slightly longer retention of riverine sediment deposits, enabling more consolidation and more enduring plant growth, all contribution to slightly less dynamic estuarine geomorphology. (5/3*3) 2. There are road and rail bridges crossing the estuary in all three zones. The bridges and especially their embankments have slight constricting effects and tend to fix the estuary channel and banks in the direct vicinity (up- & down-stream) of the bridges. (5/3*3) 3. The banks of the middle and especially the lower estuary have been heavily impacted by development (houses, bank stabilisation structures/revetments, slipways & jetties, etc.)	65	L

Variable		Summary of change	Score	Confidence
		(50/3+25/3)		
b	% similarity in area of intertidal sand- and mudflats	4. The impacts listed in (a) above also affect the intertidal areas, but less so for the developments along the banks (#3 above). (5+5+25/2) 5. The overall impacts of the frequent interventions in mouth dynamics and berm morphology, is less flushing out of sediment from the lower estuary and probably more ingress of marine sediment into the lower estuary. (25/3) 6. Overall catchment changes are considered to result in slightly increased riverine fine sediment load to the estuary, but slightly reduced coarser load (sand & gravel) to the estuary. (5/3*3)	64	L
c	% similarity in area of subtidal/submerged sand and mud substrates	7. The impacts listed in (a)(1, 2) and (b) (5, 6) above also affect the subtidal areas. (5+5+25/3+5)	77	L
d	% similarity in bathymetry/ estuary water volume	8. The impacts listed in (a) (1, 2) would have a slight effect on bathy volume, while (a) (5) would result in significant reduction in the volume of the lower estuary. (5+5+25/3)/2	91	L
Physical habitat score min (a to d)			**64**	**L**
% of impact due to non-flow factors			90	
Adjusted score			96	L

Table 4.8 Wilderness Lakes: Present physical habitat scores, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable		Summary of change	Score	Confidence
a	% similarity in supratidal area	1. There are significant resort settlements around the lakes, also some farming and roads within the floodplain. Hotels, camping, picknicking, boat launching are concentrated around and west of Eilandvlei	80	L
b	% similarity in area of intertidal sand- and mudflats	2. Obstructions in the serpentine channel, and siltation of the channels between all the lakes and the estuary.	85	L
c	% similarity in area of subtidal/submerged sand and mud substrates	3. Expected increased sediment inputs into the lakes from catchments and surrounding areas 4. The rate of segmentation of the lakes and Touw Estuary (and infilling of the lakes) has been increased through anthropogenic actions	90	L
d	% similarity in bathymetry/ estuary water volume	5. The impacts listed in (b) and (c) above would affect the volume, but in relation to the total lakes volume very little	95	L
Physical habitat score min (a to d)			**80**	**L**
% of impact due to non-flow factors			95	
Adjusted score			99	L

4.3 HYDRODYNAMICS

4.3.1 Baseline description

A summary of the hydrodynamic characteristics in the Touw Estuary and Wilderness Lakes for various abiotic states is presented in **Tables 4.9** and **4.10**, respectively. Marked seasonality is observed in the Touw Estuary mouth state, with it being open most frequently (> 30%) during summer and autumn (November to April), less frequently (20–30%) in early and late winter and spring (May and August to October) and seldom (<10%) in mid-winter (June and July).

Table 4.9 **Touw Estuary: Summary of the abiotic states, and associated hydrodynamic characteristics (refer to Table 3.3 for colour coding of abiotic states)**

Parameter	State 1: Closed	State 2: Salinity gradient	State 3: Fresh
Flow range (m$^{3/}$s)	Reference: 0.3 Present: 0.5	Reference: 0.3 – 2.0 Present: 0.5 – 2.0	2
Mouth condition	Closed	Open	Open
Water level (m to MSL)	Max Reference: 3.0 – 3.5 Max Present/Future: 2.1 – 2.4 **Average**: Ref 2.0 Present 1.3 Sc 1 1.2 Sc 2 1.15 Sc 3 1.1 Sc 4 1.0	1.0	Reference: 3.0 – 3.5 Present: 2.4
Inundation	Yes	No	Yes, during floods
Tidal range	0	**Reference:** 1.3 (spring) - 0.3 (neap) **Present/Future 1 & 2:** 1.0 (spring) - 0.3 (neap) **Scenario 3:** 0.8 (spring) - 0.3 (neap) **Scenario 4:** 0.75 (spring) - 0.3 (neap)	**Reference:** 1.8 (spring) - 0.5 (neap) **Present /Future 1 & 2:** 1.6 (spring) - 0.5 (neap) **Scenario 3:** 1.55 (spring) - 0.5 (neap) **Scenario 4:** 1.5 (spring) - 0.5 (neap)
Dominant circulation process	Wind	Tidal	River & inflow from the lakes
Retention	Weeks	Days - weeks	< 1 week

Table 4.10 Wilderness Lakes: Summary of the abiotic states, and associated hydrodynamic characteristics

<table>
<tr><th>Parameter</th><th>State 1: High water level</th><th>State 2: Low water levels</th><th>State 3: Very high water level</th></tr>
<tr><td>Mouth condition</td><td>Closed</td><td>Open</td><td>Open</td></tr>
<tr><td>Water level (m to MSL)</td><td>Max Reference:
3.0 – 3.5
Max Present/Future:
2.1 – 2.4<table><tr><th colspan="2">Average</th></tr><tr><td>Ref</td><td>2.0</td></tr><tr><td>Present</td><td>1.3</td></tr><tr><td>Sc 1</td><td>1.2</td></tr><tr><td>Sc 2</td><td>1.15</td></tr><tr><td>Sc 3</td><td>1.1</td></tr><tr><td>Sc 4</td><td>1.0</td></tr></table></td><td>1.0</td><td>Max Reference:
3.0 – 3.5
Max Present/Future:
2.1 – 2.4<table><tr><th colspan="2">Average</th></tr><tr><td>Ref</td><td>3.5</td></tr><tr><td>Present</td><td>2.4</td></tr><tr><td>Sc 1</td><td>2.4</td></tr><tr><td>Sc 2</td><td>2.35</td></tr><tr><td>Sc 3</td><td>2.3</td></tr><tr><td>Sc 4</td><td>2.2</td></tr></table></td></tr>
<tr><td>Inundation</td><td>Yes</td><td>No</td><td>Yes, during floods</td></tr>
</table>

4.3.2 Hydrodynamic health

The hydrodynamic health scores for the Touw Estuary and Wilderness Lakes are provided in **Tables 4.11** and **4.12**, respectively.

Table 4.11 Touw Estuary: Present hydrodynamic and mouth state scores, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable		Summary of change	Weight	Score	Confidence
a.	% similarity in abiotic states and mouth condition	Under the Reference Conditions the Touw Estuary mouth used to be open for about 40% of the time, at present it is open for about 25% of the time.	50	61	L
b.	% similarity in the water column stratification	No resolution			
c	% similarity in water retention time	No data			
d.	% similarity in water level	Under the Reference Conditions maximum water levels before a breaching were about 3.0 to 3.5 m MSL, while under the Present State the estuary is breached between 2.1 and 2.4 m MSL.	25	85	L
	Tidal amplitude	At present the tidal amplitude varies between 1.6 (spring) and 0.5 m (neap). Under the Reference Condition the tidal amplitude could have been 20 cm larger under State 2 and 3 as there would have been less sediment in the lower reaches constricting the tide.	25	78	L

Variable	Summary of change	Weight	Score	Confidence
Hydrodynamic score weighted mean (a to d)			**71**	**L**
% of impact due to non-flow factors			90	
Adjusted score			97	L

Table 4.12 Wilderness Lakes: Present hydrodynamic and mouth state scores, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable		Summary of change	Weight	Score	Confidence
a.	% similarity in abiotic states and mouth condition		50	61	L
b.	% similarity in the water column stratification	No resolution			
c	% similarity in water retention time	No data			
d.	% similarity in water level		50	85	L
Hydrodynamic score weighted mean (a to d)				**73**	**L**
% of impact due to non-flow factors				90	
Adjusted score				97	L

4.4 WATER QUALITY

4.4.1 Baseline description

A summary of the water quality characteristics for the various states, in each of the four zones is presented in **Tables 4.13** and **4.14**. This summary was derived from available information on the estuary as presented in the Water Quality Data Summary Report (**Appendix C**).

In the case of the Touw Estuary, river inflow is the primary driver of water quality as in most South African estuaries. Water quality can therefore be allocated to abiotic states, each characterised by a flow range. However, in the case of the Wilderness System, river flow is not directly influenced by flow ranges. In the lakes variability in water level (jointly affected by river inflow, mouth state and evaporation) and in situ biogeochemical processes are considered key influencing factors. As a result, it was not possible to predict water quality characteristics based on states. In the case of the lakes, average characteristics for the Reference Condition, Present State and Future Scenarios are therefore estimated for various water quality parameters – largely derived from long-term data collected in the systems (e.g. Russell, 2013; DWA water quality monitoring stations), as well as annual simulated inflows.

A summary of the average water quality condition in each of the zones of the Touw Estuary under Reference Conditions and Present State, and in the Wilderness Lakes, is presented in **Tables 4.15** and **4.16**.

Table 4.13 Touw Estuary: Summary of water quality characteristics of different abiotic states (differences in state between Reference Condition and Present State and Future Scenarios – due to anthropogenic influences other than flow – are indicated) (colour coding does not have specific meaning and is only for illustrative purposes)

Parameter	State 1: Closed mouth			State 2: Open, tidal			State 3: Open, fresh		
Salinity *(increased duration in closure causes salinities to become more homogenous and fresher)*	**Reference**			**Reference**			**Reference**		
	15	**15**	**10**	**30**	**20**	**10**	**10**	**0**	**0**
	Present/ Future 1			**Future/Present**			**Future/Present**		
	10	**10**	**5**	**25**	**15**	**5**	**5**	**0**	**0**
	Future 2								
	7	**7**	**5**						
	Future 3 & 4								
	5	**5**	**5**						
Temperature (^oC)	**Summer**								
	20 - 25, lower temperature in lower reaches (State 2) when colder upwelled waters intrude during summer								
	Winter								
	10 – 20								
pH	**Reference**								
	7– 8, increasing with increase in salinity; 4 in water with salinity 0								
	Present/Future								
	7– 8, increasing with increase in salinity; 6 in water with salinity 0								
DO (mgl/ℓ)	**6**	**6**	**6**	**8**	**8**	**8**	**8**	**8**	**8**
Turbidity (NTU)	**5**	**10**	**5**	**5**	**10**	**5**	**10**	**10**	**10**

Parameter	State 1: Closed mouth	State 2: Open, tidal	State 3: Open, fresh
Dissolved inorganic nitrogen (DIN) (µg/ℓ)	**Reference** **50 50 50** **Present/Future** **50 100 50**	**Reference** **100 50 50** **Present/Future** **100 100 50**	**Reference** **50 50 50** **Present/Future** **100 100 100**
Dissolved inorganic phosphate (DIP) (µg/ℓ)	**Reference** **10 10 10** **Present/Future** **10 20 10**	**Reference** **20 10 10** **Present/Future** **20 20 10**	**Reference** **10 10 10** **Present/Future** **20 20 20**
Dissolved reactive silicate (DRS) (µg/ℓ)	**Reference** **1000 1000 1500** **Present/Future** **1500 1500 2000**	**Reference** **100 1000 1500** **Present/Future** **200 1000 2000**	**2000 2000 2000**

Table 4.14 Wilderness Lakes: Summary of typical water quality conditions under Reference Condition, Present State and Future Scenarios (colour coding does not have specific meaning and is only for illustrative purposes)

Parameter	Characteristic			
Salinity	**Reference**			
	15 (±10)	**10 (±5)**	**12 (±4)**	**15 (±5)**
	Present			
	10 (± 5)	**6 (± 4)**	**8 (±3)**	**10 (±4)**
	Future 1			
	10 (± 4)	**5 (± 3)**	**8 (±3)**	**10 (±4)**
	Future 2			
	8 (± 4)	**4 (± 3)**	**6 (±3)**	**8 (±4)**
	Future 3			
	6 (± 3)	**3 (±2)**	**5 (±2)**	**7 (±3)**
	Future 4			
	6 (± 2)	**2 (± 1)**	**4 (±1)**	**6 (±2)**
Temperature (^{o}C)	**Summer**			
	20 – 25			
	Winter			
	10 – 20			
pH	7-9, highest pH levels associate with highest *Potamogeton* biomass in mid-summer			
DO (mgl/ℓ)	**Reference**			
	6	**8**	**8**	**8**
	Present/Future 1 and 2			
	4	**6**	**6**	**6**
	Future 3 and 4			
	2	**6**	**6**	**6**

Parameter	Characteristic			
Turbidity (NTU)	**Reference**			
	5	**5**	**5**	**5**
	Future/Present			
	5	**10**	**5**	**5**
Dissolved inorganic nitrogen (DIN) (µg/ℓ) *(modification mainly related to increased remineralisation organic matter to* NH_4*-N in lakes)*	**Reference/Present (deep)**			
	50	**50**	**50**	**50**
	Future/Present (peripheral areas)			
	90	**90**	**100**	**150**
Dissolved inorganic phosphate (DIP) (µg/ℓ) *(modification mainly related to increased remineralisation in lakes)*	**Reference/Present (deep)**			
	10	**10**	**10**	**10**
	Future/Present (peripheral areas)			
	30	**30**	**40**	**70**
Dissolved reactive silicate (DRS) (µg/ℓ)	**1000**	**1400**	**2000**	**3000**

Table 4.15 Touw Estuary: Summary of average changes in water quality from Reference Condition to Present State within each of the various zones (colour coding does not have specific meaning and is only for illustrative purposes)

Parameter	Summary of change	Zone	Reference	Present
Salinity	⇩Salinity as a result of reduced frequency and duration of the open periods (i.e. open period reduced from four months to two months on average), premature closures and siltation in lower reaches that reduces salinity penetration.	Lower	20	13
		Middle	16	10
		Upper	9	5
DIN (µg/ℓ)	Increase in occurrence of State 1 (Closed state) resulted in a small ⇩ DIN in lower estuary (especially during upwelling). During Present State, DIN ⇧ slightly in middle reaches due to anthropogenic activity along banks and inflow through Serpentine).	Lower	67	63
		Middle	50	100
		Upper	50	53
DIP (µg/ℓ)	Increase in occurrence of State 1 (Closed state) resulted in a small ⇩ DIN in lower estuary (especially during upwelling). During Present State, DIN ⇧ slightly in middle reaches due to anthropogenic activity along banks and inflow through Serpentine).	Lower	13	13
		Middle	10	20
		Upper	10	11
Turbidity (NTU)	No marked difference in turbidity	Lower	5	5
		Middle	10	10
		Upper	5	5
DO (mg/ℓ)	No marked change in DO, possibly slight ⇩ in average DO as a result of increase in State 1 (Closed)	Lower	7	7
		Middle	7	7
		Upper	7	7
Toxic substances	No marked increase in toxic pollution expected	95% similar to Reference		

Table 4.16 Wilderness Lakes: Summary of average changes in water quality from Reference Condition to Present State within each of the lakes and the Serpentine (colour coding does not have specific meaning and is only for illustrative purposes)

Parameter	Summary of change	Zone		Reference	Present
Salinity		Serpentine		15 ± 10	10 ± 5
		Eilandvlei		10 ± 5	6 ± 4
		Langvlei		12 ± 4	8 ± 3
		Rondevlei		15 ± 5	10 ± 4
DIN (µg/ℓ)	⇧ DIN (mainly NH_4-N) in the shallower peripheral areas of all zones associated with higher organic loading and remineralisation	Serpentine		50	90
		Eilandvlei	Peri	50	90
			Deep	50	50
		Langvlei	Peri	50	100
			Deep	50	50
		Rondevlei	Peri	50	150
			Deep	50	50
DIP (µg/ℓ)	⇧ DIP in the shallower peripheral areas of all zones associated with higher organic loading and remineralisation	Serpentine		10	30
		Eilandvlei	Peri	10	30
			Deep	10	10
		Langvlei	Peri	10	40
			Deep	10	10
		Rondevlei	Peri	10	70
			Deep	10	10
Turbidity (NTU)	No marked changes, except in Eilandvlei where the Duiwe River introduce slightly ⇧ turbidity associated with agricultural activity in the catchment	Serpentine		5	5
		Eilandvlei		5	10
		Langvlei		5	5
		Rondevlei		5	5
DO (mg/ℓ)	Marked ⇩ in DO in Serpentine (much shallower, protected and higher organic loading). Organic enrichment in lakes also resulted in slight ⇩ in average DO.	Serpentine		6	4
		Eilandvlei		8	6
		Langvlei		8	6
		Rondevlei		8	6
Toxic substances	Limited modification	Assume 90% similar to Reference			

4.4.2 Water quality health

The similarity in each parameter (e.g. dissolved oxygen) to Reference Condition was scored as follows:

- Define **zones** along the length of the estuary **(Z)** (i.e. Zones A, B and C)
- **Volume fraction** of each zone **(V)** (i.e. Lower = 0.4; Middle = 0.45; Upper = 0.15)
- Different **abiotic states (S)** (i.e. States 1 to 3)
- Define the **flow scenarios** (i.e. Reference, Present, Future scenarios)
- Determine the **% occurrence** of abiotic states for each scenario
- Define **water quality concentration range (C)** (e.g. 6 mg/ℓ; 4 mg/ℓ; 2 mg/ℓ)

Similarity between Present State, or any Future Scenarios, relative to the Reference Condition was calculated as follows:

- Calculate Average concentration for each Zone for Reference and Present/Future Scenarios, respectively:
- Average Conc (Z_A) = [({∑% occurrence of states in C_1}*C_1)+ ({∑% occurrence of states in C_2}*C_2)+({∑% occurrence of states in C_n}*C_n)] divided by 100
- Calculate similarity between Average Conc's Reference and Present/Future Scenario for each Zone using the Czekanowski's similarity index: $\underline{\sum(\min(ref,pres)}$ ($\sum ref + \sum pres)/2$)

For the final scores, a weighted average of the similarity scores of different zones was computed using the volume fractions (**Tables 4.17** and **4.18**).

Table 4.17 Touw Estuary: Present water quality health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable		Summary of change	Weight	Score	Confidence
1	**Similarity in salinity**	⇩ in average salinity and the variation in salinity as a result of mouth manipulation and flow reduction	40	77	M
2	**General water quality**				
a	DIN/DIP concentrations	⇩ in lower estuary (especially during upwelling). Slight ⇧ in middle reaches (anthropogenic influences)		83	M/L
b	Turbidity	No marked change		100	M
c	Dissolved oxygen	No marked change		98	M
d	Toxic substances	No marked change		95	L
General water quality in estuary: min (a to d)			60	83	
Water quality health score weighted mean (1,2)				**81**	**L/M**
% of impact non-flow related				50	
Adjusted score				90	L/M

Table 4.18 Wilderness Lakes: Present water quality health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable		Summary of change	Weight	Score	Confidence
1	**Similarity in salinity**	⇩Salinity as a result of reduced frequency (and duration) of the open periods	**40**	**78**	M
2	**General water quality in estuary**				
a	DIN/DIP concentrations	⇧ in the shallower peripheral areas of all zones associated with higher organic loading and remineralisation		80	M
b	Turbidity	Slightly ⇧ turbidity in Eilandvlei (introduced from Duiwe River)		88	M
c	Dissolved oxygen	⇩⇩ Serpentine, ⇩ in lakes due to some organic enrichment		85	M
d	Toxic substances	Limited modification (agriculture via Duiwe River)		90	L
General water quality in estuary: min (a to d)			60	80	
Water quality health score weighted mean (1,2)				**79**	**L/M**
% of impact non-flow related				50	
Adjusted score				90	L/M

4.5 MICROALGAE

4.5.1 Baseline description

4.5.1.1 Main grouping and baseline description

Based on the results of Harrison (unpublished data), van Ginkel and Hohls (2001), and December 2013 results (this study), phytoplankton chlorophyll *a* was generally low; ranging from below detectable limits to <10 µg/ℓ for 80% of the time. Phytoplankton cell density was low too and dominated by flagellates (90%) when the estuary mouth was open with few diatoms and dinoflagellates. The estuary is prone to dense stands of filamentous algae when the mouth is closed and conditions stable. These results suggest the estuary is oligo- to mesotrophic but benthic microalgal results contract these findings. Average benthic chlorophyll *a* exceeded 100 mg/L in December 2013 in the middle and middle-upper reaches of the estuary, which is considered to be extremely high. Many of the dominant diatoms have a high tolerance for polluted or eutrophic conditions. Water column nutrients were low at the time of sampling so it is most likely that local diffuse seepage of nutrients or the mineralisation of nutrients from the sediment support such high benthic microalgal biomass. Factors such as tidal flushing, coarse-grained sediment and low-nutrient river flow limited benthic microalgal biomass at sites near the mouth and the head of the estuary. Fortunately, the estuary is relatively shallow and the water column well-oxygenated. This prevents the release of nutrients from the sediment into the water column, preventing the development of phytoplankton blooms (e.g. cyanobacteria).

4.5.1.2 Description of factors influencing microalgae

Table 4.19 summarises the key responses of estuarine microalgae to changes in abiotic and other biotic components, while **Tables 4.20** and **4.21** translates these into expected responses within each of the abiotic states for the Touw Estuary and Wilderness Lakes, respectively.

Table 4.19 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various microalgae groupings

Variable	**Grouping**				
	Flagellates	**Dinoflagellates**	**Diatoms**	**Chlorophytes**	**Cyanobacteria**
Nutrients (N & P)	↑	↑	↓	↑	-
Herbicides	↓	↓	↓	↓	↓
Tidal flushing	↓	↓	↓	↓	↓
Turbidity	↓	↓	↓	↓	↓
Dissolved oxygen	-	-	-	-	↑

Variable	**Grouping**			
	Diatoms (Epipelic)	**Diatoms (Episammic)**	**Cyanobacteria**	**Euglenophytes**
Fines (silt & clay)	↑	↓	↑	↑
Organic loading	**-**	**-**	↑	↑
Nutrients (N & P)	↑	↑	↑	↑

Table 4.20 Touw Estuary: Summary of microalgal biotic responses to various abiotic states

Abiotic state	**Response**
Closed	When the mouth is closed for an extended period the water column is likely to become nutrient-poor, limiting phytoplankton growth (bdl - <3 µg/ℓ). The low turbidity, mineralisation of organic-rich fine sediment, and diffuse seepage of nutrient-enriched water from the sediment will support elevated benthic microalgal growth (50 – 100 mg/ℓ) in the middle to middle-upper reaches of the estuary. The calm, clear and shallow (<1 m) reaches are likely to support relatively dense stands of filamentous algae such as *Cladophora glomerata*, *Enteromorpha intestinalis* and *Tribonema* sp.
Open (saline gradient)	When there is slightly elevated river flow and the mouth of the estuary is open the water column is likely to have slightly elevated nutrients in the middle reaches of the estuary (double the N & P compared to reference) supporting slightly elevated phytoplankton biomass (~7 µg/ℓ). Low turbidity, mineralisation of organic-rich fine sediment, and diffuse seepage of nutrient-enriched water from the sediment will support elevated benthic microalgal growth (> 100 mg/ℓ) in the middle to middle-upper reaches of the estuary. Tidal flushing will restrict the growth of filamentous algae.

Abiotic state	Response
Open (freshwater dominated)	Strong river flow will limit phytoplankton growth (<3 µg/ℓ; low residence time) and benthic microalgal growth (<50 mg/ℓ; elevated TSS and scouring of sediments)

Table 4.21 Wilderness Lakes: Summary of microalgal biotic responses to various abiotic states

Abiotic state	Response
High water and very high water levels	The conditions (water quality etc.) are unlikely to change drastically in the lakes unless there is a large infrequent flood event. When the water is high the increased volume and area of the lakes compared to the open phase will have the largest effect (more habitat for phytoplankton and benthic microalgae). Assuming a 5% increase in phytoplankton biomass (5% increase in volume) and a 10% increase in benthic microalgal biomass (10% increase in subtidal area).
Low water level	Biomass of phytoplankton and MPB likely to be low (oligotrophic; <3 µg/ℓ and <20 mg/m^2 respectively). Conditions in the lakes are stable so the biggest change is likely to be seen in the climax community (fringing and submerged aquatic vegetation).

4.5.1.3 Reference Condition

Expected changes in microalgae from the Reference Condition to the Present State in the Touw Estuary and Wilderness Lakes are summarised in **Tables 4.22** and **4.23**, respectively.

Table 4.22 Touw Estuary: Summary of relative changes in microalgae from Reference Condition to Present State

Key drivers	Change
Phytoplankton	
Residence time	As river flow has decreased by 15% and there has been an associated 15% shift from State 2 (open) to State 1 (closed), residence time has increased. This favours a shift from pelagic to benthic primary production (phytoplankton biomass ↓).
Nutrient availability	Nutrient concentrations have doubled in the middle reaches of the estuary supporting and increase in primary production (↑ phytoplankton biomass).
Light availability (low TSS)	TSS was low and Secchi depths were to the bottom so light is not limiting to microalgal growth (no change).
Estuary volume	When the mouth closes, the volume of the estuary increases by 5% (total phytoplankton biomass ↑).
Benthic microalgae	
Light availability (low TSS)	TSS was low and Secchi depths were to the bottom so light is not limiting to microalgal growth (no change).
Deposition and mineralisation of organic-rich fine sediments	Increased fine sediment load and higher residence time favour the settling of organic-rich fine sediments. This environment favours the growth of benthic microalgae (mineralisation of nutrients ➔ ↑ mpb biomass).

Key drivers	Change
Extended calm conditions	A 15% shift from State 2 (open) to State 1 (closed) favours a shift from pelagic to benthic primary production (mpb biomass ↑).
Additional habitat during State 1	There have been many anthropogenic changes to estuary bathymetry/morphology but the 15% shift from State 2 to State 1 represents a 10% increase in benthic habitat when the estuary mouth is closed (total mpb biomass ↑).
Water column nutrients	Nutrient concentrations have doubled in middle reaches of the estuary supporting an increase in primary production (mpb biomass ↑).

Table 4.23 Wilderness Lakes: Summary of relative changes in microalgae from Reference Condition to Present State

Key drivers	Change
Nutrients	An increase in nutrients (perimeter only) favours an increase in microalgal growth (strong competition for resources with emergent vegetation and submerged aquatic vegetation will limit growth; 10% ↑ in biomass.
Water volume	When the water is high (mouth closed 15% more) the increased volume of the lakes compared to the open phase will have the largest effect (more habitat for phytoplankton); 5% ↑ in total phytoplankton biomass (represents ~1% overall increase).
Lake area	When the water is high (mouth closed 15% more) the increased area of the lakes compared to the open phase will have the largest effect (more habitat for benthic microalgae); 10% ↑ in MPB biomass (represents ~2% overall increase).

4.5.2 Microalgae health

The microalgae health scores for the Present State in the Touw Estuary and Wilderness Lakes are presented in **Tables 4.24** and **4.25**, respectively.

Table 4.24 Touw Estuary: Present microalgae health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable	Summary of change	Score	Confidence
Phytoplankton			
a. Species richness	The slightly elevated nutrients may have resulted in the loss of pollution/nutrient sensitive species.	95	M
b. Abundance	There has been an increase in phytoplankton biomass (< 3 µg/L to a peak of 7µg/L in the middle reaches); 22% overall ↑.	78	M
c. Community composition	The calmer conditions with slightly elevated nutrients support an increase in the flagellate: diatom ratio and an increase in dinoflagellates during State 2.	80	M

Variable	Summary of change	Score	Confidence
Benthic microalgae			
a. Species richness	The diversity and evenness scores for the estuary were 1.86 and 0.66 respectively; low relative to other estuaries in the region and changes may be related to sensitivity to nutrients, a slight shift to finer sediments (episammics to epipelics), and mouth closing more frequently. Assume slight change related to loss of sensitive species (5%) and some episammic species in middle reaches (5%).	90	L
b. Abundance	There has been a dramatic increase in MPB biomass (from <10 mg/m^2 to values exceeding 100 mg/m^2 throughout the middle and middle-upper reaches); 61% increase from reference.	53	M
c. Community composition	Reference Condition would have had lower nutrients (oligotrophic) and coarser sediments supporting more episammic species than epipelics. Assume change (10%) related to loss of nutrient-sensitive species.	80	L
Microalgae health score: min (a to c)		**53**	**L/M**
% of impact non-flow related (nutrients and sediments) -		50	
Adjusted score		77	L/M

Table 4.25 Wilderness Lakes: Present microalgae health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable	Summary of change	Score	Confidence
a. Species richness	There is a small chance that species have been lost (e.g. nutrient sensitive taxa) and cyanobacteria species have been gained; 10% change.	90	L
b. Abundance	An increase in nutrients in perimeter water will favour the growth of microalgae. This will be limited by competition for resources with emergent and submerged aquatic vegetation. Approximately 20% ↑ in biomass.	80	M
c. Community composition	Stable oligotrophic conditions would have favoured a low flagellate: diatom ratio and cyanobacteria would have been absent/negligible. It is likely that there has been a slight increase in the flagellate: diatom ratio and cyanobacteria have become dominant at times in the Eilandvlei and Langvlei (van Ginkel & Hohls 2001). Approximately 30% change in community composition.	70	L
Microalgae health score: min (a to c)		**70**	**L**
% of impact non-flow related (nutrients)		80	
Adjusted score		94	L

4.6 MACROPHYTES

4.6.1 Baseline description

4.6.1.1 Main grouping and baseline description

Reeds and sedges are dominant in the Wilderness lake system with smaller areas of salt marsh and submerged macrophytes. These primary producers are essential for food production; they provide habitat diversity and play an important role in bank stabilisation and recycling of nutrients. Similarly to Swartvlei Lake the centre of biological productivity for the lakes would lie in the littoral zone to a depth of 2 m (Howard-Williams and Allanson, 1979). Weisser and Howard-Williams (1982) provide a comprehensive description of vegetation distribution for the Wilderness Lakes in Howard-Williams and Allanson, (1979) and Russell (2003) provides maps, a comprehensive description for 1997 and assessment of changes over time.

Common reed *Phragmites australis* is abundant as well as the sedge *Schoenoplectus scirpoideus*. Other recorded sedge species are *Bolboschoenus maritimus* and *Typha capensis* (bulrush). *Juncus kraussii* (sharp rush) occurs on more saline soils than the reeds and sedges. The succulent salt marsh plant *Sarcocornia* spp. is also present as well as *Cotula coronopifolia*. Submerged macrophytes were represented by *Potamogeton pectinatus* within the more brackish regions as well as *Ruppia cirrhosa* and *Zostera capensis*. Charophyta and filamentous algae such as *Enteromorpha* (*Ulva* spp.) are also abundant.

4.6.1.2 Description of factors influencing macrophytes

Table 4.26 summarises the key responses of estuarine macrophytes to changes in abiotic and other biotic components, while **Tables 4.27** and **4.28** translate these into expected responses within each of the abiotic states in the Touw Estuary and Wilderness Lakes, respectively.

Table 4.26 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various macrophyte groupings

Variable	Macrophytes
Mouth condition	Open mouth conditions would create intertidal habitat, however intertidal salt marsh is not abundant in the Touw Estuary. Artificial breaching has reduced water level fluctuations causing reed expansion.
Retention times of water masses	Closed mouth conditions and longer water retention times promote macroalgal growth. Submerged macrophytes would also grow and expand under these conditions.
Flow velocities (e.g. tidal velocities or river inflow velocities)	High flow velocity would remove macroalgae and also prevent the extensive growth of submerged macrophytes.
Total volume and/or estimated volume of different salinity ranges	The longitudinal salinity gradient promotes species richness, different macrophyte habitats are distributed along the length of the estuary and lakes.

Variable	Macrophytes
Floods	Floods would increase turbidity and reduce submerged macrophyte biomass.
Salinity	Submerged macrophytes are distributed according to their salinity preferences. The estuary and lakes have become fresher over time causing common reed, *Phragmites australis* to displace *Juncus kraussii* which would have occurred in more saline soils.
Turbidity	Increased sediment load within the water column results in a reduction in the photic zone and will limit submerged macrophyte establishment.
Dissolved oxygen	High biomass of macroalgae and submerged macrophytes can cause localised increases in oxygen concentrations. Mouth closure, a lack of flushing and decaying organic detritus can decrease $O_{2.}$
Nutrients	Increased nutrient inputs would increase macrophyte growth particularly that of the reeds in the littoral zone. Nutrients would also increase macroalgal blooms resulting in smothering and loss of submerged macrophytes.
Sediment characteristics (including sedimentation)	There has been some marine sedimentation and reed encroachment in the estuary.
Other biotic components	Waterfowl grazing would naturally control biomass of submerged macrophytes.

Table 4.27 Touw Estuary: Summary of macrophyte responses to various abiotic states

Abiotic state	Response
State 1: Closed state	High water level would result in some flooding of macrophyte habitats. Macroalgae and submerged macrophytes flourish in this state.
State 2: Open with full salinity gradient	Maximum macrophyte diversity with different submerged macrophytes species occurring in different salinity zones.
State 3: Open, freshwater dominated	Reeds and sedges would thrive under this state.

Table 4.28 Wilderness Lakes: Summary of macrophyte responses to different abiotic states

Abiotic state	Response
State 1: Low water level	Emergent macrophytes would grow and expand their area cover.
State 2 and 3: High and very high water levels	Macroalgae and submerged macrophytes would grow and expand their area cover.

4.6.1.2 Reference Condition

A summary of the relative changes in macrophytes in the Touw Estuary and Wilderness Lakes from Reference Condition to Present State is summarised in **Tables 4.29** and **4.30**, respectively.

Table 4.29 Touw Estuary: Summary of relative changes in macrophytes from Reference Condition to Present State

Key drivers	Change
⇩ water level fluctuations	⇧ reeds, more stable estuary with sedimentation
⇩ salinity	⇩ salt marsh
⇧ nutrients	⇧ macroalgae ⇩ submerged macrophytes
TOTAL CHANGE	⇧ reeds ⇧ macroalgae ⇩ salt marsh

Table 4.30 Wilderness Lakes: Summary of relative changes in macrophytes from Reference Condition to Present State

Key drivers	Change
⇩ water level fluctuations	⇧ reeds
⇩ salinity	⇧ reeds
⇧ nutrients	⇧ macroalgae ⇩ submerged macrophytes
TOTAL CHANGE	⇧ reeds ⇧ macroalgae ⇩ submerged macrophytes

4.6.2 Macrophyte health

The macrophyte health scores for the Present State in the Touw Estuary and Wilderness Lakes are presented **in Tables 4.31** and **4.32**, respectively.

Table 4.31 Touw Estuary: Present macrophyte health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable	Summary of change	Score	Confidence
a. Species richness	Disturbance and decrease in salinity may have resulted in loss of some saline species.	90	M
b. Abundance	There has been an increase in reed area at the expense of open water area and salt marsh habitat. Some loss of overall habitat due to development and bank stabilisation.	70	M
c. Community composition	Loss of salt marsh habitat. Possible displacement of submerged macrophytes by macroalgae.	80	M
Macrophyte health score		**70**	**M**
% of impact non-flow related		90	
Adjusted score		97	M

Table 4.32 Wilderness Lakes: Present macrophyte health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable	Summary of change	Score	Confidence
a. Species richness	Disturbance and decrease in salinity may have resulted in loss of some saline species.	90	M
b. Abundance	There has been an increase in reed area at the expense of open water area. Some loss of overall habitat due to development.	80	M
c. Community composition	Lower water level and drying would result in loss of some wetland habitat. Possible displacement of submerged macrophytes by macroalgae.	80	M
Macrophyte health score		**80**	**M**
% of impact non-flow related		90	
Adjusted score		98	M

4.7 INVERTEBRATES

4.7.1 Baseline description

4.7.1.1 Main grouping and baseline description

Four major invertebrate groups (Mesozooplankton, hyperbenthos, subtidal macrozoobenthos and the intertidal macrozoobenthos) are identified for the purposes of reserve determination studies in estuaries. In the Wilderness Lakes complex, research has mostly concentrated on the zooplankton and benthic community, with most studies done on the Touw Estuary. Russell *et al.* (2009) provided an update on the state of knowledge on the Garden Route National Park which includes the Touw Estuary. Although reference is made to zooplankton studies undertaken by Grindley & Wooldridge (1973) and Coetzee (1983), no other invertebrate studies in the Touw Estuary are mentioned by Russell *et al.* (2009). Davies (1984) however, provided a detailed report on the benthos of Wilderness Lagoon, Touw River and the Serpentine. In addition, some information is provided on the benthos of Eilandvlei. Langvlei and Rondevlei.

Previous information on the zooplankton from the Touw Estuary in non-quantitative, although a measure of abundance provided by Grindley & Wooldridge (1973) and refers to the biomass of zooplankton. Overall, zooplankton in the estuary was considered low. Eighteen species were present, dominated by *Pseudodiaptomus hessei*. Other species of relative importance were the amphipod *Grandidierella* sp. (probably *G. lignorum*) and the cumacean *Iphinoe truncata*. Eight species were present in Eilandvlei, five in Langvlei and seven species in Rondevlei, although numbers were very low.

Coetzee (1983) described the zooplankton from the Touw Estuary as typically estuarine, with marine species appearing occasionally when the mouth opened to the sea. Freshwater associated species appeared at times of high rainfall. Consequently, species richness over the study period of one year was relatively high, with ca 29 species recorded. In the three lake systems, very similar patterns were recorded although Lamellibranch veliger larvae were more abundant, the average (for the 12-month study) ranging between 3000 and 11200 ind.m^{-3}. These veliger larvae were considered to be those of *Musculus virgiliae.* Overall, veligers were the most abundant zooplankters in Eilandvlei, Langvlei and Rondevlei; and the second most abundant in the Touw Estuary after nauplii larvae.

Davies (1984) recorded 37 taxa (the list included two species of zooplankton). The amphipods *Melita zeylanica*, *Corophium triaenonyx*, *Grandidierella lignorum*, the isopod *Cyathura carinata*, the Tanaeid *Apseudes digitalis*, dipteran larvae (Chironomidae) and the mollusc *Musculus virgiliae* dominated standing stock values. The Lagoon area was the only site where the anomuran burrowing prawns *Callichirus kraussi* and *Upogebia africana* were recorded in the Touw Estuary or in the three lakes investigated (Davies, 1984).

In terms of invertebrate biomass, a major difference was recorded when comparing non-vegetated vs vegetated areas opposite the Fairy Knowe. Standing stock in non-vegetated areas along this transect was similar to the lagoon transect, but a dense stand of *Potamogeton pectinatus* resulted in the biomass of the associated invertebrates increasing by an order of magnitude. Mean for the vegetated site during the study period was 128.9 g dry mass m^{-2} (range 6 to 329 g dry mass m^{-2}). Temporal changes in faunal biomass associated with *Potamogeton pectinatus also* differed from invertebrate biomass changes in non-vegetated areas. In the case of the macrophyte-associated fauna, the main shift occurred in mid-winter when macrophyte die-back occurred (from 329 to 6 g dry mass m^{-2}, May-June 1979, compared to late summer at exposed sites). This significant increase in biomass was due to the bivalve mollusc *Musculus virgiliae* that attaches itself to the macrophyte. The information provided by Davies's 1984 study is therefore supportive of zooplankton results obtained by Coetzee (1983). In the zooplankton, veligers (considered to be those of *Musculus virgiliae*) were the most abundant zooplankters in Eilandvlei, Langvlei and Rondevlei; and the second most abundant in the Touw Estuary. The *Potamogeton*-associated faunal standing stock (invertebrates) recorded in the Wilderness Lakes complex are among the highest recorded for similar lake studies elsewhere, being much higher than the Bot Estuary

In August 1979, *The Lakes Area Development Board* undertook a programme of submerged plant cutting in the Serpentine canal. As a consequence, invertebrate biomass (particularly *Musculus virgiliae*) reduced significantly. Recovery of the submerged plant was slow in the West Serpentine, while no recovery in the East Serpentine was recorded over the remainder of the study (10 months). These results underline the importance of macrophytes as a habitat for those invertebrates that utilize them. After the cutting of the submerged macrophytes, biomass of *Grandidierella lignorum, Melita zeylanica* and *Apseudes digitalis* increased.

These plant-invertebrate associations described for the Touw-Serpentine and Bot coastal lake systems underline the importance of rooted plants to the development of high-biomass invertebrate communities associated with them. In the Touw-Serpentine study undertaken by Davies (1984) biomass exceeded those values from sediments at the same stations and over the same period by a factor ranging between 7.6 and 20 times higher.

During the 2013 survey, zooplankton data supported conclusions by Coetzee (1983) that zooplankton biomass in the Touw is relatively low. Veligers were not recorded during this survey, probably as a consequence of mesh size and/or the timing of the fieldwork relative to the breeding pattern of bivalve molluscs. Species present in the zooplankton were typical of estuaries along the south coast, with amphipods, mysids, cumaceans and carid shrimps also being numerically important. The cumacean *Iphinoe truncata* and the amphipod *Grandidierella lignorum* were particularly abundant, although these two species are more typical of the hyperbenthos and the benthos. Zoel stages of the crown crab, *Hymenosoma orbiculare* were also abundant in the estuary.

The hyperbenthic sled samples supported conclusions drawn for the zooplankton, with low species richness (6) and biomass. Species richness was also relatively low in the benthos (13 species). This was much lower than the number of species reported by Davies (1984) and was probably due to the absence of marine influence at the time of the 2013 study, the impact of the flood three weeks earlier and the frequency of sampling (only one field trip in the present study, whereas Davies conducted monthly field surveys over 18 months).

4.7.1.2 Description of factors influencing invertebrates

The effect of abiotic characteristics and processes, as well as other biotic components (variables) on various invertebrate groupings are provided in **Table 4.33**.

Table 4.33 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various invertebrate groupings

Variable	Response of the zooplankton and hyperbenthos
Mouth state	Mouth closure will reduce species richness, since marine species will disappear from the estuary.
Salinity	A full salinity gradient will increase species richness and enables zonation patterns to develop within communities. Biomass also increases, particularly in the REI. If salinity falls too low (closed mouth for extended periods and salinity falls below 5-10 throughout the estuary), the communities will shift towards a more oligiohaline mix of species. The opposite occurs if salinity values exceed 10 throughout the estuary – the oligohaline community disappears or it is present in the extreme upper limit of the estuary only.
Floods	Floods will flush populations from the estuary – recovery in some cases will be relatively slow. Sediment characteristics change locally and this impacts community structure.
REI Zone	The development of the REI zone will increase biomass, particularly among the euryhaline copepods.
Phytoplankton biomass	An increase in phytoplankton biomass would lead to an increase in density of invertebrate populations – food availability.
Changes in the fringing vegetation cover	Hyperbenthic species such as the carid shrimp *Palaemon capensis* utilises stands of fringing vegetation as a habitat. A decrease in fringing macrophyte biomass will lead to a concomitant decrease in carid biomass.

Variable	Benthic response (subtidal and intertidal)
Mouth state	Some species such as the mudprawn *Upogebia africana* require a marine phase of development – recruitment to the population ceases should the mouth close during the breeding season. After about three years of mouth closure, mudprawn populations become locally extinct.
Salinity	A full salinity gradient will increase species richness and enable zonation patterns to develop within the benthic community. Low salinity zones are particularly favourable for amphipod species such as *Corophium triaenonyx* and *Grandidierella lignorum*.
Oxygen	A decrease in oxygen concentration (below 50% of surface values) will result in the disappearance of many of the benthic species.
Floods	Some populations, particularly in unconsolidated sediments will be flushed from the estuary.
Organic content of the sediments	High organic content of the sediment favours species that are associated with the surface layers particularly.
Changes in sediment characteristics	Benthic species distribution will change in accordance with the shift of habitat preference.
Expansion or decrease coverage of subtidal macrophyte beds	Biomass of benthic populations particularly will increase significantly if submerged macrophytes become more expansive. The reverse pattern holds true at times of macrophyte disappearance. The change in macrophyte coverage will also lead to shifts in the macrobenthic species mix.

Tables 4.34 and **4.35** summarise response of invertebrates to specific abiotic states in the Touw Estuary and Wilderness Lakes, respectively.

Table 4.34 Touw Estuary: Summary of invertebrate responses to various abiotic states

Abiotic state	Response
State 1: Closed	Salinity values in the lower and middle reaches of the Touw Estuary are around 10. This state will lead to a decrease in the presence of marine and even euryhaline species that require higher salinity values in order to complete their respective life cycles. Benthic species such as the mudprawn *Upogebia africana* will disappear progressively from the system if a closed mouth persists for 1-2 years or longer. Recruitment from the marine environment (post-larval migration) will not be able to provide sufficient new recruits as natural mortality and bait harvesting impact the estuarine population. Sandprawn (*Callichirus kraussi*), populations will not breed under low salinity conditions (threshold is 17-20) and the only recruitment will be during an open mouth state when adults and/or juveniles move in to the estuary from the nearshore. The period of open mouth therefore becomes critical in maintaining the population. The zooplankton community will be characterised by low biomass. Species richness will also be low and dominated *by Pseudodiaptomus heassei, Acartia natalensis*, as well as lamellibranch larvae particularly. In the upper reaches, more oligohaline species will dominate the zooplankton. The boundary zone around a salinity of 10 is important, and any increase or decrease around this value will lead to major shifts in invertebrate composition and biomass. Submerged macrophytes (mainly *Potamogeton pectinatus*) would become more expansive in the estuary and this would favour invertebrates that favour attached macrophytes as a habitat (e.g. *Musculus virgilliae*). Conversely, increased macrophyte coverage would lead to a decrease in biomass of benthic species that favour open non-vegetated habitats. Because of increased macrophyte biomass hyperbenthic species such as carid shrimps would also increase in biomass. Increased fringing vegetation cover would also provide increased habitat for the carid shrimps. The low salinity conditions will also favour amphipods *Corophium triaenonyx*, *Grandidierella lignorum*, *Melita zeylanica* and the tanaeid *Apseudes digitalis.*
State 2: Open (saline gradient)	A full salinity gradient will maximise for species richness and biomass – the latter also supported by an increase in primary production. Invertebrate zonation patterns will also be well defined along the estuary. The presence of the REI will favour zooplankton biomass. Submerged macrophyte cover will decrease relative to State 1 and this will favour burrowing forms in the benthos.
State 3: Open (Freshwater dominated)	Oligohaline species will dominate the invertebrate community, extending well downstream from the closed mouth state.

Table 4.35 Wilderness Lakes: Summary of invertebrate responses to different abiotic states

Abiotic state	Response
State 1: High water levels	From an invertebrate perspective, the only change is a slight drop in water level. The lakes currently support high biomass of bivalves (*Musculus virgiliae*) and amphipods (*Grandidierella lignorum, Melita zeylanica* and *Corophium triaenonyx*). Predatory isopods are also common (*Cyathura carinata*), as are chironomid larvae. Salinity values remain relatively unchanged in the lakes and therefore, the invertebrate community will change very little, linked to a small drop in biomass as a consequence of a reduction in habitat available (decrease in water volume).
State 2: Low water levels State 3: Very high water levels	Water levels increase by up to 1 m, and this is likely to cause die-back of the ringing vegetation (*Phragmites*). Consequently, there is likely to be a shift in the mix of species, with invertebrates utilizing reeds as a substrate decreasing marginally in biomass.

4.7.1.3 Reference Condition

Tables 4.36 and **4.37** summarise the relative changes from Reference Condition to Present State in the invertebrate component for the Touw Estuary and Wilderness Lakes, respectively.

Table 4.36 Touw Estuary: Summary of relative changes in invertebrates from Reference Condition to Present State

Key drivers	Change
Mouth state	Under Present State, the mouth is open for about 25% of the time, a decrease from 40% (natural state). Species such as mudprawn (*Upogebia africana*) will be very sensitive to mouth condition since the species requires a marine phase of development during its life cycle. Mudprawn were present in the estuary in 1979-80, but the population was confined to the lagoonal area of the Touw Estuary only. Given the nature of the sediment, the population was probably very small and limited to isolated patches where muddy sediment was present. A mudprawn population if present in the estuary, will move along a trajectory of reducing biomass over time (years). The population will increase during years when the mouth remains open in summer for > 1 month at a time. If the mouth opens occasionally for short intervals only (< 1 month) little, if any recruitment will take place and the population will decline. After ca 3-4 years, the population will become extinct in the estuary. Limited and occasional recruitment is possible from adjacent Swartvlei, but the probability is low.

Key drivers	Change
Salinity	Salinity values have deceased by ca 5 throughout the estuary, with a maximum around 10 in the lower and middle estuary (increase in low flow events by ca 10%). Sandprawns (*Callichirus kraussi*) requires a minimum salinity of 17- 20 to enable breeding to take place. Consequently, at lower salinity values (< 15) recruitment from within the estuary will cease. New recruits will populate the population from marine nearshore stock, young and adult prawns migrating in to the estuary when the mouth is open. At salinity values around 10, zooplankton biomass will be relatively low (lack of a salinity gradient along the estuary). Species richness will also be low, with oligohaline species increasing in importance. Submerged macrophytes are an important substrate for many invertebrate species and when large stands of macrophytes are present, invertebrates utilising these habitats will dominate biomass of the benthos. Low salinity values also favour isopods and amphipod species (*Cyathura carinata, Expsphaeroma hylocoetes, Grandidierella lignorum, Melita zeylanica* and *Corophium triaenonyx* are examples)
Floods	Floods scour available habitat from the estuary and the slight reduction in floods will lead to a more stable substrate (open sediment and submerged macrophytes), leading to less variability in invertebrate population biomass. However, recovery of invertebrate populations will be rapid. The increase in the salinity gradient along the estuary will lead to a temporary increase in zooplankton biomass as well as a weak zonation of species along the gradient.

Table 4.37 Wilderness Lakes: Summary of relative changes in invertebrates from Reference Condition to Present State

Key drivers	Change
Salinity	Changes in salinity in the lakes impacts the species present. Under natural conditions salinity favours community linked to salinity remaining around 5-15. Thus, the shift towards lower salinity values will result in the communities moving along a trajectory of a more oligohaline mix of species. The shift will influence the order of dominance within the invertebrate community rather than impact species richness.
Oxygen concentration	A reduction in O_2 concentration to about 70% saturation at times is unlikely to impact the invertebrates in a serious way. However, should oxygen concentrations reduce further, some species will be negatively impacted (all invertebrate groups).

4.7.2 Invertebrate health

The invertebrate health scores for the Present State are presented in **Tables 4.38** and **4.39** for the Touw Estuary and Wilderness Lakes, respectively.

Table 4.38 Touw Estuary: Present invertebrate health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable	Summary of change	Score	Confidence
Zooplankon			
a. Species richness	Species richness will decline because of the change in closed mouth conditions (estuary now connected to the sea for 25% of the time) and relatively low salinity values that persist in the estuary. At times of mouth opening, survival of marine species after incursion will be relatively short lived (days) as water-mixing will reduce salinity in the estuary below thresholds (<ca 28).	60	L
b. Abundance	The reduction in salinity levels to ca 10 in the lower and middle reaches (From ca 15) will not be favourable for all species and zooplankton abundance levels will decline. Salinity around 10 is on the threshold between oligohaline and mesohaline communities.	75	L
c. Community composition	Because of the reasons noted above, composition of the community will switch in favour of a more oligohaline mix of species.	70	L
Hyperbenthos			
a. Species richness	Species richness will decline because of the change in closed mouth conditions (estuary now connected to the sea for 25% of the time) and relatively low salinity values that persist in the estuary. At times of mouth opening, survival of species after incursion will be relatively short lived (days) as water-mixing will reduce salinity in the estuary below thresholds (< ca 28).	60	L
b. Abundance	The reduction in salinity levels to ca 10 in the lower and middle reaches (From ca 15) will not be favourable for all species and abundance levels for some species will decline. Mysids species (*Rhopalophthalmus terranatalis* and *Mesopodopsis wooldridgei*) for example, will decline in abundance. These salinity levels however will be more favourable for carid shrimps (*Palaemon capensis*) and their abundance will increase.	60	L
c. Community composition	Because of the reasons noted above, composition of the community will switch towards a more oligohaline mix of species. In addition, some species such as mysids will disappear if salinity thresholds remain around 10 in the lower-middle reaches.	60	L

Variable	Summary of change	Score	Confidence
Benthos			
a. Species richness	Species richness will decline because of the change in closed mouth conditions (estuary now connected to the sea for 25% of the time). Some species will become locally extinct – the mudprawn *Upogebia africana* is an example. Other species such as sandprawn will only survive if sufficient recruits migrate in to the estuary during open mouth conditions. Other benthic species will be impacted in a similar way, as marine associated species having a preference for a sandy substrate will become extinct because of the low salinity levels in the lower estuary. No salinity gradients will develop in the lower estuary under closed mouth conditions.	60	L
b. Abundance	The reduction in salinity levels to ca 10 in the lower and middle reaches (From ca 15) will not be favourable for all species and abundance levels for some species will decline. Some bivalve molluscs present in sandy substrata will probably become locally extinct under low salinity and closed mouth conditions that persist. The reduction in salinity to around 5 in the upper reaches of the estuary on the other hand, will favour many species of amphipods (e.g. *Grandidierella lignorum, Melita zeylanica and Corophium triaenonyx*), isopods (*Cyathura carinata*), tanaeids (*Apseudes digitalis*) and will lead to a change in abundance levels.	60	L
c. Community composition	Because of the reasons noted above, composition of the community and mix of species will switch because of low salinity conditions that persist for longer. The trajectory in salinity values will also shift towards a more oligohaline environment over time and as the mouth stays closed. Coupled to the abiotic changes noted above, the persistence and change in macrophyte coverage will further influence the species mix and dominance within the community.	55	L
Invertebrate health score: min (a to c)		**55**	**L**
% of impact non-flow related		30	
Adjusted score		69	L

Table 4.39 Wilderness Lakes: Present invertebrate health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable	Summary of change	Score	Confidence
Zooplankon			
a. Species richness	The small change in salinity in the lakes is unlikely to cause a shift in the species richness. The shift will influence the order of dominance within the invertebrate community rather than impact species richness.	100	L
b. Abundance	Under natural conditions the community was linked to salinity remaining around 5-15. Thus, the shift towards lower salinity values will result in a small shift in abundance levels for some species – more oligohaline species will increase in abundance	90	L
c. Community composition	Under natural conditions the community was linked to salinity remaining around 5-15. Thus, the shift towards lower salinity values will result in the communities moving along a trajectory of a more oligohaline mix of species and a small change in dominance within the species mix.	90	L
Hyperbenthos			
a. Species richness	The small change in salinity in the lakes is unlikely to cause a shift in the species richness.	100	L
b. Abundance	Under natural conditions the community was linked to salinity remaining around 5-15. Thus, the shift towards lower salinity values will result in a small shift in abundance levels for some species – more oligohaline species will increase in abundance	90	L
c. Community composition	Under natural conditions the community was linked to salinity remaining around 5-15. Thus, the shift towards lower salinity values will result in the communities moving along a trajectory of a more oligohaline mix of species and a small change in dominance within the species mix.	90	L
Benthos			
a. Species richness	The small change in salinity in the lakes is unlikely to cause a shift in the species richness.	100	L
b. Abundance	Under natural conditions the community was linked to salinity remaining around 5-15. Thus, the shift towards lower salinity values will result in a small shift in abundance levels for some species – more oligohaline species will increase in abundance	90	L

Variable	Summary of change	Score	Confidence
c. Community composition	Under natural conditions the community was linked to salinity remaining around 5-15. Thus, the shift towards lower salinity values will result in the communities moving along a trajectory of a more oligohaline mix of species and a small change in dominance within the species mix.	90	L
Invertebrate health score: min (a to c)		**90**	**L**
% of impact non-flow related		30	
Adjusted score		93	L

4.8 FISH

4.8.1 Baseline description

4.8.1.1 Main grouping and baseline description

The earliest assessment of the fish community within the Touw Estuary and the Wilderness Lakes was completed between 1982 and 1984 (Hall *et al.,* 1987) over a two year period and recorded a total of 32 species from 18 families. Since then work by Russell (1996) has looked at changes in fish abundance relative to various environmental factors (recording 14 species from 8 families) whilst Olds (2012) investigated the spatial and temporal abundance and distribution of native and alien fish within the system. The two previous studies utilised beach seine nets and gill nets for their sampling whilst Olds (2012) incorporated both Fyke nets and scoup nets in addition to seine and gill nets, recording 26 species from 18 families. During a once-off sampling of the Touw Estuary using beach seine and gill nets (James and Harrison, 2008) 18 species from 11 families were sampled whilst seine net sampling in 2014 (this study) resulted in 18 species from ten families being recorded.

Overall the Wilderness Lakes system ichthyofauna comprises fishes in all but one (pure marine – category III) of Whitfield's (1998) estuarine categories, the majority falling within the marine migratory component with small proportions of native estuarine species, catadromous and alien freshwater species. Estuarine resident species that spawn only within estuaries (Ia) are represented by one species whilst resident species spawning both in estuaries and nearshore marine environments (Ib) are represented by seven species. Obligate estuary dependent species (IIa) comprise nine species with four partially estuary dependent fish species (IIb and IIc). Catadromous species comprise the longfin eel (*Anguilla mossambica*) and the facultative catadromous freshwater mullet (*Myxus capensis*). Two indigenous freshwater species occur within the Touw and Duiwe rivers namely Cape Kurper (*Sandelia capensis*) and the Eastern Cape redfin (*Pseudobarbus afer*) whilst five other species are classified as alien invasive including Mozambique tilapia (*Oreochromis mossambicus*), Mosquito fish (*Gambusia affinis*), Smallmouth bass (*Micropterus dolomieu*), large mouth bass (*Micropterus salmoides*) and a more recent introduction of common carp (*Cyprinus carpio*). In describing the fish community throughout the system Olds (2012) showed that the proportion of species in each estuarine category was independent of sampling area (Olds, 2012) but in contrast the relative biomass of species in each estuarine group showed significant spatial variation throughout the system. Native estuarine species contributed between 15% and 21% in each of the lakes and the Touw Estuary (highest in the Touw Estuary and Rondevlei) and euryhaline marine species contributed between 29% (Langvlei) and 66% (Eilandvlei). Rondevlei had the highest biomass (20%) of catadromous species and Touw the lowest biomass (2.2%) whilst alien species dominated within Langvlei (52%). Overall there is a high degree of estuarine dependency with 85% of the fish assemblage comprising fish species that are either partially or completely dependent on estuaries.

4.8.1.2 Description of factors influencing fish

A summary of the effect of abiotic characteristics and processes, as well as other biotic components (variables) on various fish groupings is presented in **Table 4.40**, while a summary of fish responses to various abiotic states is presented in **Table 4.41** and **4.42** for the Touw Estuary and Wilderness Lakes, respectively.

Table 4.40 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various fish groupings

Variable	Ia. Estuarine residents (breed only in estuaries)	Ib. Estuarine residents (breed in estuaries & Sea)	IIa. Estuarine dependent marine species	IIb & c. Estuary associated species	III. Marine migrants	IV & V. Freshwater species
Mouth condition	Touw Estuary is a temporarily open/closed system.		Both the timing and the duration of mouth opening events important in determining abundance, richness and size structure of marine migrant communities. A decrease in the open phase prevents recruitment of juveniles and the seaward migration of adults.			Freshwater species confined to the headwaters of the estuary and lakes especially during low flow and weakening or absence of REI zone
Retention times of water masses	Food (zooplankton) abundance for all groups increases with increased retention times.					
Flow velocities (e.g. tidal velocities or river inflow velocities)	Resident species move upstream when flow velocities increase.	Migrant species exploit tidal currents when migrating into or out of the estuary or when feeding and following the tidal 'front' up the estuary. Eddies accumulate food and provide refugia for both adult and juvenile fish.				Freshwater species can get washed into the estuary by strong river currents. Some freshwater species (e.g. tilapia) may migrate from the Touw Estuary up the system to avoid high

Variable	Ia. Estuarine residents (breed only in estuaries)	Ib. Estuarine residents (breed in estuaries & Sea)	IIa. Estuarine dependent marine species	IIb & c. Estuary associated species	III. Marine migrants	IV & V. Freshwater species
						flow rates.
Total volume and / or estimated volume of different salinity ranges	Increased volume translates to an increase in available habitat for all species, especially those that spend most of their time in the water column. Brackish water habitat is good for resident and estuary associated marine migrants while marine water is good for marine species. High water levels that inundate supratidal areas are positive for juvenile marine fish and small estuarine species.					
Floods	The larvae of resident species are washed into the sea at the onset of floods.	Juvenile marine and catadromous species use floodwaters entering the sea as a cue for locating and migrating into estuaries, whereas adults and sub-adults exit during floods or use them to overcome obstacles to move upstream. Major river flooding associated with high sediment loads can cause gill clogging and hypoxia for fish in the estuary. Large aggregations of kob and other fish with preferences for high turbidity often occur immediately adjacent to estuary mouths during floods. Estuarine connectivity driven by flood events.				High flow velocities may flush some individuals downstream into the estuary.
Salinities	Resident and estuary associated marine species very tolerant of salinities in the range 1-35.				Tend to stay as close to 35 as possible. Stressed less than 20.	Highly variable and most prefer salinity < 10. Alien species, Bass – stenohaline, temporal and spatial variation in salinity stressful Carp – stenohaline but displays a certain tolerance, prefers salinity < 14 Mosquito fish – euryhaline Tilapia – euryhaline
Turbidity	Tolerant of a wide range of turbidity.		Turbidity preferences and tolerances vary among species. High turbidity tolerance (physiological adaptation) among some		Generally prefer low turbidity	Tolerant of a wide range of turbidity.

Variable	Ia. Estuarine residents (breed only in estuaries)	Ib. Estuarine residents (breed in estuaries & Sea)	IIa. Estuarine dependent marine species	IIb & c. Estuary associated species	III. Marine migrants	IV & V. Freshwater species
			species affords them refuge and access to a specialist ecological niche.			
Dissolved oxygen	Most resident and estuary associated marine species become stressed when oxygen drops below 4 mg/ℓ. However, surface respiration is an adaptation by most estuarine and freshwater species to overcome hypoxia. Skin respiration is also an adaptation in some species, e.g. mudskippers, whereas sole gill-morphology allows survival in hypoxic conditions.				Little tolerance to low oxygen levels/hypoxia.	Surface respiration is an adaptation by some estuarine and freshwater species to overcome hypoxia. Some indigenous species adapted to low oxygen, e.g. air-breathing organs, skin respiration and aestivation e.g. Galaxiidae.
Subtidal, intertidal and supratidal habitat	With the obvious exception of mudskippers and to a lesser extent other burrow-symbiotic gobies, “petrophyllic” blennies & clinids, most fish are confined to the subtidal at low tide but forage in the intertidal during high tide. Intertidal reaches are nonetheless extremely important foraging areas for most fish species. Shallow marginal areas tend to be warmer than deeper channel areas and are thus favourable for metabolic processes. Juveniles and small adults also use shallow water as a predation refuge.					
Other abiotic components (temperature)	Low temperatures can increase the risk of mass mortalities at very low salinities. Sex ratios can be skewed in fish where sex determination is temperature related. Increases in temperature tend to skew towards males, decreases towards females. Consequently, climate change and local scale anthropogenic influences on temperature could have a profound impact on fish populations. Growth rates and gonadal development tend to decrease either side of the optimal temperatures for individual species. Fish move according to their preferred temperature, constraints more in temporarily open/closed than permanently open estuaries.					
Sediment characteristics (including sedimentation)	Individual species preferences are highly variable and often related to preferred food sources. Burying ability and crypsis of some fish (e.g. sole *Heteromycteris capensis*) are governed by sediment characteristics. Some fish are directly and indirectly impacted e.g. *Psammogobius knysnaensis* are psammophyllic but have commensal/mutual relationships with burrowing invertebrates which are distributed according to their burrowing ability and sediment characteristics.					

Variable	Ia. Estuarine residents (breed only in estuaries)	Ib. Estuarine residents (breed in estuaries & Sea)	IIa. Estuarine dependent marine species	IIb & c. Estuary associated species	III. Marine migrants	IV & V. Freshwater species
Phytoplankton biomass	High phytoplankton production contributes to turbidity in estuaries and probably favours those species with higher turbidity preferences. Phytoplankton is also a food source for filter-feeding fish and invertebrates. Fish also benefit indirectly from proliferation of invertebrates that feed on phytoplankton. Omnivorous filter-feeding fish will out-compete selective feeders during periods of high phytoplankton biomass. Harmful algal blooms in estuaries, usually a result of eutrophication, have a number of direct (toxicity) and indirect (e.g. hypoxia) impacts on fish. Blue-green *Microcystis* blooms, common in SA estuaries, can cause skin and/or organ lesions in fish resulting in poor health, reduced reproductive success and mortalities. Golden algae *Prymnesium parvum*, an invasive species recorded in Zandvlei, causes fatal gill haemorrhaging and induces abortion and premature spawning in fish.					
Benthic micro-algae biomass	Detritivores, especially mullet, benefit from high microphytobenthos biomass. South African fish biomass in estuaries is dominated by mullet (> 60%) and therefore overall fish biomass is largely reflective of benthic algal biomass.					
Zooplankton biomass	Most juvenile fish in estuaries feed on zooplankton. Filter and particulate feeders benefit from increased zooplankton biomass. Many fish species are able to switch between filter and targeted feeding modes to take advantage of dominant zooplanktonic food sources. One caveat is that predatory marine zooplankters (e.g. chaetognaths) may have a devastating impact on recruiting fish larvae. Jellyfish may do the same.					
Aquatic macrophyte cover	Juveniles of most fish species find refuge in littoral macrophyte beds during the daytime but move into open water or to the surface during the night as oxygen levels drop in the littoral zone.					
Benthic invertebrate biomass	Many estuary associated fish species feed on benthic invertebrates and will thus benefit from increases in benthic invertebrate biomass. Burrow-associated fish (e.g. gobies) diversity and numbers will vary according to that of benthic invertebrates (e.g. sand prawn).					

Variable	Ia. Estuarine residents (breed only in estuaries)	Ib. Estuarine residents (breed in estuaries & Sea)	IIa. Estuarine dependent marine species	IIb & c. Estuary associated species	III. Marine migrants	IV & V. Freshwater species
Fish biomass	No major piscivorous species in these categories. Most of the fish biomass consists of planktivores and small zoobenthivores. Probably inter and intraspecific competition for space, habitat and food resources though.		Fish biomass dominated by estuary associated marine species that utilise different food chains, e.g. groovy mullet *Liza dumerili* is a detritivore, spotted grunter *Pomadasys commersonnii* a zoobenthivore and dusky kob *Argyrosomus japonicas* a piscivore. The piscivores benefit from the high biomass of estuarine resident and small marine migrants in the estuary.			Introduced freshwater fish may outcompete and eat estuary fish, and prey on catadromous recruits moving upstream but also result in a substantial increase in biomass, e.g. the sharp tooth catfish *Clarias gariepinus* has invaded the Great Fish system via the Orange River water transfer scheme. Introduced species are usually more tolerant of poor water quality, thereby becoming the dominant fish in some systems.

Table 4.41 Touw Estuary: Summary of fish responses to different abiotic states

Abiotic state	Response
State 1: Closed	Water levels will increase and flood macrophyte habitats – these areas could become important for juvenile fish as feeding and refugia areas. This will however also provide better conditions for two alien freshwater species (*G. affinis* and *O. mossambicus*). Species that predominantly feed on benthic algal sources (e.g. *L. richardsonnii*) and epibenthic invertebrates and filamentous algae (*R. holubi, O. mossambicus*) will benefit. Stratification may result in low oxygen in deeper water which will impact various species.
State 2: Open (saline gradient)	Fish will be distributed according to their salinity preferences and overall recruitment into the estuary along the salinity gradient, should be at a maximum. An increase in phytoplankton and zooplankton will provide a greater food source for juvenile and larval fish of most species. Increased benthic algal biomass will benefit all mullet species. The decrease in submerged macrophyte cover and increase in burrowing macro-invertebrates will provide a greater food source for species such as *P. commersonnii* and *L. lithognathus*, whilst also benefiting *P. knysnaensis* (commensal relationship with burrowing invertebrates) and *Heteromycteris capensis* (improved habitat). The alien freshwater species will more than likely migrate within the system to areas of lower salinity (in particular *C. carpio*).
State 3: Open (Freshwater dominated)	Estuary residents, e.g. *G. aestuaria* will be confined to the upper reaches to avoid being swept out to sea. The remaining fish with an REI preference will still be dispersed throughout the estuary as will some freshwater species (although *O. mossambicus* may move from the estuary into the Lakes to avoid stronger flow conditions). REI and facultative catadromous species, e.g. *M. falciformis* and *M. capensis* may use elevated water levels to overcome obstacles and swim upstream into the river's freshwater reaches. Catadromous glass eels will recruit into the catchment or adult silver eels migrate back via the estuary into the sea (freshwater catchment habitat degraded though). Elevated silt loads will replenish specialist habitat for young-of-the-year *A. japonicus* and similar species. Fish will be concentrated in eddies and backwaters where food is accumulated and entrained. Burrowing invertebrates such as sandprawn *Callichirus kraussi* will burrow down to their preferred salinity thereby escaping fish preying upon them. Most marine vagrant species will leave the estuary.

Table 4.42 Wilderness Lakes: Summary of fish responses to different abiotic states

Abiotic state	Response
1: Closed	As water levels increase, movement between lakes will become easier for early recruits and adult fish. Due to the reverse salinity gradient up the system, some fish species may move up the system and stay in Rondevlei. Generally fish will be distributed according to their salinity preferences. Increased habitat may favour juvenile fish and the alien invasive *G. affinis*.
2: Open (saline gradient)	Open phase has very little influence on the system beyond Island Lake. Lower water levels may prevent recruitment and movement between the lakes (obstructions).

Abiotic state	Response
3: Open (Freshwater dominated)	As above, open phase has very little influence on the system beyond Island Lake. REI and facultative catadromous species e.g. *M. falciformis* and *M. capensis* may use elevated water levels to overcome obstacles and swim upstream into the Duiwe River's freshwater reaches. As water levels drop recruitment and movement between the lakes may be prevented (obstructions).

4.8.1.3 Reference Condition

Tables 4.43 and **4.44** summarise the key drivers and changes in fish assemblages from Reference Condition to Present State for the Touw Estuary and Wilderness Lakes, respectively.

Table 4.43 Touw Estuary: Summary of relative changes in fish assemblage from Reference Condition to Present State

Key drivers	Change
Increased closed phase	Recruitment potential has decreased as seen in length frequency histograms of euryhaline marine species (larger size classes and intermittent recruitment). Estuarine shoaling species are dominant throughout the estuary. Rising water levels should provide increased habitat for juveniles as feeding and refugia areas.
Decreased salinity	The decrease in salinity associated with the closed phase has resulted in a general decrease in the biomass of fish within the Touw Estuary and shift within the Wilderness Lakes. Although three of the alien fish species are able to tolerate wide changes in salinity the general decrease (and limited fluctuation) will benefit these species. Decreased salinity will be beneficial for *C. carpio* and successful spawning may occur in certain years (generally low salinity combined with a freshwater pulse). Lower zooplankton biomass in association with decreased salinity will negatively impact the adults and juveniles of filter and particulate feeders (e.g. *M. falciformis*).
Increased macroalgae	All mullet species and *O. mossambicus* would have benefited through the increase in benthic algae and filamentous algae, however at the same time benthic species such as *P. knysnaensis* and *Heteromycterus capensis* will be negatively impacted as the sandy habitat is transformed.
TOTAL CHANGE	Fish assemblage has lost some euryhaline marine species (e.g. *S. salpa, D. capensis*) whilst others have decreased in abundance (*A. japnicus, L. amia, L. lithognathus*). A possible increase in the abundance of estuarine shoaling species, *G. aesturia* and in particular *A. breviceps*.

Table 4.44 Wilderness Lakes: Summary of relative changes in fish assemblage from Reference Condition to Present State

Key drivers	Change
Increased closed phase	Recruitment potential has decreased. Rising water levels provide increased habitat for juveniles as feeding and refugia areas, however this also provides more ideal habitat preferences for alien invasive species (in particular *G. affinis* and *C. carpio*).
Decreased salinity	A decrease in salinity provides a more ideal condition for alien invasive species. Reversed salinity gradient up the lakes may become more pronounced leading to movement of adult euryhaline marine species up into Rondevlei – these adults seem to remain in this lake and do not migrate back out.
Dissolved oxygen	Low DO in the channels will limit movement and recruitment of adult and juvenile fish through the system.
Microalgae	Increase in benthic microalgae will benefit in particular mugillids
TOTAL CHANGE	Diversity indices between 1985 and 2012 very similar for Rondevlei, Langvlei and Island Lake but fewer species sampled in Serpentine. Increase in the number of alien invasive species and an increase in the biomass of alien species (in particular *O. mossambicus* within Langvlei). Obstructions in the interconnecting channels limits recruitment past Island lake and the contribution of euryhaline marine species within Langvlei and Rondevlei has decreased. Possible increase in estuarine shoaling species (*G. aesturia, A. breviceps* and also Cape halfbeak (*Hyporhamphus capensis*). A general reduction in the abundance of euryhaline marine species.

4.8.2 Fish health

The fish health scores for the Present State are presented in **Table 4.45 and 4.46** for the Touw Estuary and Wilderness Lakes, respectively.

Table 4.45 Touw Estuary: Present fish health scores, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable	Summary of change	Score	Confidence
a. Species richness	Three alien invasive freshwater species (*C. carpio*, *O. mossambicus and G. affinis*). Decrease in large estuarine-dependent (*A. japonicus*) and other euryhaline marine species (*D. capensis, Rhabdosargus sarba* and *Sarpa salpa*). Estuary dominated by estuarine shoaling species (*G. aesturia* & *A. breviceps*). Total species (excluding alien invasive freshwater species) decreased from 23 to 17 between 1983 and 2012 (extensive surveys).	70	M

Variable	Summary of change	Score	Confidence
b. Abundance	Decrease in abundance of large euryhaline species. Possible increase in small bodied shoaling species and a decrease in the contribution of Mugilidae species (in particular *Myxus capensis*). Increase in abundance of freshwater alien species.	60	M
c. Community composition	REI fish component distributed throughout the estuary (closed phase) with an increase in contribution to overall fish assemblage in terms of numbers and mass. Decrease in large euryhaline marine species in particular large piscivorous predators – upper trophic levels depleted by overfishing throughout the coast.	80	M
Fish health score: min (a to c)		**60**	**M**
% of impact non-flow related		40	
Adjusted score		76	M

Table 4.46 Wilderness Lakes: Present fish health scores, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable	Summary of change	Score	Confidence
a. Species richness	An increase in alien invasive freshwater species (*C. carpio*) and absence of *Heteromycteris capensis* within recent sampling.	70	M
b. Abundance	A decrease in the abundance of large estuarine dependent and other euryhaline marine species, in particular Langvlei and Rondevlei. Possible increase in biomass of estuarine shoaling species in particular *Hypophamphus capensis*. An increase in the biomass of *O. mossambicus* within Langvlei and Rondevlei.	65	M
c. Community composition	REI fish component distributed throughout the lakes with an increase in contribution to overall fish assemblage in terms of numbers and mass. Increase in alien invasives. Decrease in large euryhaline marine species in particular large piscivorous predators – upper trophic levels depleted by overfishing throughout the coast.	70	M
Fish health score: min (a to c)		**65**	**M**
% of impact non-flow related		40	
Adjusted score		79	M

4.9 BIRDS

4.9.1 Baseline description

4.9.1.1 Main grouping and baseline description

For the purposes of this study, the birds found on the estuary have been grouped into nine groups based on a combination of diet and taxonomic groupings (**Table 4.47**).

Table 4.47 Major bird groups found in the Wilderness System and their defining features

Bird groups	Defining features, typical/dominant species
Cormorants	These swimming piscivores catch their prey by following it under water and therefore prefer deeper water habitat. These include Reed Cormorant, Cape Cormorant, White-breasted Cormorant and African Darter.
Wading birds	This group comprises the egrets, herons, ibises and spoonbill. Loosely termed piscivores, their diet varies in plasticity, with fish usually dominating, but often also includes other vertebrates, such as frogs, and invertebrates. The ibises were included in this group, though their diet mainly comprises invertebrates and is fairly plastic. They tend to be tolerant of a wide range of salinities. Wading piscivores prefer shallow water up to a certain species dependant wading depth.
Herbivorous waterfowl	This group is dominated by species that tend to occur in lower salinity or freshwater habitats and are associated with the presence of aquatic plants such as *Potamageton* and *Phragmites*. The group includes some of the ducks (e.g. Southern Pochard), and all the rallids (e.g. Redknobbed Coot, African Purple Swamphen). Some herbivorous waterfowl such as Egyptian Goose probably feed in terrestrial areas away from the estuary and floodplain as well as in the estuary.
Omnivorous waterfowl	This group comprises ducks which eat a mixture of plant material and invertebrate food such as small crustaceans – Yellow-billed Duck, Cape Teal, Red-billed Teal and Cape Shoveller. Although varying in tolerance, these species are fairly tolerant of more saline conditions.
Piscivorous waterfowl	This group comprises the grebes. While the Great Crested Grebe is largely piscivorous, Black-necked and Little Grebes include insects and other small animals in their diet.
Waders	This group includes all the waders in the order Charadriiformes (e.g. Greenshank, Curlew Sandpiper). They are the smallest species on the estuary, and feed on benthic macroinvertebrates in exposed and shallow intertidal areas. Invertebrate-feeding waders forage mainly on exposed sandbanks, mudflats and in the inter-tidal zone.
Gulls & terns	This group comprises the rest of the Charadriiformes, and includes all the gull and tern species using the estuary. These species are primarily piscivorous, but also take invertebrates. Most are euryhaline, but certain tern species on the estuary tend to be associated with low salinity environments.
Kingfishers	Kingfishers breed and perch on the river banks and prefer areas of open water with overhanging vegetation. While all are piscivorous, the Pied Kingfisher has a more varied diet.
Birds of prey	Birds in this group are not confined to a diet of fish, but also take other vertebrates and invertebrates. Species in this group include African Fish Eagle and Osprey.

The avifauna of the Wilderness System is dominated by herbivorous waterfowl both in summer and winter. Herbivorous waterfowl were dominated by Red-knobbed Coot which was by far the most common bird overall. In winter the bird community was also dominated by the herbivorous waterfowl group (72%). The numbers of piscivorous cormorants and herbivorous waterfowl were higher in winter than in summer.

Waterfowl in the system have been dominated by Redknobbed Coot in all counts. Abundance of herbivorous waterfowl is highest in Langvlei for all species apart from Egyptian Goose. The strong correlation between coot and duck numbers with macrophytes biomass has been documented by Russell (2009). Numbers of Southern Pochard appear to have declined significantly, and numbers of other species such as Yellowbilled Duck, Cape Shoveller, Cape Teal and Maccoa Duck were also considerably higher in the first count than the averages of subsequent counts. Species such as African Black Duck and South African Shelduck have seldom been recorded, and recent data on these were not available. White-backed duck appear to have become more common, probably due to regional population increases.

There appears to have been a major reduction in the numbers of Black-necked Grebe. This species, which breeds in inland wetlands, had a highly seasonal occurrence on the system in the 1980s, occurring in their thousands each winter. Since it favours relatively saline coastal habitats for wintering grounds, it is possible that it has been discouraged by the reduced salinity in the lakes. Numbers of all grebes are highest on Langvlei.

Reed Cormorant and African Darter were common in the early counts, but recent count data suggest that African Darter may have declined. This could be in due to illegal gillnetting in the system as well as increased submerged macrophytes and encroachment of reeds into the channels. Whitebreasted Cormorant has become more common. This appears to be a phenomenon on several estuaries, in spite of the fact that their regional population has remained fairly stable. Cormorants and darters are highly seasonal, occurring mainly in winter.

The diversity of herons, egrets, ibis and spoonbill has increased over time. While the species recorded in the 1980s remain on the system in similar numbers, the system now also supports small numbers of several additional species such as African Sacred Ibis, Glossy Ibis, Hadeda Ibis and Affrican Spoonbill. This is largely due to regional increases in the populations of these species.

Numbers of other piscivorous birds, the birds of prey and kingfishers, appear to have been relatively stable. While Kelp Gulls continue to be recorded in small numbers, numbers of Common tern may have declined, due to changes in the mouth dynamics, and Whitewinged Terns have not been recorded in the CWAC counts.

While fifteen wader species amounting to 2671 birds were recorded in 1980, subsequent counts have recorded far fewer species and numbers, with under 100 being recorded on average in CWAC counts. The species originally recorded included species that would have been associated with sand and mudflats in the estuary area, but were dominated by species more common in wetlands and pans. The latter are likely to have occupied marginal habitats around the lakes. Many of these species were also present in the monthly counts of the 1980s. While the decline in global populations of many wader species may have played a role to some extent, the recent data suggest that conditions have changed locally. Data suggest that the availability of habitats has declined markedly, and would also suggest that water levels in Langvlei and Rondevlei were relatively low at the time of the count. Species that were not counted again or that have only been seen since in much smaller numbers include Ruddy Turnstone, Common Ringed Plover, Kittlitz's Plover, Grey Plover, African Snipe, Curlew Sandpiper, Little Stint, Ruff, Common Sandpiper, Wood Sandpiper, Marsh Sandpiper, Common Greenshank, African Snipe, Pied Avocet and Black-winged Stilt.

4.9.1.2 Description of factors influencing birds

Avifaunal communities in estuaries are likely to be affected primarily by the availability of suitably-sized food (plants, invertebrates or fish) and availability of suitable feeding, roosting and breeding habitat, but will also be influenced by inter- and intraspecific competitive interactions, as well as external factors such as breeding success on distant breeding grounds or human disturbance. These relationships may vary seasonally, from estuary to estuary, or between biogeographical zones. Certain groups or species are liable to be more responsive to changes in system variables than others, depending on their ability to adapt to a range of circumstances (e.g. Turpie and Hockey, 1997). Very few quantitative studies have been made of the influence of abiotic and biotic factors on bird community structure and abundance in South African estuaries, but studies of the Wilderness Lakes system have made a significant contribution to this literature. Predictions regarding the reference state and future scenarios have to be made on the basis of these studies as well as expert understanding of the relationships between elements of estuarine bird communities and their main drivers (**Table 4.48**).

Table 4.48 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various bird groupings

Variable	Cormorants & wading piscivores	Kingfishers & fish-eagle	Waterfowl	Waders, gulls and terns
Mouth condition	Indirectly, through influence on water level and fish		Indirectly, through influence on macrophytes	Mouth closures has negative effect on preferred sandbanks in lower estuary
Salinities			Certain species of waterfowl prefer lower salinities	
Turbidity	Negatively affects visibility for foraging	Negatively affects visibility for foraging		
Intertidal area				Waders rely mostly on intertidal areas for feeding.
Sediment characteristics (including sedimentation)				Most waders prefer medium to fine sand; a few prefer coarse sand
Primary productivity	Indirectly though influence on food supply			

Variable	Cormorants & wading piscivores	Kingfishers & fish-eagle	Waterfowl	Waders, gulls and terns
Submerged macrophyte abundance			Has positive influence on herbivorous waterfowl numbers	
Abundance of reeds and sedges			Has positive influence on some herbivorous waterfowl species	
Abundance of zooplankton			Assumed positive for some omnivorous species	
Benthic invertebrate abundance				Primary food source for invertebrate-feeding waders
Fish biomass	Numbers and availability of small to medium-sized fish can have a positive influence on piscivore abundance			

Different trophic groups of birds were assumed to be influenced primarily by the availability of food, in turn influenced by its abundance and size class distribution. In addition to the relationship between food groups, the availability of food is in turn expected to be influenced by salinity, nutrients and relative availability of different habitat types (e.g. mudflats, sandflats, vegetated habitats). The latter variables are influenced by freshwater inputs to the estuary.

Where the composition and productivity of a food group is determined by abiotic factors such as salinity or sediment particle size, these variables may indirectly determine the nature of the avifaunal community. For example, a broad assumption applied to invertebrate feeding waders could be that wader densities are negatively correlated with sediment sand fraction, because the latter is negatively correlated with invertebrate density/availability. In general, it must be borne in mind that increased availability of food or habitat would not necessarily have a positive impact if other factors are limiting.

A summary of responses to various abiotic states is summarised in **Tables 4.49** and **4.50** for the Touw Estuary and Wilderness Lakes, respectively.

Table 4.49 Touw Estuary: Summary of bird responses to various abiotic states

Abiotic state	Response
State 1: Closed	The estuary will become nutrient poor, fresher and deeper and will be more encroached with reeds. There will a loss of waders, gulls and terns, while waterfowl will become more common.
State 2: Open (saline gradient)	This state is likely to lead to a diverse community, but numbers of birds will remain low.
State 3: Open (Freshwater dominated)	Few birds will be present during this state. It is likely that terns, gulls and a few wading birds would be attracted to the estuary.

Table 4.50 Wilderness Lakes: Summary of bird responses to different abiotic states

Abiotic state	Response
State 1: High water levels State 3: Very high water levels	In high water conditions, the marginal shallow and exposed areas of the lakes will be absent, leading to a loss of waders and wading birds, and certain waterfowl. In the short term there could be a negative impact on herbivorous waterfowl, but these would recover.
State 2: Low water levels	Low water conditions will provide a high diversity of habitats, leading to a high diversity of waterbirds. This state is likely to favour herbivorous waterfowl and dabbling ducks, and waders, whereas those favouring deeper and more saline habitats may be absent.

4.9.1.3 Reference Condition

Estimation of the Reference Condition takes into account the expected response to flow-related and non-flow related drivers into account, in conjunction with any evidence from existing data. Key flow-related changes and their expected effect are summarised below.

Comparison of the available count data suggests that there have been major changes in the avifauna of this system. These changes are described above. However it should be borne in mind that comparison of these counts is difficult, since raw data were not available with which to properly analyse trends. The conclusions that can be drawn from this are therefore of a low confidence.

While freshwater inflows to the system have been only moderately reduced, artificial breaching of the mouth at lower than natural water levels has led to a reduction of flow and salt input into the lakes, leading to lower and more stable water levels and lower salinity. This is understood to have led to encroachment of reeds and submerged macrophytes, increased invertebrate abundance. The abundance of small fish in the system has remained similar, albeit changed in composition. The drivers and expected impacts on present day avifaunal communities is summarised in **Tables 4.51** and **4.52** for the Touw Estuary and Wilderness Lakes, respectively.

Table 4.51 Touw Estuary: Summary of relative changes in birds from Reference Condition to Present State

Key drivers	Change
⇩Salinities, and ⇧ Emergent veg/reed marsh	Increased suitable habitat for waterfowl.
⇧ Marine sediment and ⇩exposure of intertidal area	Reduced suitability for waders.
⇩Salt marsh and marginal habitat	Loss of these habitats is likely to have had a negative impact on waders and wading birds.
⇩⇧ Benthic invertebrate biomass	Reduction in prawns at the mouth will not have had much impact due the composition of closed estuaries; the fact that benthic invert abundance is estimated to have increased is also unlikely to have been a significant influence, since habitat is more of a limiting factor.
Fish abundance	This has remained high, and will not have driven changes.

Table 4.52 Wilderness Lakes; Summary of relative changes in birds from Reference Condition to Present State

Key drivers	Change
⇩Salinities,	Reduced abundance of certain species and increased abundance of others, based on salinity tolerances.
⇧ Emergent veg/reed marsh and submerged macrophytes	Increased suitable habitat for several species of waterfowl, also favourable for skulking herons and rallids.
⇩Water level	Increased availability of marginal habitat for waders
⇧ Benthic invertebrate biomass	Benthic invert abundance is estimated to have increased but this is unlikely to have been a significant influence, since habitat is more of a limiting factor.
Fish abundance	This has remained high, and will not have driven changes.

4.9.2 Bird health

The bird health scores for the Present State are presented in **Tables 4.53** and **4.54** for the Touw Estuary and Wilderness Lakes, respectively.

Table 4.53 Touw Estuary: Present bird health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable	Summary of change	Score	Confidence
a. Species richness	Significant reduction in average species richness.	70	L
b. Abundance	Always likely to have been relatively low; some loss of waders expected.	70	L
c. Community composition	Loss of waders, more waterfowl and wading birds.	70	L
Bird health score: min (a to c)		**70**	**L**
% of impact non-flow related		90	
Adjusted score		97	L

Table 4.54 Wilderness Lakes: Present bird health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable	Summary of change	Score	Confidence
a. Species richness	Significant reduction in average species richness	70	L
b. Abundance	Earliest count suggests possible very large reduction in birds (to 30% of reference), but evidence is contradictory, with later counts suggesting little change (85%).	60	L
c. Community composition	Loss of waders, certain more specialist species, replacement with other species. Significant shifts in species composition, also community composition now more dominated by herbivorous waterfowl	55	L
Bird health score: min (a to c)		**55**	**L**
% of impact non-flow related		90	
Adjusted score		96	L

5 PRESENT ECOLOGICAL STATUS

5.1 OVERALL ESTUARINE HEALTH INDEX SCORE

The individual present health scores for the various abiotic and biotic components are used to determine the PES, in accordance with the EHI. In the case of the Wilderness System, the Touw Estuary and Wilderness Lakes were classified as two separate resource units. **Tables 5.1** and **5.2** summarises the PES of the Touw Estuary and wilderness Lakes, respectively.

Table 5.1 Touw Estuary: Present Ecological Status

Variable	Weight	Score
Hydrology	25	79
Hydrodynamics and mouth condition	25	71
Water quality	25	81
Physical habitat alteration	25	64
Habitat health score		**74**
Microalgae	20	53
Macrophytes	20	70
Invertebrates	20	55
Fish	20	60
Birds	20	70
Biotic health score		**62**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**68**
PRESENT ECOLOGICAL STATUS (PES)		**C**
OVERALL CONFIDENCE		**Low**

Table 5.2 Wilderness Lakes: Present Ecological Status

Variable	Weight	Score
Hydrology	25	79
Hydrodynamics and mouth condition	25	73
Water quality	25	79
Physical habitat alteration	25	80
Habitat health score		**78**
Microalgae	20	70
Macrophytes	20	80
Invertebrates	20	90
Fish	20	65
Birds	20	55
Biotic health score		**72**

Variable	Weight	Score
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**75**
PRESENT ECOLOGICAL STATUS (PES)		**B/C**
OVERALL CONFIDENCE		**Low**

This Rapid level assessment indicated that the Estuarine Health Score for the **Touw Estuary of 68, corresponds to a PES of Category C**. The **Wilderness Lakes EHI score of 75 corresponds to a PES of Category B/C.** These results suggest that the lakes are under less direct development and fishing pressure and may also be slightly more resilient to the flow reduction and water quality changes affecting this system compared with the estuary.

5.2 RELATIVE CONTRIBUTION OF FLOW AND NON-FLOW RELATED IMPACTS ON HEALTH

In scoring the various abiotic and biotic components, specialists were also asked to estimate the extent to which the shift from Reference Condition to Present State was attributed to flow related or non-flow related effects. Flow related effects specifically relate to changes caused by a modification in river (volume) inflow (i.e. either base flows, seasonal distribution of flows or flood characteristics). Non-flow related effects include, for example, pollution from land-based activities such as agriculture, urban runoff and wastewater discharges, fishing, human disturbance of birds, habitat destruction associated with development and over-harvesting of estuarine vegetation.

Specialists concluded that non-flow related factors contributed significantly to ecological modifications in the Wilderness System from Reference Condition to the Present State (see earlier Present Health Score tables) as summarised in **Table 5.2**.

Table 5.3 Estimated effect of non-flow related factors on the present health of the Wilderness System

Variable	% of modification in health (non-flow related factors)		Key non-flow related factors
	Estuary	Lakes	
Hydrology	N/A	N/A	
Hydrodynamics and mouth condition	90	90	▪ Breaching of mouth at too low levels
Water quality	50	50	▪ Alteration in salinity patterns caused by inappropriate breaching of estuary mouth ▪ Some enrichment from anthropogenic activities along banks and in catchment (especially from Duiwe catchment)
Physical habitat alteration	90	95	
Microalgae	50	80	
Macrophytes	90	90	

Variable	% of modification in health (non-flow related factors)		Key non-flow related factors
	Estuary	Lakes	
Invertebrates	30	30	
Fish	40	40	▪ Aliens fish ▪ Obstructions ▪ Fishing & nationwide depletion of exploited spp.
Birds	90	90	

Specialists estimated that removing the non-flow related factors (**Table 5.2**) could improve the Present Ecological Status of the Wilderness System to a **Category B.** This demonstrates that the modification in river inflow patterns only partly contributed to the present ecological health status in the Klein Brak Estuary (i.e. Category C and B/C). The key flow related factor contributing to the modification in health condition is numerous farm dams, run-off river abstraction and afforestation.

5.3 OVERALL CONFIDENCE

The overall confidence of this study is **Low (40-60% certainty)** mainly because of the low confidence in the hydrology (especially low flows) and the uncertainty about the Reference Condition (breaching levels, duration of mouth closure, bathymetry in the lower estuary). This, in turn affects the confidence of the definition and characterisation of abiotic states which is the primary mechanism by which modification in health condition from the Reference Condition to Present State is determined, together with simulated river runoff scenarios. Due to limited data on other abiotic and biotic component the confidence of most components ranged between low to medium confidence. Even though specialists drew on experience from their collective research on other, related estuarine systems, the complexity of the lake system, as well as the low confidence in the hydrology resulted in a low overall confidence of this study. However, the recommended monitoring programme should focus on improving confidence for future reviews.

6 THE RECOMMENDED ECOLOGICAL CATEGORY

6.1 ECOLOGICAL IMPORTANCE

The EIS takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account. Biodiversity importance, in turn, is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. These importance scores ideally refer to the system in its present state. The scores have been determined for all South African estuaries (Turpie and Clark, 2007), apart from functional importance, which is scored by the specialists in the workshop (**Table 6.1**). The EIS for the Wilderness System and importance rating is presented in **Tables 6.2** and **6.3**, respectively.

Table 6.1 Estimation of the functional importance score of the Wilderness System

Functionality	Score
a. Estuary: Input of detritus and nutrients generated in estuary	20
b. Nursery function for marine-living fish and crustaceans	100
c. Movement corridor for river invertebrates and fish breeding in sea	80
d. Refuge function for water birds	80
e. Catchment detritus, nutrients and sediments to sea	40
f. Coastal connectivity (way point) for fish	100
Functional importance score - Max (a to f)	**100**

Table 6.2 Estuarine Importance scores (EIS) for the Wilderness System

Criterion	Weight	Score
Estuary Size	15	90
Zonal Rarity Type	10	70
Habitat Diversity	25	70
Biodiversity Importance	25	88
Functional Importance	25	100
Weighted Estuary Importance Score		**85**

Referring to the estuarine importance rating system (DWAF, 2008), the importance score of the Wilderness Estuarine System – a score of **85** – translates into an importance rating of **'Highly Important"** albeit just below the rating of "Important' (**Table 6.3**). The Wilderness System scores high as it is a very important nursery for collapsed and endangered fish species, e.g. Dusky cob and elf. The system also plays an important role as a way point/refuge area for fish along a coast that is known for extreme upwelling events that can cause fish kills. Further, the Wilderness Estuarine System also forms part of the Garden Route National Park and contributes significantly towards South Africa's overall estuarine biodiversity targets.

Table 6.3 Estuarine Importance rating system (DWAF, 2008)

Importance score	Importance rating
81 – 100	Highly important
61 – 80	Important
0 – 60	Of low to average importance

6.2 RECOMMENDED ECOLOGICAL CATEGORY

Applying the guidelines for the determination of the Recommended Ecological Category (**Table 6.4**), the Wilderness System, being **"Highly important"** and a **Protected Area** should managed in a **Category A,** or at least the **Best Attainable State (BAS)**.

Table 6.4 Guidelines to assign REC based on protection status and importance, as well as PES of estuary (DWAF, 2008)

Protection status and importance	REC	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health
Desired Protected Area (based on complementarity)		
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B category
Important	PES + 1, min C	Important estuaries should be in an A, B or C category
Of low to average importance	PES, min D	The remaining estuaries can be allowed to remain in a D category

* BAS = Best Attainable State

The PES of the Wilderness System resembled a **Category C (Touw Estuary) and B/C (Wilderness Lakes)**. By far the most dominant factor determining the PES of this system is the low water levels at which the system is regularly breached to protect low lying development. Any change of rehabilitating the system to a Category A mostly likely will require the removal of those developments from the estuarine functional zone. Specialist concluded that it may not be realistic to go back to natural breaching levels (i.e. +3.5 m MSL), but that there were certain other, non-flow related impacts on the system that could be mitigated to at least improve the Ecological Category of the system, both the estuary and lakes, to a Category B. The REC for the Wilderness System, therefore, was set as a **Category B,** but realising that this will entail improvements to the present situation.

7 CONSEQUENCES OF ALTERNATIVE SCENARIOS

7.1 DESCRIPTION OF SCENARIOS

The proposed scenarios for the Wilderness System are summarised in **Table 7.1.**

Table 7.1 Summary of flow scenarios

Scenario	Description	MAR (million m^3)	Percentage remaining
Reference Conditions	Natural flows	29.66	100
Present day	Present day uses	25.15	85
Scenario 1	18% decrease in flow	23.22	78
Scenario 2	30% decrease in flow	20.55	69
Scenario 3	40% reduction in flow	16.99	57
Scenario 4	60% reduction in flow	11.68	39

7.2 HYDROLOGY

7.2.1 General

The net seepage and evaporation losses from the Wilderness System are estimated at 6.2 million m^3 per year (Fijen, 1995). This is equivalent to a monthly volume of 0.516 million m^3. An evaluation of the simulated flow data indicate that the combined inflow to the system exceeded this monthly volume 69 % of the time under the Reference Condition, while it is only exceeded for about 55%, 58%, 48%, 43%, and 37% of the time under the Present State and Scenario 1 to 4 respectively (**Table 7.2**).

Table 7.2 Touw Estuary: Summary of changes in the low flow conditions under the different scenarios

Variable	Scenario					
	Reference	Present	1	2	3	4
Percentage occurrence of low flows (monthly volume <0.516 x 103 m3)	31	45	53	64	72	83

Confidence: Low

To provide an indication of the change in flood regime from the Reference Condition to the Present State the ten highest simulated monthly flow volumes were compared for the 75-year period (summarised in **Table 7.3**). The analysis of the simulated monthly flow data indicate that under Reference Conditions floods were about 5% higher than at present, depending on the size class.

A further 1% reduction occurs under Scenario 1 to 3, while Scenario 4 reduces flood volumes by 17% from Reference Conditions.

Table 7.3 Summary of the ten highest simulated monthly volumes to the Wilderness Estuarine Lake System under Reference Condition, Present State and a range of flow scenarios

Date	Monthly volume (million m^3/month)					
	Natural	**Present**	**1**	**2**	**3**	**4**
Dec 1931	41.4	40.2	39.686	40.5	39.8	39.3
Mar 1963	28.8	26.7	26.406	26.7	26.0	24.6
Nov 1996	27.9	26.1	25.546	26.4	26.1	26.1
Aug 1954	27.9	27.0	26.449	28.0	27.7	27.9
Nov 1928	24.3	22.6	22.145	22.2	21.7	16.2
Sep 1925	23.8	23.1	22.605	23.6	23.3	9.0
Aug 1962	22.6	21.8	21.261	21.7	20.6	18.8
Sep 1932	22.3	21.6	21.155	21.7	20.9	18.5
Apr 1967	22.0	20.6	20.179	20.9	20.6	20.6
Sep 1993	21.5	20.8	20.32	21.0	20.4	19.3
% Similarity in floods		**95.3**	**93.5**	**96.1***	**93.9**	**82.7**

**Hydrological model over estimated flood composition, simulated values assumed to be similar to Scenario 1*

Confidence: Low

7.2.2 Touw River

The occurrences of the flow distributions (mean monthly flows in m^3/s) under the future Scenarios of the Touw Estuary, derived from an 85-year simulated data set are provided in **Tables 7.4** to **7.7** and **Figure 7.1.** The full sets 85-year series of simulated monthly runoff data for the future Scenarios are provided in **Tables 7.8** to **7.11**.

Table 7.4 Summary of the monthly flow (in m^3/s) distribution under Scenario 1 (refer to Table 3.3 for colour coding of abiotic states)

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	3.61	5.94	8.55	4.48	4.23	5.84	4.62	4.57	1.62	2.59	5.92	5.29
99	3.34	5.34	4.15	4.03	3.74	4.32	3.46	4.23	1.14	1.74	5.03	5.03
90	2.25	2.05	1.14	1.03	1.27	1.97	1.13	0.83	0.33	0.79	1.23	1.54
80	1.14	1.16	0.70	0.62	0.51	1.05	0.57	0.44	0.21	0.38	0.45	0.64
70	0.58	0.58	0.36	0.31	0.27	0.67	0.27	0.22	0.14	0.16	0.31	0.38
60	0.38	0.32	0.16	0.11	0.14	0.54	0.17	0.12	0.10	0.09	0.19	0.21
50	0.21	0.08	0.00	0.06	0.01	0.26	0.09	0.07	0.07	0.06	0.13	0.15
40	0.14	0.02	0.00	0.00	0.00	0.12	0.04	0.02	0.03	0.01	0.08	0.11
30	0.06	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.04	0.05
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7.5 Summary of the monthly flow (in m^3/s) distribution under Scenario 2 (refer to Table 3.3 for colour coding of abiotic states)

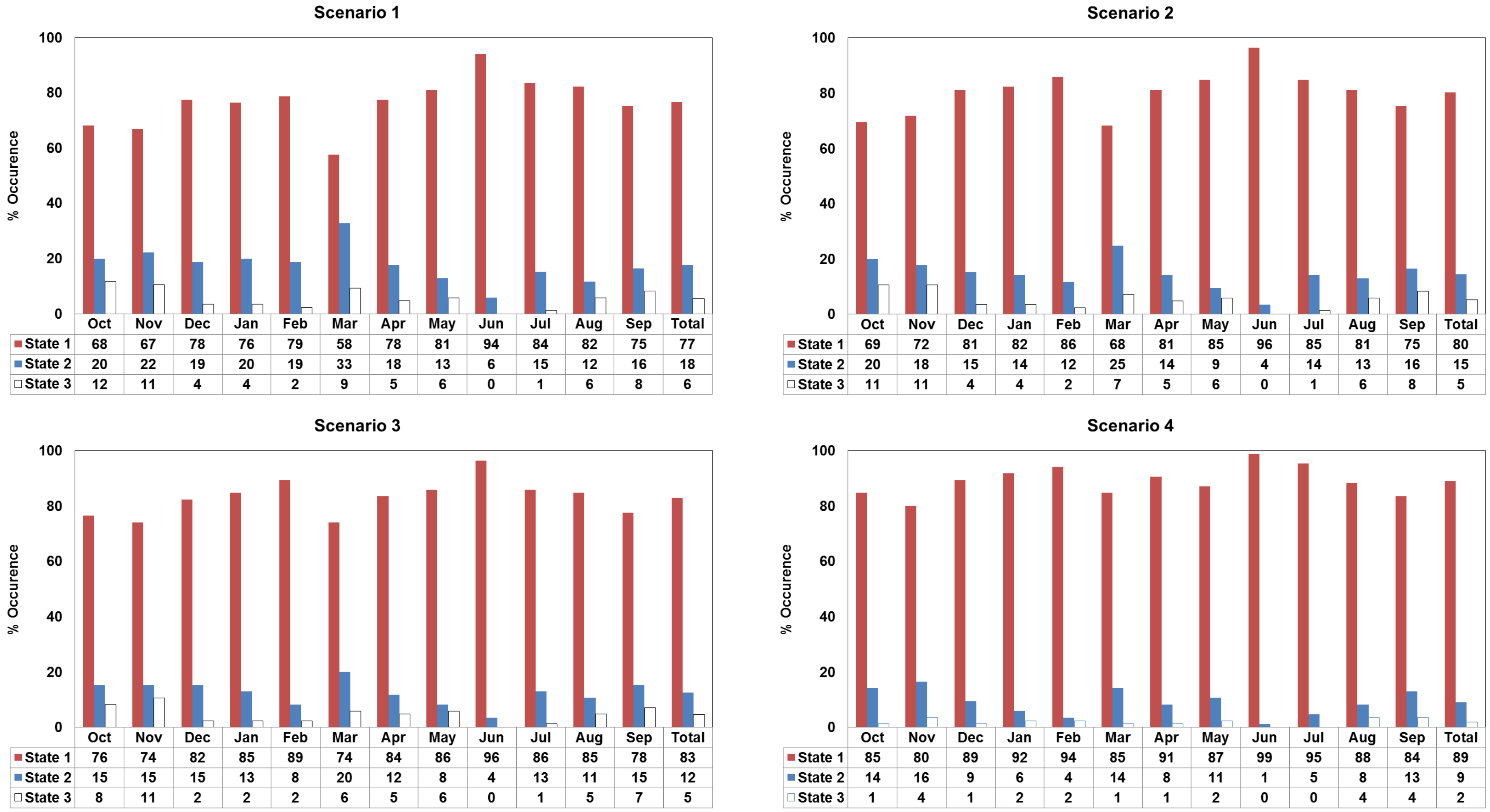
%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	3.75	6.12	8.70	4.54	4.29	5.84	4.76	4.78	1.30	2.68	6.25	5.52
99	3.40	5.38	4.07	4.10	3.86	3.80	3.38	4.28	1.13	1.69	5.16	5.18
90	2.10	2.07	1.04	0.97	0.85	1.83	1.15	0.87	0.30	0.72	1.24	1.58
80	1.15	1.03	0.40	0.37	0.24	0.96	0.42	0.37	0.15	0.36	0.43	0.63
70	0.52	0.49	0.15	0.07	0.07	0.52	0.18	0.17	0.11	0.12	0.30	0.35
60	0.30	0.20	0.00	0.00	0.00	0.28	0.08	0.06	0.06	0.05	0.12	0.15
50	0.16	0.00	0.00	0.00	0.00	0.09	0.01	0.02	0.00	0.00	0.08	0.08
40	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.03
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7.6 **Summary of the monthly flow (in m^3/s) distribution under Scenario 3 (refer to Table 3.3 for colour coding of abiotic states)**

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	3.69	6.06	8.55	4.48	4.09	5.65	4.70	4.68	0.94	2.59	6.18	5.44
99	3.31	5.27	3.90	4.04	3.77	3.30	3.31	3.82	0.66	1.27	4.96	5.01
90	1.83	1.97	0.95	0.86	0.68	1.63	1.03	0.79	0.18	0.57	1.06	1.34
80	0.80	0.92	0.22	0.17	0.06	0.62	0.33	0.20	0.07	0.21	0.27	0.52
70	0.28	0.37	0.01	0.00	0.00	0.39	0.02	0.03	0.01	0.02	0.08	0.27
60	0.12	0.06	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.04
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7.7 **Summary of the monthly flow (in m^3/s) distribution under Scenario 4 (refer to Table 3.3 for colour coding of abiotic states)**

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	3.62	5.95	8.43	3.88	3.73	5.33	4.64	4.64	0.55	2.51	6.22	4.60
99	2.84	4.18	3.69	3.65	3.69	2.93	2.88	3.41	0.27	1.17	4.93	4.55
90	0.96	1.58	0.50	0.37	0.11	1.34	0.37	0.65	0.05	0.10	0.68	1.17
80	0.23	0.37	0.00	0.00	0.00	0.16	0.00	0.04	0.00	0.00	0.02	0.25
70	0.09	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



Scenario 1

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
🟥 State 1	68	67	78	76	79	58	78	81	94	84	82	75	77
🟦 State 2	20	22	19	20	19	33	18	13	6	15	12	16	18
☐ State 3	12	11	4	4	2	9	5	6	0	1	6	8	6

Scenario 2

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
🟥 State 1	69	72	81	82	86	68	81	85	96	85	81	75	80
🟦 State 2	20	18	15	14	12	25	14	9	4	14	13	16	15
☐ State 3	11	11	4	4	2	7	5	6	0	1	6	8	5

Scenario 3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
🟥 State 1	76	74	82	85	89	74	84	86	96	86	85	78	83
🟦 State 2	15	15	15	13	8	20	12	8	4	13	11	15	12
☐ State 3	8	11	2	2	2	6	5	6	0	1	5	7	5

Scenario 4

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
🟥 State 1	85	80	89	92	94	85	91	87	99	95	88	84	89
🟦 State 2	14	16	9	6	4	14	8	11	1	5	8	13	9
☐ State 3	1	4	1	2	2	1	1	2	0	0	4	4	2

Figure 7.1 Occurrence of the various abiotic states under Scenarios 1 to 4 (refer to Table 3.3 for colour coding of abiotic states)

Table 7.8 Simulated monthly flows (in m^3/s) for Scenario 1 (Touw River) (refer to Table 3.3 for colour coding of abiotic states)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.00	0.00	0.98	0.00	1.71	0.54	1.09	0.12	0.15	0.06	0.12	0.17
1921	0.00	0.02	1.06	0.96	0.17	1.28	0.09	0.33	0.06	1.01	0.17	0.16
1922	0.16	2.21	0.00	0.00	0.00	0.00	0.79	0.09	0.31	0.05	0.00	0.00
1923	0.05	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.14
1924	0.14	0.05	0.48	0.01	0.00	1.02	0.24	0.04	0.14	0.01	0.39	5.32
1925	0.39	0.02	0.62	0.00	0.00	0.03	0.00	0.00	0.14	0.16	0.08	0.04
1926	0.89	1.27	0.00	0.09	0.70	0.12	0.00	0.24	0.00	0.00	0.03	0.00
1927	0.00	0.00	0.00	0.00	0.00	2.08	0.17	0.00	0.00	0.00	0.19	0.42
1928	0.00	5.21	1.19	0.00	0.01	0.25	0.00	0.12	0.08	0.77	0.55	1.04
1929	0.19	0.00	0.92	0.07	1.50	0.43	0.20	0.63	0.22	0.13	0.56	0.35
1930	0.30	0.00	0.00	0.95	0.00	0.04	0.83	0.03	0.00	0.38	0.10	0.12
1931	0.72	0.00	9.04	0.32	0.98	0.10	0.00	0.00	0.24	0.06	0.00	4.98
1932	0.38	0.35	0.00	0.00	0.11	0.24	0.11	0.24	0.04	0.00	1.88	0.14
1933	0.00	0.87	0.00	0.39	0.27	1.01	0.00	0.00	0.00	0.50	0.30	0.15
1934	1.88	1.39	0.00	0.00	0.00	0.00	0.34	4.16	0.34	0.16	0.12	1.27
1935	0.20	0.51	0.37	0.00	0.23	0.15	0.00	0.32	0.00	0.70	0.07	0.55
1936	0.38	2.70	0.26	0.00	0.02	1.99	0.00	0.00	0.00	0.01	0.00	0.40
1937	0.30	0.19	0.98	0.39	0.00	0.26	0.25	0.00	0.00	0.00	0.00	0.03
1938	0.25	0.26	0.37	0.00	1.87	2.55	0.07	0.00	0.00	1.13	1.62	0.54
1939	0.14	0.33	0.00	0.28	4.28	0.70	0.01	0.00	0.00	0.00	0.00	0.09
1940	0.00	0.35	0.00	0.25	0.00	0.03	3.21	0.10	0.14	0.00	0.01	0.12
1941	0.96	0.07	0.40	1.90	0.00	0.68	0.09	0.47	0.09	0.00	0.00	0.00
1942	0.17	0.02	0.75	1.01	0.00	0.60	0.13	0.00	0.00	0.00	0.10	1.46
1943	0.38	1.54	0.37	0.00	0.00	0.59	0.00	1.52	0.18	0.95	0.18	1.37
1944	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.43	0.12	0.45	0.09
1945	1.53	0.00	0.00	0.00	0.29	2.65	0.00	0.00	0.00	0.00	0.00	0.00
1946	0.00	0.00	0.00	0.00	0.00	2.71	0.06	0.19	0.12	0.55	0.06	0.45
1947	0.40	0.31	0.00	1.25	0.00	0.52	0.60	0.03	0.00	0.00	0.00	0.24
1948	1.71	0.08	0.00	0.49	0.00	0.00	0.14	0.57	0.01	0.00	0.00	0.20
1949	0.00	4.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.15	0.17
1950	1.35	3.77	0.86	3.93	0.00	0.10	0.00	0.00	0.09	1.05	0.39	0.96
1951	0.00	0.00	0.00	0.72	0.23	0.00	0.18	0.03	0.00	0.00	0.48	2.17
1952	0.22	0.43	0.00	0.06	0.31	0.00	0.64	0.01	1.04	0.62	1.24	0.78
1953	3.63	1.61	0.00	0.00	0.00	0.24	0.41	2.26	0.24	0.35	6.02	0.30
1954	0.05	2.24	0.00	2.28	3.64	0.11	0.09	0.10	0.13	0.06	0.04	0.25
1955	0.59	0.94	0.00	0.03	0.21	0.97	0.15	0.99	0.09	0.00	0.00	0.03
1956	1.31	0.03	0.89	0.00	0.51	0.55	0.00	0.10	0.41	0.12	0.31	1.76
1957	0.13	0.00	0.00	0.00	0.00	0.93	0.15	1.91	0.17	0.00	0.40	0.03
1958	0.15	0.00	0.19	1.44	0.20	1.64	1.15	0.17	0.00	0.44	0.79	0.10
1959	2.83	0.02	0.39	1.04	0.00	2.15	0.41	0.28	0.10	0.06	0.00	0.61
1960	0.01	0.65	0.98	0.10	0.33	1.93	1.04	0.25	0.02	0.07	0.09	0.13
1961	0.30	0.04	0.00	0.20	0.00	1.19	0.35	0.02	0.00	0.00	4.84	0.15
1962	2.24	1.09	0.00	0.63	0.00	6.01	0.08	0.06	0.00	0.10	0.00	0.00
1963	0.13	0.00	0.69	0.92	0.00	0.18	0.07	0.00	0.85	0.07	0.52	4.51
1964	0.11	0.06	0.00	0.00	0.00	0.54	0.09	0.72	0.13	0.07	0.00	0.00
1965	2.26	2.56	0.18	0.98	0.01	0.00	0.02	0.20	0.00	0.00	1.21	0.34
1966	0.00	0.00	0.15	0.00	1.46	1.70	4.75	2.16	0.23	0.34	0.13	0.57
1967	0.02	0.27	0.00	0.00	0.00	0.12	0.07	0.08	1.68	0.13	0.27	0.17
1968	0.09	1.28	0.00	0.00	0.00	0.45	0.02	0.00	0.51	0.05	0.06	0.02
1969	0.20	0.00	0.00	0.02	0.72	0.00	0.00	0.00	0.00	0.00	0.46	0.04
1970	0.76	0.00	1.65	0.00	0.86	0.42	1.08	0.62	0.14	2.68	2.07	0.15
1971	0.00	1.13	0.00	0.00	1.70	0.65	0.05	0.11	0.07	0.10	0.27	0.01
1972	0.00	0.00	0.00	0.06	0.00	0.00	0.42	0.03	0.23	0.08	0.08	0.05
1973	0.00	0.12	0.00	0.93	0.81	0.70	0.00	0.53	0.03	0.00	0.18	0.12
1974	0.00	0.00	0.00	0.47	0.00	0.06	0.00	0.00	0.14	0.18	0.43	1.59
1975	0.03	0.43	0.33	0.00	0.18	0.56	0.00	0.18	0.07	0.27	0.07	0.10
1976	2.34	0.59	0.00	0.00	1.84	0.28	0.00	3.35	0.18	0.00	0.23	0.47
1977	0.07	0.60	0.04	0.01	0.00	0.00	0.06	0.00	0.08	0.00	0.14	0.02
1978	0.64	0.90	0.25	0.09	0.01	0.00	0.00	0.31	0.08	1.16	0.53	1.00
1979	0.04	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.20	0.00	0.09	0.37
1980	0.99	0.86	0.27	4.53	0.61	1.79	2.19	4.61	0.29	0.14	4.59	0.26
1981	0.46	0.00	0.31	0.13	0.42	0.28	2.99	0.07	0.40	0.21	0.05	2.29
1982	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	1.56	0.18	0.38
1983	1.20	0.36	0.12	0.00	0.00	0.60	0.00	0.00	0.00	0.82	0.06	0.01
1984	0.47	0.01	0.05	0.60	0.55	0.00	0.55	0.02	0.07	0.39	0.07	0.00
1985	2.93	0.55	1.32	0.09	0.00	0.00	0.00	0.00	0.00	0.00	2.54	0.13
1986	1.78	0.03	0.05	0.00	0.07	0.00	1.63	0.00	0.05	0.00	0.14	2.19
1987	0.05	0.00	0.22	0.00	0.00	0.00	0.28	0.15	0.09	0.01	0.44	0.10
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.00	0.00	0.00	0.00
1989	2.53	1.81	0.00	0.00	1.61	0.18	0.56	0.14	0.22	0.01	0.03	0.00
1990	0.39	0.05	0.00	0.05	0.06	0.00	0.04	0.00	0.04	0.03	0.00	0.00
1991	2.34	0.00	0.42	0.22	0.25	0.39	0.01	0.12	0.07	0.68	0.22	0.01
1992	3.29	0.23	0.00	0.36	0.00	0.00	1.64	0.43	0.09	0.02	0.03	4.78
1993	0.08	0.19	1.61	0.12	0.50	0.96	0.44	0.05	0.02	0.28	1.66	0.20
1994	0.56	0.00	3.21	0.52	0.50	1.29	1.62	0.23	0.13	0.01	0.01	0.00
1995	0.00	2.65	1.27	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
1996	3.03	6.01	0.14	0.00	0.43	0.66	0.18	0.83	0.19	0.08	0.25	0.05
1997	0.30	0.00	0.00	0.11	0.00	1.64	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.00	0.00	0.27	0.01	0.80	0.23	0.00	0.00	0.00	0.00	0.34
1999	1.13	0.00	0.00	1.70	0.12	2.48	0.02	0.00	0.00	0.00	0.00	0.00
2000	0.00	1.44	1.47	0.00	0.18	0.26	1.27	0.08	0.00	0.00	0.36	0.11
2001	0.10	1.39	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.23	0.41	0.81
2002	0.00	0.00	0.00	0.00	0.00	4.00	0.03	0.84	0.13	0.00	0.07	0.00
2003	0.09	0.00	0.00	0.07	0.28	0.10	0.22	0.00	0.00	0.00	0.13	0.14
2004	0.74	0.00	2.45	0.61	0.00	0.00	0.26	0.05	0.02	0.00	0.00	0.00

Table 7.9 Simulated monthly flows (in m^3/s) for Scenario 2 (Touw River) (refer to Table 3.3 for colour coding of abiotic states)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.10	0.17	0.04	0.09	0.14
1921	0.00	0.00	0.82	0.92	0.06	1.32	0.06	0.36	0.03	1.08	0.12	0.14
1922	0.11	2.22	0.00	0.00	0.00	0.00	0.22	0.07	0.32	0.00	0.00	0.00
1923	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1924	0.00	0.00	0.19	0.00	0.00	0.72	0.25	0.02	0.14	0.00	0.37	5.56
1925	0.35	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
1926	0.91	1.27	0.00	0.00	0.45	0.05	0.00	0.18	0.00	0.00	0.00	0.00
1927	0.00	0.00	0.00	0.00	0.00	1.38	0.18	0.00	0.00	0.00	0.08	0.44
1928	0.00	5.22	1.13	0.00	0.00	0.05	0.00	0.03	0.08	0.86	0.61	1.12
1929	0.16	0.00	0.73	0.00	1.52	0.44	0.23	0.67	0.24	0.13	0.60	0.36
1930	0.27	0.00	0.00	0.62	0.00	0.00	0.71	0.00	0.00	0.35	0.09	0.10
1931	0.73	0.00	9.22	0.25	0.93	0.06	0.00	0.00	0.15	0.04	0.00	5.10
1932	0.35	0.26	0.00	0.00	0.00	0.02	0.04	0.18	0.02	0.00	1.98	0.09
1933	0.00	0.74	0.00	0.12	0.19	1.00	0.00	0.00	0.00	0.36	0.30	0.12
1934	1.93	1.39	0.00	0.00	0.00	0.00	0.00	4.18	0.34	0.15	0.11	1.33
1935	0.15	0.45	0.27	0.00	0.00	0.04	0.00	0.25	0.00	0.67	0.01	0.57
1936	0.33	2.76	0.11	0.00	0.00	1.83	0.00	0.00	0.00	0.00	0.00	0.15
1937	0.22	0.13	0.91	0.28	0.00	0.05	0.18	0.00	0.00	0.00	0.00	0.00
1938	0.00	0.18	0.24	0.00	1.64	2.64	0.01	0.00	0.00	1.07	1.69	0.57
1939	0.07	0.27	0.00	0.03	4.34	0.67	0.00	0.00	0.00	0.00	0.00	0.00
1940	0.00	0.04	0.00	0.00	0.00	0.00	3.07	0.05	0.15	0.00	0.00	0.00
1941	1.00	0.00	0.27	1.89	0.00	0.50	0.08	0.50	0.06	0.00	0.00	0.00
1942	0.00	0.00	0.60	0.97	0.00	0.45	0.12	0.00	0.00	0.00	0.00	1.49
1943	0.37	1.55	0.26	0.00	0.00	0.22	0.00	1.54	0.17	1.00	0.16	1.44
1944	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.38	0.08	0.49	0.04
1945	1.59	0.00	0.00	0.00	0.00	2.48	0.00	0.00	0.00	0.00	0.00	0.00
1946	0.00	0.00	0.00	0.00	0.00	1.87	0.02	0.18	0.11	0.59	0.00	0.47
1947	0.34	0.24	0.00	1.02	0.00	0.32	0.63	0.00	0.00	0.00	0.00	0.06
1948	1.76	0.00	0.00	0.20	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.02
1949	0.00	3.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.09	0.14
1950	1.36	3.89	0.78	4.01	0.00	0.00	0.00	0.00	0.00	1.05	0.41	1.00
1951	0.00	0.00	0.00	0.19	0.13	0.00	0.08	0.03	0.00	0.00	0.51	2.31
1952	0.20	0.44	0.00	0.00	0.10	0.00	0.57	0.00	1.09	0.66	1.32	0.84
1953	3.79	1.66	0.00	0.00	0.00	0.00	0.16	2.36	0.24	0.39	6.37	0.31
1954	0.00	2.28	0.00	2.12	3.77	0.09	0.08	0.09	0.12	0.05	0.00	0.23
1955	0.56	0.91	0.00	0.00	0.00	0.80	0.10	1.03	0.04	0.00	0.00	0.00
1956	1.26	0.00	0.73	0.00	0.23	0.53	0.00	0.02	0.43	0.09	0.32	1.83
1957	0.06	0.00	0.00	0.00	0.00	0.27	0.08	1.99	0.14	0.00	0.38	0.00
1958	0.03	0.00	0.00	1.30	0.08	1.64	1.18	0.16	0.00	0.40	0.82	0.03
1959	2.88	0.00	0.15	0.98	0.00	2.02	0.41	0.29	0.09	0.04	0.00	0.56
1960	0.00	0.50	0.89	0.00	0.16	1.96	1.06	0.25	0.00	0.02	0.08	0.09
1961	0.25	0.00	0.00	0.00	0.00	0.93	0.36	0.00	0.00	0.00	4.94	0.06
1962	2.30	1.07	0.00	0.36	0.00	6.07	0.03	0.04	0.00	0.05	0.00	0.00
1963	0.00	0.00	0.44	0.82	0.00	0.02	0.04	0.00	0.84	0.02	0.55	4.68
1964	0.02	0.00	0.00	0.00	0.00	0.11	0.01	0.64	0.11	0.05	0.00	0.00
1965	2.19	2.63	0.02	0.89	0.00	0.00	0.00	0.00	0.00	0.00	1.12	0.33
1966	0.00	0.00	0.00	0.00	0.99	1.72	4.91	2.25	0.21	0.36	0.10	0.57
1967	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.07	0.27	0.16
1968	0.02	1.26	0.00	0.00	0.00	0.05	0.00	0.00	0.30	0.02	0.04	0.00
1969	0.08	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.12	0.00
1970	0.70	0.00	1.41	0.00	0.60	0.41	1.11	0.65	0.12	2.79	2.15	0.07
1971	0.00	1.02	0.00	0.00	1.29	0.59	0.00	0.10	0.05	0.08	0.27	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.00
1973	0.00	0.00	0.00	0.53	0.74	0.68	0.00	0.46	0.00	0.00	0.09	0.09
1974	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.05	0.40	1.65
1975	0.00	0.22	0.22	0.00	0.00	0.46	0.00	0.12	0.05	0.28	0.03	0.07
1976	2.40	0.53	0.00	0.00	1.41	0.23	0.00	3.41	0.15	0.00	0.18	0.48
1977	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.26	0.82	0.10	0.00	0.00	0.00	0.00	0.02	0.04	1.21	0.53	1.04
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.83	0.82	0.23	4.59	0.55	1.83	2.24	4.83	0.30	0.13	4.76	0.23
1981	0.42	0.00	0.06	0.00	0.27	0.23	3.09	0.00	0.42	0.22	0.01	2.34
1982	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	1.49	0.12	0.37
1983	1.20	0.30	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.70	0.00	0.00
1984	0.38	0.00	0.00	0.31	0.48	0.00	0.42	0.00	0.00	0.38	0.01	0.00
1985	2.96	0.48	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.14	0.06
1986	1.83	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	0.00	0.05	2.24
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.05
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00
1989	2.33	1.83	0.00	0.00	1.15	0.12	0.57	0.13	0.23	0.00	0.00	0.00
1990	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	1.95	0.00	0.13	0.09	0.15	0.35	0.00	0.05	0.06	0.73	0.20	0.00
1992	3.33	0.13	0.00	0.07	0.00	0.00	1.42	0.46	0.06	0.00	0.00	4.95
1993	0.00	0.06	1.57	0.00	0.37	0.96	0.45	0.01	0.00	0.30	1.74	0.15
1994	0.54	0.00	3.09	0.41	0.41	1.31	1.69	0.23	0.13	0.00	0.00	0.00
1995	0.00	2.47	1.22	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	2.70	6.21	0.00	0.00	0.13	0.61	0.16	0.88	0.19	0.06	0.25	0.00
1997	0.25	0.00	0.00	0.00	0.00	1.22	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.29	0.22	0.00	0.00	0.00	0.00	0.18
1999	1.14	0.00	0.00	1.32	0.01	2.52	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	1.03	1.43	0.00	0.00	0.11	1.33	0.02	0.00	0.00	0.31	0.08
2001	0.03	1.38	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.84
2002	0.00	0.00	0.00	0.00	0.00	3.37	0.00	0.85	0.11	0.00	0.02	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.07
2004	0.73	0.00	2.22	0.47	0.00	0.00	0.09	0.07	0.04	0.00	0.00	0.00

Table 7.10 Simulated monthly flows (in m3/s) for Scenario 3 (Touw River) (refer to Table 3.3 for colour coding of abiotic states)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.00	0.00	0.40	0.00	1.23	0.44	1.07	0.04	0.11	0.00	0.00	0.04
1921	0.00	0.00	0.57	0.85	0.00	1.23	0.00	0.27	0.00	0.99	0.06	0.08
1922	0.04	2.16	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
1923	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1924	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.48
1925	0.28	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1926	0.24	1.21	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1927	0.00	0.00	0.00	0.00	0.00	0.58	0.13	0.00	0.00	0.00	0.00	0.21
1928	0.00	5.10	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.55	1.07
1929	0.08	0.00	0.59	0.00	1.36	0.37	0.17	0.61	0.19	0.08	0.54	0.30
1930	0.21	0.00	0.00	0.33	0.00	0.00	0.47	0.00	0.00	0.18	0.03	0.04
1931	0.67	0.00	9.06	0.17	0.84	0.00	0.00	0.00	0.00	0.00	0.00	4.92
1932	0.28	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.58	0.02
1933	0.00	0.57	0.00	0.00	0.06	0.89	0.00	0.00	0.00	0.11	0.24	0.05
1934	1.87	1.33	0.00	0.00	0.00	0.00	0.00	3.64	0.28	0.10	0.05	1.27
1935	0.07	0.37	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.46
1936	0.25	2.70	0.01	0.00	0.00	1.56	0.00	0.00	0.00	0.00	0.00	0.00
1937	0.00	0.00	0.80	0.19	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
1938	0.00	0.00	0.00	0.00	1.35	2.58	0.00	0.00	0.00	0.83	1.63	0.51
1939	0.00	0.19	0.00	0.00	4.12	0.59	0.00	0.00	0.00	0.00	0.00	0.00
1940	0.00	0.00	0.00	0.00	0.00	0.00	2.23	0.00	0.05	0.00	0.00	0.00
1941	0.77	0.00	0.13	1.83	0.00	0.33	0.02	0.44	0.00	0.00	0.00	0.00
1942	0.00	0.00	0.21	0.90	0.00	0.32	0.06	0.00	0.00	0.00	0.00	1.17
1943	0.30	1.49	0.16	0.00	0.00	0.04	0.00	1.30	0.11	0.94	0.10	1.38
1944	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.31	0.00
1945	1.50	0.00	0.00	0.00	0.00	2.03	0.00	0.00	0.00	0.00	0.00	0.00
1946	0.00	0.00	0.00	0.00	0.00	0.98	0.00	0.08	0.05	0.53	0.00	0.32
1947	0.26	0.16	0.00	0.83	0.00	0.13	0.58	0.00	0.00	0.00	0.00	0.00
1948	1.47	0.00	0.00	0.01	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
1949	0.00	3.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1950	0.92	3.83	0.70	3.95	0.00	0.00	0.00	0.00	0.00	0.68	0.35	0.95
1951	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.08	2.25
1952	0.14	0.37	0.00	0.00	0.00	0.00	0.32	0.00	0.97	0.60	1.26	0.78
1953	3.73	1.60	0.00	0.00	0.00	0.00	0.00	2.03	0.18	0.33	6.31	0.25
1954	0.00	2.17	0.00	1.96	3.71	0.02	0.02	0.03	0.06	0.00	0.00	0.08
1955	0.49	0.84	0.00	0.00	0.00	0.43	0.04	0.97	0.00	0.00	0.00	0.00
1956	0.99	0.00	0.62	0.00	0.06	0.41	0.00	0.00	0.27	0.02	0.26	1.77
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.72	0.08	0.00	0.25	0.00
1958	0.00	0.00	0.00	0.99	0.00	1.55	1.12	0.10	0.00	0.28	0.77	0.00
1959	2.74	0.00	0.03	0.86	0.00	1.84	0.36	0.23	0.03	0.00	0.00	0.40
1960	0.00	0.36	0.81	0.00	0.00	1.86	1.00	0.19	0.00	0.00	0.00	0.00
1961	0.14	0.00	0.00	0.00	0.00	0.56	0.30	0.00	0.00	0.00	4.69	0.00
1962	2.24	1.00	0.00	0.15	0.00	5.91	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.68	0.00	0.00	0.00	0.00	0.60	0.00	0.45	4.62
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.04	0.00	0.00	0.00
1965	1.98	2.57	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.27
1966	0.00	0.00	0.00	0.00	0.47	1.67	4.86	2.19	0.15	0.30	0.04	0.51
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.22	0.10
1968	0.00	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	1.14	0.00	0.39	0.34	1.06	0.59	0.06	2.73	2.09	0.00
1971	0.00	0.90	0.00	0.00	0.96	0.51	0.00	0.00	0.00	0.00	0.19	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.33	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.22
1975	0.00	0.08	0.12	0.00	0.00	0.23	0.00	0.00	0.00	0.20	0.00	0.00
1976	2.31	0.44	0.00	0.00	1.13	0.14	0.00	3.29	0.09	0.00	0.06	0.42
1977	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.47	0.98
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.62	0.16	4.53	0.45	1.77	2.18	4.77	0.25	0.07	4.70	0.16
1981	0.35	0.00	0.00	0.00	0.03	0.07	3.01	0.00	0.28	0.17	0.00	2.23
1982	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.06	0.31
1983	1.14	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00
1984	0.19	0.00	0.00	0.10	0.35	0.00	0.28	0.00	0.00	0.24	0.00	0.00
1985	2.77	0.40	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.55	0.00
1986	1.77	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	1.99
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	1.18	1.77	0.00	0.00	0.82	0.03	0.52	0.07	0.17	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	1.03	0.00	0.01	0.00	0.04	0.21	0.00	0.00	0.00	0.63	0.14	0.00
1992	3.22	0.04	0.00	0.00	0.00	0.00	0.99	0.40	0.00	0.00	0.00	4.80
1993	0.00	0.00	1.41	0.00	0.16	0.89	0.39	0.00	0.00	0.14	1.68	0.08
1994	0.47	0.00	2.92	0.32	0.31	1.25	1.63	0.17	0.07	0.00	0.00	0.00
1995	0.00	2.10	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	2.03	6.15	0.00	0.00	0.00	0.40	0.10	0.82	0.14	0.00	0.20	0.00
1997	0.11	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.53	0.00	0.00	1.05	0.00	2.43	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.50	1.35	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.09	0.01
2001	0.00	1.24	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58
2002	0.00	0.00	0.00	0.00	0.00	2.80	0.00	0.74	0.05	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	1.91	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7.11 Simulated monthly flows (in m3/s) for Scenario 4 (Touw River) (refer to Table 3.3 for colour coding of abiotic states)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1921	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00
1922	0.00	1.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1923	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1924	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.13
1925	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1926	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1927	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1928	0.00	3.80	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	1.02
1929	0.00	0.00	0.34	0.00	1.17	0.30	0.10	0.55	0.12	0.00	0.49	0.23
1930	0.12	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
1931	0.45	0.00	8.96	0.06	0.73	0.00	0.00	0.00	0.00	0.00	0.00	4.35
1932	0.18	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00
1933	0.00	0.27	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
1934	1.70	1.25	0.00	0.00	0.00	0.00	0.00	2.96	0.21	0.02	0.00	1.19
1935	0.00	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
1936	0.15	2.64	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	0.00	0.00
1937	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1938	0.00	0.00	0.00	0.00	0.00	2.42	0.00	0.00	0.00	0.46	1.58	0.44
1939	0.00	0.00	0.00	0.00	3.74	0.49	0.00	0.00	0.00	0.00	0.00	0.00
1940	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.00	0.00	0.00
1941	0.35	0.00	0.00	1.63	0.00	0.08	0.00	0.31	0.00	0.00	0.00	0.00
1942	0.00	0.00	0.00	0.37	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.73
1943	0.22	1.41	0.02	0.00	0.00	0.00	0.00	0.76	0.03	0.89	0.01	1.33
1944	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1945	0.51	0.00	0.00	0.00	0.00	1.39	0.00	0.00	0.00	0.00	0.00	0.00
1946	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
1947	0.15	0.04	0.00	0.56	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00
1948	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1949	0.00	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1950	0.00	3.48	0.58	3.90	0.00	0.00	0.00	0.00	0.00	0.12	0.29	0.89
1951	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14
1952	0.05	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.54	1.22	0.73
1953	3.71	1.54	0.00	0.00	0.00	0.00	0.00	1.34	0.11	0.27	6.36	0.18
1954	0.00	2.00	0.00	1.73	3.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1955	0.09	0.75	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00
1956	0.58	0.00	0.37	0.00	0.00	0.12	0.00	0.00	0.01	0.00	0.13	1.72
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.08	0.00
1958	0.00	0.00	0.00	0.37	0.00	1.34	1.06	0.02	0.00	0.11	0.70	0.00
1959	2.62	0.00	0.00	0.56	0.00	1.60	0.28	0.16	0.00	0.00	0.00	0.10
1960	0.00	0.12	0.69	0.00	0.00	1.59	0.93	0.11	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.28	0.00
1962	2.06	0.91	0.00	0.00	0.00	5.59	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	4.61
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.80	2.53	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
1966	0.00	0.00	0.00	0.00	0.00	1.33	4.84	2.15	0.07	0.23	0.00	0.39
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	2.65	2.04	0.00
1971	0.00	0.56	0.00	0.00	0.49	0.40	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.21	0.33	0.00	0.00	0.65	0.03	0.00	3.16	0.00	0.00	0.00	0.23
1977	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	3.60	0.33	1.71	2.12	4.77	0.18	0.00	4.65	0.07
1981	0.25	0.00	0.00	0.00	0.00	0.00	2.51	0.00	0.11	0.10	0.00	2.05
1982	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.94	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	2.00	0.28	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00
1986	1.59	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	1.50
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.23	0.00	0.00	0.31	0.00	0.36	0.00	0.08	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	2.68	0.00	0.00	0.00	0.00	0.00	0.23	0.33	0.00	0.00	0.00	4.53
1993	0.00	0.00	1.09	0.00	0.00	0.75	0.32	0.00	0.00	0.00	1.54	0.00
1994	0.34	0.00	2.69	0.18	0.18	1.18	1.58	0.10	0.00	0.00	0.00	0.00
1995	0.00	1.60	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	1.02	6.14	0.00	0.00	0.00	0.01	0.00	0.69	0.06	0.00	0.05	0.00
1997	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.00	0.00	0.00	0.00	0.00	1.55	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.00	0.96	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.74	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	1.78	0.00	0.60	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.03	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

A summary of the hydrology scores for the Wilderness System are provided in **Figure 7.12**.

Table 7.12 Hydrology health scores for present and future scenarios

Variable	Weight	Scenario					
		Present	1	2	3	4	Confidence
a. % Similarity in period of low flows	60	68	58	48	43	37	M
b. % Similarity in mean annual frequency of floods	40	95	94	94	94	83	M
Hydrology score: weighted mean (a,b)		**79**	**72**	**66**	**63**	**55**	**M**

7.3 PHYSICAL HABITATS

The relevant change in drivers is that a further 1 % reduction in large floods occurs under Scenario 1 to 3, while Scenario 4 reduces large floods by 17% from Reference Conditions. Assuming the flow reductions are on the main river (the Touw), then there will probably be no discernible impact on the morphology & sediment dynamics of the lakes. A summary of the physical habitat changes under the various scenarios are presented in **Tables 7.13** and **7.14** for the Touw Estuary and wilderness Lakes, respectively.

Table 7.13 Touw Estuary: Summary of physical habitat changes under different scenarios

Parameter	Scenario
a. Supratidal area and sediments	Scenarios 1 to 3 cannot be distinguished from present. Under Scenario 4 there will be less large floods which flush out sediments from the estuary and deposit new sediments on the floodplain. Slightly longer retention of riverine sediment deposits, enabling more consolidation and more enduring plant growth, all contribution to slightly less dynamic estuarine geomorphology.
b. Intertidal areas and sediments	Same as above. Also slightly more ingress of marine sediments under Scenario 4.
c. Subtidal area and sediments	Same as above.
d. Estuary bathymetry/water volume	Same as above.

Table 7.14 Wilderness Lakes: Summary of physical habitat changes under different scenarios

Parameter	Scenario
a. Supratidal area and sediments	No discernible additional impact
b. Intertidal areas and sediments	No discernible additional impact
c. Subtidal area and sediments	No discernible additional impact
d. Estuary bathymetry/water volume	No discernible additional impact

The physical habitat health scores for the present and future scenarios are provided in **Tables 7.15** and **7.16** for the Touw Estuary and Wilderness Lakes, respectively.

Table 7.15 Touw Estuary: Physical habitat health scores for present and future scenarios

Variable		Scenario					
		Present	1	2	3	4	Confidence
a	Supratidal area and sediments	65	65	65	65	60	L
b	Intertidal areas and sediments	64	64	64	64	59	L
c	Subtidal area and sediments	77	77	77	77	72	L
d	Estuary bathymetry/water volume	91	91	91	91	86	L
Physical habitat score: min (a to d)		**64**	**64**	**64**	**64**	**59**	**L**

Table 7.16 Wilderness Lakes: Physical habitat health scores for present and future scenarios

Variable		Scenario					
		Present	1	2	3	4	Confidence
a	Supratidal area and sediments	80	80	80	80	80	L
b	Intertidal areas and sediments	85	85	85	85	85	L
c	Subtidal area and sediments	90	90	90	90	90	L
d	Estuary bathymetry/water volume	95	95	95	95	95	L
Physical habitat score: min (a to d)		**80**	**80**	**80**	**80**	**80**	**L**

7.4 HYDRODYNAMICS AND MOUTH CONDITION

A summary of the changes in hydrodynamics under the future scenarios for the Touw Estuary and Wilderness Lakes are in **Tables 7.17** and **7.18**, respectively.

Table 7.17 Touw Estuary: Summary of hydrodynamic changes under different scenarios

Variable	Scenario						Confidence
	Reference	Present	1	2	3	4	
% occurrence of open mouth conditions	40	25	23	20	17	11	L
Average water level (m)	1.68	1.25	1.18	1.15	1.11	1.00	L
Average tidal variation (m)	0.43	0.28	0.27	0.23	0.20	0.12	L

Table 7.18 Wilderness Lakes: Summary of hydrodynamic changes under different scenarios

Variable	Scenario						Confidence
	Reference	Present	1	2	3	4	
% occurrence of open mouth conditions	40	25	23	20	17	11	L
Average water level (m)	1.75	1.31	1.23	1.19	1.14	1.02	L

Tables 7.18 and **7.19** provide a summary of the hydrodynamics scores for the Touw Estuary and Wilderness Lakes, respectively.

Table 7.19 Touw Estuary: Hydrodynamic health scores for present and future scenarios

Variable		Weight	Scenario					Confidence
			Present	1	2	3	4	
a	% similarity in abiotic states and mouth condition	50	61	58	50	43	28	L
b	% similarity in the water column stratification		No resolution					
c	% similarity in water retention time		No data					
d	% similarity in water level	25	85	82	81	79	75	L
	% similarity tidal amplitude	25	78	76	69	63	44	L
Hydrodynamics and mouth: weighted mean (a to d)			**71**	**69**	**63**	**57**	**44**	**L**

Table 7.20 Wilderness Lakes: Hydrodynamic health scores for present and future scenarios

Variable		Weight	Scenario					Confidence
			Present	1	2	3	4	
a	% similarity in abiotic states and mouth condition	50	61	58	50	43	28	L
b	% similarity in the water column stratification		No resolution					
c	% similarity in water retention time		No data					
d	% similarity in water level (using tidal amplitude and symmetry)	50	85	83	81	79	74	L
Hydrodynamics: weighted mean (a to d)			**73**	**71**	**66**	**61**	**51**	**L**

7.5 WATER QUALITY

Table 7.21 provides a summary of the occurrence of the various flow ranges (driving abiotic states) under various flow scenarios as derived from the long-term simulated runoff data for the Touw

River. This data, together with the weighted volume ratios of the various zones are used in the calculation of the scores for the water quality parameters.

Table 7.21 A summary of the occurrence of flow distributions in flows from the Touw River

Flow range	Scenarios					
	Natural	Present	1	2	3	4
< 0.5 (State 1 in estuary)	60	75	77	80	83	89
0.1 – 1 (State 2 in estuary)	34	19	18	15	12	9
> 20 (State 3 in estuary)	6	6	6	5	5	2

Estimated changes in water quality conditions in the various zones of the Touw Estuary under Reference Condition, Present State and Future Scenarios is presented in **Table 7.22**, while a summary description of such changes in presented in **Table 7.23**.

Table 7.22 Touw Estuary: Estimated changes in water quality in different zones under different scenarios

Zones in Estuary	Volume weighting for Zone	Estimated SALINITY concentration based on distribution of abiotic states					
		Reference	Present	Scn 1	Scn 2	Scn 3	Scn4
Lower	0.40	20	13	12	10	7	7
Middle	0.45	16	10	10	8	6	6
Upper	0.15	9	5	5	5	5	5
Zones in Estuary	**Volume weighting for Zone**	**Estimated DIN concentration (µg/ℓ) based on distribution of abiotic states**					
		Reference	**Present**	**Scn 1**	**Scn 2**	**Scn 3**	**Scn 4**
Lower	0.40	67	63	63	60	59	56
Middle	0.45	50	100	101	100	100	100
Upper	0.15	50	53	54	53	53	51
Zones in Estuary	**Volume weighting for Zone**	**Estimated DIP concentration (µg/ℓ) based on distribution of abiotic states**					
		Reference	**Present**	**Scn 1**	**Scn 2**	**Scn 3**	**Scn 4**
Lower	0.40	13	13	13	12	12	11
Middle	0.45	10	20	20	20	20	20
Upper	0.15	10	11	11	11	11	11
Zones in Estuary	**Volume weighting for Zone**	**Estimated TURBIDITY (NTU) based on distribution of abiotic states**					
		Reference	**Present**	**Scn 1**	**Scn 2**	**Scn 3**	**Scn 4**
Lower	0.40	5	5	5	5	5	5
Middle	0.45	10	10	10	10	10	10
Upper	0.15	5	5	5	5	5	5

Zones in Estuary	Volume weighting for Zone	Estimated DISSOLVED OXYGEN (mg/ℓ) based on distribution of abiotic states					
		Reference	Present	Scn 1	Scn 2	Scn 3	Scn 4
Lower	0.40	7	7	7	6	6	6
Middle	0.45	7	7	7	6	6	6
Upper	0.15	7	7	7	6	6	6

Table 7.23 Touw Estuary: Summary of water quality changes under different scenarios

Parameter	Summary of changes
Changes in longitudinal salinity gradient and vertical stratification	⇩Salinity as a result of reduced frequency (and duration) of the open periods, under the various scenarios, premature closure of the mouth and siltation in lower reaches that reduces salinity penetration.
Inorganic nutrients in estuary	⇩ in lower estuary (especially during upwelling). Slight ⇧ in middle reaches (anthropogenic)
Turbidity in estuary	No marked change
Dissolved oxygen in estuary	Slight ⇩ in future scenarios as occurrence of State 1 (Closed) increase
Toxic substances in estuary	No marked change

Estimated changes in water quality conditions in the various lakes and in the Serpentine under Reference Condition, Present State and Future Scenarios is presented in **Table 7.24**, while a summary description of such changes in presented in **Table 7.25**.

Table 7.24 Wilderness Lakes: Estimated changes in water quality in different zones under different scenarios

Zone		Volume weighting for Zone	Estimated SALINITY					
			Reference	Present	Scn 1	Scn 2	Scn 3	Scn 4
Serpentine		0.05	15 ±10	10 ± 5	10 ± 4	8 ± 4	6 ± 3	6 ± 2
Eilandvlei		0.35	10 ±5	6 ± 4	5 ± 3	4 ± 3	3 ±2	2 ± 1
Langvlei		0.35	12 ±4	8 ±3	8 ±3	6 ±3	5 ±2	4 ±1
Rondevlei		0.25	15 ±5	10 ±4	10 ±4	8 ±4	7 ±3	6 ±2
Zone		**Volume weighting for Zone**	**Estimated DIN concentration (µg/ℓ)**					
			Reference	**Present**	**Scn 1**	**Scn 2**	**Scn 3**	**Scn 4**
Serpentine		0.05	50	90	90	90	90	90
Eilandvlei	Peri	0.12	50	90	90	90	90	90
	Deep	0.23	50	50	50	50	50	50
Langvlei	Peri	0.18	50	100	100	100	100	100
	Deep	0.18	50	50	50	50	50	50

Rondevlei	Peri	0.08	50	150	150	150	150	150
	Deep	0.17	50	50	50	50	50	50
Zone		**Volume weighting for Zone**	**Estimated DIP concentration (µg/ℓ)**					
			Reference	**Present**	**Scn 1**	**Scn 2**	**Scn 3**	**Scn 4**
Serpentine		0.05	10	30	30	30	30	30
Eilandvlei	Peri	0.12	10	30	30	30	30	30
	Deep	0.23	10	10	10	10	10	10
Langvlei	Peri	0.18	10	40	40	40	40	40
	Deep	0.18	10	10	10	10	10	10
Rondevlei	Peri	0.08	10	70	70	70	70	70
	Deep	0.17	10	10	10	10	10	10
Zone		**Volume weighting for Zone**	**Estimated TURBIDITY (NTU)**					
			Reference	**Present**	**Scn 1**	**Scn 2**	**Scn 3**	**Scn 4**
Serpentine		0.05	5	5	5	5	5	5
Eilandvlei		0.35	5	10	10	10	10	10
Langvlei		0.35	5	5	5	5	5	5
Rondevlei		0.25	5	5	5	5	5	5
Zone		**Volume weighting for Zone**	**Estimated DISSOLVED OXYGEN (mg/ℓ)**					
			Reference	**Present**	**Scn 1**	**Scn 2**	**Scn 3**	**Scn 4**
Serpentine		0.05	6	4	4	4	2	2
Eilandvlei		0.35	8	6	6	6	6	6
Langvlei		0.35	8	6	6	6	6	6
Rondevlei		0.25	8	6	6	6	6	6

Table 7.25 Wilderness Lakes: Summary of water quality changes under different scenarios

Parameter	Summary of changes
Changes in longitudinal salinity gradient and vertical stratification	⇩Salinity as a result of reduced frequency (and duration) of the open periods, under the various scenarios, premature closure of the mouth and siltation in lower reaches that reduces salinity penetration. Note that the salinity ranges are also decreasing with decrease in flow as the system drift towards a freshwater lake.
Inorganic nutrients in lakes	⇧ DIP/DIN in the shallower peripheral areas of all zones associated with higher organic loading and remineralisation

Parameter	Summary of changes
Turbidity in lakes	No marked changes, except in Eilandvlei where the Duiwe River introduce slightly ⇧ turbidity associated with agricultural activity in the catchment
Dissolved oxygen in lakes	⇩⇩ in Serpentine (much shallower, protected and higher organic loading). Organic enrichment in lakes also resulted in slight ⇩ in average DO.
Toxic substances in lakes	Limited modification

EHI scores for water quality under the various scenarios are presented in **Tables 7.26** and **7.27** for the Touw Estuary and Wilderness Lakes, respectively.

Table 7.26 Touw Estuary: Water quality health scores for present and future scenarios

Variable		Weight	Scenario					
			Present	1	2	3	4	Confidence
1	Similarity in salinity	40	77	76	75	66	57	M/L
2	General water quality in estuary							
a	DIN/DIP concentrations		83	83	82	82	81	M/L
b	Turbidity		100	100	100	100	99	M/L
c	Dissolved oxygen		98	98	97	96	96	M/L
d	Toxic substances		95	95	95	95	95	L
General water quality: min (a to d)		60	83	83	82	82	81	
Water quality score: weighted mean (1,2)			**81**	**80**	**79**	**76**	**71**	**M/L**

Table 7.27 Wilderness Lakes: Water quality health scores for present and future scenarios

Variable		Weight	Scenario					
			Present	1	2	3	4	Confidence
1	Similarity in salinity	40	78	75	64	56	46	M/L
2	General water quality in estuary							
a	DIN/DIP concentrations		80	80	80	80	80	M/L
b	Turbidity		88	88	88	88	88	M/L
c	Dissolved oxygen		85	85	85	84	84	M/L
d	Toxic substances		90	90	90	90	90	L
General water quality: min (a to d)		60	80	80	80	80	80	
Water quality score: weighted mean (1,2)			**79**	**78**	**74**	**70**	**66**	**M/L**

7.6 MICROALGAE

A summary of the expected changes under various scenarios for the microalgae component in the Touw Estuary and Wilderness Lakes is provided in **Tables 7.28** and **2.29**, respectively.

Table 7.28 Touw Estuary: Summary of change in microalgae under different scenarios

Scenario	Summary of changes
1	Phytoplankton: Change in estuary states has minimal impact on biomass (score 77). MPB: Changes in estuary states has minimal impact on biomass (score 41). No change in nutrients.
2	Phytoplankton: Change in estuary states has minimal impact on biomass (score 78 – 1% for nutrients). MPB: Changes in estuary states has minimal impact on biomass (score 41 – 1% for nutrients).
3	Phytoplankton: Change in estuary states has minimal impact on biomass (score 78 – 1% for nutrients). MPB: Changes in estuary states has minimal impact on biomass (score 41 – 1% for nutrients).
4	Phytoplankton: Change in estuary states has minimal impact on biomass (score 78 – 2% for nutrients). MPB: Changes in estuary states has minimal impact on biomass (score 40 – 2% for nutrients).

Table 7.29 Wilderness Lakes: Summary of change in microalgae under different scenarios

Scenario	Summary of changes
1	Lakes becoming fresher (25% change from reference), no change in nutrients.
2	Lakes becoming fresher (36% change from reference), no change in nutrients.
3	Lakes becoming fresher (44% change from reference), no change in nutrients.
4	Lakes becoming fresher (54% change from reference), no change in nutrients.

The EHI scores for microalgae under the various scenarios are presented **in Tables 7.30** and **7.31** for the Touw Estuary and Wilderness Lakes, respectively.

Table 7.30 Touw Estuary: Microalgae health scores for present and future scenarios

Variable	Scenario					
	Present	1	2	3	4	Confidence
Phytoplankton						
a. Species richness	95	95	95	95	95	L
b. Abundance	78	77	77	77	75	L
c. Community composition	80	78	75	72	66	L
Benthic microalgae						
a. Species richness	90	90	90	90	90	L
b. Abundance	53	52	51	51	49	L
c. Community composition	80	78	75	72	66	L
Microalgae score: min (a to c)	**53**	**52**	**51**	**51**	**49**	**L**

Table 7.31 Wilderness Lakes: Microalgae health scores for present and future scenarios

Variable	Scenario					
	Present	**1**	**2**	**3**	**4**	**Confidence**
a. Species richness	90	90	90	90	90	L
b Abundance	80	80	80	80	80	L
c. Community composition	70	70	70	70	70	L
Microalgae score: min (a to c)	**70**	**70**	**70**	**70**	**70**	**L**

7.7 MACROPHYTES

A summary of the expected changes under various scenarios for the macrophyte component in the Touw Estuary and Wilderness Lakes is provided in **Tables 7.32** and **2.33**, respectively.

Table 7.32 Touw Estuary: Summary of change in macrophytes under different scenarios

Scenario	Summary of changes
1-3	Little change from present conditions.
4	Loss of tidal variation in Scenario 4 as well as a decrease in salinity may lead to some loss of saline intertidal species in the Touw Estuary. Less flooding resulting in sedimentation and reed growth.

Table 7.33 Wilderness Lakes: Summary of change in macrophytes under different scenarios

Scenario	Summary of changes
1-4	Decrease in salinity in the lakes may result in the loss of saline species and increased reed growth. Reeds would also grow in response to a drop in water level. Average water level for State 1 (closed high water level) would change from 1.3 m (present) to 1.1 m (Scenario 3) to 1.0 m (Scenario 4).

The EHI scores for macrophytes under the various scenarios are presented in **Tables 7.34** and **7.35** for the Touw Estuary and Wilderness Lakes, respectively.

Table 7.34 Touw Estuary: Macrophyte health scores for present and future scenarios

Variable	Scenario					
	Present	**1**	**2**	**3**	**4**	**Confidence**
a. Species richness	90	90	90	90	85	M
b. Abundance	70	70	70	70	65	M
c. Community composition	80	80	80	80	75	M
Macrophyte score: min (a to c)	**70**	**70**	**70**	**70**	**65**	**M**

Table 7.35 Wilderness Lakes: Macrophyte health scores for present and future scenarios

Variable	Scenario					
	Present	**1**	**2**	**3**	**4**	**Confidence**
a. Species richness	90	90	85	80	75	M
b. Abundance	80	80	75	75	70	M
c. Community composition	80	80	75	75	70	M
Macrophyte score: min (a to c)	**80**	**80**	**75**	**75**	**70**	**M**

7.8 INVERTEBRATES

A summary of the expected changes under various scenarios for the invertebrate component in the Touw Estuary and Wilderness Lakes is provided in **Tables 7.36** and **2.37**, respectively.

Table 7.36 Touw Estuary: Summary of change in invertebrates under different scenarios

Scenario	Summary of changes
1	This scenario represents a further small shift in the time the mouth remains open to the sea (23% vs 25% at present). The mouth opens to the sea during any month of the year, and for up to one month at a time. A relatively small proportion of opening events occur during the mudprawn (*Upogebia africana*) breeding season (summer) and the estuary may remain closed for years at a time. The lifespan of mudprawns is around three years and on average, the estuary remains closed for more than three years during summer. In addition, the window of opportunity to colonise the estuary from the marine environment (post-larvae originating from the adjacent Swartvlei Estuary and bay) is very small and it is very unlikely that colonisation by post larvae would occur. The net result is the extinction of the species from the Touw Estuary. Sandprawn (*Callichirus kraussi*) would recolonize the estuary from the marine nearshore, but the estuarine population would continue to decline in biomass relative to the Present State. Colonisation would be very sporadic and during some years when the estuary mouth remains closed for longer than the lifespan of sandprawns, estuarine populations would become extinct. The net result is likely to be the occaional presence of sandprawns in the Touw Estuary. No colonisation would occur from estuarine populations as salinity values are below threshold levels to allow successful breeding. Composition of the benthic communiity would remain similar to present, although species would become widespread throughout the estuary. Attached macrophytes would increase in biomass and colonize suitable habitat throughout the estuary. The net result would be a switch towards invertebrate species favouring attached plants as a substrate. Biomass therefore, would increase and dominate the whole estuary. Zooplankton and hyperbenthic populations would continue along a trajectory of becoming more oligohaline, with riverine species appearing in the plankton (cyclopoid and harpacticoid copepods). Zonation patterns would break down and the freshwater associated community would spread throughout the estuary.

Scenario	Summary of changes
2 3 4	Salinity in the Touw Estuary becomes progressively lower as the mouth remains closed for longer periods. Patterns for the respective groups described under scenario one would persist with only the occasional presence of the sandprawn *Callichirus kraussi.* The invertebrate community would continue along a trajectory of becoming more freshwater associated, with increasing biomass of cyclopoid and harpacticoid copepods in the zooplankton. Benthic invertebrate biomass would mostly be associated with attached plants. In summary, the Touw Estuary would continue along a trajectory that is increasingly similar to the invertebrate community present in the adjacent lake systems, losing its estuarine characteristics. Expressed another way, loss in diversity of the Wilderness Lakes Complex.

Table 7.37 Wilderness Lakes: Summary of change in invertebrates under different scenarios

Scenario	Summary of changes
1 2 3 4	These four scenarios represent a continuum towards a freshwater lakes complex. The species mix under the Present State would reflect this, moving progressively towards a freshwater community. There will also be a gradual loss of species compared to present, with different freshwater forms colonising the system. Variability could increase as a consequence of occasional and sharp declines in the oxygen concentration of bottom waters. This will result in mass invertebrate mortality, particularly among benthic forms. The decline in oxygen concentrations to very low levels in the Serpentine will also act as a barrier to invertebrates moving between the Touw and Eilandvlei.

The EHI scores for invertebrates under the various scenarios are presented in **Tables 7.38** and **7.39** for the Touw Estuary and Wilderness Lakes, respectively.

Table 7.38 Touw Estuary: Invertebrate health scores for present and future scenarios

Variable	Scenario					
	Present	1	2	3	4	Confidence
Zooplankton						
a. Species richness	60	60	58	55	52	L
b. Abundance	75	72	58	55	52	L
c. Community composition	70	67	50	45	40	L
Hyperbenthos						
a. Species richness	60	60	58	55	52	L
b. Abundance	75	72	58	55	52	L
c. Community composition	70	67	50	50	40	L
Benthos						
a. Species richness	60	60	58	55	52	L
b. Abundance	60	72	55	52	48	L
c. Community composition	55	50	48	46	40	L
Invertebrate score: min(a to c)	**55**	**50**	**48**	**46**	**40**	**L**

Table 7.39 Wilderness Lakes: Invertebrate health scores for present and future scenarios

Variable	Scenario					
	Present	1	2	3	4	Confidence
Zooplankton						
a. Species richness	100	95	90	85	80	L
b. Abundance	90	85	80	75	70	L
c. Community composition	90	82	77	72	65	L
Hyperbenthos						
a. Species richness	100	95	90	85	80	L
b. Abundance	90	85	80	75	70	L
c. Community composition	90	82	77	72	65	L
Benthos						
a. Species richness	100	90	85	80	75	L
b. Abundance	90	80	75	70	65	L
c. Community composition	90	77	72	65	55	L
Invertebrate score: min(a to c)	**90**	**77**	**72**	**65**	**55**	**L**

7.9 FISH

A summary of the expected changes under various scenarios for the fish component in the Touw Estuary and Wilderness Lakes is provided in **Tables 7.40** and **7.41**, respectively.

Table 7.40 Touw Estuary: Summary of change in fish under different scenarios

Scenario	Summary of changes
1	Little difference to present with reduced recruitment windows. The mouth would remain closed for longer periods which would impact on juvenile and larval recruitment into the estuary. Salinity decreases slightly but there will be a decrease in the REI. Estuarine residents will continue to be dispersed throughout the estuary with possible increases in the biomass of alien invasive species. Increased closed phase may increase the occurrence of stratification within the water column and development of localised areas of low DO. The contribution of euryhaline marine species may decline slightly due to limited recruitment and size class frequencies will shift towards large sizes. Low flow rates (closed mouth) will promote the growth of filamentous algae and attached macrophyte growth. This combined with limited recruitment of mudprawn and possible decreases in sandprawn abundance will result in a decrease in prey availability for adult benthic feeders(*L.lithognathus*, *P. commersonnii*). Benthic species such as *P. knysnaensis* and *Heteromycterus capensis* will likely decrease in abundance.

Scenario	Summary of changes
2 – 4	The patterns referred to above persist. The mouth remains closed for progressively longer periods and recruitment opportunity decreases. Estuarine shoaling species will dominate throughout the estuary whilst euryhaline marine species are likely to decrease in abundance. The decrease in salinity will favour alien invasive freshwater species with higher water levels providing more shallow water marginal habitat (preferred habitat for *G. affinis* and possibly important for spawning of *C. carpio*). Populations of euryhaline marine species may become dominated by larger size classes as recruitment decreases.

Table 7.41 Wilderness Lakes: Summary of change in fish under different scenarios

Scenario	Summary of changes
1	Little difference to present, in particular with regards to Langvlei and Rondevlei. Decreasing salinity will favour alien invasive freshwater species.
2 - 4	The lakes will continue on a trajectory towards a freshwater lakes complex. Conditions will become more favourable towards alien invasive freshwater species with potential successful breeding of *C. carpio* very likely. Recruitment potential of euryhaline marine species will become more restricted and importantly a decrease in predator fish (*L.amia*) will reduce predation pressure on *O. mossambicus* and *C. carpio* juveniles.

The EHI scores for fish under the various scenarios are presented in **Tables 7.42** and **7.43** for the Touw Estuary and Wilderness Lakes, respectively.

Table 7.42 Touw Estuary: Fish health scores for present and future scenarios

Variable	Scenario					
	Present	1	2	3	4	Confidence
a. Species richness	70	68	68	65	60	M
b. Abundance	60	60	60	55	45	M
c. Community composition	80	78	78	75	70	M
Fish score: min (a to c)	**70**	**60**	**60**	**55**	**45**	**M**

Table 7.43 Wilderness Lakes: Fish health scores for present and future scenarios

Variable	Scenario					
	Present	1	2	3	4	Confidence
a. Species richness	70	70	70	65	60	M
b. Abundance	65	65	65	60	50	M
c. Community composition	70	70	70	65	60	M
Fish score: min (a to c)	**65**	**65**	**65**	**60**	**50**	**M**

7.10 BIRDS

A summary of the expected changes under various scenarios for the bird component in the Touw Estuary and Wilderness Lakes is provided in **Tables 7.44** and **2.45**, respectively.

Table 7.44 Touw Estuary: Summary of change in birds under different scenarios

Scenario	Summary of changes
1-4	The four scenarios represent a continuum away from natural, with the direction of change being the same as from reference to present. The drivers and trends are as described for the Present State.

Table 7.45 Wilderness Lakes: Summary of change in birds under different scenarios

Scenario	Summary of changes
1-4	The four scenarios represent a continuum away from natural, with the direction of change being the same as from reference to present. The drivers and trends are as described for the Present State. It is possible, however, that as water levels decline, so the amount of available marginal habitat would increase.

The EHI scores for birds under the various scenarios are presented in **Tables 7.46** and **7.47** for the Touw Estuary and Wilderness Lakes, respectively.

Table 7.46 Touw Estuary: Bird health scores for present and future scenarios

Variable	Scenario					
	Present	1	2	3	4	Confidence
a. Species richness	70	70	70	70	70	L
b. Abundance	70	70	65	60	55	L
c. Community composition	70	65	60	55	50	L
Bird score: min (a to c)	**70**	**65**	**60**	**55**	**50**	**L**

Table 7.47 Wilderness Lakes: Bird health scores for present and future scenarios

Variable	Scenario					
	Present	1	2	3	4	Confidence
a. Species richness	70	70	70	70	70	L
b. Abundance	60	58	55	52	50	L
c. Community composition	55	53	50	45	40	L
Bird score: min (a to c)	**55**	**53**	**50**	**45**	**40**	**L**

7.11 ECOLOGICAL CATEGORIES ASSOCIATED WITH SCENARIOS

The individual health scores for the various abiotic and biotic components are used to determine the ecological status or ecological category for the Wilderness System under each of the future scenarios, using the Estuarine Health Index (EHI), is presented in **Tables 7.48** and **7.49** for the Touw Estuary and Wilderness Lakes, respectively.

Table 7.48 Touw Estuary: EHI score and corresponding Ecological Categories under present and future scenarios

Variable	Weight	Scenario					
		Present	1	2	3	4	Confidence
Hydrology	25	79	72	66	63	55	L
Hydrodynamics and mouth condition	25	71	69	63	57	44	L
Water quality	25	81	80	79	76	71	M/L
Physical habitat alteration	25	64	64	64	64	59	L
Habitat health score		**74**	**71**	**68**	**65**	**57**	
Microalgae	20	53	52	51	51	65	L
Macrophytes	20	70	70	70	70	40	M
Invertebrates	20	55	50	48	45	45	L
Fish	20	60	60	60	55	50	M
Birds	20	70	65	60	55	50	L
Biotic health score		**62**	**59**	**58**	**55**	**50**	
ESTUARY HEALTH SCORE		**68**	**65**	**63**	**60**	**54**	**L**
ECOLOGICAL STATUS		**C**	**C**	**C/D**	**C/D**	**D**	**L**

Table 7.49 Wilderness Lakes: EHI score and corresponding Ecological Categories under present and future scenarios

Variable	Weight	Scenario					
		Present	**1**	**2**	**3**	**4**	**Confidence**
Hydrology	25	**79**	**72**	**66**	**63**	**55**	**L**
Hydrodynamics and mouth condition	25	73	71	66	61	51	L
Water quality	25	79	78	74	70	66	M/L
Physical habitat alteration	25	80	80	80	80	80	L
Habitat health score		**78**	**75**	**71**	**69**	**63**	
Microalgae	20	70	70	70	70	70	L
Macrophytes	20	80	80	75	75	70	M
Invertebrates	20	90	77	72	65	55	L
Fish	20	65	65	65	60	50	M
Birds	20	55	53	50	45	45	L
Biotic health score		**72**	**69**	**66**	**63**	**57**	
ESTUARY HEALTH SCORE		**75**	**72**	**60**	**66**	**60**	**L**
ECOLOGICAL STATUS		**B/C**	**B/C**	**C**	**C**	**C/D**	**L**

8 RECOMMENDATIONS

8.1 ECOLOGICAL FLOW REQUIREMENTS

The EWR methods for estuaries (DWAF, 2008) set the following as a guideline for the Ecological Flow Requirement Scenario: *"The recommended Ecological Flow Requirement scenario is defined as the flow scenario (or a slight modification thereof) that represents the highest change in river inflow that will maintain the estuary in the Recommended Ecological Category".*

In the case of the Wilderness System a **Category B** was proposed as the REC. However, a hydrological scenario, increasing inflow above the Present scenario was not considered realistic, given the agricultural demand from water in the catchment (and that the system still receives 85% of its natural MAR). Also, even by hypothetically returning some of the MAR (15%) it will not be possible improve a PES Category C (in the case of the Touw Estuary) and Category B/C (in the case of the Wilderness Lakes) to a REC of Category B due to the significant impact of other non-flow related factors. In the case of the Wilderness System mitigation of other non-flow related factor, therefore will be required to improve to the REC. **However, the present inflow into the systems remains a critical force to maintain open mouth conditions and further reduction in inflows to the system will increase the contribution of river flow in modification to conditions in the estuary.** Applying the above guideline, there is therefore not a scenario that is able to improve the health of the Wilderness System to a Category B. However, as a minimum, present flows should be maintained to prevent further deterioration.

Present total inflow to the system (i.e. presented as the total present inflow into the Wilderness System from adjacent catchments) is therefore set as the recommended ecological flow scenario for the Wilderness System (**Table 8.1**).

Table 8.1 Recommended ecoligical flow scenario for the Wilderness System (Category B)

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	6.08	9.94	14.20	7.52	7.10	9.69	7.73	7.66	2.78	4.38	9.90	8.85
99	5.65	8.92	6.92	6.77	6.29	7.07	5.69	7.08	1.98	2.98	8.46	8.43
90	3.85	3.50	1.90	1.76	2.10	3.29	1.97	1.63	0.64	1.45	2.16	2.64
80	1.99	1.97	1.14	1.02	0.83	1.88	1.04	0.83	0.43	0.74	0.86	1.18
70	1.04	1.00	0.60	0.55	0.40	1.16	0.50	0.46	0.33	0.35	0.61	0.75
60	0.70	0.56	0.31	0.27	0.27	0.90	0.36	0.29	0.25	0.24	0.45	0.50
50	0.41	0.16	0.06	0.16	0.06	0.51	0.23	0.21	0.21	0.19	0.31	0.33
40	0.27	0.08	0.00	0.04	0.01	0.25	0.17	0.12	0.14	0.10	0.22	0.28
30	0.15	0.02	0.00	0.00	0.00	0.12	0.09	0.07	0.08	0.08	0.16	0.17
20	0.06	0.00	0.00	0.00	0.00	0.01	0.05	0.04	0.03	0.05	0.09	0.10
10	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.06	0.01
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

However, the REC for the Wilderness System, namely a **Category B**, can only be realised if some **non-flow related factors** are improved. Key interventions that should be undertaken:

- Increase breaching level, at least to +2.9 m MSL (currently the system is breached between 2.1-2.4 m MSL). These higher levels match levels experienced during the 2007 and 2011 floods. If the system can be breached at these higher water levels, more sediment will be removed and the system will remain open to the sea for longer periods.
- The practice of artificially closing the system when the inlet becomes constricted should also be terminated.
- Alien fish and vegetation in the system should be controlled/eradicated.[e.g. establish fishery for alien invasive fish (e.g. design seine for tilapia) and Working for Water].
- Interim management measures should be considered to improved connectivity (interlinking channels) between the estuary and lakes, e.g. harvesting excessive macrophyte growth
- Terminate ad hoc riparian protection practices along the banks of the estuary and the lakes and consider developing strategic guidelines for bank protection that will be more appropriate for this system.

These interventions should be undertaken in collaboration with various responsible departments in DWS, as well as other national and provincial departments and institutions responsible for estuarine resource management such as DAFF, Department of Environmental Affairs (DEA: Oceans and Coasts) and South African National Parks (SANParks) authorities. It is recommended that the estuarine management planning process and the associated institutional structures (as required under the Integrated Coastal Management Act 2008) be used as a mechanisms through which to facilitate the implementation these interventions.

8.2 ECOLOGICAL SPECIFICATIONS

The EcoSpecs and associated TPCs representative of a **Category B for the Wilderness System** are presented in **Table 8.2**.

Table 8.2 EcoSpecs and TPCs for the Wilderness System

Component	EcoSpecs	Thresholds of Potential Concern
Hydrology	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ River inflow distribution patterns differ by more than 5% from that of Present day ▪ Monthly river inflow < 0.1 m^3/s persists for longer than 20% of the time
Hydrodynamics	Maintain intermittent connectivity with marine environment	▪ During the open state average tidal amplitude < 30% of present observed data from the water level recorder in the estuary near the mouth ▪ Mouth closure > 60% of the time over a five-year period

Component	EcoSpecs	Thresholds of Potential Concern
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) for biota ▪ No significant changes in sediment grain size distribution patterns for biota ▪ No significant change in average sediment composition and characteristics ▪ No significant change in average bathymetry ▪ Connecting channel bathymetry to be such that adequate flow connectivity is maintained.	▪ Average sediment composition in any survey (% fractions) along estuary change from that of the Present State (2014 baseline, to be measured) by 30% ▪ Average sediment composition in any survey (% fractions) in each of the lakes change from that of the Present State (2014 baseline, to be measured) by 5% ▪ Average bathymetry along main channel change by 30% in any survey along estuary from that of the Present State (2014 baseline, to be measured) (system expected to significantly fluctuate in terms of bathymetry between flood and extended closed periods) ▪ Average bathymetry change by 2 to 5% in any survey in each of the lakes from that of the Present State (2014 baseline, to be measured) ▪ Average bathymetry along connecting channels to be maintained (average depth threshold to be determined following a baseline monitoring survey)
Water quality	Salinity	Estuary in the closed state: ▪ Average salinity in Zone A < 12, ▪ Average salinity in Zone B: < 10 ▪ Average salinity in Zone C < 5 Lakes average salinity +2 from baseline (2013) and variability do not increase as below: ▪ Serpentine: 12 ± 10 ▪ Eilandvlei: 8 ± 5 ▪ Langvlei: 10 ± 4 ▪ Rondevlei: 10 ± 5
	System variables (pH, dissolved oxygen and turbidity) not to cause exceedance of TPCs for biota (see below)	River inflow: ▪ 6.0 < pH > 7.0 (Touw) ▪ 7.0 < pH > 8.0 (Duiwe) ▪ DO < 5 mg/ℓ ▪ Suspended solids > 5 mg/ ℓ (low flow) Estuary: ▪ Average turbidity > 5 NTU (low flow) ▪ Average 6.0 < pH > 8.5 (increasing with increase in salinity) ▪ Average DO < 5 mg/ℓ Lakes: ▪ Average turbidity > 5 NTU ▪ Average 7.0 < pH > 8.5 ▪ Average DO < 5 mg/ℓ

Component	EcoSpecs	Thresholds of Potential Concern
	Inorganic nutrient concentrations (NO_3-N, NH_3-N and PO_4-P) not to cause exceedance of TPCs for macrophytes and microalgae (see below)	River inflow: ▪ NO_x-N > 50 µg/ℓ over two consecutive months ▪ NH_3-N > 10 µg/ℓ over two consecutive months ▪ PO_4-P > 10 µg/ℓ over two consecutive months Estuary (except during upwelling or floods): ▪ Average NO_x-N > 50 µg/ℓ single concentration > 100 µg/ℓ ▪ Average NH_3-N > 10 µg/ℓ during survey, single concentration > 100 µg/ℓ ▪ Average PO_4-P > 10 µg/ℓ during survey, single concentration > 50 µg/ℓ Lakes: ▪ Average NO_x-N > 50 µg/ℓ during survey, single concentration > 100 µg/ℓ ▪ Average NH_3-N > 20 µg/ℓ during survey (to be confirmed) ▪ Average PO_4-P > 20 µg/ℓ during survey (to be confirmed)
	Presence of toxic substances (e.g. trace metals and pesticides/herbicides) not to cause exceedance of TPCs for biota (see below)	River inflow: ▪ Trace metals (to be confirmed) ▪ Pesticides/herbicides (to be confirmed) Estuary: ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Microalgae	▪ Maintain low median phytoplankton biomass ▪ Maintain medium median benthic microalgal biomass ▪ Prevent formation of phytoplankton blooms ▪ Prevent dramatic shift of phytoplankton community structure	▪ Median phytoplankton chlorophyll a (minimum five sites) exceeds 3.5 µg/ℓ during any survey ▪ Median intertidal benthic chlorophyll a (minimum five sites) exceeds 23 mg/m^2 during any survey ▪ Site specific chlorophyll a concentration exceeds 20 µg/ℓ and/or cell density exceeds 10 000 cells/ml during any survey ▪ Dinoflagellates, cyanobacteria and/or chlorophytes > 10% of relative abundance during any survey

Component	EcoSpecs	Thresholds of Potential Concern
Macrophytes	▪ Maintain the distribution of sensitive macrophyte habitats (e.g. salt marsh, submerged macrophytes) ▪ No invasive plants ▪ Prevent the spread of reeds into open water	▪ Greater than 20 % change in the area covered by submerged macrophytes and salt marsh due to disturbance, freshening of the system and changes in turbidity ▪ Presence of invasive floating aquatic macrophytes ▪ Invasive plants cover > 5% of total floodplain area. ▪ Increase in reeds & sedges and encroachment into main water channel due to infilling and drop in water level
Invertebrates	▪ Maintain presence of sand prawn *Callichirus kraussi* on sand banks in lower Touw Estuary ▪ Maintain rich populations of the benthic amphipod *Grandidierella lignorum* throughout the lakes and estuary	Populations should not deviate from average baseline values (as determined in first three visits) by more 30%

Component	EcoSpecs	Thresholds of Potential Concern
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference (see 2015 EWR report). Relative proportions should be roughly similar to that currently in the Touw Estuary and Wilderness Lakes. Numerically, assemblage should comprise: ▪ Ia estuarine residents (20-60% of total abundance) ▪ Ib marine and estuarine breeders (20-60%) ▪ IIa obligate estuarine-dependent (5-10%) ▪ IIb estuarine associated species (1-10%), ▪ IIc marine opportunists (5-20%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least 4 species (including *G.aestuaria, Hyporamphus capensis, Omobranchus woodii*). Category IIa obligate dependents should be well represented by large exploited species especially *A. japonicus, L. lithognathus, P. commersonii, Lichia amia.* REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 20% ▪ Ib marine and estuarine breeders < 20% ▪ IIa obligate estuarine-dependent < 5% ▪ IIb estuarine associated species < 1% ▪ IIc marine opportunists < 5% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species < 1% ▪ Ia represented only by *G. aestuaria*. ▪ IIa exploited species in very low numbers or absent ▪ REI species represented only by *G. aestuaria*, *Myxus capensis* absent
Birds	The estuarine lake system should contain a diverse avifaunal community that includes representatives of all the original groups, and that sustains the populations for which the system has acquired Ramsar status	Numbers of waterbirds on the entire system, other than those that have or are increasing regionally such as Egyptian Goose, drops below 40 species or below 1500 birds for three consecutive counts

8.3 BASELINE SURVEYS AND LONG-TERM MONITORING PROGRAMME

Additional baseline studies that are important to the improvement of the confidence of the EWR study is provided in **Table 8.3.** These components are all important to improves the confidence overall, priority components are highlighted. Especially, data needs to be collected to improve the relationship hydrology, mouth condition, hydrology and breaching levels. The recommended long-term monitoring programme, the purpose of which is to test for compliance with EcoSpecs and TPC and to continuously improve understanding of ecosystem function, is presented in **Table 8.4**. While all components in the long-term monitoring programme remain important, certain primary (abiotic) data, as highlighted in **Table 8.4**, is of highest priority.

The implementation of the baseline and long-monitoring programme should be undertaken in collaboration of various responsible departments in DWS, as well as other national and provincial departments and institutions responsible for estuarine resource management such as DAFF, DEA: Oceans and Coasts and SANParks. It is recommended that the estuarine management planning process and the associated institutional structures (as required under the Integrated Coastal Management Act 2008) be used as a mechanisms to coordinate and execute this long-term monitoring programme.

Table 8.3 Additional baseline surveys to improve confidence of EWR study on the Wilderness System (priority components are highlighted)

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (No. stations)
Sediment dynamics	Monitoring berm height using appropriate technologies	Quarterly	Mouth
	Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 300 m intervals, but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm	Once-off	Entire estuary All three connecting channels
	Bathymetric survey lines extending from the entrance of the western connecting channel to the entrance of the eastern connecting channel (or eastern bank), as well as a survey line from the southern to northern banks through the approximate centre of each lake	Once-off	Each of the three lakes (exact position of survey lines to be confirmed during baseline survey)
	Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations)	Once-off	Entire estuary and each of the three lakes
Water quality	Collect samples for herbicides and pesticides in river inflow	Once-off	Near head of estuary in: Touw River (station K3H5) Duiwe River (station K3H11) Langspruit River

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (No. stations)
	Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – see Newman and Watling, 2007)	Once-off	Entire estuary and lakes, including depositional areas (i.e. muddy areas)
	Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, dissolved oxygen and turbidity profiles	Quarterly, preferably over two years	Entire estuary (nine stations) All lakes and connecting channels (including stations in deeper middle, and shallower peripheral areas of lakes)
Microalgae	▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC, fluoroprobe ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe	Quarterly, preferable over two years	Entire estuary (minimum three stations) All lakes, including stations in deeper middle, and shallower peripheral areas of lakes (minimum five stations each)
Macrophytes	▪ Ground-truthed maps to update changes over time in emergent vegetation after the SANParks 1997 assessment (Russell 2003). ▪ Measurement of area covered by submerged macrophytes, SANParks annual field assessment to be included in vegetation map. ▪ Assess and map extent of invasive plants within the 5 m contour line	Once-off	Entire estuary and lakes

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (No. stations)
Invertebrates	▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 um mesh) along estuary ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 um). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 um) ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (5 replicates per site). Establish the species concerned using a prawn pump. Check for the presence of mudprawn in muddy intertidal substrate in the lower estuary ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton)	Quarterly, preferable over two years	Minimum of three sites along length of entire estuary and one site in each of the lakes For hole counts – three sites in Touw Estuary near the N2 bridge.

Table 8.4 **Recommended long-term monitoring programme for the Wilderness System (priority components are highlighted)**

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
Hydrodynamics	Record water levels	Continuous	Touw Estuary (station K3T006) Eilandvlei (station K3R005) Langvlei (station K3R004) Rondevlei (station K3R003)
	Measure freshwater inflow into the estuary	Continuous	Near head of estuary in: Touw River (station K3H005) Duiwe River (station K3H011) Langspruit River
	Aerial photographs or high resolution satellite imagery (5 x 5 m) of estuary	Every three years	Entire estuary
Sediment dynamics	Monitoring berm height using appropriate technologies	Quarterly	Mouth

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
	Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 300 m intervals, but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm	Every three years (and after large resetting event)	Entire estuary All three connecting channels
	Bathymetric survey lines extending from the entrance of the western connecting channel to the entrance of the eastern connecting channel (or eastern bank), as well as a survey line from the southern to northern banks through the approximate centre of each lake	Every three years (and after large resetting event)	Each of the three lakes (exact position of survey lines to be confirmed during baseline survey)
	Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations)	Every three years	Entire estuary and each of the three lakes
Water quality	Collect data on conductivity, temperature, suspended matter/turbidity, dissolved oxygen, pH, inorganic nutrients and organic content in river inflow	Monthly continuous	Near head of estuary in: Touw River (K3H5) Duiwe River (K3H11) Langspruit River Also in Lakes: Eilandvlei (K3R005) Langvlei (K3R004) Rondevlei (K3R003)
	Collect in situ continuous salinity data with mini CTD probe at a depth of about 1 m	Continuous	Six sites - at the mouth, ebb and flow, head of the estuary, Eilandvlei, Langvlei and Rondevlei.
	Collect samples for herbicides and pesticides in river inflow	Every 3 – 6 years	Near head of estuary in: Touw River (K3H5) Duiwe River (K3H11) Langspruit River
	Record in situ salinity, temperature, pH, DO, turbidity profiles	Seasonally, every year	Entire estuary (nine stations) All lakes and connecting channels (including stations in deeper middle, and shallower peripheral areas of lakes)

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
	Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, dissolved oxygen and turbidity profiles	Every three years (high flow and low flow) or when significant change in water quality expected	Entire estuary (nine stations) All lakes and connecting channels (including stations in deeper middle, and shallower peripheral areas of lakes)
	Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – see Newman and Watling, 2007)	Every 3 – 6 years	Entire estuary and lakes, including depositional areas (i.e. muddy areas)
Microalgae	▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC, fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Every three years during low flow	Entire estuary (minimum three stations) All lakes, including stations in deeper middle, and shallower peripheral areas of lakes (minimum five stations each)
Macrophytes	Map the area covered by the different macrophyte habitats. Compile a species list and check for expansion of invasive plants, reed, sedges and grass areas.	Summer surveys every three years	Entire estuary and lakes
	SANParks to continue their monitoring including that of submerged macrophytes which includes four littoral transects around each lake and five transects in the Touw Estuary for biomass measurements. At the same time assessments of area covered should be made.	Bi-annually	Entire estuary and lakes

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
Invertebrates	▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 um mesh) along estuary ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 um). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 um) ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (5 replicates per site). Establish the species concerned using a prawn pump. Check for the presence of mudprawn in muddy intertidal substrate in the lower estuary ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton)	Every two years mid-summer	Minimum of three sites along length of entire estuary and one site in each of the lakes For hole counts – three sites in Touw Estuary near the N2 bridge.
Fish	As per SANParks detailed monitoring programme		
Birds	Undertake counts of all water associated birds, identified to species level	Continued winter and summer counts. A series of monthly counts carried out for two years each decade.	Entire system, divided into its component sections (estuary, Serpentine, three lakes)

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APPENDIX A: DATA SUMMARY REPORT FOR HYDRODYNAMICS

A.1 MOUTH CLOSURE

Artificial breaching of estuaries has been undertaken along the South Coast since the early nineteenth century. Flooding of agricultural land along Langvlei and Eilandvlei motivated farmers to combine their labour force to excavate a trench by hand through the sandbar blocking the mouth. Apparently the original mouth was located in the vicinity of Leentjiesklip. The estuary mouth was fixed in its current position by the construction of the railway bridge in 1928 (Fijen, 1995). In the1950s the mouth was for the first time open by mechanical means. As development increased in the area, breachings were conducted at lower and lower levels. The Lakes Area Development Board took over the management of the system in 1975 and insisted on higher breaching levels. SANParks took over in 1983 and currently allows the sandberm height near the mouth to grow to 2.4 m MSL, after which it is skimmed to 2.1 m mean sea level (MSL). Naturally the berm height would have been between 3.0 and 3.5 m MSL (Fijen, 1995) L. At present the estuary mouth is also closed artificially once the inlet channel becomes constricted to prevent sedimentation in the lower reaches.

The Touw Estuary mouth is closed most often during the winter period that is associated with high wave conditions (**Figure A.1**). The duration of an open mouth state is also shorter, with a duration three weeks versus the average of about eight to ten weeks observed for the system.

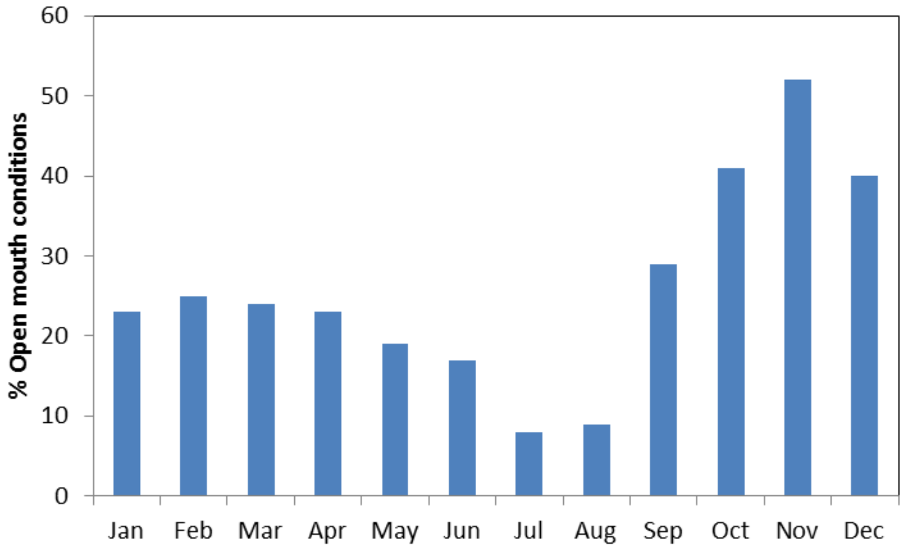

Figure A.1 Relative percentage open mouth conditions

A.2 SEEPAGE AND EVAPORATION LOSSES

A water balance of the Wilderness Lakes during the closed mouth periods indicate that nett annual seepage and evaporation losses equates to about 6.2 million m^3/a or 17 000 m3/day. This is equivalent to a decrease of about 6.6 cm/month (Fijen, 1995).

A.3 WATER LEVELS

The average water level in the Touw Estuary during open mouth conditions are about 0.8 m MSL, which is higher than the average high tide in the sea as a result of significant sediment in the lower reaches of the estuary. The minimum water level in Eilandvlei is about 1.0 m MSL and cannot decrease below that as a result of the depth of the Serpentine channel. The minimum water levels in Langvlei and Rondevlei are also 1.0 m MSL, which again correspond to the bottom-levels in the interconnecting channels and the road crossing culverts bisecting the channels.

Water level variation in the estuary is significant and driven by floods from the Touw River (maximum) and the scoring after a breaching (minimum). Small floods, not sufficient to break through the mouth, causes a rapid rise in water level after which levels decline as water flows from the estuary into the Eilandvlei and the rest of the lake system.

Water level in Eilandvlei under the closed mouth state are similar to those measured in the Touw Estuary, but minimum water levels are higher during the open tidal phase and maximum water levels are lower during floods (restricted by limited connectivity and lower inflows from Duiwe River). Water level fluctuations are about 1.6 m (between 1.0 to 2.6 m MSL). The water levels in Langvlei and Rondevlei are virtually identical and fluctuate by about 0.9 m (from about 1.0 to 1.9 m MSL) (**Figure A.2**).

Rondevlei has no influent rivers, while Langvlei has only a small tributary flowing into it. The water levels in these two lakes are determined by direct rainfall, groundwater inflow, in flow from Eilandvlei and evaporation. The water levels of Rondevlei and Langvlei are of a cyclic nature in that high evaporation rates from November to March can cause a decrease in lake levels while inflow from Eilandvlei can cause levels to increase between April to October.

The hydrodynamic relationship between the estuary and the three lakes are demonstrated by **Figure A.3**. A flood in the Touw Estuary results in a rapid rise in water levels in the estuary as a result of its relative small surface area and restricted flow to Eilandvlei through the Serpentine channel. On opening of the mouth, the water level in the estuary rapidly declines within 5 to 10 hours. The maximum water level in Eilandvlei can be very similar to that of the estuary depending on whether the Duiwe River also floods. Maximum levels in Eilandvlei are achieved within 30 hours after maximum levels in the estuary. After breaching levels in Eilandvlei also decline rapidly, but are somewhat retarded as a result of the constriction of the Serpentine channel.

Water levels in Langvlei and Rondevlei respond very sluggishly to floods from the Touw and Duiwe Rivers as a result of the constriction link channels. The water levels are much lower and maximum water levels occur 3 to 7 days later than in the estuary. Outflow from Langvlei and Rondevlei occurs for a period of 2 months after a breaching.

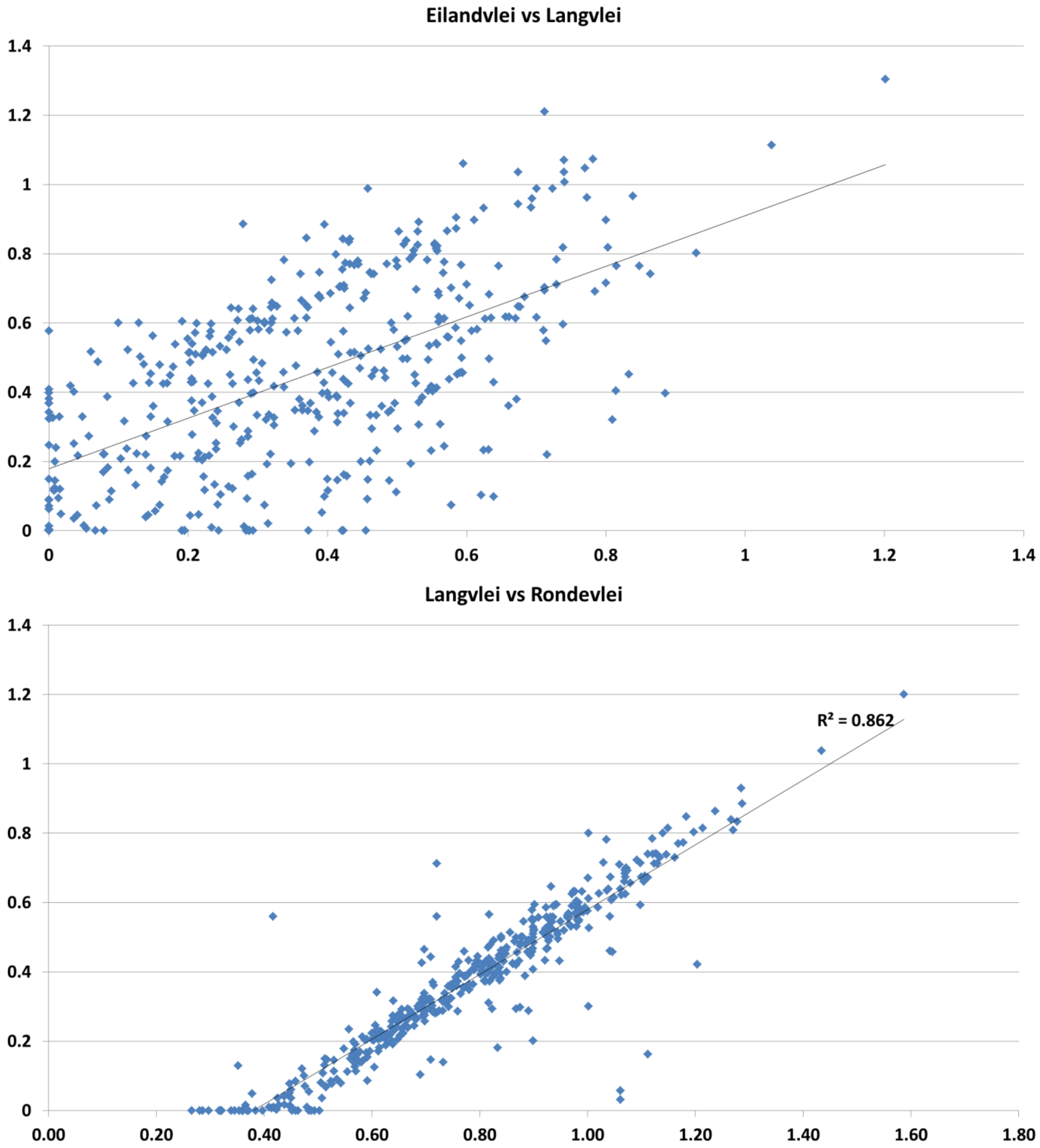

Figure A.2 Correlation of the median monthly water levels for Eilandvlei, Langvlei and Rondevlei

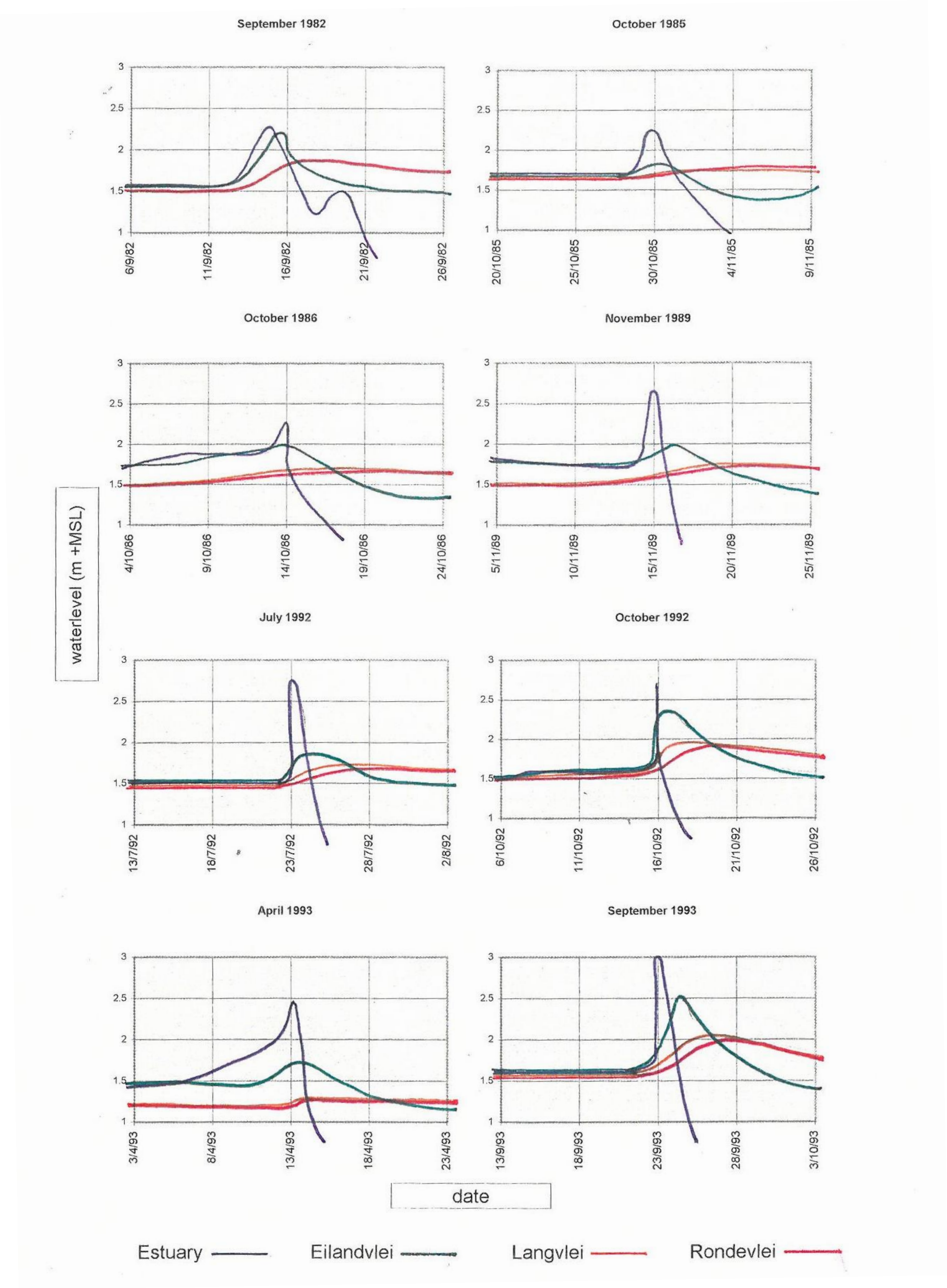

Figure A.3 Water levels during flood conditions (Fijen, 1995)

A.4 RELATIONSHIP BETWEEN RIVER INFLOW, MOUTH BREACHING AND WATER LEVELS

At present the sand berm at the mouth is artificially kept between 2.1 and 2.4 m MSL. When a flood occurs, water rapidly rises to the level of the berm and the system is either artificially breached or over tops (**Figure A.4**). Under the current restricted water levels, limited spill over occurs from the Touw Estuary into Eilandvlei and from there into Langvlei and Rondevlei.

Flooding in the Reference Condition with low initial water levels (e.g. 1.4 m MSL) would have resulted in the water level in the Touw Estuary (and in Eilandvlei if the Duiwe floods) increasing quickly and spilling over into Langvlei and Rondevlei (**Figure A.5**). There would then be a slower buildup of water levels in the Langvlei and Rondevlei, but as the water levels rises in the estuary and vleis the connectivity would increase, with through flow becoming more efficient with increasing water levels. The maximum water level would stay below the berm height, with no rapid break through to sea. Under this model, water level in the estuary will dissipate after small floods as water gets distributed over the entire lake system. The effect of a flood is that the total water level increases after a flood with final lake levels dependent on the size of the flood. For example, a 1:5 year flood with a volume of 5.5 x 10 m^3 would increase the initial water levels from 1.4 m to 2.1 m MSL. It will also lead to an overall reduction in salinity levels. The same effect could also be achieved if there was a steady inflow from the rivers without actual having a flood.

During high initial levels (e.g. 2.1 m MSL) there would be a quick rise in water level in the estuary and in Eilandvlei into Langvlei and Rondevlei with relative ease (less friction in link channels under higher water levels) (**Figure A.6**). Water levels will build up to higher than the berm height (3. 0 – 3.5 m MSL) and the mouth would break open to the sea. The outflow to the sea would now consist of both the estuary volume and the volume of water stored in the lakes. There would be a large outflow from the combined system, with flow from Langvlei and Rondevlei decreasing as water level decreases and interconnectivity in the channels declines. The combined outflow would take place over a long period. The result would be larger outflow volumes, higher outflow velocities, increased sediment scour in lower reaches, increase tidal flows and longer open mouth periods. It should also be noted that the higher berm level in itself would reduce ingress of marine sediment during the closed period through over wash. Leading to a deeper mouth area which would assist with maintain longer open mouth condition and increased salinity penetration.

It is therefore envisaged that under natural conditions, the estuary mouth would have been open less often, as initial, high runoff and flood volumes need to fill up the lake system. However, when the mouth breaches, it would have stayed open for longer periods of time compared to present.

During low runoff periods (i.e. droughts) the mouth would have stayed closed for long periods. At present when the mouth breaches the estuary stays open for about 8 to 10 weeks on average. Fijen (1995) estimated that under the natural condition the mouth would have remained open for about 40% of the time, roughly 20 weeks per year.

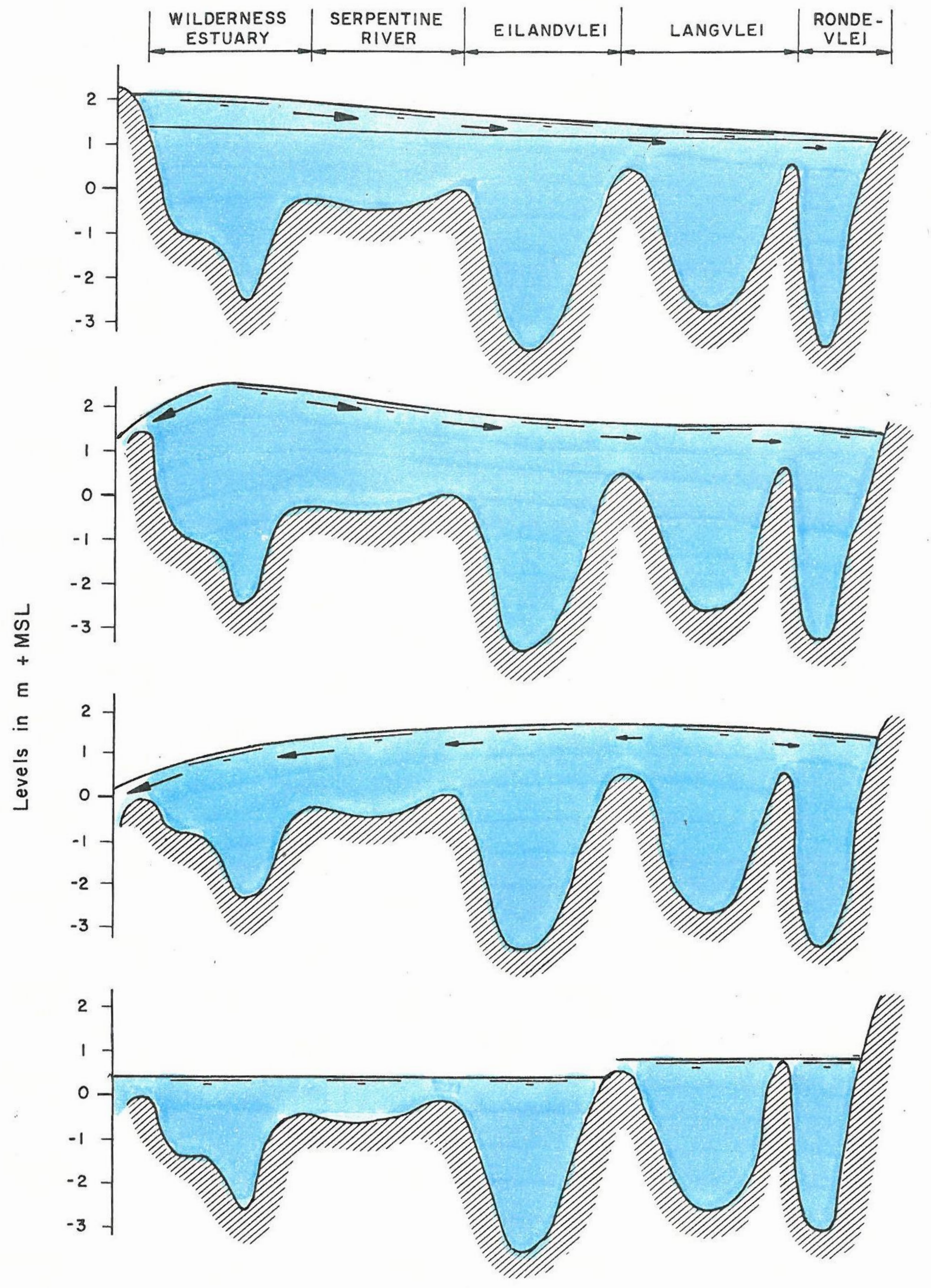

Figure A.4 Present State, flood volumes cause breaching (Fijen, 1995)

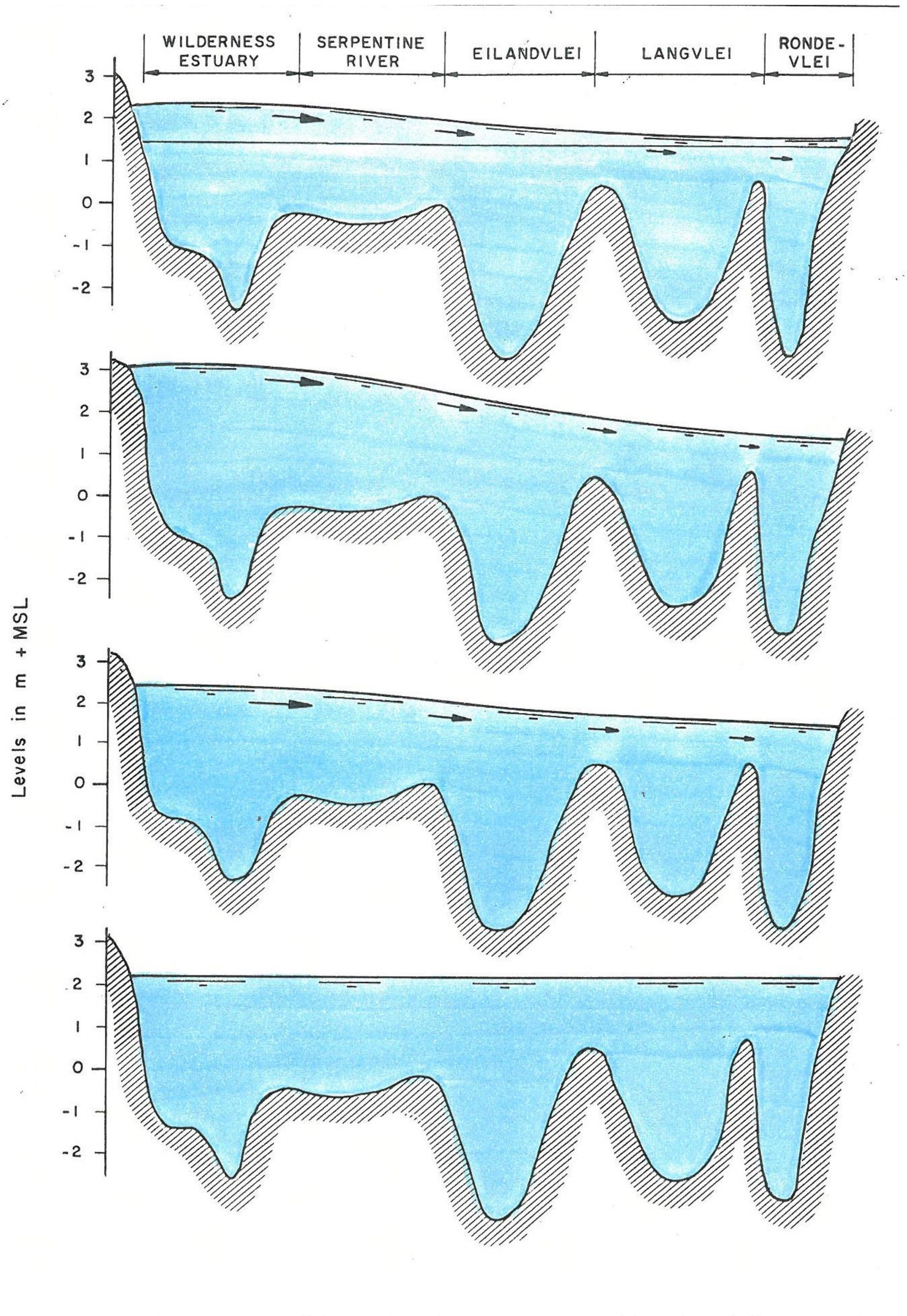

Figure A.5 Reference Conditions, flood volumes stored in lakes (Fijen, 1995)

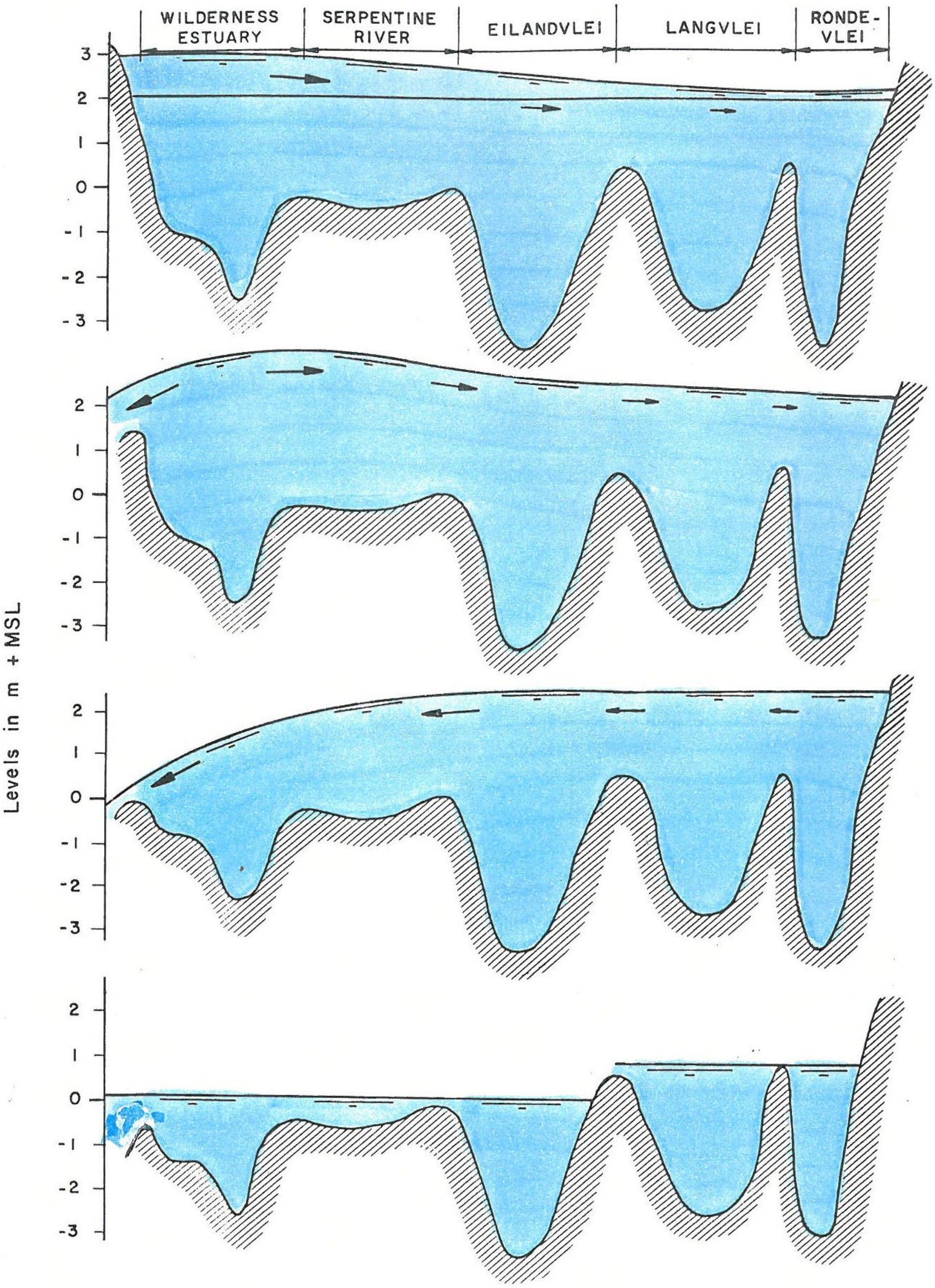

Figure A.6 **Reference Conditions, large outflow through the Touw Estuary mouth (Fijen, 1995)**

APPENDIX B: DATA SUMMARY REPORT FOR SEDIMENT DYNAMICS

Observations on the Touw River mouth and lower estuary hydrodynamics that directly affect or impact on the sediment dynamics and geophysical morphology (adapted from P Huizinga pers com, 2014, with additions by the author):

1. The mouth of the Touw Estuary is intermittently open and closed. The mouth is situated on the exposed high energy Wilderness beach. This dynamic beach is relatively wide and together with the primary dune contains large volumes of sand. Thus, during sea storms, the mouth can easily be closed naturally if river flows are low (e.g. base flows).
2. The lower estuary is connected to Eilandvlei through the Serpentine channel, which is connected through a narrow and shallow channel to Langvlei, which in turn through another small channel is connected to Rondevlei.
3. The main inflow is from the Touw River directly into the estuary. Much lesser inflow normally originates from the other lakes through the Duiwe and Spruit contributories.
4. During major floods, large inflow normally takes place from the Touw River directly into the estuary. Because of the comparatively low surface area of the estuary the water level increases in a short time to high flood levels, necessitating the breaching of the mouth to prevent flooding of properties. The increasing water levels in the estuary also result in increased flow through the Serpentine into Eilandvlei and through the other channels also to Langvlei and Rondevlei. The water-levels in these other lakes are normally still much lower than in the estuary when the mouth is breached.
5. During such major floods relatively little time is often available to breach the mouth and therefore some precautionary measures are being taken:
    a. A bulldozer is on stand-by to ensure for quick mobilisation.
    b. When the water levels and the berm are high the top of the berm is often skimmed and maintained at a lower level to reduce the time required for the excavation of the breaching channel.
    c. Additionally a deeper trench is excavated on the backside of the berm to allow stronger outflow after a breaching. This trench can for example be observed on the Google photographs from 22 November 2006, 28 February 2010 and 2 September 2011.
6. An additional concern is the accumulation of sediment on the inside of the berm. Especially when high waves occur at incoming tides and also when the mouth is already closed and when the berm is still low, large quantities of sediment can be flushed into the estuary. The height of the berm is therefore often artificially increased after closure to prevent this from happening.

The overall impacts of these frequent interventions in mouth dynamics and berm morphology, is less flushing out of sediment from the lower estuary and probably more ingress of marine sediment into the lower estuary.

Pertinent aspects/factors about the Touw River catchment regarding flows and sediment yields to the estuary (based on the Touws River PES and other observations):

- Largely unregulated catchment which generally maintains floods (although slightly reduced baseflows and/or occurrence of floods) and thus from river flow perspective, this driver (at head of the estuary) is similar to the Reference Condition, but slightly reduced. The present MAR of the Touw River is estimated to have been decreased by 11% compared to the natural MAR.

Under Reference Conditions floods were about 5% higher than at present, (based on ten highest simulated monthly flow volumes compared for the 75-year period).

- The river channel is wide, riparian zone poorly vegetated – similar to, but slightly reduced compared to the Reference Condition. The loss of vegetation may result in slightly increased sediment yield to the estuary.
- Farm dams in the catchment reduce small floods and trap some sediment (small impacts), but agricultural land-use increased sediment yield. A larger dam is observed on the 2003 image of the catchment, but this appears to be an off-channel dam, which would therefore only have a small impact on reducing rivers flows (very little on large floods), and also only small impact (reduction) on coarser sediment yield to the estuary.
- During floods, the Touw River is fast flowing, carrying a wide range of sediments into the estuary from fines to cobbles (**Figure B.1**).

Figure B.1 Cobble bed near the head of the estuary (Photo: A Theron)

Overall catchment changes are considered to result in slightly increased riverine fine sediment load to the estuary, but slightly reduced coarser load (sand and gravel) to the estuary. The small reduction in large floods would tend to result in slightly less flushing of sediments from all parts of the estuary, also enabling marine sediment to ingress slightly further into the estuary on average. An additional effect would be slightly longer retention of riverine sediment deposits, enabling more consolidation and more enduring plant growth, all contribution to slightly less dynamic estuarine geomorphology.

In the Reference Condition the middle reaches of the estuary would have been more directly connected to the coastal dynamics, probably occasionally breaching to the sea at the big bend in the middle reaches (green circle in **Figure B.2**) during extreme flood events. There would also have been significant aeolian sediment input into the estuary at this location, especially over the spring to autumn period (prevailing SE-SW winds). With the construction of the highway, such breaching is no longer possible, and no aeolian sediment transport can reach the middle estuary from the adjacent beach (red circle in **Figure B.2**). The road construction also involved some infilling of the seaward side of the channel at this location, narrowing the channel slightly from the southern (road) side.

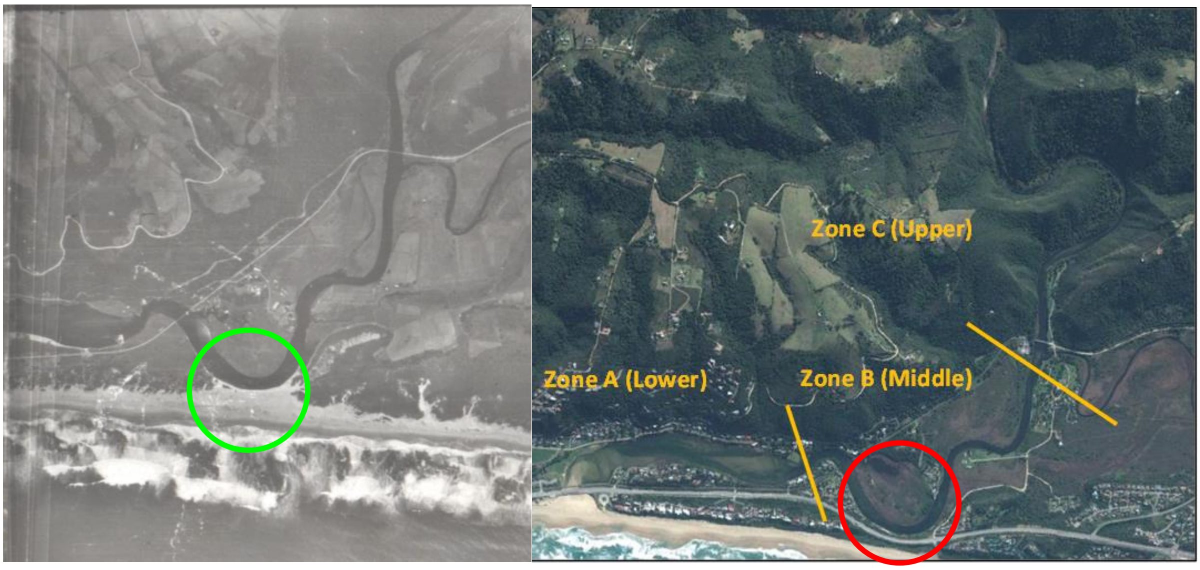

Figure B.2 **Former (1936) versus present (Google Earth) connectivity of the middle reaches of the Touw Estuary to the sea**

There are road and rail bridges crossing the estuary in all three zones. Although the bridge openings are relatively large, the bridges and especially their embankment all have slight constricting effects and tend to fix the estuary channel and banks in the direct vicinity (up- and down-stream) of the bridges. The banks of the middle and especially the lower estuary have been heavily impacted by development (houses, banks stabilisation structures/revetments, slipways and jetties, etc.).

The catchment of the lakes tributaries is less pristine than that of the Touw River. Agriculture and forestry occur in patches, also exotic species in some areas, otherwise indigenous. There are significant resort settlements around the lakes. Hotels, camping, picnicking, boat launching are concentrated around and west of Eilandvlei. Thus expected increased sediment inputs into the lakes from catchments and surrounding areas. The lakes are naturally a virtually total sediment sink (trap) for sediments from the catchments and surrounding areas. Only a small amount of fine sediments could be exported through the lakes to the Touw Estuary during high flows. A “sluice” gate was constructed on the Serpentine channel (Allanson and Whitfield, 1983). The channel between Eilandvlei and Langvlei is severely overgrown; the consequent siltation of the channel has created an effective block to lake interflow when levels fall below +1.2 m MSL (Allanson and Whitfield, 1983).

Over the past 700 years the rate of segmentation of the lakes and Touw Estuary (and infilling of the lakes) has been increased through anthropogenic actions (based on Allanson and Whitfield, 1983).

APPENDIX C: DATA SUMMARY REPORT FOR WATER QUALITY

C.1 AVAILABLE DATA

The following abiotic data sets were available for the Touw Estuary and Wilderness Lakes, while sampling stations are indicated in **Figure C.1**.

Data required	Availability	Reference
Longitudinal salinity/EC and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: ▪ end of low flow season ▪ peak of high flow season	Salinity and Temp: 1991-2010 Salinity and Temp: Jan, Apr, Jul 2013 Salinity and Temp: Dec 2013 EC: 1978-2013	Russell (1999, 2013) CSIR, unpublished data This study www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp
Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: ▪ end of low flow season ▪ peak of high flow season	System variables: 1991-2010 All: Jan, Apr, Jul 2013 All: Dec 2013 Nutrients and some system variables:1978-2013	Russell (1999, 2013) CSIR, unpublished data This study www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp
Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary	Trace metals (1977)	Watling (1979)
Water quality (e.g. system variables, nutrients and toxic substances) measurements on river water entering at the head of the estuary	Nutrients and some system variables:1978-2013	www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp
Water quality (e.g. system variables, nutrients and toxic substances) measurements on near-shore seawater	From literature	DWAF (1995)

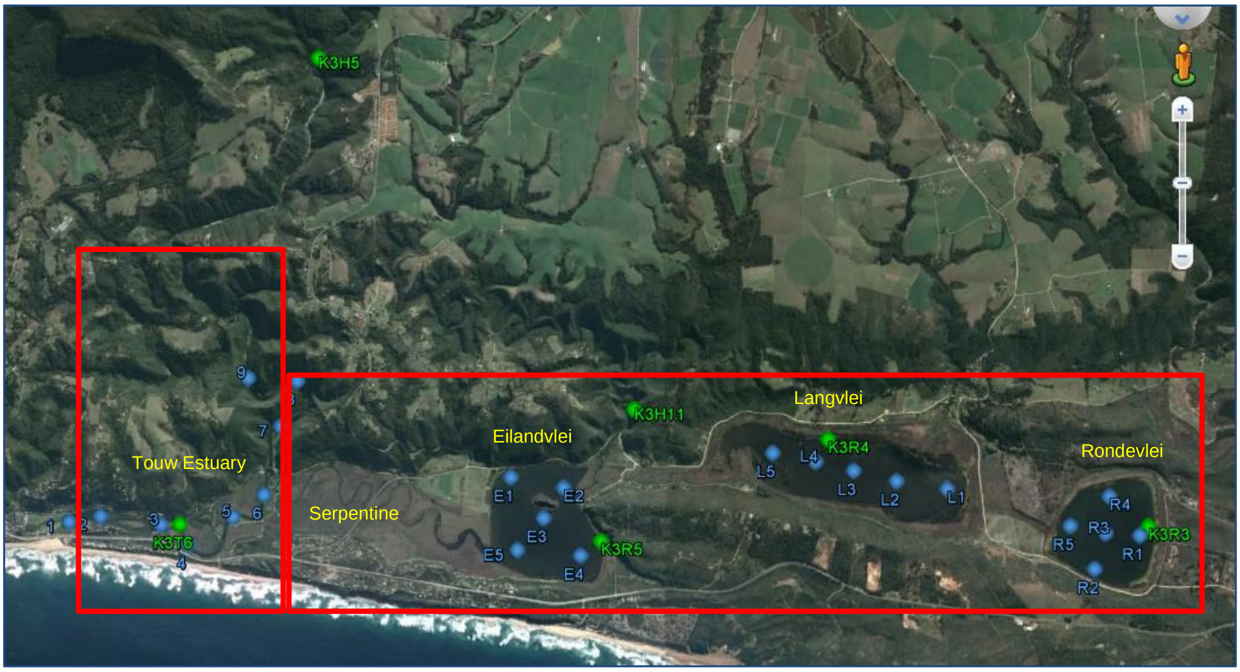

Figure C.1 **Sampling locations in the Touw Estuary and Wilderness Lakes (Green – DWA stations; Blue – SANParks stations and this study – only estuary)**

C.2 SALINITY/ELECTRICAL CONDUCTIVITY

A summary of Electrical Conductivity in river inflow is provided in **Figure C.2a**. During January 2013 (**Figure C.2b**) the Touw River inflow was relative low (< 0.2 m^3/s) for the preceding weeks, but on the day of sampling, inflow increased to about 3 m^3/s. Therefore, the system was relatively fresh (between 7 and 10) with only remnants of more saline water (> 20) in the deeper areas. In contrast, during December 2013 **(Figure C.2b)**, about 21 days before the sampling event a large resetting flood flushed the system, but as inflow decreased to between 1.0 to 0.5 m^3/s, salinity penetrated 4.5 km upstream, with marine water (> 30) detected 3.0 km upstream in the deeper areas. Surface salinity varied between 10 and 20 in the middle reaches (Zone B), while Zone A was marine-dominated.

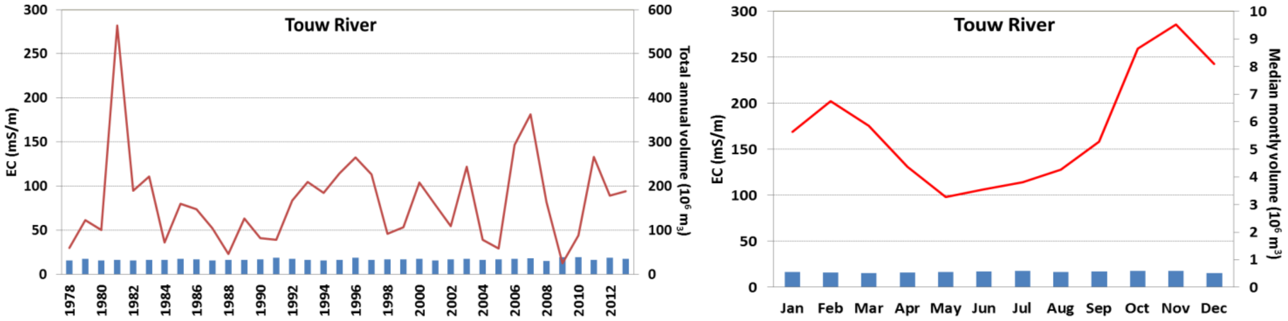

Figure C.2a **Median annual Electrical Conductivity and median monthly EC (1978-2013) measured in the Touw River (K3H005) (red lines represent flow volumes on the secondary axes)**
(data obtained from www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp)

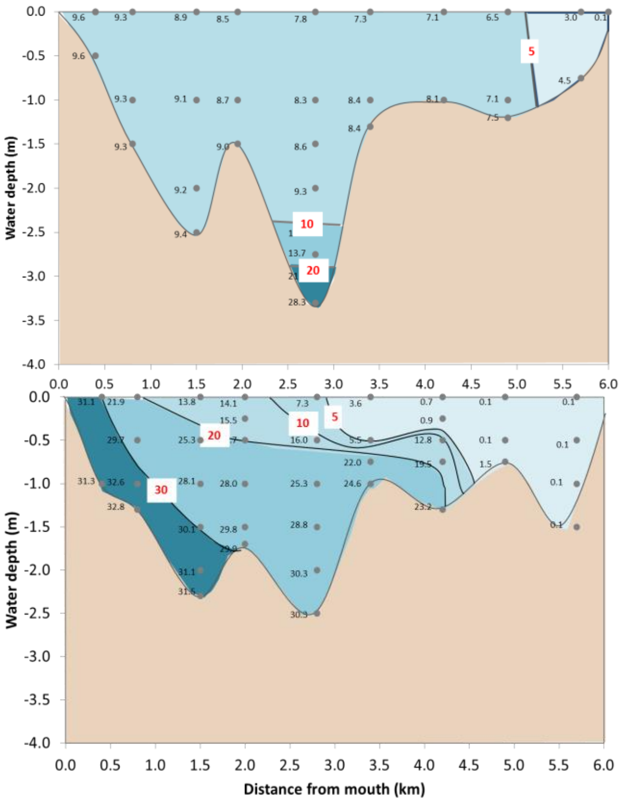

Figure C.2b **Salinity profiles measured in Touw Estuary on 30 January 2013 (mouth closed) and 8 December 2013 (mouth open) (CSIR, unpublished data; this study)**

Patterns of change in relation to freshwater and saltwater inflows differed between the Touw Estuary and the lakes. Open conditions are associated with high runoff (e.g. **Figure C.2c** and **C.2d**), with such events occurring either during the open states (2 and 3) or triggering breaching in response to rises in water level in the estuary. This enabled the inflow of sea water that causes higher salinity within the estuary. However, extended mouth closure, often associated with low-rainfall periods (**Figure C.2e**), did not always result in reduced salinity levels. Periods of both sustained high salinity (Mar 2001–Sep 2002), as well as periods of declining salinity (Dec 2008–July 2010) coincided with closed estuary conditions (Russell, 2013). A significant decline in salinity has occurred in both Langvlei and Rondevlei, despite shorter-term increases during the low rainfall period of 2008–2010 (Russell, 2013) (**Figure C.2e**). Eilandvlei showed a five-year oscillation between higher and lower salinity states, but no significant trend was evident. Russell (2013) explained that the dominant trend in the Touw Estuary, was an increase in salinity when the estuary was open for a protracted (> 3 month) period, and a decline in salinity when the estuary was closed. The opposite trend was predominant in the lakes, with a decline in salinity following the increased freshwater inflow, which frequently precipitated estuary breaching, and increasing salinity during periods when the estuary mouth was closed.

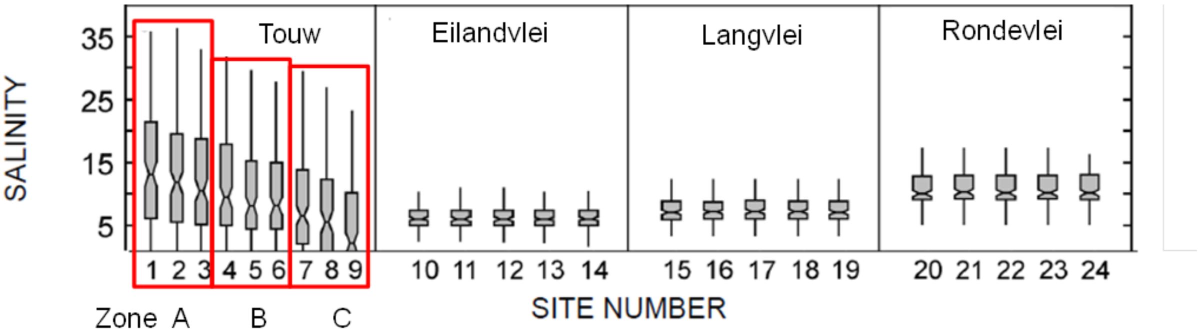

Figure C.2c Box-and-whisker plot of salinity at various sites in the four estuarine waterbodies of the Wilderness Lakes System in 1991–2010. Plots include all monthly (1991–1999) and quarterly (2000–2010) data from nine sample sites in the Touw Estuary, and five sites each in Eilandvlei, Langvlei and Rondevlei. The narrowest point of the notch in the box is the median of the data, the top and bottom of the box are the 25th and 75th percentiles (quartiles), and the ends of the whiskers are the 5th and 95th percentiles (Russel, 2013)

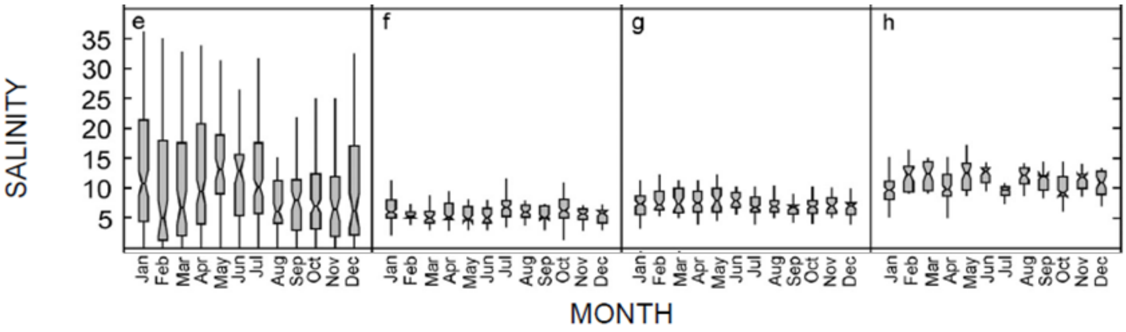

Figure C.2d Box-and-whisker plot of salinity in various months in the four estuarine waterbodies in the Wilderness Lakes System in 1991–2010. Plots include all monthly (1991–1999) and quarterly (2000–2010) data from all sample sites in the Touw Estuary, Eilandvlei, Langvlei and Rondevlei (Russel, 2013)

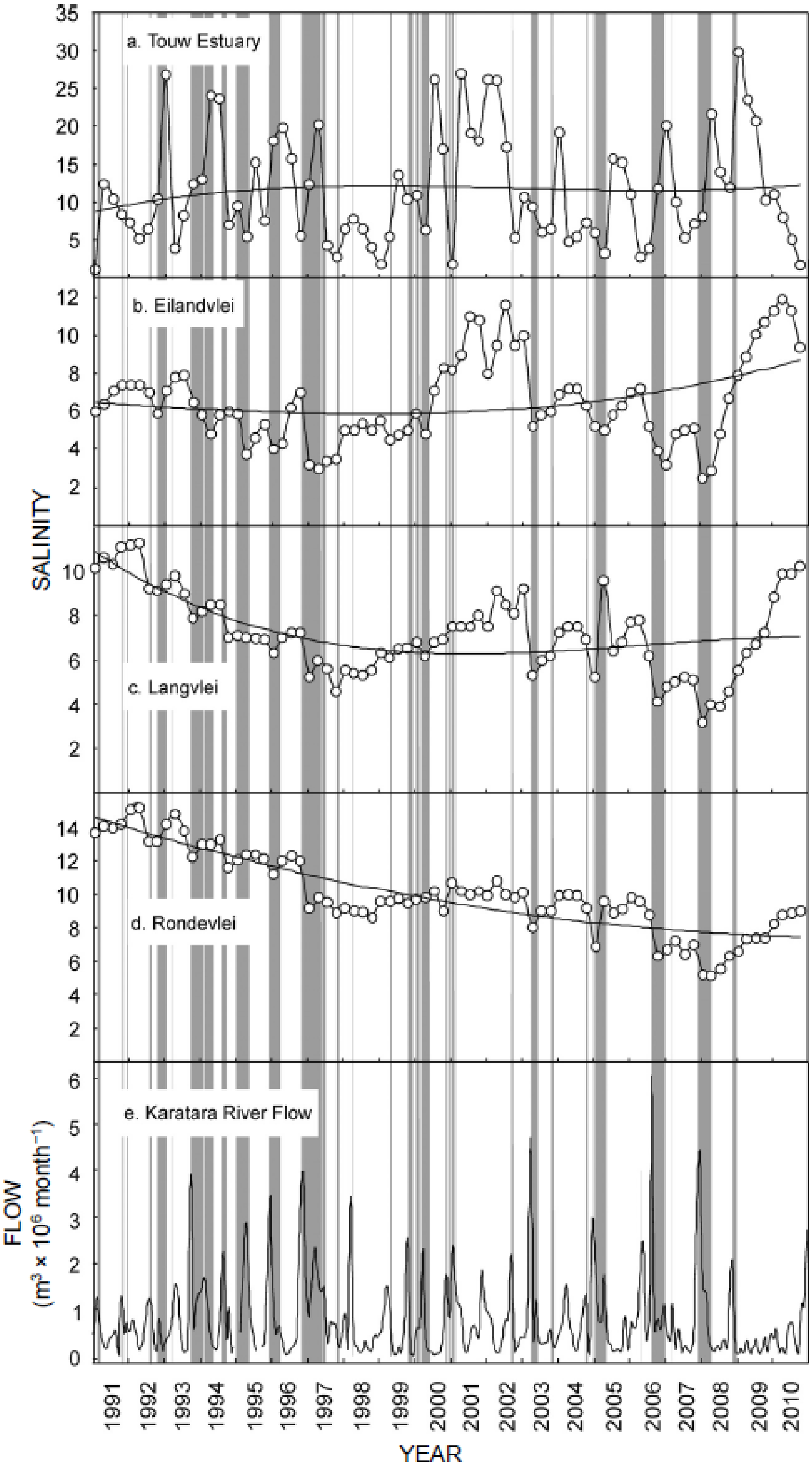

Figure C.2e Median annual and median monthly Electrical Conductivity measured in the Duiwe River (1998-2013) (K3H011) and the Wilderness Lakes (K3R003, K3R004 AND K3R005) (1978-2013) (red lines in the top graphs represent flow volumes on the secondary axes)
(data obtained from www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp)

Electrical connectivity (EC) for the period 1978 to 2013 show a similar decline in salt content with increased freshwater inflow (**Figure C.2f**), while EC value tend to rise during peiods of low flow as a result of evaporation during the closed state (State 1). While the effect of the long-term wet-dry cycle can be observed between years, very little seasonal patterns can be seen from the data set (**Figure C.2g**).

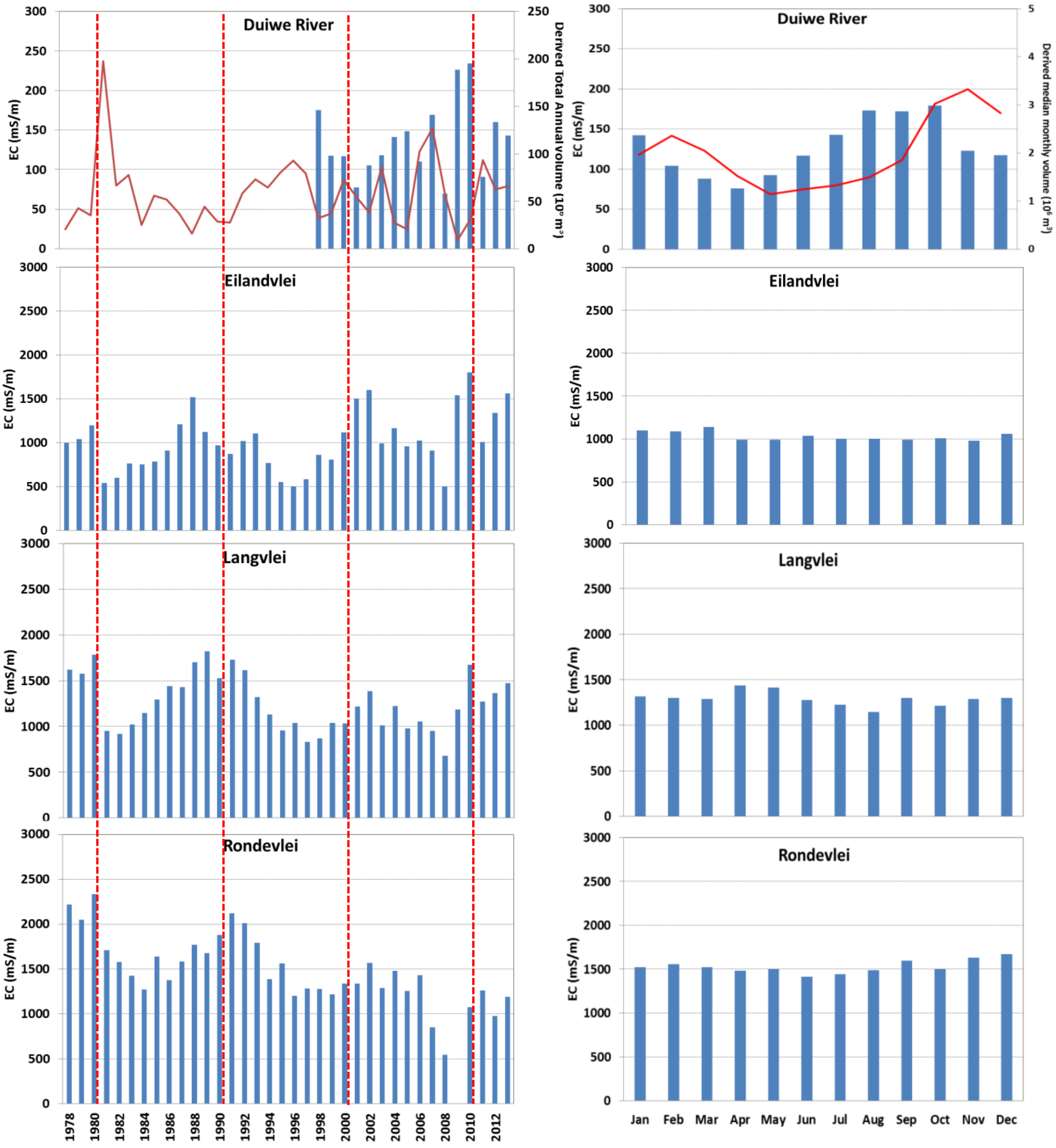

Figure C.2f **Median annual and median monthly Electrical Conductivity measured in the Duiwe River (1998-2013) (K3H011) and the Wilderness Lakes (K3R003, K3R004 AND K3R005) (1978-2013) (red lines in the top graphs represent flow volumes on the secondary axes)**
(data obtained from www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp)

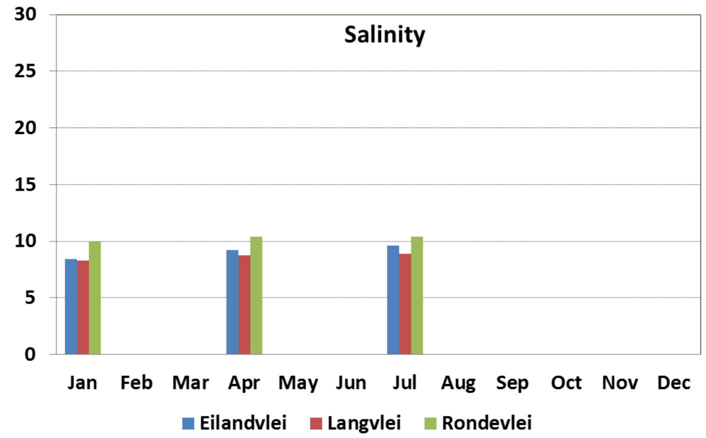

Figure C.2g: **Average salinity measured in the Wilderness Lakes during once-off field surveys (January 2013, April 2013, July 2013) (CSIR, unpublished data)**

C.3 TEMPERATURE

C.3.1 Touw Estuary

Temperature data collected in the Touw Estuary during once-off surveys in 2013 are presented in **Figure C.3a** (CSIR, unpublished data, this study). During January, April and July 2013 the mouth of the estuary was closed, but the system was open during December 2013. Results show strong seasonal signal with highest temperature during summer and lowest during winter. Long-term temperature data sets (1991-2010) collected in the Touw Estuary (Russell, 2013) also revealed strong seasonal variability with highest water temperatures occurring in December and January (summer) and the lowest in July (mid-winter) with average summer temperature generally above 20°C and winter temperature below 20 °C. Russell (2013) recorded exceptionally low temperature in the estuary at times (8.2 °C) which was attributed to upwelling during open, tidal states.

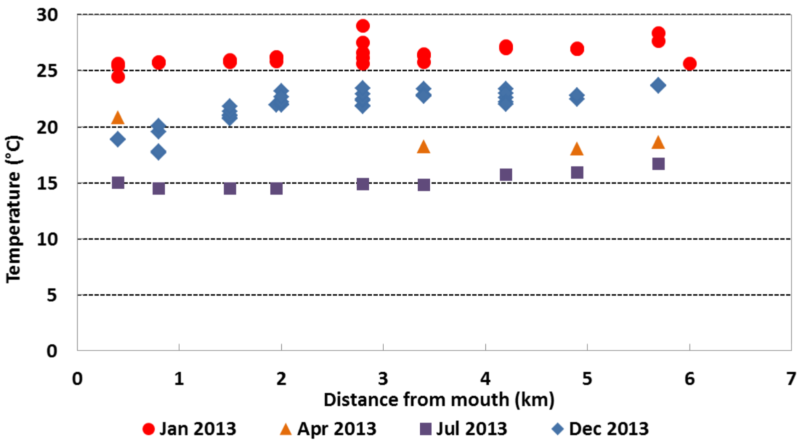

Figure C.3a **Temperatures measured along the length of the Touw Estuary during field surveys conducted by in January 2013, April 2013, July 2013 (CSIR, unpublished data) and December 2013 (this study)**

Water temperature in the system therefore is primarily influenced by atmospheric conditions. However, seawater temperature may affect conditions in the lower estuary during tidal intrusion of new seawater when the mouth is open. For example, during upwelling in summer cold water (well below ambient temperature) can be introduced to the estuary when the mouth is open. The lower temperature recorded near the mouth (up to 2 km from the mouth) during the open phase in December 2013 (summer) was attributed to such influence from upwelling.

4.1.2 Wilderness Lakes

As for the Touw Estuary, long-term temperature data (1991-2010) collected in the three Wilderness Lakes (Russell, 2013) revealed strong seasonal variability with highest temperatures occurring in December and January (summer) and the lowest in July (mid-winter). The temperature range in Eilandvlei, Langvlei and Rondevlei were 11.0–26.2 °C, 11.5–27.4 °C and 12.3–26.5 °C, respectively. The strong seasonal signal was also observed during four surveys conducted during 2013 as illustrated in **Figure C.3b** (CSIR, unpublished data, this study).

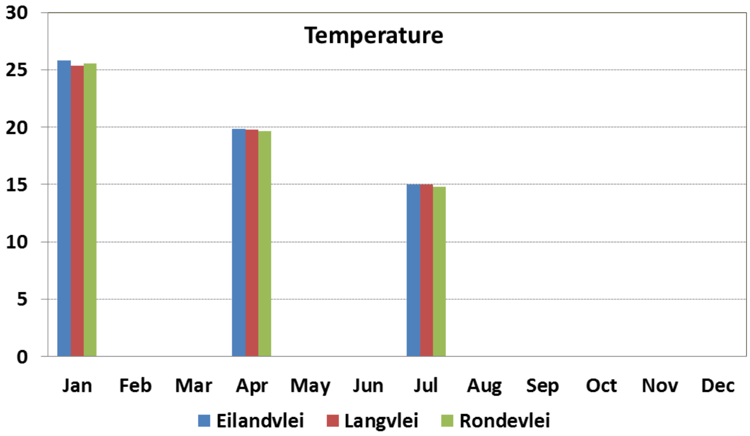

Figure C.3b Average temperature measured in the Wilderness Lakes during once-off field surveys in January 2013, April 2013, July 2013 (CSIR, unpublished data)

C.4 pH

C.4.1 Touw Estuary

Comparing the median annual pH levels measured in the Touw River (feeding into the Touw Estuary) from 1978 to 2013, data show a tendency for pH levels to have increased with time (**Figure C.4a**). In the mid-1990s median annual pH levels averaged 4.8, but since then median annual levels increased slightly averaging 5.7. The Touw River is a black water system where low pH levels are expected. However, black water systems are weakly buffered. Therefore even slight anthropogenic interference can elevate pH levels, possibly the reason for the slight increase since 1995.

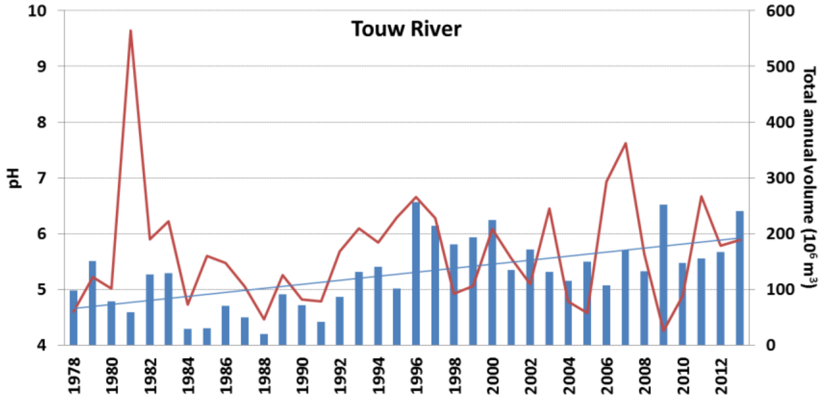

Figure C.4a Median annual pH measured in the Touw River (K3H005) (red line represents flow volumes on the secondary axis) (data obtained from www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp)

pH levels in seawater is naturally around 8 – 8.2. This is reflected in the relatively higher pH levels measured in the Touw Estuary (**Figure C.4b**) compared with the Touw River (**Figure C.4a**). In the estuary pH levels generally ranged between 7 and 8, with a tendency to decrease with decrease in salinity moving upstream. During December 2013 the stronger influence of more acidic, black water from the Touw River was particularly evident in the upper estuary. These trends were also observed by Russell (2013), concluding that in the Touw Estuary pH levels were predominantly influenced by relative inflows from low pH fresh (river) water and high pH seawater.

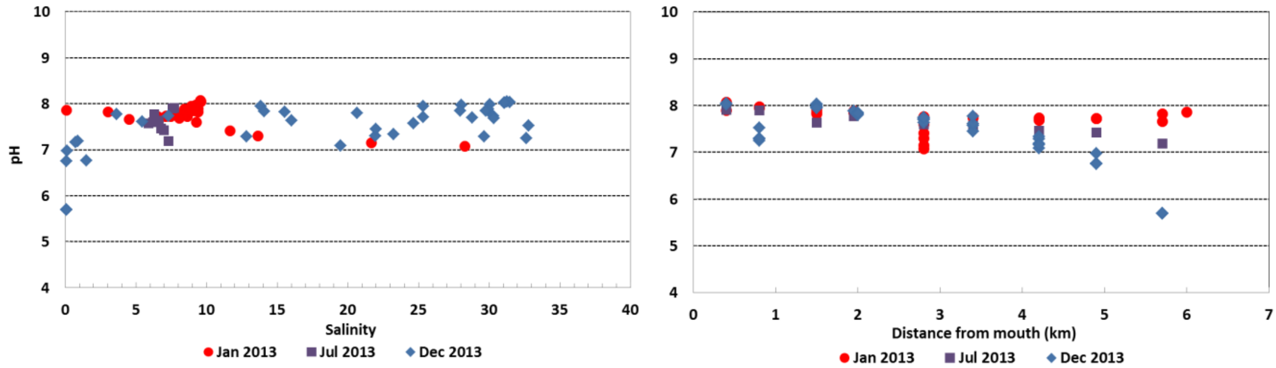

Figure C.4b pH levels measured in the Touw Estuary against salinity (top) and along length of estuary (bottom) during once-off field surveys in January 2013, July 2013) (CSIR, unpublished data) and December 2013 (this study)

C.4.2 Wilderness Lakes

pH levels in the Duiwe River (feeding into Eilandvlei) have only been recorded since 1998. Over this period pH levels remained fairly constant with median annual levels ranging between 7.1 and 7.7 (**Figure C.4c**).

pH records in the Wilderness Lakes (collected by DWA) go back to 1978. Over the 35 year period there was a tendency for pH levels to increase slightly with levels from before 1995 usually < 8 and after 1995 ~8, possibly attributed to anthropogenic influences in the catchment. This was somewhat contradictory to the finding of Russell (2013) that found pH levels in Eilandvlei and Langvlei to decline over the period 1991 to 2010. Studies conducted by Russell (2013) from 1991 to 2010, found marked seasonal variation in pH in the lakes with levels in summer (January/February) being higher compared with winter (March). This trend was associated with the higher submerged macrophyte biomass occurring in the lakes during summer. Median monthly values derived from the DWA long-term data set (1978 to 2013) did not reflect as marked a seasonal pattern, although there was a tendency for levels to be generally higher in the spring/summer months, compared with autumn/winter (**Figure C.4c**).

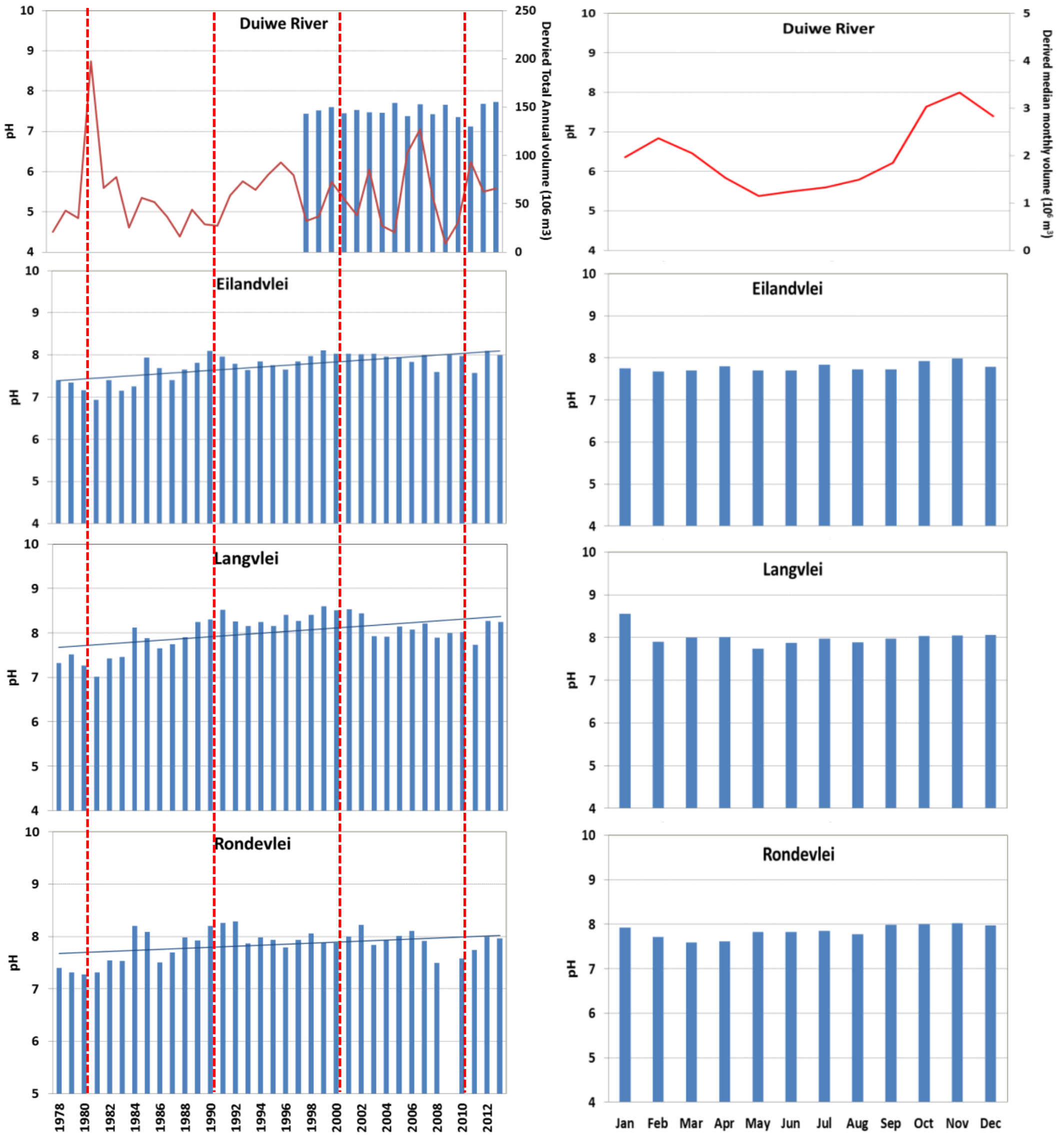

Figure C.4c **Median annual pH measured in the Duiwe River (K3H011) and the Wilderness Lakes (K3R003, K3R004 AND K3R005) (red lines in the top graphs represent flow volumes on the secondary axes)**
(data obtained from www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp)

C.5 DISSOLVED OXYGEN

C.5.1 Touw Estuary

Dissolved oxygen (DO) profiles were collected from the Touw Estuary in January 2013 and December 2013 (**Figure C.5a**).

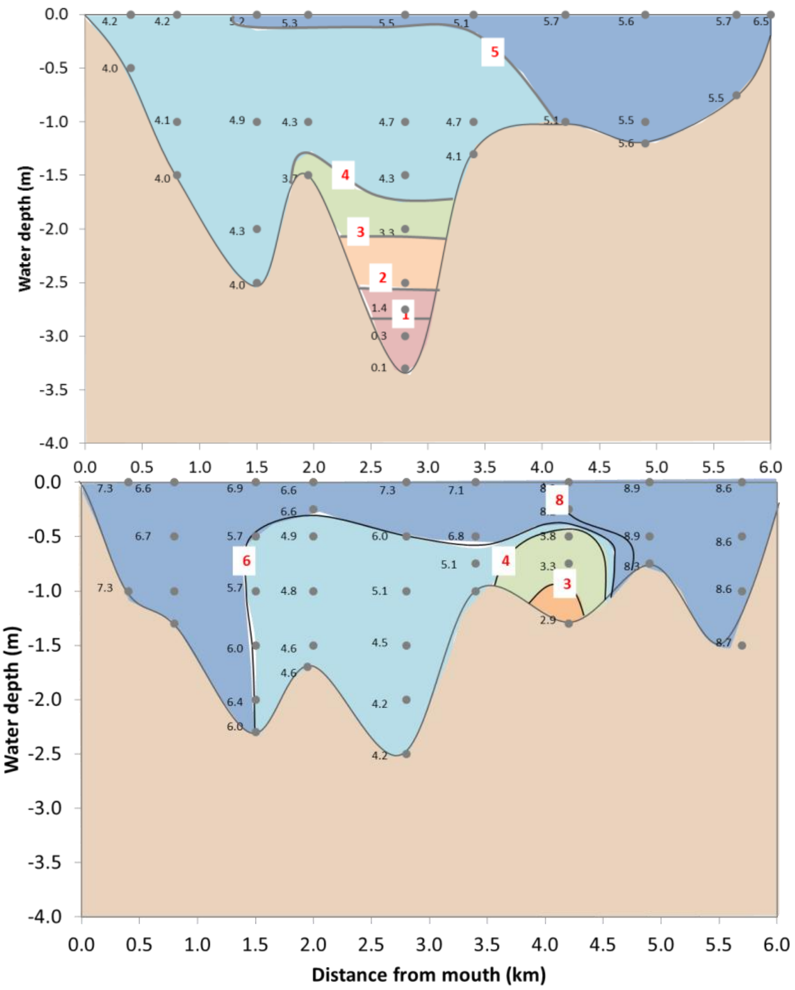

Figure C.5a Dissolved oxygen concentration (mg/ℓ) profiles measured in the Touw Estuary on 30 January 2013 (mouth closed) and 8 December 2013 (mouth open) (CSIR, unpublished data; this study)

During January 2013, the estuary was closed with a plug of older saline water trapped in a deeper area 2-3 km from the mouth (**Figure C.5b**). As with salinity, vertical stratification was evident in DO concentrations in this deeper section, where a small pool of low oxygen water remained trapped (corresponding to the pool of higher salinity). This suggests that the more sheltered middle reaches of the estuary is protected from strong wind mixing allowing re-oxygenation during periods of extended closure, albeit a small fraction of the estuary's total volume. Vertical stratification is expected to occur naturally in this estuary and low sub-surface DO concentrations in sheltered deeper area may therefore be expected and not necessarily caused by anthropogenic enrichment. During December 2013 (open mouth) stronger river inflow and tidal exchange flushed the estuary, as reflected in the salinity (**Figure C.5b**). Strong vertical stratification remained in a small section of the system (4 and 4.5 km from the mouth) trapping a small pool of lower oxygen water.

C.5.2 Wilderness Lakes

Average DO concentrations measured in the Wilderness Lakes during once-off surveys in 2013 are presented in **Figure C.5b** (CSIR, unpublished data). The lakes were generally well-oxygenated showing no horizontal or vertical stratification. The marked increase in DO concentrations moving from summer (January) to autumn (April) into winter (July) is correlated with a corresponding decreased in water temperature (**Figure C.3b**), reflecting DO saturation dynamics (DO is more soluble in colder water compared with warmer waters). Russell (2013) on average also recorded well-oxygenated conditions in the lakes during the period studies conducted from 1991 to 2013, showing similar seasonal trends related to oxygen saturation dynamics.

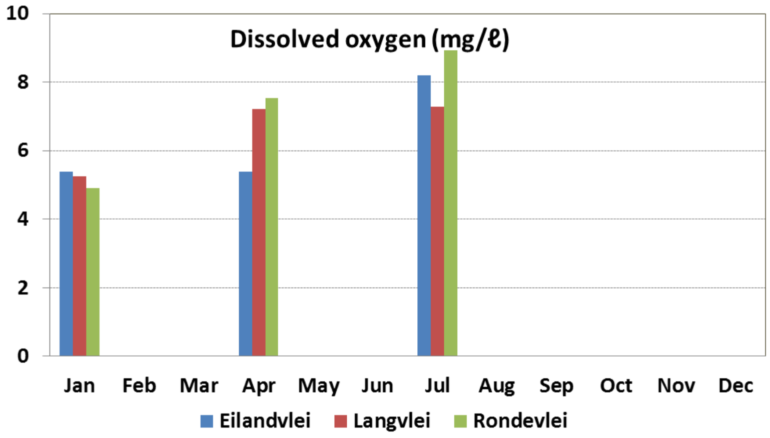

Figure C.5b Average dissolved oxygen concentrations measured in the Wilderness Lakes during once-off surveys in January 2013, April 2013, July 2013) (CSIR, unpublished data)

During January 2013, high DO concentrations were measured in rooted macrophyte beds along the northern shores of Langvlei (9.2 mg/ℓ, saturation 119%). Similar higher oxygen levels were recorded previously in a shallow station in Langvlei (Russell, 2013) also associated with dense beds of submerged macrophyte beds.

Also during January 2013, lower DO concentrations (< 1mg/ℓ) were recorded in the shallow channel linking Rondevlei and Langvlei, as well as in the Serpentine (< 4 mg/ℓ) linking Eilandvlei with the estuary. These lower DO concentrations were associated with high organic loading (visual observations) and the sheltered nature of these channels. Other periodic low DO conditions also have been observed in the Wilderness Lakes but are considered a natural phenomenon (Russell, 1994). The extent to which the occurrence of these phenomena may have been altered anthropogenic input is, however, not known. A wide-spread low oxygen event recorded in Rondevlei on occasion was associated with the senescence of an algal (dinoflagellate) bloom (Russell, 1994).

C.6 TURBIDITY

C.6.1 Touw Estuary

Average turbidity levels recorded in the Touw Estuary during once-off surveys in 2013 were generally low (< 5 NTU) (**Figure C.6a**). Results, however, did show a tendency to increase with increase in salinity (2-5 NTU), especially during the December 2013 survey when the mouth was open. This suggests that seawater intrusion may introduce limited turbidity to the estuary at times although levels remain very low.

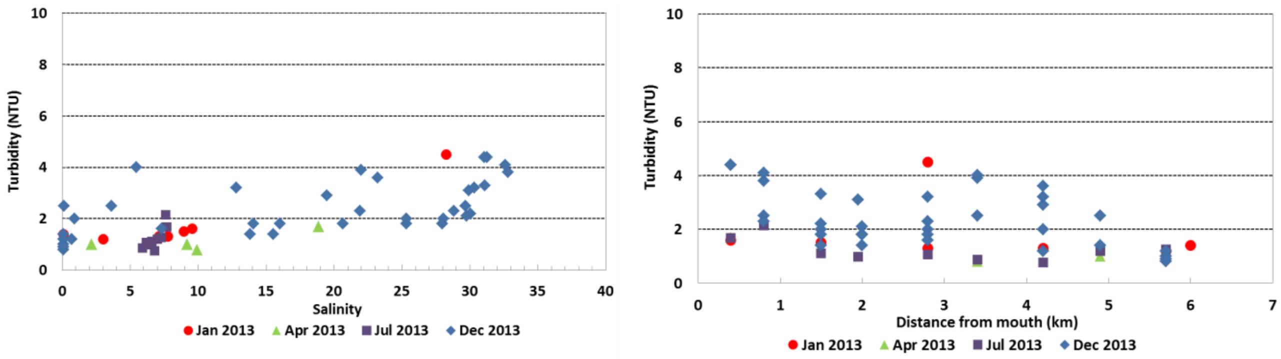

Figure C.6a **Turbidity concentrations versus salinity and along the length of the Touw Estuary during once-off surveys in January 2013, April 2013, July 2013 (CSIR, unpublished data) and December 2013 (this study)**

During the period 1991a and 2010, Russell (2013) also recorded low turbidity levels in the Touw Estuary (typically < 5 NTU). Stations in the estuary opposite the inflow from the Serpentine channel (draining from Eilandvlei) showed increased levels albeit still relatively low (~10 NTU). Taking into account the characteristics of the Touw River catchment, it is not expected for the river to introduced significant turbidity in the estuary, unless perhaps during major floods. Secchi depth in the Touw Estuary was to water depth (this study; CSIR unpublished data).

C.6.2 Wilderness Lakes

Average turbidity levels recorded in the Wilderness Lakes during once-off surveys in 2013 were low (< 10 NTU) (**Figure C.6b**). Similarly results were observed by Russell (2013) with median annual turbidity levels recorded during 1991 to 2010 were also generally low (< 10 NTU). Small differences, however, were observed. For example, median and range of turbidity in Rondevlei and Eilandvlei were on average slightly higher compared with Langvlei. In the case of Eilandvlei, fluvial input from the Duiwe River was proposed as a reason, while periodic algal blooms in Rondevlei were proposed as a possible reason for the slightly higher turbidity. Russell (2013) did observe a general decrease in lake turbidity over this period 1991 to 2010, especially in Eilandvlei and Rondevlei.

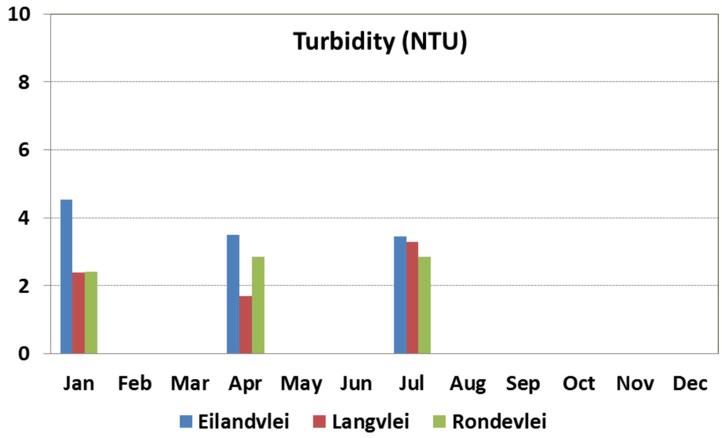

Figure C.6b **Average turbidity concentrations measured in the Wilderness Lakes during once-off field surveys (January 2013, April 2013, July 2013) (CSIR, unpublished data)**

While it is expected for river flooding to markedly increase turbidity in the lakes (especially Eilandvlei), the influence of two substantial rain events in August 2006 and November 2007 had a small effect on turbidity levels (< 10 NTU) and elevated levels were also short lived (Russell, 2013). Based on once-off surveys conducted by the CSIR in 2013 (CSIR unpublished data), Secchi depths in the lakes varied with Eilandvlei being least clear (generally $\leq$ 2 m) compared with Langvlei and Rondevlei (Secchi depth 3-4 m).

C.7 DISSOLVED INORGANIC NUTRIENTS

C.7.1 Touw Estuary

The distribution patterns of dissolved inorganic nutrient concentrations (i.e. ammonium-N [NH_4-N], nitrite plus nitrate [NO_x-N], phosphate [DIP] and reactive silicate [DRS]) in the Touw River over the period 1978 to 2013 are presented in **Figure C.7a** (DWA's long-term data sets).

Results show that NH_4-N and NO_x-N (constituting Dissolve inorganic nitrogen [DIN] fraction) in the Touw River inflow to the estuary is low, as is expected from a black water system. Median annual concentrations remained low (below 100 µg/ℓ, mostly below 50 µg/ℓ). Results suggest a slight increase in NH_4-N during the 1990s, but this returned to near pristine levels in the 2000s. De Villiers and Thiart (2007) estimated natural concentrations of DIN in these systems to be about 50 µg/ℓ, which suggest the nutrient levels on inflow from the Touw River is still near pristine which reflects the low anthropogenic disturbance in this catchment. DIP concentrations in the Touw River was also low (typically less than 20 µg/ℓ), especially over the past 6 years. The median monthly distribution (1978-2013) suggests some correlation with river inflow volumes, with median DIP concentration being slightly higher during periods of higher river inflow. De Villiers and Thiart (2007) estimated natural concentrations of DIP in these systems to be about 10 µg/ℓ, which suggest some anthropogenic enrichment of the system during higher river flows under the Present State compared with reference, although not severe. DRS concentrations were high, but expected for fluvial systems linked to catchment geological characteristics (Eagle and Bartlett, 1984). Monthly median concentrations suggest an inverse relationship with river volumes with highest DRS measured during periods of low flow volumes (mid-year).

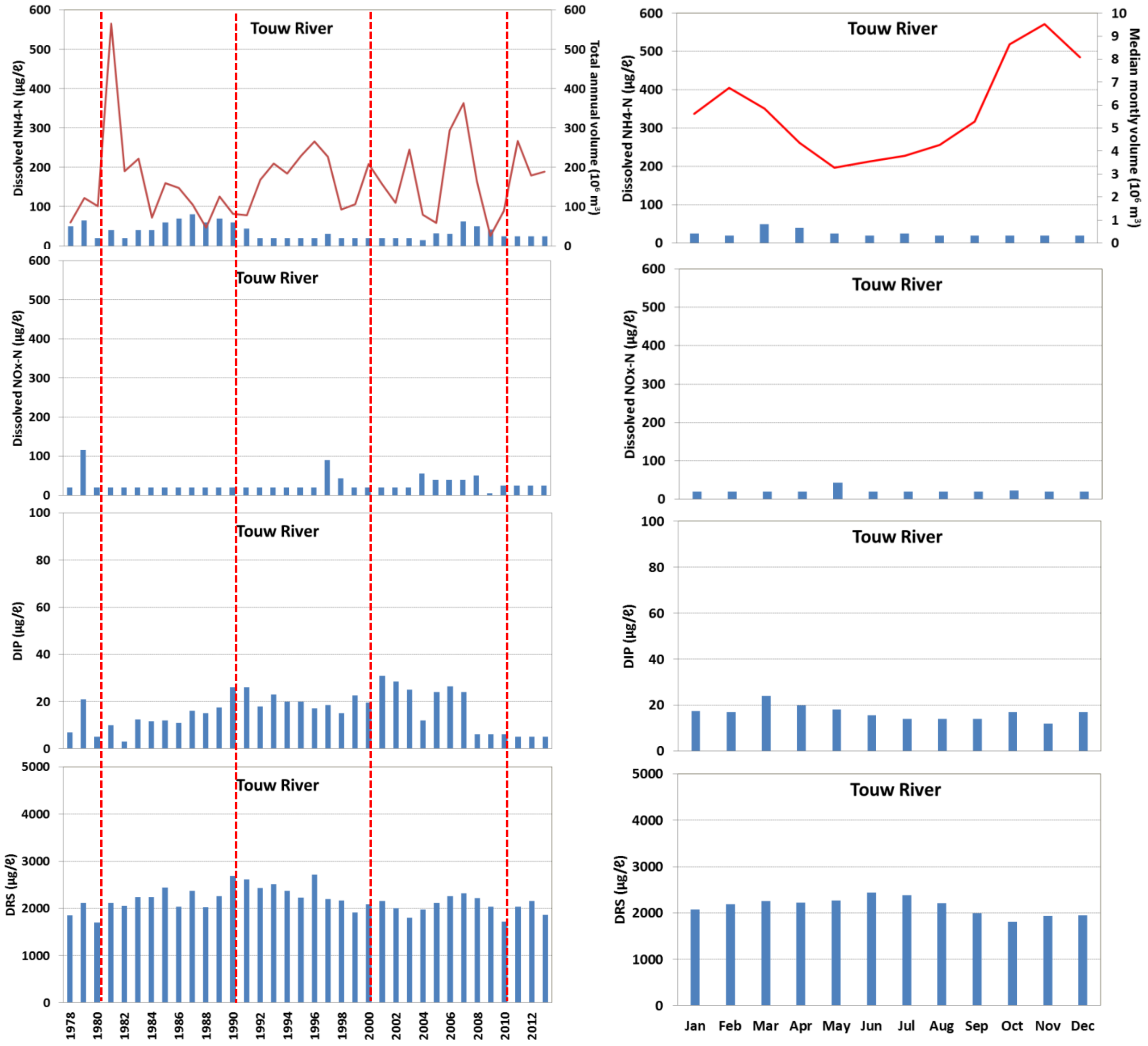

Figure C.7a **Median annual and median monthly (1978-2013) dissolved inorganic nutrient concentrations measured in the Touw River (K3H005) (red lines in the top graphs represent flow volumes on the secondary axes) (data obtained from www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp)**

Dissolved inorganic nutrient concentrations in the estuary measured on once-off surveys during 2013 is presented in **Figure C.7b**[1]. DIN concentrations were generally below 50 µg/ℓ and DIP below

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[1] The DWA sampling station in the Touw Estuary (K3T6) is situated relatively close to the mouth of the estuary (Figure 1.1). As a result salinity (or EC) at this station is often high. Of note is that the methods for inorganic nutrient analyses differ between fresh and more saline waters. It is not clear whether the saline samples from the estuary were analysed using the standard freshwater methods or whether these were done using adapted methods for saline waters. As aa result that data set was not used here (e.g., given the oligotrophic nature of river inflow to the estuary from the Touw, elevated NH_4-N concentrations is not expected in the main channel of the estuary)

10 µg/ℓ. DRS concnetrations showed increase with decrease in salinity, but this is expected as DRS introduced from fluvial systems are significantly higher compared to conetntations in seawater. These results show that the Touw Estuary remains generally oligotrophic with no serious threats of nutrient enrichment.

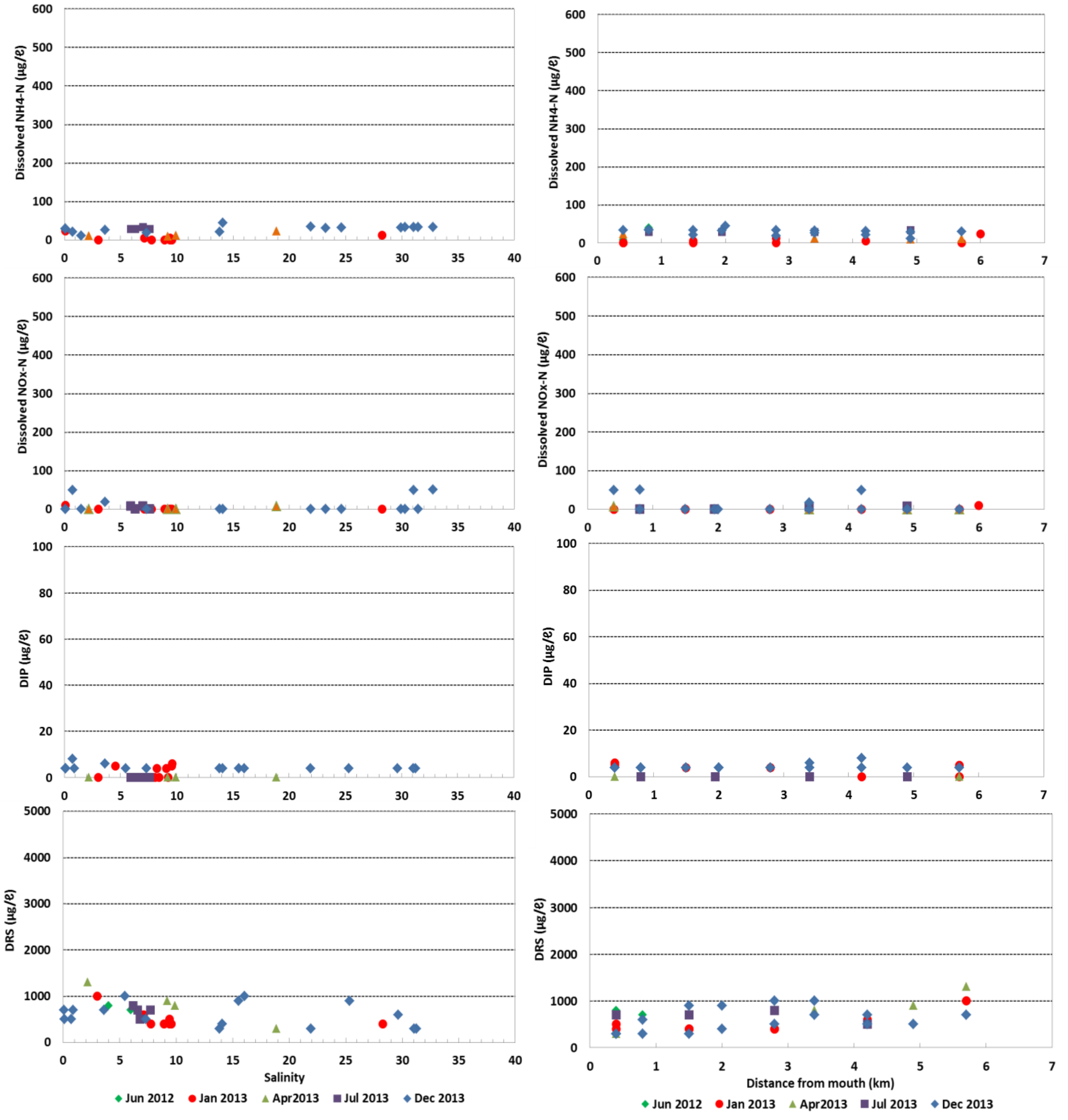

Figure C.7b **Dissolved inorganic nutrient concentrations versus salinity and along the length of the Touw Estuary measured during once-off surveys conducted in January 2013, April 2013, July 2013 (CSIR, unpublished data) and this study (December 2013)**

This is expected in view of the low inorganic nutrient concentrations entering from the Touw catchment, a main nutrient source to the estuary, as well as fairly low density development along the estuary's banks. Note that during upwelling at sea, elevated inorganic nutrient concentrations may be introduced to the lower estuary when the mouth is open, but this would also have been the case during reference. In fact, extended period of closure may have reduced this type of nutrient input from the sea. Estimated DIN concentrations along this part of the coast are expected to be relative low - 50-100 µg/ℓ - except during upwelling when concentration when concentrations can be around 300 µg/ℓ (e.g. DWAF, 1995). Estimated DIP concentration in seawater along this part of the coast is expected to be relative low, approximately 10-20 µg/ℓ (e.g. DWAF, 1995).

C.7.2 Wilderness Lakes

The distribution patterns of dissolved inorganic nutrient concentrations (i.e. ammonium-N [NH_4-N], nitrite plus nitrate [NO_x-N], phosphate [DIP] and reactive silicate [DRS]) in the Duiwe River (feeding into Eilandvlei) over the period 1998 to 2013 are presented in **Figure C.7c** (median annual concentrations and **Figure C.7d** (median monthly concentrations) (DWA's long-term data sets).

Considering extensive agricultural activities taking place in the catchment, NH_4-N and NO_x-N concentrations (constituting dissolve inorganic nitrogen [DIN] fraction) at this station in the Duiwe River (just above Eilandvlei) is unexpectedly low although somewhat elevated above reference (De Villiers and Thiart [2007] estimated natural concentrations of DIN in these systems to be about 50 µg/ℓ). This is probably indicative of the river system being able to still assimmilate excessive nutrient input from the cathcment prior to reaching the lakes. Of note is that NO_x-N concentrations are generally higher compared with NH_4-N (**Figure C.7c**), and that highest concentrations typically occurred during periods of low river flow volumes (**Figure C.7d**).

The sudden increase in 2013, however, could not be explained. DIP concentrations were elevated above reference (De Villiers and Thiart [2007] estimated natural concentrations of DIP in these systems to be about 10 µg/ℓ) although less than expected given the extent of agricultural development in the catchment. Again, this probably relates to the system's ability to significantly assimilate excessive nutrients prior to reaching the lakes. Seasonal distribution patterns suggested DIP concentrations to be slightly out of phase with river volumes; highest concentrations slightly lagged periods of highest river volumes. As with DIN there was a marked decrease in DIP concentrations from the late 1990s into 2000s which may be attributed to improved agricultural practices (e.g. the application of fertilisers), but the sudden increase in 2013, however, also could not be explained. DRS concentrations ranges were considered typical of fluvial systems and showed a similar seasonal relationship with river volume as DIP concentrations.

The distribution patterns of dissolved inorganic nutrient concentrations (i.e. ammonium-N [NH_4-N], nitrite plus nitrate [NO_x-N], phosphate [DIP] and reactive silicate [DRS]) in the Wilderness Lakes over the period 1978 to 2013 are presented in **Figure C.7c** (median annual concentrations and **Figure C.7d** (median monthly concentrations) (DWA's long-term data sets).

Further, there was a marked decrease in NO_x-N concentrations from the late 1990s into 2000s which may be attributed to improved agricultural practices (e.g. the application of fertilisers).

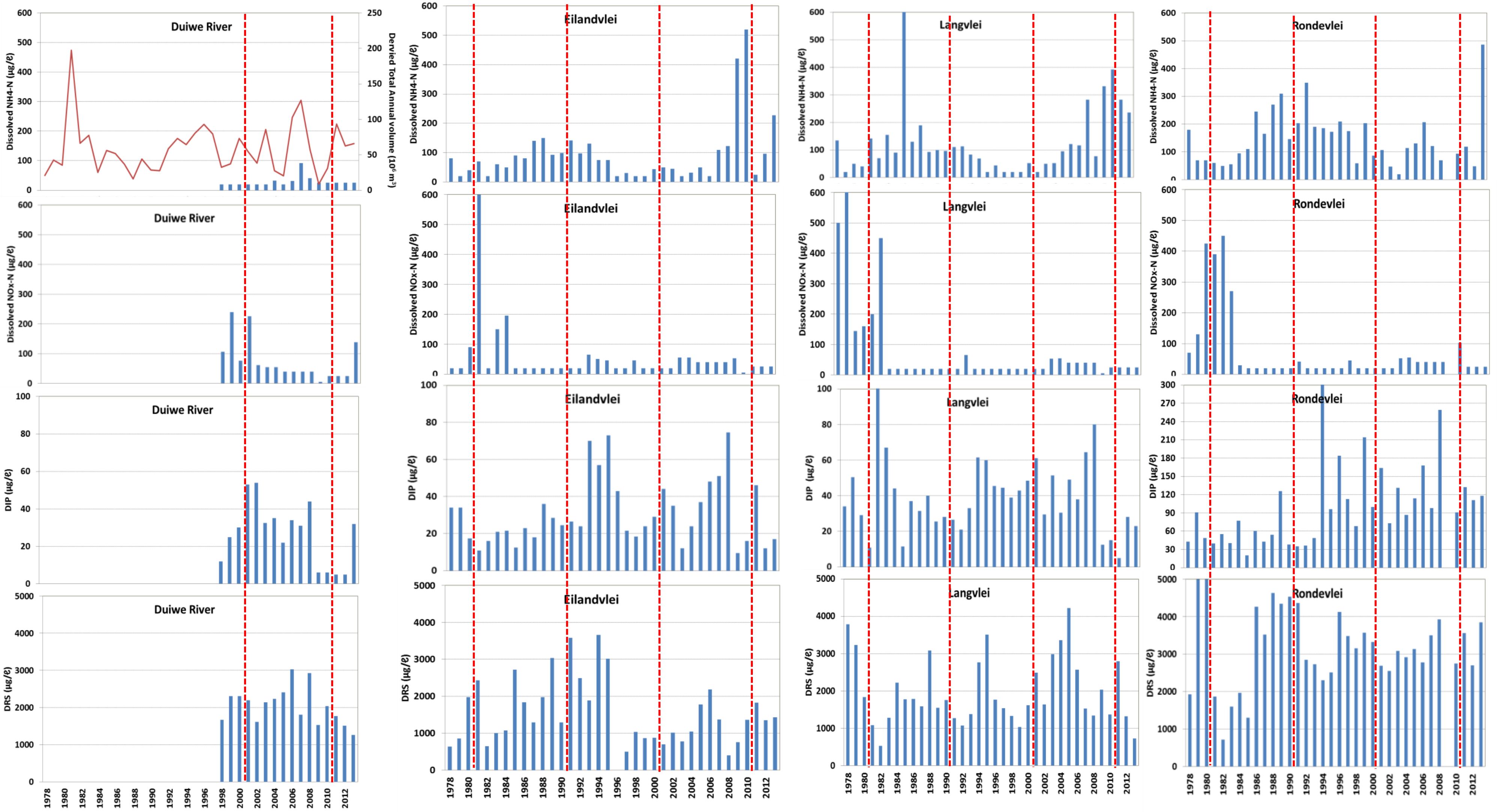

Figure C.7c Median annual dissolved inorganic nutrient concentration measured in the Duiwe River (K3H011) (1998-2013) and the Wilderness Lakes (K3R003, K3R004, K3R005) (red line in the top graphs represent flow volumes on the secondary axis) (data obtained from www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp)

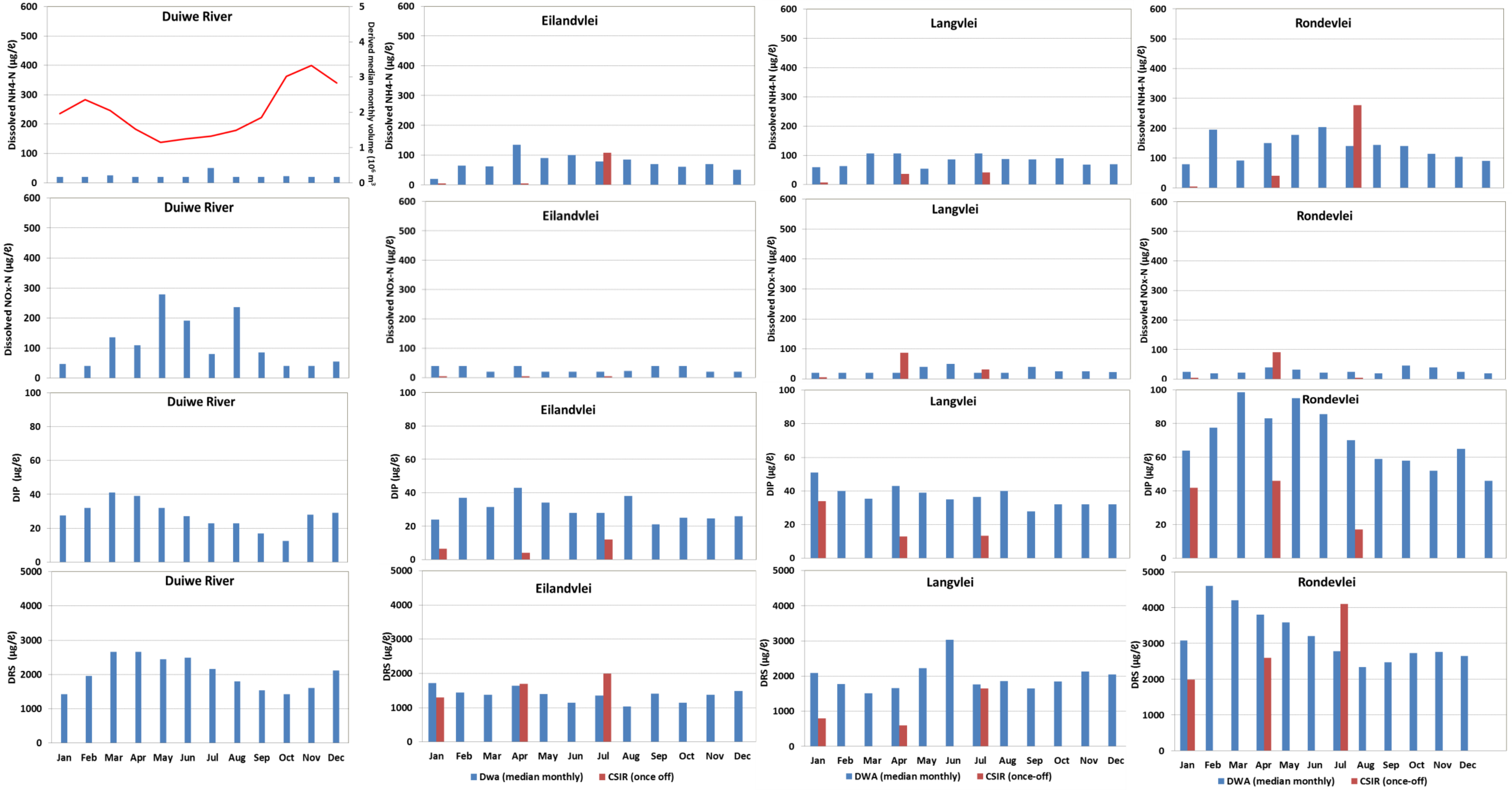

Figure C.7d Median monthly dissolved inorganic nutrient concentrations measured in the Duiwe River (K3H011) (1998-2013) and Wilderness Lakes (K3R003, K3R004 AND K3R005) (1977-2013) (red line in the top graph represent flow volumes on the secondary axis) (data obtained from www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp)

Comparing DIN concentrations in the lakes with that of the Duiwe River, of significance is that the main component of DIN in the lakes comprises NH_4-N, with concentrations in Rondevlei being highest. Further, median monthly distribution of NH_4-N concentrations in Rondevlei suggested highest concentrations to occur during winter months (low rainfall period) (signal not as pronounced in other two lakes). This is different from the dominant DIN species in the Duiwe River – draining into Eilandvlei – where NO_x-N (mostly nitrate) is generally highest. The elevated NH_4-N levels in the lake could therefore not be linked directly to river inflow. The elevated NH_4-N concentrations could also not be linked to any major anthropogenic inputs along the banks (e.g. sewage) considering the relatively large volume of the lake and the fairly low level of development along most banks. The DWA sampling stations is situated along the shallower peripheries of the lakes (**Figure C.1**), where rooted macrophyte beds (e.g. reeds, *Potemageton*, *Ruppia*) are common phenomena contributing to organic matter stock. Organic loading from agricultural activities in the catchment – entering the lakes through the Duiwe River and Langvleispruit during high flow events – may contribute to increased organic loading under the Present State. Considering poor flushing in these lakes organic build up stimulate in situ remineralisation (i.e. when NH_4-N and DIP) are released to the water column during organic matter decay) may become an in situ source of inorganic nutrients (e.g. Taljaard *et al.*, 2009). While Taljaard *et al.* (2009) argued that most South African estuaries lack sufficient organic matter stocks to support large-scale in situ remineralisation, these larger lake systems that are not flushed properly probably do build up organic matter stock. In situ remineralisation, therefore, could be the main source of the elevated DIN (NH_4-N) concentrations observed in the shallower periphery of the Wilderness Lakes (DWA sampling stations). An inter-annual distribution pattern in present in the median annual distribution of NH_4-N concentrations in the peripheries, but the cause of this needs further investigation. Of note, is that in the January 2013 survey (CSIR, unpublished data) sampling in the lakes focussed on the middle, deeper sections (**Figure C.7d**). During this survey DIN (both NO_x-N and NH_4-N) were depleted in all the deeper areas of the lakes. Studies conducted by Howard-Williams and Allanson's (1981) on the dynamics of DIP in the adjacent Swartvlei found that the exchange of DIP between shallower peripheries (littoral zone of the lake supporting extensive *Potamogeton* sp. beds) and the deeper, central open waters of the system was low, which they attributed to rapid nutrient recycling within the littoral zone. This poses a possible explanation for the N dynamics observed in the Wilderness lake system – the quantity of elevated "reworked" DIN generated within the littoral zone is largely re-used in the littoral zone and do not exchange to the deeper central waters (e.g,. as observed in the January 2013 survey). However, it is possible that a stage could be reached where the littoral zone becomes "saturated" with "re-worked" DIN, and then spilling over into the deeper, middle section of these lakes, possibly triggering algal blooms. The extent to which anthropogenic activities may have altered these processes are not yet clear.

DIP concentrations in the lakes varied with median monthly concentrations in Eilandvlei and Langvlei typically < 40 µg/ℓ (**Figure C.7d**). These concentrations were similar to those measured in the Duiwe River. Median monthly DIP concentrations in Rondevlei were markedly higher compared to the other two lakes (as with DIN) ranging between 40-100 µg/ℓ. Further, median monthly distribution of DIP concentrations in Rondevlei suggested highest concentrations to occur during late summer/autumn) (just lagging the higher rainfall period) (signal not as pronounced in other two lakes). Of note is that the once-off January 2013 survey (when sampling in the lakes focussed on the middle, deeper sections) (**Figure C.7d**) DIP concentrations in these areas were also lower compared with the data from shallower stations (e.g. DWA data), although not depleted as was the case with DIN. In all the lakes DRS concentrations were representative of river-dominated systems with Rondevlei showing highest concentrations. Further, median monthly distribution of DRS concentrations in Rondevlei suggested highest concentrations to occur during late summer) (coinciding with a higher rainfall period) (signal not as pronounced in other two lakes).

C.8 TOXIC SUBSTANCES

Data on toxic substances (specifically metals) was collected from the Touw Estuary and Wilderness Lakes in April 1977 1978 (Watling, 1979). A comparison of this data with quality guidelines recommended for the Western Indian Ocean (UNEP/Nairobi Convention Secretariat and CSIR, 2009) is presented in **Table C.8**.

Table C.8: Average metal concentrations measured in the Touw Estuary and Wilderness Lakes during April 1977, as well as recommended quality guidelines for the protection of marine aquatic life

	Mean in water (µg/ℓ)				**WIO guidelines**
	Touw Estuary	**Eilandvlei**	**Langvlei**	**Rondevlei**	
Cd	1.3	0.3	0.2	0.6	**5.5**
Cu	0.7	0.5	0.4	0.6	**1.3**
Ni	0.3	0.1	0.1	0.2	**70**
Pb	0.7	0.6	1.2	1.0	**4.4**
Zn	1.8	1.0	0.8	1.3	**15**

	Mean in sediment (mg/kg)				**WIO guidelines**
	Touw Estuary	**Eilandvlei**	**Langvlei**	**Rondevlei**	
Cd	0.3	0.3	0.2	0.3	**0.68**
Cu	4.9	4.4	6.3	8.8	**18.7**
Ni	3.2	3.0	7.5	8.6	**15.9**
Pb	3.6	3.2	13.6	16.0	**30.2**
Zn	13.5	12.4	28.9	38.5	**124**

Results suggest that at the time (1977) average metal concentrations in system were well within the recommended guidelines. The authors concluded that levels remain generally low and do not reflect significant levels of pollution, although signs of anthropogenic enrichment were evident in places (e.g. Eilandvlei). However, since the late 1970s development in the area increased and stormwater runoff to the estuary and lakes may have introduced some toxic substances (e.g. hydrocarbons and metals) over time, although not considered to have resulted in heavy toxic pollution. No data is available on pesticides and herbicide levels in the systems which are likely to have occurred considering the intensive agricultural activities (e.g. fruit and vegetables; sheep; and cattle farming), especially in the catchment of the Duiwe River feeding into Eilandvlei. Again, it is not considered to be heavily polluted considering the low volumes of river inflow.

Annexure C1: Water quality data collected in the Touw Estuary on 8 December 2013

Time	Stn	Depth (m)	Distance from mouth (km)	Temp	Sal	pH	Diss. Oxygen (mg/l)	Diss Oxygen (% sat)	Turbidity (NTU)	Secchi (m)	SS (mg/l)	NO2-N (µg/l)	NH4-N (µg/l)	NOx-N (µg/l)	PO4-P (µg/l)	Total P (µg/l)	SiO4-Si (µg/l)
10:00:00	TE1	1.0	0.4	18.8	31.3	8.0	7.3	94.2	4.4								
10:00:00	TE1	0.0	0.4	18.9	31.1	8.0	7.3	94.1	4.4	>1	9	2	33	50	4	180	300
10:50:00	TE2	1.3	0.8	17.7	32.8	7.5	8.0	102.0	3.8			2	34	51	4		300
10:50:00	TE2	1.0	0.8	17.8	32.6	7.3	8.2	104.1	4.1								
10:50:00	TE2	0.5	0.8	19.6	29.7	7.3	6.7	87.9	2.5								
10:50:00	TE2	0.0	0.8	20.1	21.9	7.3	6.6	83.1	2.3	>1.23		1	35	<5	4		600
11:08:00	TE3	2.3	1.5	20.7	31.5	8.0	6.0	80.0				1	33	<5	4		300
11:08:00	TE3	2.0	1.5	20.8	31.1	8.0	6.4	85.9	3.3								
11:08:00	TE3	1.5	1.5	21.1	30.1	8.0	6.0	80.3	2.2								
11:08:00	TE3	1.0	1.5	21.0	28.1	8.0	5.7	75.7	2.0								
11:08:00	TE3	0.5	1.5	21.4	25.3	7.9	5.7	73.9	1.8								
11:08:00	TE3	0.0	1.5	21.9	13.8	7.9	6.9	85.4	1.4			1	21	<5	4		900
11:20:00	TE4	1.7	2.0	22.0	29.9	7.9	4.6	62.6	3.1			1	32	<5	4		300
11:20:00	TE4	1.5	2.0	22.0	29.8	7.8	4.6	62.8	2.1								
11:20:00	TE4	1.0	2.0	22.0	28.0	7.8	4.8	64.8	1.8								
11:20:00	TE4	0.5	2.0	22.2	20.7	7.8	4.9	63.3	1.8								
11:20:00	TE4	0.3	2.0	23.2	15.5	7.8	6.6	84.9	1.4								
11:20:00	TE4	0.0	2.0	22.7	14.1	7.8	6.6	82.5	1.8	>1.7		1	44	<5	4		900
12:16:00	TE5	2.5	2.8	21.9	30.3	7.7	4.2	56.6				1	34	<5	4		400
12:16:00	TE5	2.0	2.8	21.8	30.3	7.7	4.2	57.5	3.2								
12:16:00	TE5	1.5	2.8	22.3	28.8	7.7	4.5	62.2	2.3								
12:16:00	TE5	1.0	2.8	22.5	25.3	7.7	5.1	68.6	2.0								
12:16:00	TE5	0.5	2.8	23.0	16.0	7.6	6.0	76.3	1.8								
12:16:00	TE5	0.0	2.8	23.5	7.3	7.7	7.3	91.3	1.6	2.3		1	19	<5	4		1000
12:46:00	TE6	1.0	3.4	23.4	24.6	7.6	7.4	65.2				1	32	<5	4		500
12:46:00	TE6	0.8	3.4	22.9	22.0	7.5	5.1	66.0	3.9								
12:46:00	TE6	0.5	3.4	22.8	5.5	7.6	6.8	81.1	4.0								
12:46:00	TE6	0.0	3.4	22.8	3.6	7.8	7.1	89.5	2.5		2	1	26	18	4	<50	1000
13:33:00	TE7	1.3	4.2	23.4	23.2	7.3	2.9	38.0	3.6			1	31	<5	6		700
13:33:00	TE7	0.8	4.2	22.6	19.5	7.1	3.3	42.0	2.9								
13:33:00	TE7	0.5	4.2	23.0	12.8	7.3	3.8	50.2	3.2								
13:33:00	TE7	0.3	4.2	22.2	0.9	7.2	8.2	94.2	2.0								
13:33:00	TE7	0.0	4.2	22.0	0.7	7.2	8.3	96.0	1.2			1	21	50	4		700
14:00:00	TE8	0.8	4.9	22.5	1.5	6.8	8.3	97.0				1	11	<5	8		500
14:00:00	TE8	0.5	4.9	22.8	0.1	7.0	8.9	103.0	2.5								
14:00:00	TE8	0.0	4.9	22.8	0.1	6.8	8.9	104.0	1.4			2	28	<5	4		500
14:20:00	TE9	1.5	5.7	23.7	0.1	5.7	8.7	102.5	0.8								
14:20:00	TE9	1.0	5.7	23.7	0.1	5.7	8.6	101.7	1.2								
14:20:00	TE9	0.5	5.7	23.7	0.1	5.7	8.6	102.0	1.0								
14:20:00	TE9	0.0	5.7	23.7	0.1	5.7	8.6	102.0	0.9		1	2	30	<5	4	<50	700

APPENDIX D: DATA SUMMARY REPORT FOR MICROALGAE

D.1 AVAILABLE DATA

Harrison (unpublished data) sampled three sites in the Touw Estuary on 19 June 1994 (winter) when the mouth was closed. The sites ranged from 0.2 m to 1.6 m deep and the water was clear to the bottom throughout. The pH range was 7.9 – 8.2, temperature 13 – 14ºC, salinity 19 – 23, and dissolved oxygen 8.0 – 10.1 mg/ℓ. This suggests that the estuary was well mixed throughout. Nutrient concentrations were generally low (NH_3-N = 0 – 2 µg/ℓ; PO_4-P = 0 – 10 µg/ℓ; NO_3-N = 0 – 220 µg/ℓ) and phytoplankton chlorophyll *a* was below detectable limits at all sites.

Van Ginkel and Hohls (2001) reported on a study of the Wilderness Lagoon (Touw Estuary) that was sampled monthly for a year at four sites in 1998 (**Figure D.1**). The data were averaged for each site, aggregating results for the entire year (open and closed mouth conditions). During the study the phytoplankton chlorophyll a was < 10 mg.l-1 for 80% of the year and 10 – 20 mg/ℓ the remaining 20%; never exceeding 20 mg/ℓ.

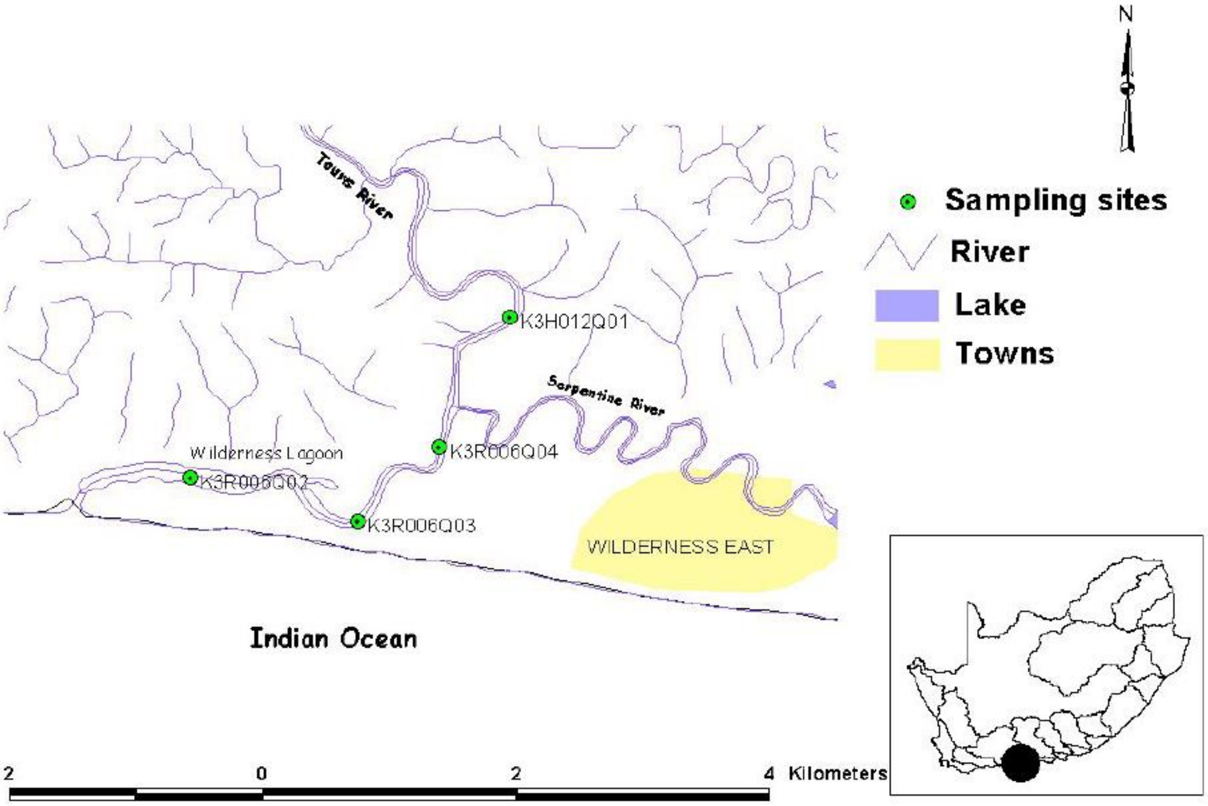

Figure D.1 Study site map of the 1998 sampling sites in the Wilderness Lagoon (Touw Estuary) (van Ginkel and Hohls 2001)

The phytoplankton was dominated by Pyrrhophyta (dinoflagellates; *Peridinium* sp.) during spring and summer. During winter the Chrysophytes were dominant (typically this group would be included with the flagellates but in this case the dominant species was the filamentous yellow-green *Tribonema* sp.). Other groups that were present included the Chlorophytes (*Ankistrodesmus* sp.), Cryptophyta (*Cryptomonas* sp.) and Euglenophyta (*Euglena* sp.) (**Figure D.2**).

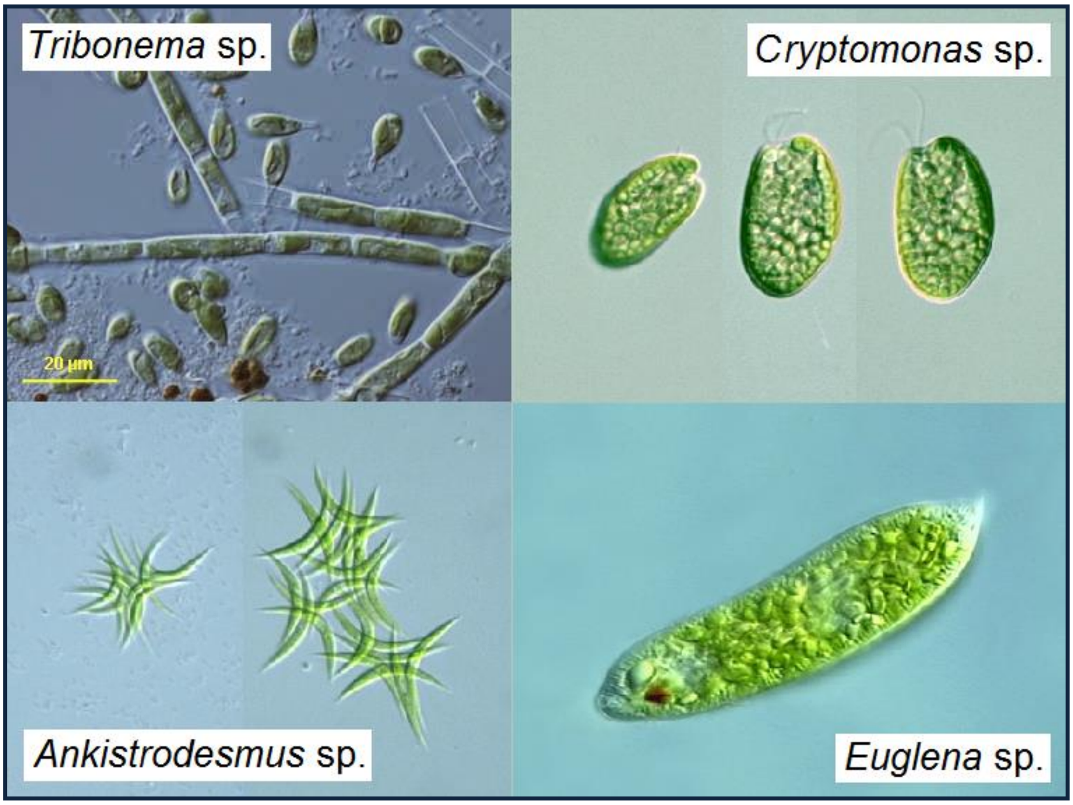

Figure D.2 Images of typical phytoplankton species recorded during the van Ginkel and Hohls (2001) study of the Touw Estuary

Some cyanobacteria (blue-greens; *Anabaena* sp.) were recorded during the study but their numbers were low and considered to be negligible.

Van Ginkel and Hohls (2001) concluded that the estuary had the potential to develop occasional eutrophic conditions and that the low chlorophyll *a* in the water column may have been the result of salinity and the low nutrient conditions in the system.

D.2 SUMMARY OF RESULTS FROM THIS STUDY

Four sites were sampled in the Touw Estuary on 8 December 2013 (**Figure D.3**) measuring microalgal variables. These data included phytoplankton and microphytobenthos (MPB) biomass (using chlorophyll *a* as an index), phytoplankton group composition, and dominant (> 10% of relative abundance) benthic diatoms.

Figure D.3: **Study site map of the Touw Estuary indicating the locations of sampling stations (8 December 2013) (Distance from mouth: 1 = 0.5 km; 2 = 1.9 km; 3 = 3.4 km; 4 = 5.1 km)**

Phytoplankton chlorophyll *a* ranged from 1.98 ± 0.30 μg/ℓ to 7.59 ± 3.52 μg/ℓ, subtidal chlorophyll *a* from 10.81 ± 6.05 mg/m^2 to 225.44 ± 20.66 mg/m^2, and intertidal chlorophyll *a* from 4.90 ± 1.55 mg/m^2 to 144.25 ± 2.92 mg/m^2 in **Table D.1**. Benthic chlorophyll *a* exceeding 100 mg.m^{-2} is extremely high and indicative of a eutrophic environment (WWTW, septic tanks, etc.?).

Table D.1 **Phytoplankton and microphytobenthos biomass, using chlorophyll *a* as an index, in the Touw Estuary (8 December 2013)**

Site (km from mouth)	Phytoplankton chlorophyll *a* (μg/ℓ)	Intertidal chlorophyll *a* (mg/m^2)	Subtidal chlorophyll *a* (mg/m^2)
1 (0.5 km)	1.98 ± 0.30	4.90 ± 1.55	10.81 ± 6.05
2 (1.9 km)	4.97 ± 0.81	121.40 ± 11.64	196.45 ± 38.44
3 (3.4 km)	7.59 ± 3.52	144.25 ± 2.92	225.44 ± 20.66
4 (5.1 km)	0.68 ± 0.15	8.27 ± 0.12	-

Phytoplankton group composition was dominated (up to 90%) by flagellates throughout the estuary, ranging from a low vertical average of 239 to 470 cells/ml (**Figure D.4**). Diatoms ranged from 3 to 25 cells/ml and dinoflagellates from 4 to 28 cells/ml. There were no other phytoplankton groups present in the estuary.

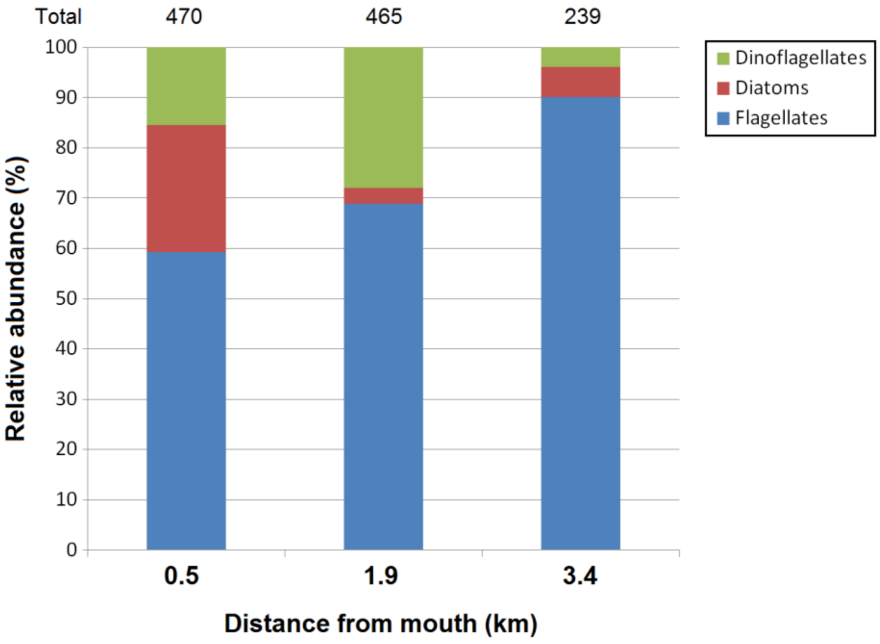

Figure D.4 **Relative abundance (%) of phytoplankton groups at five sites in the Touw Estuary on 8 December 2013 (total cell density data are included as cells/ml)**

There were few benthic diatoms in the sandy sediment near to the mouth of the estuary (0.5 km), which was dominated by *Amphora* sp. in the intertidal (81% relative abundance) and subtidal (58%) sampling sites. Site 2 (1.9 km) was much muddier, typically dominated by epipelic diatoms, and was dominated by *Stauroneis dubitabilis* (59%), *Fallacia pygmaea* (13%) and by *Cocconeis placentula* in the intertidal zone. (25%). Both *F. pygmaea* and *C. placentula* are tolerant of eutrophic conditions. The sediment at site 3 (3.4 km) was course with rocks and pebbles, and had high benthic microalgal biomass. The intertidal zone was dominated by *C. engelbrechtii* (19%), *Entomoneis paludosa* var. *paludosa* (17%) and *Opephora horstiana* (15%). The subtidal zone was dominated by *C. placentula* var. *euglypta* (36%) and *F. pygmaea* (15%). Site 4 (5.1 km) was located near to the head of the estuary and the sediment was coarse with rocks and pebbles. The water was extremely shallow and it was only possible to collect intertidal samples that were dominated by *Diploneis elliptica* (29%), *Tabellaria flocculosa* (29%) and *Eunotia rhomboidea* (20%). All three dominant species typically occur in oligotrophic and circumneutral/slightly acidic waters. The Shannon diversity and evenness scores for the Touw Estuary were 1.86 and 0.66 respectively; lower than the nearby Keurbooms (2.08 and 0.81) and Klein Brak (1.95 and 0.73) estuaries. Based on these results the water in the Touw River was oligotrophic but was severely polluted in the middle reaches of the estuary (based on the benthic microalgal results only).

APPENDIX E: DATA SUMMARY REPORT FOR MACROPHYTES

E.1 AVAILABLE DATA

Topic	Reference
Aquatic vegetation	Aquatic macrophyte communities of the Wilderness Lakes (Howard-Williams, 1980)
Submerged macrophytes	Checklist of the aquatic and floodplain vegetation of the Wilderness Lakes (Jacot Guillarmod, 1982)
Changes over time, 1978 vs 1997	Vegetation of the Wilderness lake system and the macrophyte encroachment problem (Weisser and Howard-Williams, 1982)
	Recovery and dynamics of submerged aquatic macrophyte vegetation in the Wilderness Lakes (Weisser *et al.* 1992)
Dynamics of submerged macrophytes	Changes in the distribution of emergent aquatic plants in Wilderness System (Russell, 2003)
	Relationships between the biomass of waterfowl and submerged macrophytes (Russell *et al*. 2009)
Management of reeds	Effects of cutting *Phragmites australis* along an inundation gradient of Wliderness system (Russell and Kraaij, 2008)

E.2 HABITAT AREA, SPECIES COMPOSITION AND DISTRIBUTION

The vegetation of the Wilderness Lakes has been well studied over the years. Reeds and sedges are dominant in the lake system with smaller areas of salt marsh and submerged macrophytes. Estimates of macrophyte habitat areas (**Table E.1**) are taken from Russell (2003). These primary producers are essential for food production; they provide habitat diversity and play an important role in bank stabilisation and recycling of nutrients. Similarly to Swartvlei Lake the centre of biological productivity for the lake lies on the edges to a depth of 2 m. In Swartvlei Lake this littoral zone contributed almost 10 times more organic matter to the lake than the pelagic zone (Howard-Williams and Allanson, 1979). Weisser and Howard-Williams (1982) provide a comprehensive description of vegetation distribution for the Wilderness Lakes in 1978 and Russell (2003) provides maps and a comprehensive description for 1997 and compares changes over time.

There has been an increase in common reed *Phragmites australis* that is believed to be the result of the artificial breaching of the estuary mouth and lower stable water levels. Within the Touw Estuary *Phragmites australis* forms dense continuous bands along the river and *Schoenoplectus scirpoideus* and *Juncus kraussii* occur in certain areas. Submerged macrophytes were represented by *Potamogeton pectinatus* within the more brackish regions and *Ruppia cirrhosa* towards the lower section of the river (Weisser and Howard-Williams, 1982). The Serpentine connects the Touw River and Wilderness Lagoon with Eilandvlei and the rest of the Wilderness Lakes. Lower salinity within this section of the system limits the distribution of more saline species such as *Zostera capensis* and *Ruppia cirrhosa*, at the same time promoting the establishment of species such as *Potamogeton pectinatus* and *Typha latifolia* subsp. *capensis*. Charophyta and filamentous algae are also abundant.

Assessments of standing biomass of the submerged macrophytes were conducted from 1992 to 2005 at Eilandvlei, Rondevlei and Langvlei (Russell *et al.*, 2009). Fluctuations in biomass were thought to be the result of fungal diseases, changes in water nutrients, shading by *Enteromorpha* and dinoflagellate blooms, reductions in water transparency and reduced calcium: magnesium ratios in the water column (Russell *et al.*, 2005).

Howard-Williams (1980) showed that higher organic content occurs in the sediment below the emergent macrophytes as opposed to that below the submerged macrophytes due to the greater accumulation of detritus. This occurs as the emergent species have higher productivity but slower decomposition rates. Productivities of the various macrophytes in the system were in the order of *Typha latifolia* > *Phragmites australis* > *Scirpus littoralis* > *Potamogeton pectinatus* > *Chara globularis* > *Ruppia cirrhosa*.

Table E.1 Estimates of macrophyte habitat area (ha) in the Touw Estuary and entire Wilderness Lakes

Habitat type	Defining features, typical/dominant species	All	Touw
Open surface water area	Serves as a possible habitat for phytoplankton.		21.1
Sand and mud flats	Intertidal zone provides a possible area for microphytobenthos to inhabit.		
Macroalgae	Charophyta, *Cladophora* spp., *Enteromorpha* spp.		
Submerged macrophytes	*Zostera capensis, Ruppia cirrhosa, Potamogeton pectinatus*	4	-
Salt marsh	*Juncus kraussii* (sharp rush) occurs on more saline soils than the reeds and sedges. The succulent salt marsh plant *Sarcocornia* spp. is also present as well as *Cotula coronopifolia*.	42.3	0
Reeds and sedges	Common reed *Phragmites australis* is abundant as well as the sedge *Schoenoplectus scirpoideus*. Other recorded species are *Bolboschoenus maritimus* and *Typha capensis* (bulrush).	227.9	19.7
Floodplain (grassland and fields)	This area has possibly expanded because of lower water levels and drying of some wetland areas as well as the removal of wetland vegetation to make way for development. In the Serepentine channel area *Juncus* stands have been replaced by kikuyu and buffalo grass.	107.2	12.9

E.3 ENVIRONMENTAL DRIVERS FOR MACROPHYTE HABITATS

The Wilderness Lakes area has been disturbed by man’s activities for many years. The declaration of the National Park in 1983 and listing as a Ramsar site in 1991 reduced some of the pressures such as encroaching development and livestock grazing. Dredging of the channels between the different lake sections would have changed water level and salinity causing changes in wetland vegetation. Dredged spoil was deposited adjacent to canals, forming vegetated levees and interfering with water movement (Russell, 2003). Historical aerial photographs (**Figure E.1**) indicate the changes over time caused by development. Macrophyte habitat associated with the banks of the middle and especially the lower Touw Estuary has been disturbed by houses, bank stabilisation, slipways and jetties. Hotels, camping, picnic sites, boat launching concentrated around and west of Eilandvlei would have resulted in removal of some estuarine vegetation.

The data in **Tables E.2** and **E.3** gives some indication of overall changes over time; namely a decrease in open water area and salt marsh habitat due to reed encroachment. There has been an increase in reeds and sedges, floodplain and developed areas. **Tables E.4** and **E.5** provide an assessment of macrophyte health using the estuarine health index.

Mapping of the distribution of plants in the 1970s (Weisser and Howard-Williams, 1982) and 1990s (Russell, 2003) indicated localised increases in *P. australis, T. capensis,* scrub or trees, and grass or fields, and decreases in *Juncus kraussii, Schoenoplectus scirpoideus* and low scrub or fynbos in the Touw River system. Probable causes of change in the distribution of wetland plants include the natural tendency of plants to colonise new areas, as well as anthropogenic manipulation of physical, chemical and biological processes, including the cessation of disturbance by large herbivores, water-level stabilisation, changes in soil salinity and the accumulation of plant litter within wetland areas (Russell, 2003).

The changes recorded by Russell (2003) from vegetation mapping of the Wilderness Lakes between 1975 and 1997 were *Phragmites australis* (53.9 ha; +53%), grass or fields (23.1 ha; +35%) and scrub or trees (12.2 ha; +45%). Over the same period the area of human habitation more than doubled (10.8 to 23.3 ha). Substantial declines occurred in the distribution of *Juncus kraussii* (76.2 ha; –243%), *Schoenoplectus scirpoideus* (10.1 ha; –38%) and low scrub or fynbos (7.8 ha; –66%).

Stabilisation of the water level has resulted in the proliferation of the robust common reed, *P. australis.* The feared loss of biodiversity due to the encroachment of *P. australis* since the 1970s has led to a number of management interventions being suggested such as cutting, burning, and increasing water and salinity levels (Russell and Kraaij, 2008). Cutting alone has been ineffective in the eradication of *P. australis* as it results in higher density. Cutting combined with flooding was more effective as the regeneration of shoots are less likely the longer the flooding period and the higher the water level. For best results, cutting and flooding should coincide with periods of high salinity.

The submerged macrophytes in the lake also respond to salinity. Howard-Williams (1980) showed that lowered water levels coincided with increased salinity and in 1975 *Potamogeton pectinatus* disappeared from Rondevlei when salinity increased to 22. As observed for the Swarvlei system the horizontal zonation of the submerged macrophytes was maintained by salinity with *Zostera capensis* at the saline end (salinity 35), *Potamogeton pectinatus* at the fresh (salinity < 10) end and *Ruppia cirrhosa* inbetween.

There may have been some drying of high lying areas due to breaching at low water levels to prevent the flooding of low lying residential areas. Decreases in soil salinity would account for loss of saline macrophytes such as *Juncus kraussii* at the expense of freshwater reeds, sedges and rushes.

Disturbance from changes in surrounding land use will have led to increases in nutrients. This would increase growth of the littoral vegetation, lead to macroalgal blooms and smothering of submerged macrophytes. In the Swartvlei Lake Howard-Williams and Allanson (1981) found that the major nutrient pathway was from the sediments to the water via the macrophytes. *Potamogeton* took up sediment nutrients, upon decomposition there was almost complete breakdown of macrophyte tissue with little sedimenting as particulate matter. Nutrient flows in the littoral zone depended not only on the macrophytes but on the complex of bacteria, macrophyte epiphyte algae and fauna. The dense submerged macrophyte beds with their associated epiphytic algae were useful nutrient filters. Any disturbance to these macrophytes would change the nutrient dynamics of the system.

Table E.2 Vegetation units and their area (ha) in the Wilderness Lakes system for 1975 / 1978 (modified from Weisser and Howard-Williams) and for 1997 (modified from Russell 2003)

	1978	**1997**	**1978 total**	**1997 total**	
Open Water in Wetland	2.21	0.33	2.21	0.33	⇩
Submerged macrophytes					
Potamogeton pectinatus and/or *Ruppia cirrhosa*	42.7	No data	46.59	-	
Ruppia cirrhosa	3.89				
Salt marsh					
Cotula coronopifolia	1.52	0.96			
Juncus kraussii	111.66	40.4			
Sarcocornia spp	0	1.13	113.18	42.49	⇩
Reeds and sedges					
Phragmites australis	102.14	176.71			
Scirpus littoralis Schoenoplectus scirpoideus)	33.6	27.08			
Scirpus maritimus (*Bolbochoenus maritimus*)	0.38	3.10			
Sedge marsh	1.13				
Cladium mariscus	4.24	3.25			
Cyperus textilis	0	3.39			
Ficinia nodosa	0	0.74			
Schoenoplectus triquester	0	0.38			
Typha latifolia subsp. *Capensis*	8.82	13.2	150.3	227.85	⇧

	1978	1997	1978 total	1997 total	
Floodplain					
Grassland and Fields	66.46	107.18	66.46	107.18	⇧
Other					
Riparian vegetation	30.71				
Development					
Human Use areas	10.76	34.5	15.38	34.5	⇧
Roads	4.62				
Total			394.12	412.35	

Biomass of submerged macrophytes would also be influenced by waterbird grazing. Red-knobbed Coot feeds almost exclusively on *Potamogeton pectinatus* and *Chara* spp. (Russell *et al*., 2009). Between 1992 and 2005 decreases in submerged macrophyte biomass in Eilandvlei (decreases) and increases in Rondevlei were associated with changes in ducks. There was a dieback of submerged macrophytes in Wilderness Lakes between 1979 and 1981 which was attributed to phytoplankton blooms, development of periphyton on the plants and uprooting of plants by wave action during strong winds (Weisser and Howard-Williams, 1982).

Table E.3 Vegetation units and their area (ha) in the Touw Estuary for 1975 / 1978 (Modified from Weisser and Howard-Williams) and for 1997 (modified from Russell 2003)

	1978	1997	
Salt marsh *Juncus kraussii*	1.06	-	⇩
Reeds and sedges (total)	**9.3**	**19.7**	⇧
Phragmites australis	7.51	19.38	
Scirpus littoralis (Schoenoplectus scirpoideus)	1.55	-	
Scirpus maritimus (*Bolbochoenus maritimus*)	0.11	0.04	
Cyperus textilis	-	0.27	
Typha latifolia subsp. *Capensis*	0.13	-	
Floodplain Grassland and Fields	**4.71**	**12.9**	⇧
Human Use areas	**6.56**	**23.62**	
Total	21.63	56.22	

E.4 ACKNOWLEDGEMENTS

This summary report would not have been possible without the intensive studies completed in the past and listed in the Reference section. The report has been written based on this available and published information.

1936

1967

1979

1980

Figure E.2 **Changes over time for the lower to middle reaches of the Touws/Wilderness Estuary**

APPENDIX F: DATA SUMMARY REPORT FOR INVERTEBRATES

F.1 AVAILABLE DATA

Although the Wilderness Lakes complex has been intensively researched, available information on estuarine invertebrates in the Touw Estuary is surprisingly under-represented. Russell *et al.* (2009) provided an up-date on the state of knowledge on the Garden Route National Park which includes the Touw Estuary. Although reference is made to zooplankton studies undertaken by Grindley and Wooldridge (1973) and Coetzee (1983), no other invertebrate studies in the Touw Estuary are mentioned by Russell *et al*. (2009).

Zooplankton collected in January 1969 by Grindley and Wooldridge (1973) included two sites in the Touw Estuary, one in Eilandvlei, one in Langvlei and one in Rondevlei. Salinity values recorded at the five sites are given in **Table F.1.** Samples in the Touw Estuary were collected in the mouth and just below the railway bridge above the mouth. Unfortunately, quantitative information (ind.m^{-3}) for species present in the plankton was not determined during these early investigations, although a measure of abundance can be estimated from crude biomass (Settled Volumes, **Table F.1**) calculations obtained from standard 4-minute tows per site (Zooplankton net 30 cm in diameter). Based on these settled volumes, zooplankton biomass was considered low.

Table F.1 Surface salinity, water depth and Settled volumes of zooplankton recorded at the five sites sampled by Grindley and Wooldridge (1973) in the Touw Estuary and the three lake systems linked to the estuary

Parameter	Touw Estuary 1	Touw Estuary 2	Eilandvlei	Langvlei	Rondevlei
Salinity	17.5	16	4.5	6.5	14.5
Depth (m)	1	2	1	1	1
Settled volumes (cc)	2.5	7.5			

In the Touw Estuary, 18 species were recorded by Grindley and Wooldridge (1973). The copepod *Pseudodiaptomus hessei* was the most abundant, followed by the amphipod *Grandidierella* sp. (probably *G. lignorum*) and the cumacean *Iphinoe truncata*. Eight species were present in Eilandvlei, five in Langvlei and seven species in Rondelei, although numbers were very low. **Table F.2** lists the five dominant species in the Touw Estuary. *P. hessei* was not recorded in Eilandvlei or Langvlei, although it was present in Rondevlei (salinity 14.5).

Table F.2 The five dominant species of zooplankton recorded in the Touw Estuary by Grindley and Wooldridge (1973). Data are based on relative abundance information and are ranked in order of numerical importance

Species	Group
Pseudodiaptomus hessei	Copepod
Polychaete juveniles	Polychaete worms
Grandidierella sp	Amphipod
Iphinoe truncata	Cumacean
Small unidentified copepods	Copepod

The only other published information on zooplankton from the western section of the Wilderness Lakes complex is provided by Coetzee (1983), who sampled a single station in the Touw Estuary, Eilandvlei, Langvlei and Rondevlei respectively. Samples were collected once a month between January and December 1976 by pumping 1 m^3 of water through an 80 µm mesh net. Touw samples were collected near the water surface and at 2 m depth intervals at the other sites. All sampling was carried out during daytime.

Coetzee (1983) described the zooplankton from the Touw Estuary as typically estuarine, with marine species appearing occasionally when the mouth opened to the sea. Freshwater associated species appeared at times of high rainfall. Consequently, species richness over the study period of one year was relatively high, with ca 29 species recorded. However, abundance (ind.m^{-3}) were relatively low, dominated by copepod nauplii (< 2000 m^{-3} on average for the 12 month study). **Table F.3** provides summary information of the ten most common species recorded the Touw Estuary.

Table F.3 The ten numerically dominant species of zooplankton recorded in the Touw Estuary by Coetzee (1983). Data represent abundance (ind.m^{-3}) and were extracted from monthly data collected over one year

Species	Average abundance	Maximum abundance
CRUSTACEA		
Cladocera	56	336
Ostracoda	9	55
Nauplii larvae	1951	10570
Acartia natalensis	8	74
Oithona sp. (mouth open)	93	1120
Ergasilidae (copepod fish parasites)	35	343
Cyclopoid spp.	9	44
Harpacticoid spp.	10	54
MOLLUSCA		
Lamellibranch veliger larvae	224	889
Gastropod veliger larvae	9	100

In the three lake systems, very similar patterns were recorded although Lamellibranch veliger larvae were more abundant, the average (for the 12-month study) ranging between 3000 and 11200 ind.m^3. More detailed information shown in **Table F.4.** These veliger larvae were considered to be those of *Musculus virgiliae.* Overall, veligers were the most abundant zooplankters in Eilandvlei, Langvlei and Rondevlei; and the second most abundant in the Touw Estuary after nauplii larvae.

Absent from the list in **Table F.3** is the copepod *Pseudodiaptomus hessei*, although it was present in the three lake systems. This is likely due to the time of sampling, with adults particularly remaining near or on the bottom during daylight (Hart and Allanson, 1976). Kibirige and Perissinotto (2003) recorded similar results, with day-time values 1-3 orders of magnitude lower compared to night-time samples. Copepod nauplii are less influenced by bright light and these were the most abundant organisms in samples. These nauplii probably represented both *P. hessei* and *Acartia natalensis* (Coetzee, 1983). Because of the sampling technique, other species were also likely to be under-represented in samples since they are able to avoid suction currents caused by the pump (mysids, cumaceans, amphipods are examples). Lamellibranch veligers were considered to be those of the bivalve *Musculus virgiliae* (Coetzee, 1983).

Table F.4 The three numerically dominant species of zooplankton recorded in Eilandvlei, Langvlei and Rondevlei by Coetzee (1983). Data represent abundance (ind.m^{-3}) and were extracted from monthly data collected over one year. Except for Ergasilidae, other taxa were present in low numbers and did not exceed 250 ind.m^{-3}

Species	Average abundance	Maximum abundance
Eilandvlei		
Nauplii larvae	2985	9920
Acartia natalensis	352	2640
Lamellibranch veliger larvae	11159	82088
Langvlei		
Nauplii larvae	1149	6780
Acartia natalensis	23	284
Lamellibranch veliger larvae	3234	45744
Rondevlei		
Nauplii larvae	1598	10868
Acartia natalensis	657	13550
Gastropod veliger larvae	10405	286125

Davies (1984) reported on the macrozoobenthos of the lower and middle reaches of the Touw Estuary (Lagoon and Fairy Knowe transects respectively), sampled monthly over 18 months. Other transects sampled by Davies (1984) included sites across the west and east Serpentine channel as well as transects in Eilandvlei, Langvlei and Rondevlei. Samples were collected along each of the transects using a van Veen scissor grab (bite 0.024 m^2) and passing the contents through a series of sieves down to 160 µm mesh size. Three replicates were pooled at every station across each transect that included vegetated and non-vegetated areas. Stands of *Potamogeton pectinatus* were sampled differently and benthos associated with submerged vegetation were collected by using a submerged weed cutter having an area of 0.063 m^2. Multiple washing of the cut vegetation and sieving recovered ca 99% of the invertebrates present. In the following discussion only results from the two transects in the Touw Estuary are discussed.

In the lagoon area, pooled biomass data for the study period of 18 months had a mean value (excluding *Callichirus kraussi*) of 19.25 g dry mass m^{-2}. Biomass appeared to increase during summer, falling rapidly as winter approached in 1979 and 1980 (after March 1979, biomass fell from 24.53 to 8.05 g dry mass m^{-2}). Thirty-seven taxa were recorded (although two zooplanktonic species – *Acartia natalensis* and *Pseudodiaptomus hessei* were included in Davies's list). This site had a small number of taxa present that were not recorded at other sites, due to higher salinity values (Davies 1984). The amphipods *Melita zeylanica*, *Corophium triaenonyx*, *Grandidierella lignorum*, the isopod *Cyathura carinata*, the Tanaeid *Apseudes digitalis*, dipteran larvae (Chironomidae) and the mollusc *Musculus virgiliae* dominated standing stock values. This was the only site where the anomuran burrowing prawns *Callichirus kraussi* and *Upogebia africana* were recorded in the Touw Estuary or in the three lakes investigated (Davies, 1984).

Species dominating biomass values along the Fairy Knowe transect were the same as those listed for the Lagoon transect. Composition along the two transects was also similar, although species number decreased to 33 at the upstream site.

In terms of invertebrate biomass, a major difference was recorded when comparing non-vegetated vs vegetated areas along the Fairy Knowe transect. Standing stock in non-vegetated areas along this transect was similar to the lagoon transect, having a mean value of 13.06 g dry mass m^{-2} (range 2.88 to 26.16 g dry mass m^{-2}). However, a dense stand of *Potamogeton pectinatus* was also present at this site and resulted in the biomass of the associated invertebrates increasing by an order of magnitude. Mean for the vegetated site during the study period was 128.9 g dry mass m^{-2} (range 6 to 329 g dry mass m^{-2}). Temporal changes in faunal biomass associated with *Potamogeton pectinatus also* differed from invertebrate biomass changes in non-vegetated areas. In the case of the macrophyte-associated fauna, the main shift occurred in mid-winter when macrophyte die-back occurred (from 329 to 6 g dry mass m^{-2}, May-June 1979, compared to late summer at exposed sites).

Although the seven dominant species (in terms of biomass) were the same when comparing the Fairy Knowe and Lagoon transects, the significant increase in biomass at the former site was due to the bivalve mollusc *Musculus virgiliae* that attaches itself to the macrophyte. When *Potamogeton pectinatus* was present, *M. virgiliae* contributed more than 90% to dry biomass when compared to the other species dominating the benthos. This species did not contribute < 50% for any month sampled over the 18 month study period (51.3% in September 1979).

It is important to note that in August 1979, *The Lakes Area Development Board* undertook a programme of submerged plant cutting in the Serpentine canal. As a consequence, invertebrate biomass (particularly *Musculus virgiliae*) reduced significantly. Recovery of the submerged plant was slow in the West Serpentine, while no recovery in the East Serpentine was recorded over the remainder of the study (10 months). These results underline the importance of macrophytes as a habitat for those invertebrates that utilize them.

The *Potamogeton*-associated faunal standing stock (invertebrates) recorded in the study are among the highest recorded for similar lake studies elsewhere. For example, they are also much higher when compared to the Bot Estuary (quoted in Davies, 1984). *Apseudes digitalis* was numerically the most abundant invertebrate in the Bot study, with the bivalve *Arcuatula capensis* contributing 76% to total biomass. As in the Touw study, relatively few species (six) contributed over 90% to total invertebrate biomass in the Bot system. *A. digitalis* and *Corophium trianonyx*, were also key species in Lake Sibayi invertebrate benthic studies (Hart ,1979).

These plant-invertebrate associations described for the Touw-Serpentine and Bot coastal lake systems underline the importance of rooted plants to the development of high-biomass invertebrate communities associated with them. In the Touw-Serpentine study undertaken by Davies (1984) biomass exceeded those values from sediments at the same stations and over the same period by a factor ranging between 7.6 and 20 times higher. A decline in rooted plant biomass will therefore severely impact invertebrate communities in a negative way and have a rippling effect through higher trophic levels.

F.2 SUMMARY OF RESULTS FROM THIS STUDY

F.2.1 Physico-chemical data

Physico-chemical information was collected at four stations, particularly water temperature, salinity, and oxygen content of the water. Data were collected at the surface and at 0.5 m depth intervals (**Figure F.1**).

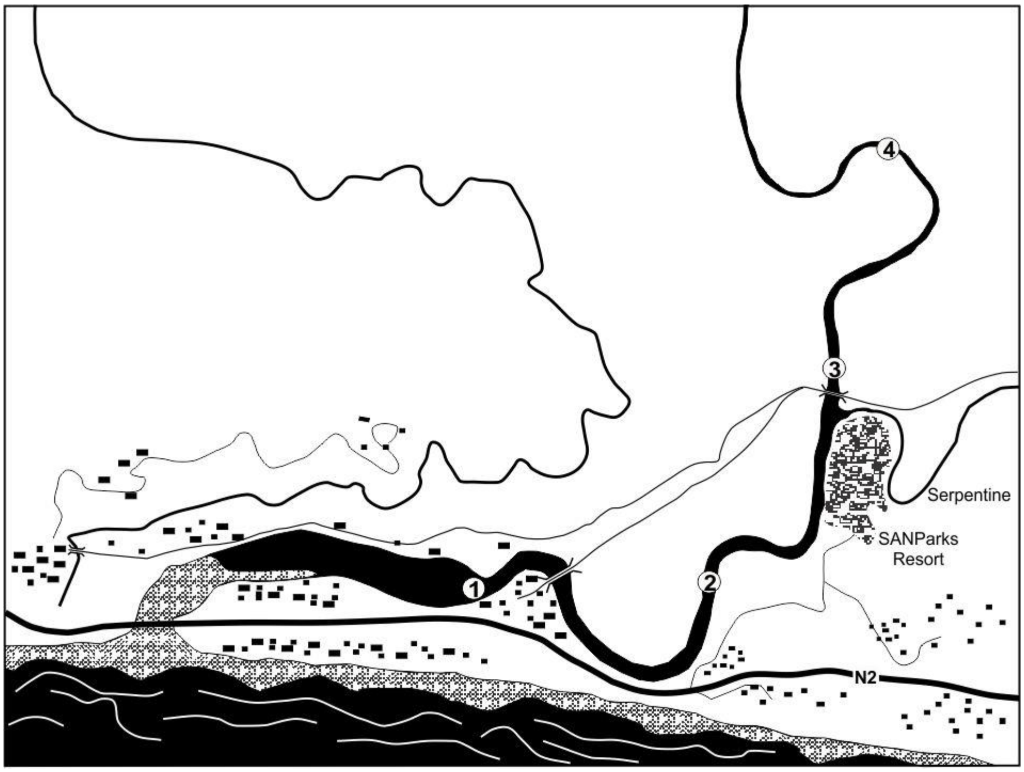

Figure F.1 Invertebrate sampling station positions in the Touw Estuary (Distance from mouth: 1 = 0.5 km; 2 = 1.9 km; 3 = 3.4 km; 4 = 5.1 km)

The Touw Estuary was almost closed at the time of sampling, with overtopping occurring around high tide. Physico-chemical results are shown in **Table F.5** and in **Figure F.2** for water temperature and salinity. Only near-surface and near-bottom data are reflected in the latter figure.

Salinity stratification characterised the water column along much of the estuary length. At the deepest station (Station 3, depth 5 m), salinity values near the surface were < 8, while those at the bottom exceeded 30. Oxygen concentration below 3 m water depth was also low at this station (< 50% saturation compared to near-surface layers). Vertical temperature differences were also evident in the lower estuary (Stations 1 and 2), with a maximum difference near the mouth (> 5.5°C). At the uppermost station, the water column was well mixed and oligohaline. Here, water depth was (< 1 m).

Table F.5: Physico-chemical readings recorded on 8 December 2013 in the Touw Estuary. Readings taken at 0.5 m depth intervals

Station	Depth (m)	Temp (^oC)	Salinity	DO (%)	DO (mg/l)	pH
1	0	25.18	17.73	97.4	7.26	7.93
	0.5	21.22	28.32	97.4	7.33	7.92
	0.75	19.56	32.26	110.9	8.38	8
2	0	24.55	15.3	116.5	8.94	8.22
	0.5	23.41	22.77	84.2	6.23	7.96
	1	23.01	28.96	66.1	4.75	7.89
	2	22.12	31.74	12.1	5.22	7.89
3	0	22.86	7.4	93.8	7.73	7.04
	0.5	22.52	7.98	95.2	7.87	7.11
	1	23.86	25.48	76.9	5.5	7.15
	2	22.93	30.42	53.7	3.85	7.44
	3	22.83	30.61	55.1	2.94	7.61
	4	2207	30.64	45	3.3	7.64
	5	22.65	30.65	41	2.85	7.65
4	0	19.7	0.12	99	9.6	7.81
	0.5	19.59	0.12	99	9.7	7.67

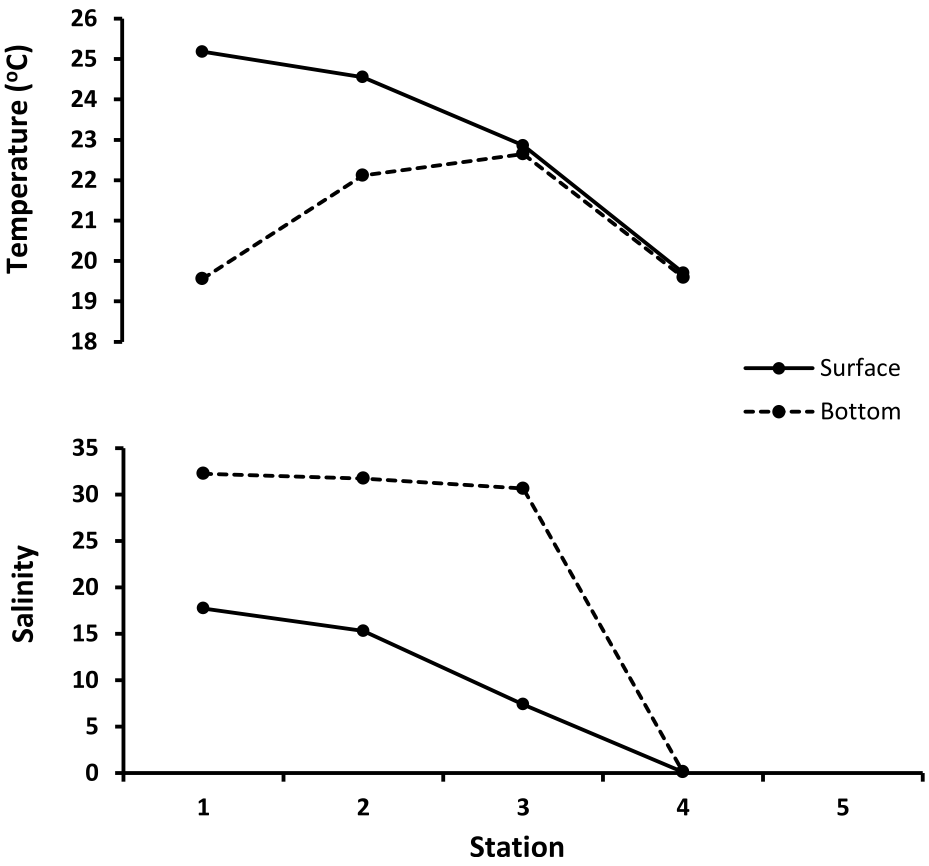

Figure F.2 **Temperature and salinity readings measured just below the water surface and near the substrate at four stations in the Touw Estuary (stations shown in Figure F.1)**

Unlike the other estuaries sampled, surface water temperatures were considerably cooler in the upper reaches (Range 25.18 – 19.7°C).

F.2.2 Zooplankton

Zooplankton samples were collected after dark at five sites respectively, using a flat-bottomed boat. Two replicates at each site were taken at mid-depth levels using modified WP2 nets (57 cm diameter and 190 µm mesh) suspended from a boom on either side of the bow of the boat. Approximately 12 – 15 m^3 of water was sampled during tows. Nets were held at the required water depth using a graduated T-pole operated by workers on the boat. Samples were concentrated at the cod-end of the net and washed into labelled plastic bottles. Approximately 5% formaldehyde solution was added to samples. In the laboratory, samples were analysed for species composition and enumerated. Final abundance was expressed as the average number of each species per m^3 of water (ind m^{-3}) at each site.

Twenty taxa were recorded in the zooplankton. Abundance (ind.m^{-3}) was relatively low for most species (**Table F.6**), although the copepod *Pseudodiaptomus hessei* followed a more typical pattern for temperate estuaries. This species is often the numerically dominant taxon in the zooplankton and the Touw, like the Klein Brak follows this broader pattern (**Figure F.3**). However, abundance was still an order of magnitude lower relative to many other temperate systems.

The zooplankton species present were typical of estuaries along the south coast, with amphipods, mysids, cumaceans and carid shrimps also being numerically important. The cumacean *Iphinoe truncata* and the amphipod *Grandidierella lignorum* were particularly abundant, although these two species are more typical of the hyperbenthos and the benthos. Zoel stages of the crown crab, *Hymenosoma orbiculare* were also abundant in the estuary.

Table F.6 Abundance of zooplankton (ind. m^{-3}) in the Touw Estuary (data represent mean values of two replicates collected in December 2013 at four stations)

Zooplankton	Station			
	1	2	3	4
Copepoda				
Copepod spp	513.0	0.0	0.0	0.0
Halicyclops sp.	0.0	0.0	265.0	18.0
Pseudodiaptomus hessei	2937.0	3113.0	983.0	3876.0
Mysidacea				
Mesopodopsis wooldridgei	5.0	5.0	0.0	0.0
Cumacea				
Iphinoe truncata	720.0	49.0	0.0	0.0
Isopoda				
Anthurid sp.	15.0	0.0	0.0	1.0
Cirolana fluviatilis	4.0	1.0	1.0	0.0
Corallana africana	0.0	1.0	0.0	1.0
Munna sp.	22.0	0.0	0.0	0.0
Sphaeromid sp.	7.0	0.0	0.0	5.0
Amphipoda				
Amphipod sp.	0.0	1.0	0.0	0.0
Corophium triaenonyx	0.0	0.0	0.0	20.0
Grandidierella lignorum	236.0	147.0	13.0	19.0
Melita zeylanica	15.0	0.0	0.0	0.0
Brachyura				
Hymenosoma orbiculare larvae	1020.0	245.0	113.0	29.0
Insecta				
Chironomid lavae	0.0	0.0	26.0	1.0
Insect larvae	0.0	0.0	13.0	1.0
Pisces				
Fish eggs	26.0	2.0	1.0	0.0
Fish larvae	15.0	0.0	0.0	0.0
Gobiid larvae	0.0	16.0	0.0	0.0

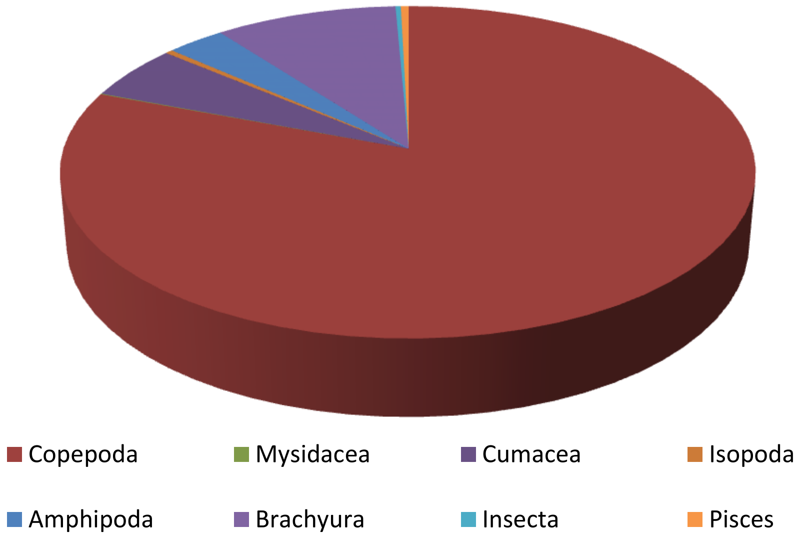

Figure F.3 **Pie diagram of the most abundant zooplankton taxa in the Touw Estuary. Values represent their total abundance at all sites in the estuary (see Table F.6) and expressed as percentage contribution of each group**

F.2.3 Hyperbenthos

Hyperbenthic animals were sampled at four or five stations in the estuary using a sled mounted on broad skids. Two replicates were collected at each site. The rectangular opening to the sled measured 75 x 70 cm. Attached to this frame was a 500 µm mesh net. A calibrated flowmeter mounted in the entrance quantified water volume passing through the net. Animals collected were then stored in 500 ml plastic bottles and preserved in 10% formaldehyde solution. In the laboratory animals were identified to species level under a microscope and final abundance expressed as average numbers per m^3 of water calculated from the two samples collected at each site. Animals captured in sled samples are usually fairly large, measuring up to 1-2 centimetres in length. Most of the smaller organisms such as copepods escape through the mesh and were therefore not enumerated or identified in sled samples, although their presence was noted.

Analysis of biological samples was completed in the laboratory. Final abundance was expressed as the average number of each species per m^2 of substratum at each site, determined from the six replicates respectively. Invertebrates were identified to species level wherever possible and the data analysed using multivariate statistics from the statistical package, PRIMER V.6 (Plymouth Routines in Multivariate Ecological Research). If multivariate techniques were not appropriate, other packages using MS Excel or Statistica for Windows were used.

Only six taxa were recorded in the hyperbenthos (**Table F.7** and **Figure F.4**). Of the species present, zoel stages of the crown crab *Hymenosoma orbiculare* reached high numbers in the middle estuary. The amphipod *Grandidierella lignorum* was also relatively abundant.

Table F.7 **Abundance of hyperbenthic organisms (ind. m^{-3}) in the Touw Estuary. Data represent mean values of two replicates collected in December 2013 at four stations**

Hyperbenthos	Station			
	1	2	3	4
Ostracoda				
Ostracod sp	205.0	0.0	0.0	0.0
Copepoda				
Pseudodiaptomus hessei	0.0	34.0	13.0	15.0
Amphipoda				
Corophium triaenonyx	0.0	0.0	0.0	4.0
Grandidierella lignorum	0.0	39.0	63.0	22.0
Melita zeylanica	0.0	2.0	48.0	0.0
Brachyura				
Hymenosoma orbiculare larvae	0.0	4556.0	6374.0	27.0

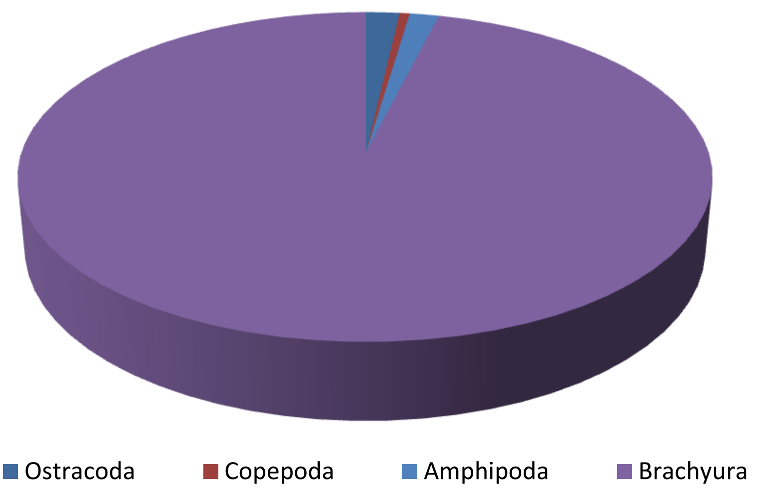

Figure F.4 **Pie diagram of the most abundant hyperbenthic taxa in the Touw Estuary. Values represent their total abundance at all sites in the estuary (see Table F.7) and expressed as percentage contribution of each group**

F.2.4 Benthos

Subtidal benthic invertebrates were collected from the deck of a flat-bottomed boat using a Van Veen type grab. Stations were the same in each estuary wrt the invertebrate group sampled. Six replicates were collected at each site and the contents of each grab sample sieved through a 500 µm mesh screen bag. The grab sampler had a 564 cm^2 bite that penetrated the sediment down to about 10 cm depth. Animals retained by the sieve were stored in 500 ml plastic bottles and preserved with 5% formaldehyde solution for further analysis in the laboratory.

A sediment sample collected at each station provided information on particle size distribution and percent organic content. Dry samples (dried at 60°C for 48 h and then weighed) were incinerated at 550°C for 12 h to burn off the organic matter. The difference in weight of the sample after incineration provided information on organic content, expressed as a percentage. Three replicates from each sediment sample were used to obtain a final value. Samples were then soaked in distilled water for 24 h to remove salts. Excess water was carefully siphoned off and the sample again dried at 60°C for 72 h. Dried sediment was then vibrated through a series of metal test sieves (2 mm, 1 mm, 500 µm, 355 µm, 250 µm, 180 µm, 125 µm, 90 µm, 63 µm and < 63 µm).

Analysis of biological samples was completed in the laboratory. Final abundance was expressed as the average number of each species per m^2 of substratum at each site (ind.m^{-2}), determined from the six replicates respectively. Invertebrates were identified to species level wherever possible and the data analysed using multivariate statistics from the statistical package, PRIMER V.6 (Plymouth Routines in Multivariate Ecological Research). If multivariate techniques were not appropriate, other packages using MS Excel or Statistica for Windows were used.

Sediment particle size distribution and organic content of the sediment is shown in **Table F.8**. Fine sand rather than mud (< 0.065 µm) dominated the sediment at Stations 1 and 4, with coarser sand dominating the middle station. At Station 2, 60.24% of the sediment particles exceeded 500 µm in diameter. Organic content of the sediment was generally very low, only exceeding 1% at Station 4.

Table F.8 Sediment particle size distribution at three stations in the Touw Estuary. Size distribution grouped into four categories and expressed as percentage contribution of any category to the whole sample. Organic content of the sediment (expressed as percentage) shown in the last column

Station	> 0.500 µm	< 0.500 - 0.125 µm	< 0.125 - 0.065 µm	< 0.065 µm	Organic matter (%)
1	0	11.88	87.33	0.77	0.7
2	60.24	39.59	0.00	0.63	0.72
4	0	0.00	97.56	2.24	2.53

Thirteen taxa were recorded in the benthos (**Table F.9**) and must be considered low by comparison to other tidal estuaries in the temperate region. Abundance of individual species (ind.m^{-2}) was also low. Species present were typical of estuaries along the south and west coast, with the community dominated by Polychaetes (*Lumbrinereis* sp. and *Prionospio* sp.) and the amphipod Gr*andidierella lignorum.* Although larvae of the crown crab *Hymenosoma orbiculare* were abundant in the hyperbenthos (daylight sampling), adults were surprisingly not recorded in the benthos.

The bivale *Modioulis capensis* was the only other relatively common species. In terms of biomass, the benthic community was dominated by gastropods and bivalve molluscs.

Figure F.5 summarises **Table F.9** in visual format and emphasises the dominance of amphipods at most stations sampled.

Table F.9 Abundance of macrozoobenthic organisms (ind. m^{-2}) in the Touw Estuary (data represent mean values of two replicates collected in December 2013 at four stations)

Macrozoobenthos	Station			
	1	2	3	4
Polychaeta				
Ceratonereis keiskama	0.0	8.9	0.0	0.0
Lumbrinereis sp.	0.0	206.9	0.0	0.0
Nephys sp.	53.2	0.0	0.0	0.0
Prionospio sp.	0.0	198.0	65.0	0.0
Mysidacea				
Gastrosaccus brevifissura	3.0	0.0	0.0	0.0
Isopoda				
Cyathura estuaria	0.0	0.0	0.0	5.9
Amphipoda				
Corophium triaenonyx	0.0	0.0	0.0	3.0
Grandidierella lignorum	3.0	523.0	53.2	53.2
Urothoe sp.	17.7	0.0	0.0	0.0
Brachyura				
Paradylodiplax algoense	0.0	20.7	0.0	0.0
Mollusca				
Nassa kraussianus	3.0	0.0	0.0	0.0
Bivalve spat	17.7	0.0	0.0	0.0
Modiolus capensis	0.0	97.5	0.0	0.0

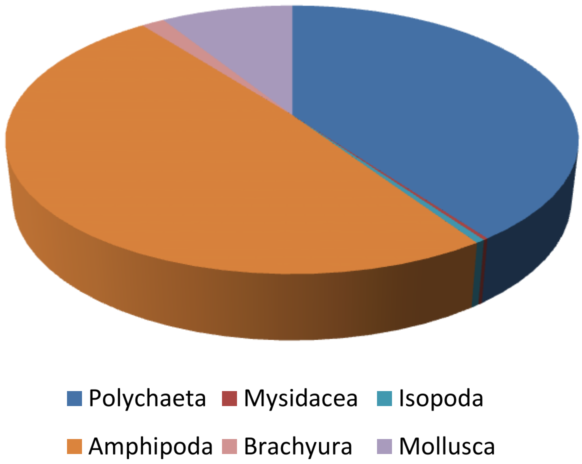

Figure F.5 **Pie diagram of the most abundant macrozoobenthic taxa in the Touw Estuary. Values represent their total abundance at all sites in the estuary (see Table F.8) and expressed as percentage contribution of each group**

APPENDIX G: DATA SUMMARY REPORT FOR FISH

Prepared by K Smith (SANParks, Wilderness) and S Lamberth (Department of Agriculture, Forestry and Fisheries, Cape Town)

G.1 AVAILABLE DATA

The earliest assessment of the fish community within the Touw Estuary and the Wilderness Lakes was completed between 1982 and 1984 (Hall *et al.*, 1987) over a two year period and recorded a total of 32 species from 18 families. Since then work by Russell (1996) has looked at changes in fish abundance relative to various environmental factors (recording 14 species from 8 families) whilst Olds (2012) investigated the spatial and temporal abundance and distribution of native and alien fish within the system. The two previous studies utilised beach seine nets and gill nets for their sampling whilst Olds (2012) incorporated both Fyke nets and scoop nets in addition to seine and gill nets, recording 26 species from 18 families. During a once-off sampling of the Touw Estuary using beach seine and gill nets (James and Harrison, 2008) 18 species from 11 families were sampled whilst seine net sampling in 2014 as part of this project resulted in 18 species from 10 families being recorded. All tables in this document are after Olds (2012).

G.2 SUMMARY ASSESSMENT OF FISH DATA

Overall the Wilderness Lakes system ichthyofauna comprises fishes in all but one (pure marine – category III) of Whitfield's (1998) estuarine categories, the majority falling within the marine migratory component with small proportions of native estuarine species, catadromous and alien freshwater species (**Tables G.1** and **G.2**). Estuarine resident species that spawn only within estuaries (Ia) are represented by one species whilst resident species spawning both in estuaries and nearshore marine environments (Ib) are represented by seven species. Obligate estuary dependent species (IIa) comprise nine species with four partially estuary dependent fish species (IIb and IIc). Catadromous species comprise the longfin eel (*Anguilla mossambica*) and the facultative catadromous freshwater mullet (*Myxus capensis*). Of the four freshwater species found within the system, none are endemic and all are classified as alien invasive. In describing the fish community throughout the system Olds (2012) showed that the proportion of species in each estuarine category was independent of sampling area (Olds, 2012) but in contrast the relative biomass of species in each estuarine group showed significant spatial variation throughout the system. Native estuarine species contributed between 15% and 21% in each of the lakes and the Touw Estuary (highest in the Touw Estuary and Rondevlei) and euryhaline marine species contributed between 29% (Langvlei) and 66% (Eilandvlei). Rondevlei had the highest biomass (20%) of catadromous species and Touw the lowest biomass (2.2%) whilst alien species dominated within Langvlei (52%). Overall there is a high degree of estuarine dependency with 85% of the fish assemblage comprising fish species that are either partially or completely dependent on estuaries.

During both Hall's (1987) and Olds (2012) surveys the Touw Estuary and Eilandvleiheld the highest number of species indicating that these areas form the major nursery areas of the system.There were slight variations between studies but overall Mugilidae (5 species), Sparidae (2 to 5 species) and Gobidae (2 to 4 species) were the most important families represented (**Tables G.3** and **G.4**). Numerically, *Atherina breviceps* (60%) and *Gilchristella aestuaria* (38.6%) dominated the fish assemblage in the Touw Estuary during the 2012 seine net surveys (Olds, 2012). However these surveys were conducted after a prolonged drought period (closed mouth) with limited recruitment potential of euryhaline marine species (highlighted by a lack of juveniles sampled throughout the system). Dominant species caught within the gillnet surveys included *Galeichthys feliceps* (39%), *Liza richardsonii* (17%), *Pomadasys commersonnii* (15%), *Monodactylus falciformis* (9%), *Oreochromis mossambicus*, *Myxus capensis*, *Lichia amia* (all 4.5%) and *Lithognathus lithognathus* (3%). The most important species by mass in the gill nets were *O. mossambicus* (30%), *P. commersonnii* (26%), *L. richardsonii* (16%) and *L. amia* (9.8%) (Olds, 2012). In comparison to Hall *et al*. (1987), *L. richardsonii* dominated by numerically followed by *Rhabdosargus holubi* (15%), *G. aestuaria* (8%) and *Mugil cephalus* (7%). However, in terms of biomass although *L. richardsonii* dominated (22%) this was followed by *Argyrosomus japonicas* (18%), *L. lithognathus* (14%), *Liza dumerilii* and *L. amia* (both 12%). The low representation of both *A. japonicus* and *L. lithognathus* in later studies is more than likely a reflection of their national decline rather than local recruitment changes. The dominant species in terms of numbers during the once-off survey by James and Harrison (2008) were *L. richardsonii* (36.8%), *R. holubi* (18%), juvenile mugillids (13%), *L. dumerili* (8.4%), *Psammogobius knysnaensis* (7.3%) and *Caffrogobius gilchristi* (4%). The most important species by mass were *L. richardsonii* (60.6%), *L. dumerili* (15.5%), *O. mossambicus* (7.2%) and *L. lithognathus* (4.4%).

Olds (2012) determined the establishment success of the alien invasive species concluding that Mozambique tilapia (*Oreochromis mossambicus*) and mosquito fish (*Gambusia affinis*) are established (widespread, abundant and breeding), the common carp (*Cyprinus carpio*) are in an establishing phase (widespread and breeding but low abundance) and the largemouth bass (*Micropterus salmoides*) are causal in that their distribution is limited, abundance is low and no breeding occurs in the Lakes system.

In comparing the fish community between 1985 and 2012, Olds (2012) has shown an increase in the number of alien invasive freshwater species but relatively little change in the composition and relative abundance of species within other estuarine categories. At the time of the study there was no evidence that the alien invasive species had had a negative impact on the native fish abundance. However, the fish assemblages within each of the lakes differed.

Table G.1 Fish species sampled in the 30 m seine net in the Touw Estuary, Eilandvlei Lake, Langvlei and Rondevlei expressed as percent relative number of fish (%N), frequency of occurrence (%FO), percentage mass of fish (%M) and the index of relative importance (%IRI) (n is shown in parenthesis)

		Touw Estuary				Eilandvlei				Langvlei				Rondevlei			
Species	EA	%N	%FO	%M	IRI	%N	%FO	%M	IRI	%N	%FO	%M	IRI	%N	%FO	%M	IRI
		(51439 fish)	(36 hauls)	(158098g)		(58184 fish)	(24 hauls)	(179472g)		(18751 fish)	(18 hauls)	(79798g)		(21681 fish)	(13 hauls)	(80706g)	
Atherina breviceps	Ib	60.1	72.2	14.5	50.70	54.0	83.3	17.4	47.12	15.3	38.9	10.8	9.60	26.5	53.8	14.7	15.75
Gilchristella aestuaria	Ib	38.6	63.9	16.0	32.80	41.5	79.2	16.6	36.48	73.2	66.7	16.1	56.27	39.3	84.6	16.9	33.80
Caffrogobius gilchristi	Ib	0.002	2.8	0.01	0.0002	0	0	0	0	0	0	0	0	0	0	0	0
Psammogobius knysnaensis	Ib	0.4	63.9	0.2	0.33	0.2	50.0	0.2	0.14	0.01	5.6	0.001	0.0004	0.03	30.8	0.01	0.007
Redigobius dewaali	Ib	0.01	8.3	0.001	0.001	0.002	4.2	0.0004	0.0001	0	0	0	0	0	0	0	0
Hyporhamphus capensis	Ia	0.004	2.8	0.0001	0.0001	0.7	66.7	3.3	2.14	11.2	77.8	15.6	19.72	34.0	76.9	44.2	42.74
Syngnathus acus	Ib	0.1	30.6	0.02	0.03	0.02	25.0	0.01	0.01	0	0	0	0	0.02	15.4	0.01	0.004
Lichia amia	IIb	0.01	11.1	2.2	0.23	0.01	8.3	7.9	0.52	0	0	0	0	0	0	0	0
Monodactylus falciformis	IIa	0.03	22.2	0.6	0.12	0	0	0	0	0	0	0	0	0	0	0	0
Mugil cephalus	IIa	0	0	0	0	0.002	4.2	0.3	0.01	0	0	0	0	0	0	0	0
Liza richardsonii	IIc	0.04	11.1	7.7	0.80	0.03	12.5	6.1	0.61	0.1	22.2	11.2	2.35	0.1	30.8	9.78	2.154
juvenile Mugilidae	IIa	0.2	5.6	0.1	0.01	0	0	0	0	0	0	0	0	0	0	0	0
Lithognathus lithognathus	IIa	0.1	27.8	15.3	4.00	0.1	62.5	13.9	6.91	0	0	0	0	0	0	0	0
Rhabdosargus holubi	IV	0.2	30.6	22.3	6.50	0.1	20.8	9.2	1.53	0	0	0	0	0	0	0	0
Oreochromis mossambicus	IV	0.2	22.2	20.9	4.40	3.4	25.0	13.9	3.42	0.1	38.9	22.5	8.31	0.1	53.8	14.4	5.543
Cyprinus carpio	IV	0.004	2.8	0.0003	0.0001	0.01	12.5	11.1	1.10	0.03	16.7	20.6	3.25	0	0	0	0
Gambusia affinis	IV	0.2	27.8	0.01	0.06	0	0	0	0	0	0	0	0	0	0	0	0
Myxus capensis	Vb	0.002	2.8	0.2	0.005	0	0	0	0	0.02	16.7	3.1	0.49	0	0	0	0

Table G.2 Fish species sampled in the gill nets in the Touw Estuary, Eilandvlei, Langvlei and Rondevlei expressed as percent relative number of fish (%N), frequency of occurrence (%FO), percentage mass of fish (%M) and the index of relative importance (%IRI) (IRI=FO(N%+M%) (n is indicated in parentheses)

		Touw Estuary (n= 134)				Eilandvlei (n= 414)				Langvlei (n= 580)				Rondevlei (n= 355)			
Species	EA	%N	%FO	%M	%IRI	%N	%FO	%M	%IRI	%N	%FO	%M	%IRI	%N	%FO	%M	%IRI
		(134 fish)	(16 nets)	(68.0kg)		(414 fish)	(24 nets)	(278.3kg)		(580 fish)	(24 nets)	(237.3kg)		(355 fish)	(24 nets)	(317.3kg)	
Galeichthys feliceps	IIb	39.6	18.8	4.4	14.53	0	0	0	0	0	0	0	0	0	0	0	0
Lichia amia	IIb	4.5	18.8	9.8	4.72	1.7	16.7	9.4	1.33	0	0	0	0	0.3	4.2	3.4	0.13
Elops machnata	IIa	0	0	0	0	0.2	4.2	0.5	0.02	0	0	0	0	0	0	0	0
Pomadasys commersonnii	IIa	14.9	56.3	26	40.59	15.9	75.0	22.1	20.4	0	0	0	0	0.3	4.2	1.4	0.06
Monodactylus falciformis	IIa	9.0	18.8	1.1	3.34	3.4	33.3	0.7	0.97	47.9	87.5	9.8	42.6	26.5	75.0	5.9	20.40
Mugil cephalus	IIa	0.7	6.3	1.7	0.27	3.1	25.0	6.3	1.70	0.5	12.5	2.2	0.29	2.3	25.0	5.3	1.58
Liza dumerili	IIb	1.5	12.5	0.7	0.47	20.8	75.0	8.9	16.00	0.2	4.2	0.1	0.01	0	0	0	0
Liza richardsonii	IIc	17.2	37.5	15.8	21.84	39.9	91.7	35.8	49.70	9.8	70.8	16.2	15.50	23.7	79.2	21.1	29.90
Liza tricuspidens	IIb	0	0	0	0	0.5	8.3	0.8	0.08	0	0	0	0	0.8	8.3	0.7	0.11
Argyrosomus japonicus	IIa	0	0	0	0	0.2	4.2	0.2	0.01	0	0	0	0	0	0	0	0
Lithognathus lithognathus	IIa	3.0	12.5	3.3	1.40	5.8	50.0	8.7	5.19	0	0	0	0	1.7	16.7	8.9	1.49
Rhabdosargus holubi	IV	0	0	0	0	1.7	20.8	1.3	0.44	0.3	4.2	0.3	0.02	5.1	25.0	0.1	1.08
Oreochromis mossambicus	IV	4.5	12.5	29.9	7.59	0.2	4.2	0.03	0.01	36.2	50.0	53.5	37.8	8.2	45.8	23.3	12.10
Cyprinus carpio	IV	0.7	6.3	0.2	0.10	0	0	0	0	0	0	0	0	0	0	0	0
Myxus capensis	Vb	4.5	25	7.2	5.217	6.5	50.0	5.0	4.14	5.0	45.8	4.8	3.78	31.0	70.8	24.6	33.20

Table G.3 Summary table showing the overall distribution of fish species sampled from the Wilderness Lakes system, Western Cape, South Africa between autumn 2010 and summer 2011.

EA = Estuarine Association category (after Whitfield 1998), Locality: TE= Touw Estuary; SC= Serpentine channel; EV= Eilandvlei; C= channel; LV= Langvlei, RLC= Rondevlei-Langvlei channel and RV= Rondevlei. Sampling gear type: F= Fyke, 10m= 10m seine net, 30m= 30m seine net, G= gill net and A= angling. Black shading indicates confirmed distribution and grey indicates probable distribution due to a catch higher up the system.

Family	**Species**	**EA**	**Locality**							**Gear type**
			TE	**SC**	**EV**	**C**	**LV**	**RLC**	**RV**	
Anguilidae	*Anguilla mossambica*	Va	■	▨	■					F
Ariidae	*Galeichthys feliceps*	IIb	■							G,F
Atherinidae	*Atherina breviceps*	Ib	■	▨	■	▨	■	■	■	10m, 30m
Carangidae	*Lichia amia*	IIa	■	■	■	▨	▨	▨	■	G, 30m
Cichlidae	*Oreochromis mossambicus**	IV	■	■	■	■	■	■	■	F, 10m, 30m, G
Clupidae	*Gilchristella aestuaria*	Ib	■	▨	■	▨	■	■	■	10m, 30m
Cyprinidae	*Cyprinus carpio**	IV	■	■	■	▨	■	▨	■	F, 30m
Elopidae	*Elops machnata*	IIa	▨	▨	■					G
Gobiidae	*Caffrogobius gilchristi*	Ib	■	■	■					F, 30m
	Glossogobius callidus	Ib	■	■						F
	Psammogobius knysnaensis	Ib	■	■	■	▨	■	■	■	F, 30m,10m
	Redigobius dewaali	Ib	■	▨	■					10m, 30m
Haemulidae	*Pomadasys commersonnii*	IIa	■	■	■	■	▨	▨	■	G
Hemiramphidae	*Hyporhamphus capensis*	Ia	■	▨	■	▨	■	■	■	10m, 30m
Monodactylidae	*Monodactylus falciformis*	IIa	■	■	■	▨	■	▨	■	F, 30m, G
Mugilidae	*Mugil cephalus*	IIa	■	▨	■	▨	■	▨	■	G
	Myxus capensis	Vb	■	■	■	■	■	▨	■	G, 30m
	Liza dumerili	IIb	■	▨	■	▨	■			G
	Liza richardsonii	IIc	■	■	■	■	■	▨	■	F, G, 30m
	Liza tricuspidens	IIb	▨	▨	■	▨	▨	▨	■	G
	juvenile Mugilidae	II	■	■						30m
Poeciliidae	*Gambusia affinis**	IV	■	■	■	■	■	■	■	30m, 10m, S
Sciaenidae	*Argyrosomus japonicus*	IIa	▨	▨	■					G
Soleidae	*Solea bleekeri*	IIa	■	■	■					F
Sparidae	*Lithognathus lithognathus*	IIa	■	▨	■	▨	▨	▨	■	30m, G
	Rhabdosargus holubi	IIa	■	▨	■	▨	■	▨	■	F, 30m, G
Syngnathidae	*Syngnathus acus*	Ib	■	■	■	■	■	■	■	30m, 10m, G

* Alien fish species

Table G.4 A list of all species and families recorded in the Touw Estuary and Wilderness Lakes. The species are classified into five major categories of estuarine-dependence as suggested by Whitfield (1994)

Family name	Species name	Common name	Dependence
OSTEICHTHYES			
Anabantidae	*Sandelia capensis*	Cape kurper	IV
Anguillidae	*Anguilla mossambica*	Longfin eel	Va
	Anguilla bengalensis	African mottled eel	Va
	Anguilla marmorata	Madagascar mottled eel	Va
Ariidae	*Galeichthyes feliceps*	Barbel	IIb
Atherinidae	*Atherina breviceps*	Cape silverside	Ib
Carangidae	*Lichia amia*	Leervis	IIa
	Trachurus capensis	Maasbanker	III
Centrarchidae	*Micropterus dolomieu*	Smallmouth bass	IV
	Micropterus salmoides	Largemouth bass	IV
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	IV
Clinidae	*Clinus superciliosus*	Super klipvis	Ib
Clupeidae	*Gilchristella aestuaria*	Estuarine round herring	Ia
Cyprinidae	*Cyprinus carpio*	Carp	IV
	Pseudobarbus afer	Eastern Cape redfin	IV
Elopidae	*Elops machnata*	King springer, ladyfish	IIa
Gobiidae	*Caffrogobius gilchristii*	Prison goby	Ib
	Glossogobius callidus	River goby	Ib
	Psammogobius knysnaensis	Knysna sandgoby	Ib
	Redigobius dewaali	Checked goby	Ia
Haemulidae	*Pomadasys commersonnii*	Spotted grunter	IIa
Hemiramphidae	*Hyporhamphus capensis*	Cape halfbeak	Ia
Monodactylidae	*Monodactylus falciformis*	Cape moony	IIa
Mugilidae	*Liza dumerili*	Groovy mullet	IIb
	Liza richardsonii	Harder	IIc
	Liza tricuspidens	Striped mullet	IIb
	Mugil cephalus	Flathead mullet	IIa
	Myxus capensis	Freshwater mullet	Vb
Poeciliidae	*Gambusia affinis*	Mosquito fish	IV
Pomatomidae	*Pomatomus saltatrix*	Elf	IIc
Sciaenidae	*Argyrosomus japonicus*	Dusky kob	IIa
Soleidae	*Heteromycterus capensis*	Cape sole	IIb

Family name	**Species name**	**Common name**	**Dependence**
	Solea bleekeri	Blackhand sole	IIb
Sparidae	*Lithognathus lithognathus*	White steenbras	IIa
	Rhabdosargus holubi	Cape Stumpnose	IIa
	Rhabdosargus sarba	Tropical stumpnose	IIa
	Sarpa salpa	Strepie	III
Syngnathidae	*Syngnathus temminckii*	Longsnout pipefish	Ib
Tetraodontidae	*Amblyrhynchotes honckenii*	Blaasop	III

APPENDIX H: DATA SUMMARY REPORT FOR BIRDS

H.1 AVAILABLE DATA

Several bird counts have been conducted in the Wilderness estuarine lake system in both summer and winter, although summer counts have been more frequent (**Table H.1**). The first published count carried out from 30 December 1978 to 1 January 1979 (Underhill and Cooper, 1984, *in litt*.) provides data for the system as a whole, broken down into its component lakes and estuary (**Table H.2**). Following this, Boshoff and colleagues undertook monthly counts of the lakes (not including the estuary) from 1980 to 1984. While the raw data are not available apart from counts of Reed Cormorant (**Table H.3**), summary data and analyses are provided in five published papers (Boshoff *et al*., 1991a,b,c; Boshoff and Piper 1992, 1993). These include total counts for each lake, and min, median and max counts of each species over the period. Data provided by Boshoff *et al*. (1991a,b,c) are in **Annexure H1**, and a further summary of these data is provided in **Table H.2**. Seasonality can be ascertained from graphs and text, but data summaries are not given on a seasonal basis.

Table H.1 Summary of all bird count data available for the Wilderness estuarine lake system

Reference	Underhill and Cooper 1984	Boshoff and Piper 1992	Russell *et al.* 2014 #		CWAC data^^	Anchor 2013^	Russell 2014	
Season	**Summer**	**Monthly**	**Summer**	**Winter**	**All**	**Summer**	**Summer**	
Year of count/s	**1978/9**	**1980-1984**	**1992-2010**	**1992-2010**	**1996-2009**	**Dec 2013**	**Jan 2014**	
Touw Estuary no. species		-	19	21		21	22	
Eilandvlei no. species		23*	30	30			19	
Langvlei no. species		35*	44	41			34	37
Rondevlei no. species		29*		38			21	
Total number of species	**49**		**49**	**44**	**73**	**33**	**46**	
Touw Estuary no. birds			77*	158*		157	84	
Eilandvlei no. birds		1170*	791*	1633*			971	
Langvlei no. birds		4378*	2624*	5945*			3405	
Rondevlei no. birds		1799*		2156*			1404	
Total number of birds	**13545**	**7347**^{1}	**3492***	**9892***			**5864**	

* mean values
$^{\#}$ only counting species with >10% occurrence across all lakes (including Swartvlei system)
$^{\wedge\wedge}$ only species list available
$^{\wedge}$ partial count only
^{1} excluding estuary

The next set of count data are the annual winter and summer CWAC[2] counts that started in 1992. The raw data for these counts are not on the CWAC website as they have been withheld by Ian Russell for completion of a PhD analysis, but summary data and analyses are published in Russell (2009) and Russell *et al*. (2014). These include overall average numbers of each species recorded in summer and winter counts from 1992 to 2010 (**Table H.2**). However, a number of species with low occurrences were not reported in the Russell *et al.* (2014) data. Only the January 2014 CWAC count data were supplied by SANParks (Ian Russell) for this study. In addition, a site visit was conducted by Anchor during December 2013, during which a count of the Touw Estuary was completed, and partial counts and observations were made of the Lakes.

Since CWAC data are summarised as means, and the earlier Boshoff data were summarised as median values, the two data sets are difficult to compare at the species level. Thus not having access to the raw data has unfortunately compromised the confidence rating for this study, as did the time allocation for a Rapid-level analysis. Enough data exist for a comprehensive analysis.

Table H.2 Numbers of species recorded on the estuary using Underhill and Cooper 1984, Russell *et al.* 2014, CWAC presence/absence data and the Russell 2014 surveys (non-passerine waterbirds, excluding vagrants)

Common name	**Underhill and Cooper 1984 Jan 1980**	**Boshoff *et al.* 1991a, b c. Average of annual medians for monthly counts 1980-84**			**Russell *et al.* 2014 (1992-2010)**		**Russell Jan 2014**
		Eilandvlei	**Langvlei**	**Rondevlei**	**S**	**W**	
Grebe, Great Crested	134	7	65	57	78	144	195
Grebe, Black-necked	1668	17	298	64	2	68	3
Grebe, Little	319	13	101	6	125	693	68
Cormorant, White-breasted	5	10	31	9	33	101	39
Cormorant, Cape	0	0	0	0	1	160	0
Cormorant, Reed	61	7	36	9	82	325	64
Darter, African	67	7	8	8	9	54	1
Heron, Grey	13	2	7	7	4	13	1
Heron, Black-headed	1				1	2	0
Heron, Purple	6	1	3	1	4	11	2
Egret, Little	34	2	20	7	16	15	20
Egret, Yellow-billed	0				1	2	1
Egret, Cattle	36				0	0	0
Heron, Squacco	0				0	0	0
Heron, Black	1				0	0	0
Bittern, Little	0				0	0	5

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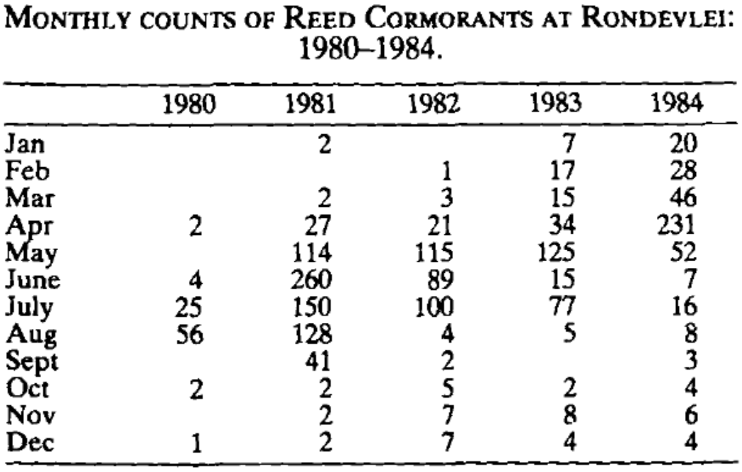
[2] CWAC data were obtained from the Animal Demography Unit, University of Cape Town

Common name	**Underhill and Cooper 1984 Jan 1980**	**Boshoff *et al.* 1991a, b c. Average of annual medians for monthly counts 1980-84**			**Russell *et al.* 2014 (1992-2010)**		**Russell Jan 2014**
		Eilandvlei	**Langvlei**	**Rondevlei**	**S**	**W**	
Night-Heron, Black-crowned	2				0	0	0
Hamerkop, Hamerkop	0				0	0	0
Ibis, African Sacred	0				0	0	12
Ibis, Glossy	0				6	5	14
Ibis, Hadeda	0				12	9	3
Spoonbill, African	0	0	3	0	2	40	15
Flamingo, Greater	0		0	6	0	0	0
Goose, Spur-winged	0	0	0	0	6	3	3
Goose, Egyptian	40	2	3	15	127	99	230
Shelduck, South African	2				0	0	0
Shoveler, Cape	552	10	191	24	351	270	328
Duck, African Black	2				0	0	0
Duck, Yellow-billed	1259	44	173	90	455	439	327
Teal, Red-billed	63	0	4	0	11	82	18
Teal, Cape	69	0	9	2	5	15	2
Teal, Hottentot	0	0	0	1	3	2	0
Duck, White-faced	0				0	0	0
Duck, Fulvous	0				0	0	0
Pochard, Southern	1214	9	219	93	68	148	104
Duck, Maccoa	218	0	69	3	4	83	1
Duck, White-backed	7	0	8	0	13	128	18
Fish-Eagle, African	4				4	5	3
Osprey, Osprey	2				0	0	1
Rail, African	0				0	0	0
Crake, Black	0				2	5	0
Swamphen, African Purple	7	2	6	2	7	11	7
Moorhen, Common	6	7	11		31	139	49
Coot, Red-knobbed	5000	737	2101	711	1887	6686	4201
Jacana, African	0				0	0	0
Turnstone, Ruddy	2				0	0	0
Plover, Common Ringed	35	0	0	0	0	0	3
Plover, White-fronted	0	0	0	4	0	0	0
Plover, Kittlitz's	16	0	5	4	4	4	1

Common name	**Underhill and Cooper 1984 Jan 1980**	**Boshoff *et al.* 1991a, b c. Average of annual medians for monthly counts 1980-84**			**Russell *et al.* 2014 (1992-2010)**		**Russell Jan 2014**
		Eilandvlei	**Langvlei**	**Rondevlei**	**S**	**W**	
Plover, Three-banded	0	2	1	1	1	5	3
Plover, Grey	4			1	0	0	0
Lapwing, Blacksmith	59	4	10	8	20	23	23
Snipe, African	35				0	0	0
Sandpiper, Curlew	1395	4	28	37	6	0	0
Stint, Little	393	0	3	1	0	0	0
Ruff, Ruff	427	4	64	16	34	0	1
Sandpiper, Common	2	0	0	0	1	0	1
Sandpiper, Marsh	19	0	3	0	5	0	0
Greenshank, Common	24	0	0	1	2	0	2
Sandpiper, Wood	40	0	3	0	2	0	0
Avocet, Pied	100	0	5	2	0	0	0
Stilt, Black-winged	120	0	5.4	2.4	19	33	31
Thick-knee, Water	0	1.6	21.6	12.4	4	7	8
Gull, Kelp	24				17	24	10
Gull, Grey-headed	0	45.4	3	4	0	0	7
Tern, Caspian	0				0	1	0
Tern, Common	65				9	11	14
Tern, White-winged	24	2.6	13.6	8.6	0	0	0
Tern, Whiskered	0	0.4	2.6	0	0	0	0
Kingfisher, Pied	14				6	7	2
Kingfisher, Giant	0	2.2	4.4	4.2	1	1	0
Kingfisher, Half-collared	0				1	1	2
Kingfisher, Malachite	0				4	7	12
Total	**13590**				**3482**	**9881**	**5855**

A total of 75 non-passerine waterbird species have been recorded within the Wilderness estuarine lake system (Russell *et al.*, 2014). A total of 47 species were counted in the Underhill and Cooper 1984 survey, a total of 47 in summer and 42 in winter from the Russell *et al.* (2014) study and a total of 44 from the most recent count in January 2014 (Russell, 2014). Species richness is lowest in the estuary, and among the lakes is highest at Langvlei, followed by Rondevlei and Eilandvlei.

Table H.3 Raw data on cormorants published by Boshoff et al. (1991)



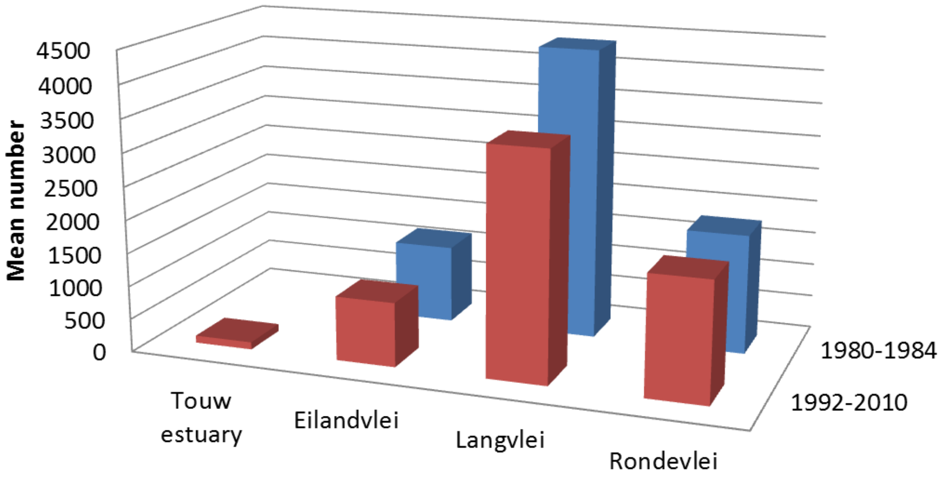
MONTHLY COUNTS OF REED CORMORANTS AT RONDEVLEI: 1980–1984.

	1980	1981	1982	1983	1984
Jan		2		7	20
Feb			1	17	28
Mar		2	3	15	46
Apr	2	27	21	34	231
May		114	115	125	52
June	4	260	89	15	7
July	25	150	100	77	16
Aug	56	128	4	5	8
Sept		41	2		3
Oct	2	2	5	2	4
Nov		2	7	8	6
Dec	1	2	7	4	4

H.2 SPECIES RICHNESS AND ABUNDANCE

A total of 75 non-passerine waterbird species have been recorded within the Wilderness estuarine lake system (Russell *et al.*, 2014). A total of 47 species were counted in the Underhill and Cooper 1984 survey, a total of 47 in summer and 42 in winter from the Russell *et al.* (2014) study and a total of 44 from the most recent count in January 2014 (Russell, 2014). Species richness is lowest in the estuary, and among the lakes is highest at Langvlei, followed by Rondevlei and Eilandvlei (**Table H.1**).

The overall abundance of birds was very much greater in the 1980 survey than the average numbers given for the subsequent counts, as well as the latest count, which was higher than the long term average for CWAC counts (**Table H.2**). However, the average numbers counted in the Boshoff and CWAC surveys were more comparable overall, with the latter being about 85% of the former, as well as being similar in distribution among the different lakes (**Figure H.1**).



	Touw estuary	Eilandvlei	Langvlei	Rondevlei
🟥 1992-2010	109	968	3405	1797
🟦 1980-1984		1170	4378	1799

Figure H.1 Comparison of mean abundance of birds in two sets of counts – the monthly counts of 1980-1984 and the twice yearly counts of 1992-2010

H.3 BIRD GROUPS AND COMMUNITY COMPOSITION

The community composition recorded in the Underhill and Cooper 1984 survey was significantly different to that recorded in subsequent counts (**Figures H.2** and **H.3**). In the earlier survey, there were much higher proportions of both piscivorous waterfowl and waders than in the later counts.

The avifauna of the Wilderness System is dominated by herbivorous waterfowl both in summer and winter (**Figure H.4**). Herbivorous waterfowl were dominated by Red-knobbed Coot which was by far the most common bird overall. In winter the bird community was also dominated by the herbivorous waterfowl group (72%). The numbers of piscivorous cormorants and herbivorous waterfowl were higher in winter than in summer.

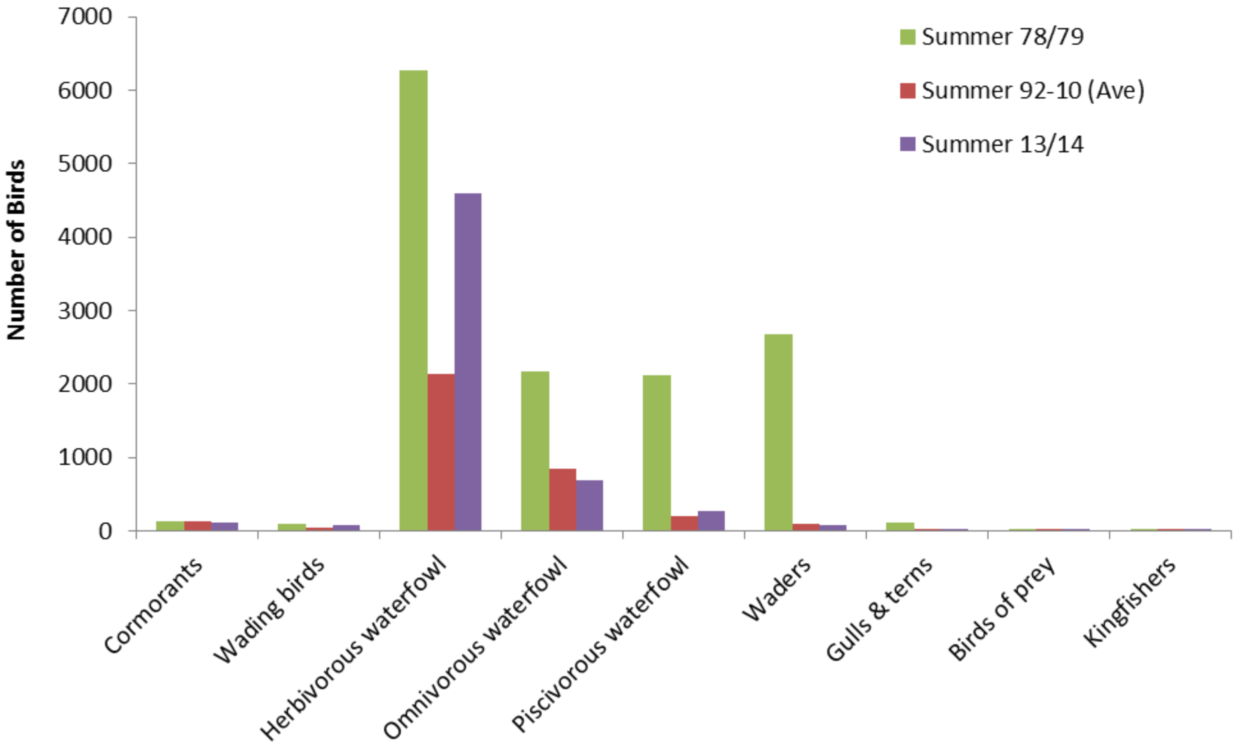


Figure H.2 **Counts of different groups of birds in summer in different counts. (Source: Underhill and Cooper, 1984; Russell *et al*. 2014; Russell, *in litt*)**

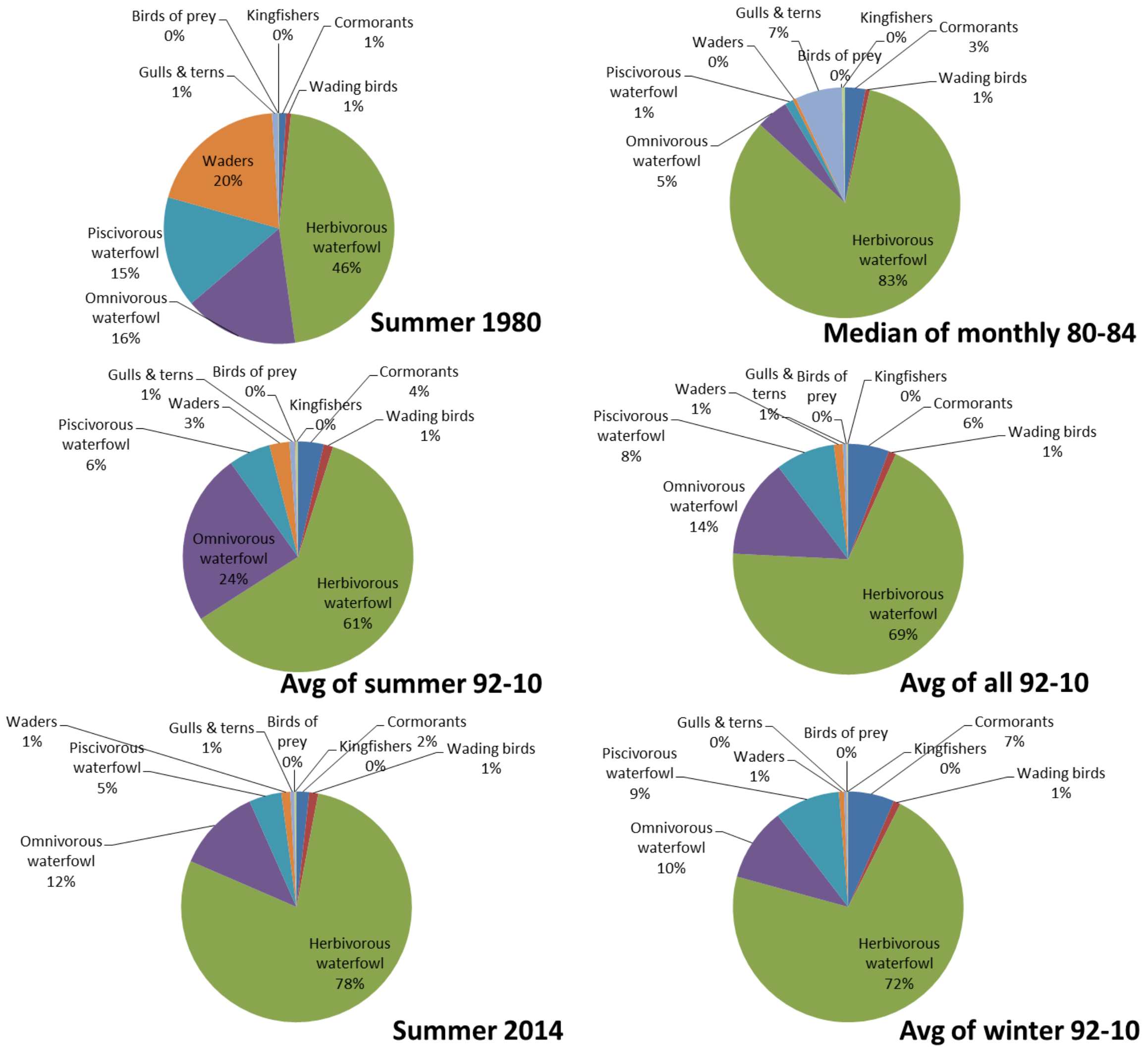


Figure H.3 Avifaunal composition recorded across the entire system in different counts or sets of counts

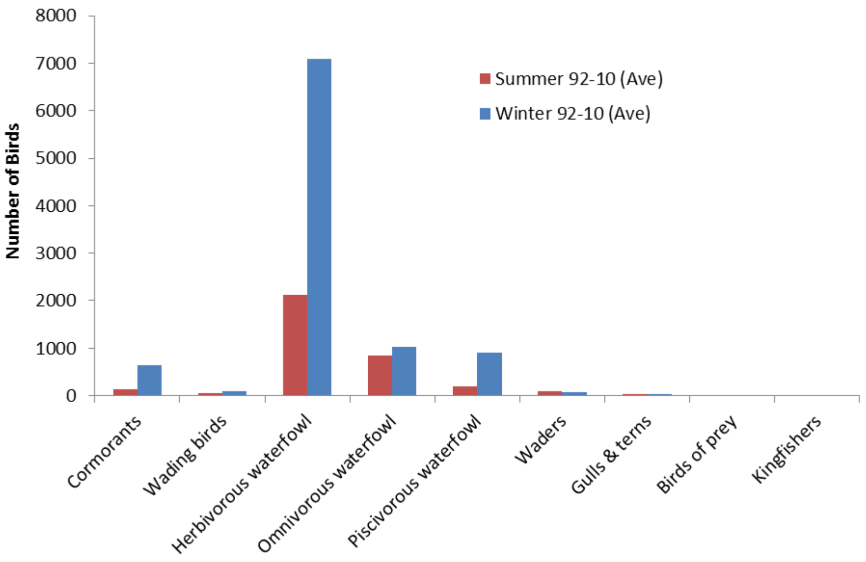


Figure H.4 Average counts of different groups of birds in summer and winter using data from 1992-2010 (Russell et al. 2014)

The different areas within the Wilderness estuarine lake system had different community compositions during the Dec/Jan 1978/9 and the January 2014 surveys in **Figure H.5**.

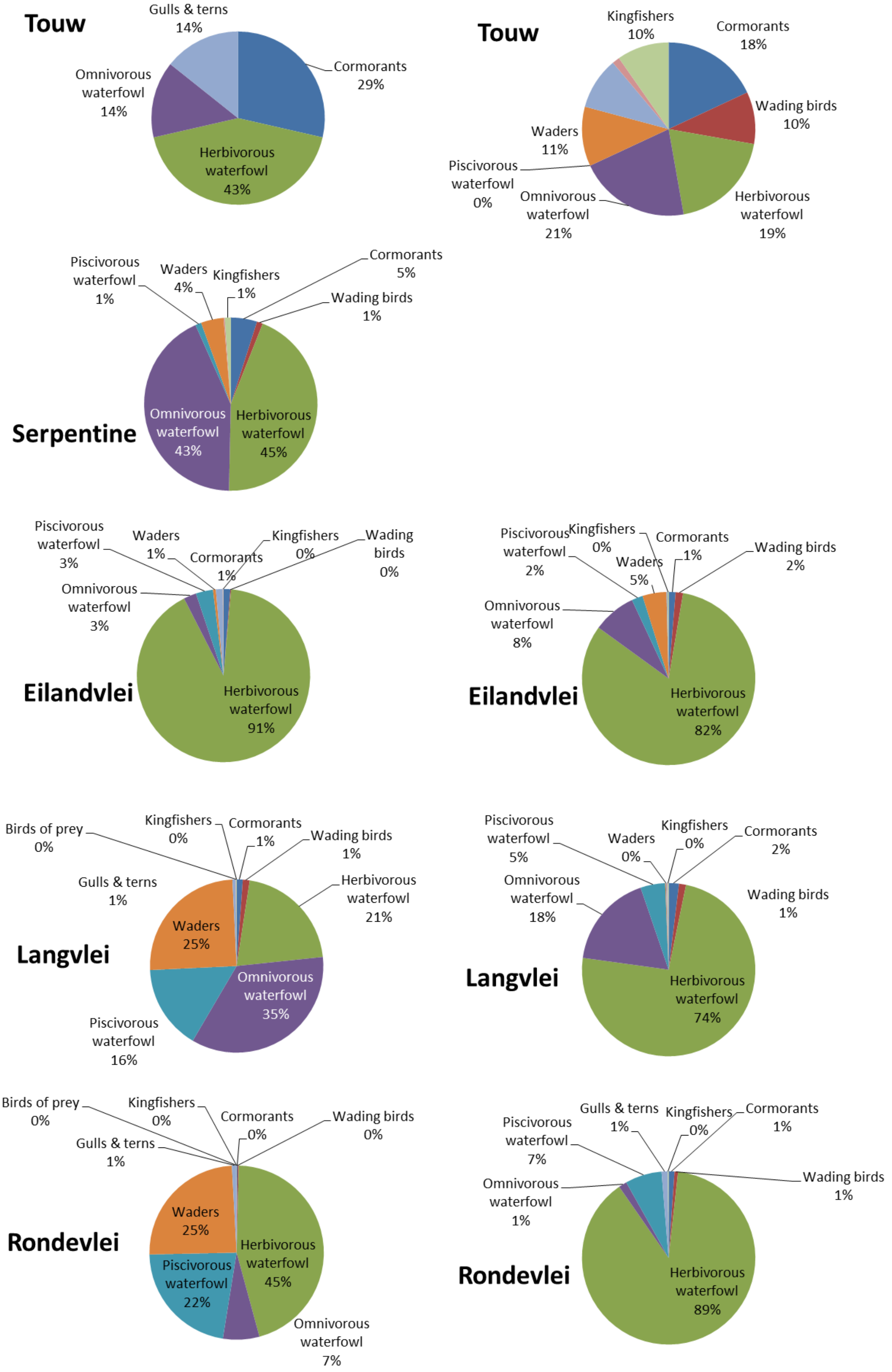


Figure H.5 **Community composition in different parts of the system recorded in 1978/9 (left) and January 2014 (right). Source: Underhill and Cooper 1984, Russell 2014, both unpublished data**

Note that the estuary was closed for the earlier survey and open at the time of the recent survey. Estuary composition is relatively diverse when numbers are high enough. The Serpentine had a relatively high diversity, though dominated by Yellow billed Duck and Redknobbed Coot. Elandvlei was dominated by herbivorous waterfowl (mainly coot) in both counts. The higher diversity in the more recent count is an artefact of the lower number of coots. Both Langvlei and Rondevlei had a very much higher diversity of birds in the earlier than in the recent count. Among the waterfowl at Langvlei, numbers were far more evenly distributed, with Yellowbilled Duck being more abundant than coot. Numbers of coot were much higher in the recent count, while those of other species were considerably lower or absent. Rondevlei was dominated by herbivorous waterfowl in both counts, but again diversity was far higher in the earlier count. The water levels leading up to the counts in the lakes are shown in **Figure H.6**. Water levels were not lower in the earlier counts as one might have expected, although the early counts in Langvlei and Rondevlei were preceded by a period of receding water levels. The differences in available habitat for waders are therefore likely to have been due to a lower extent of emergent macrophytes at the time of the earlier survey, with reedbeds extending much further into the vleis in the more recent counts.

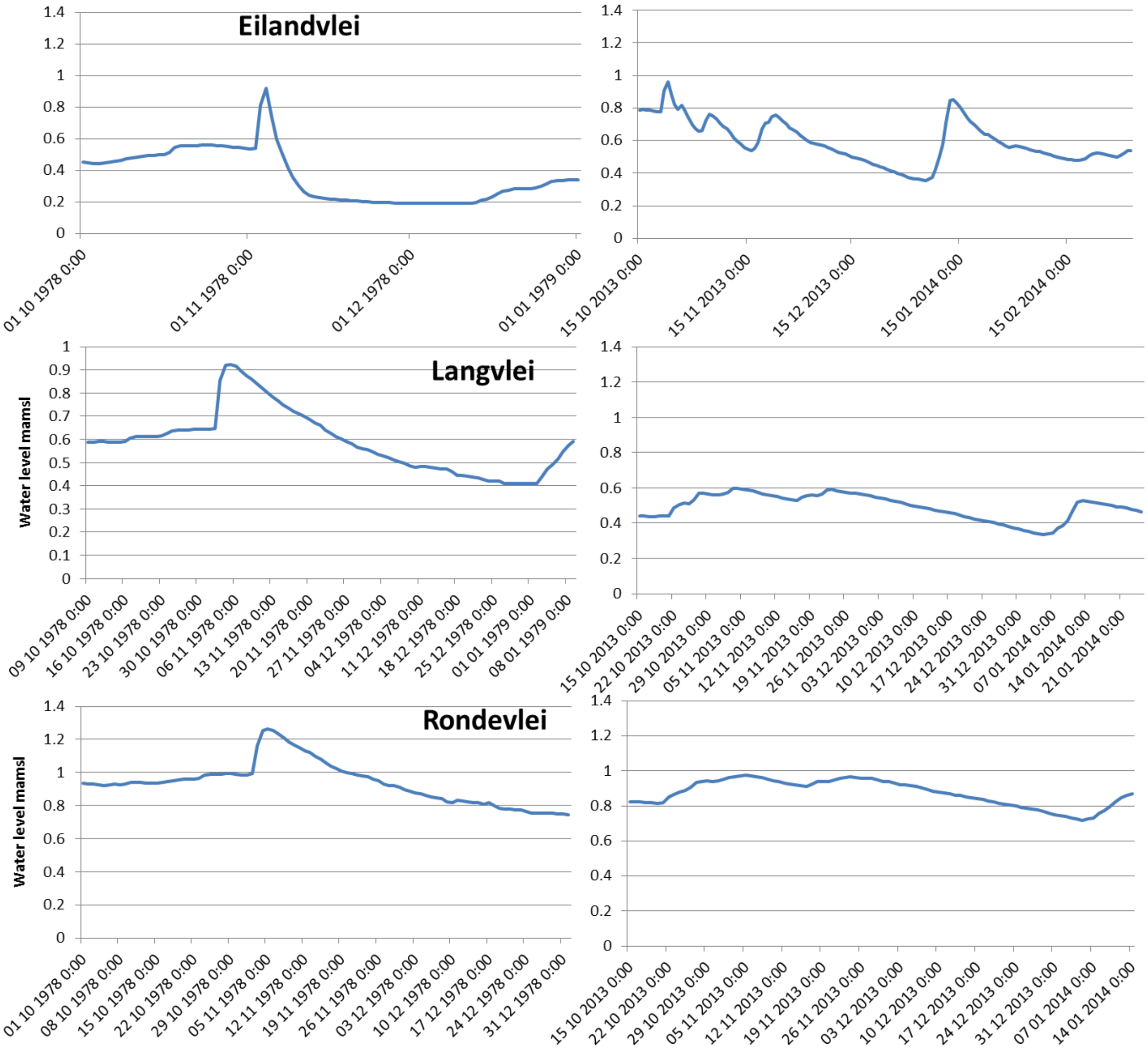


Figure H.6 Water level data for the two months prior to the counts in 1978/9 and 2014

Annexure H1 Data published by Boshoff *et al.* (1991a, b, c)

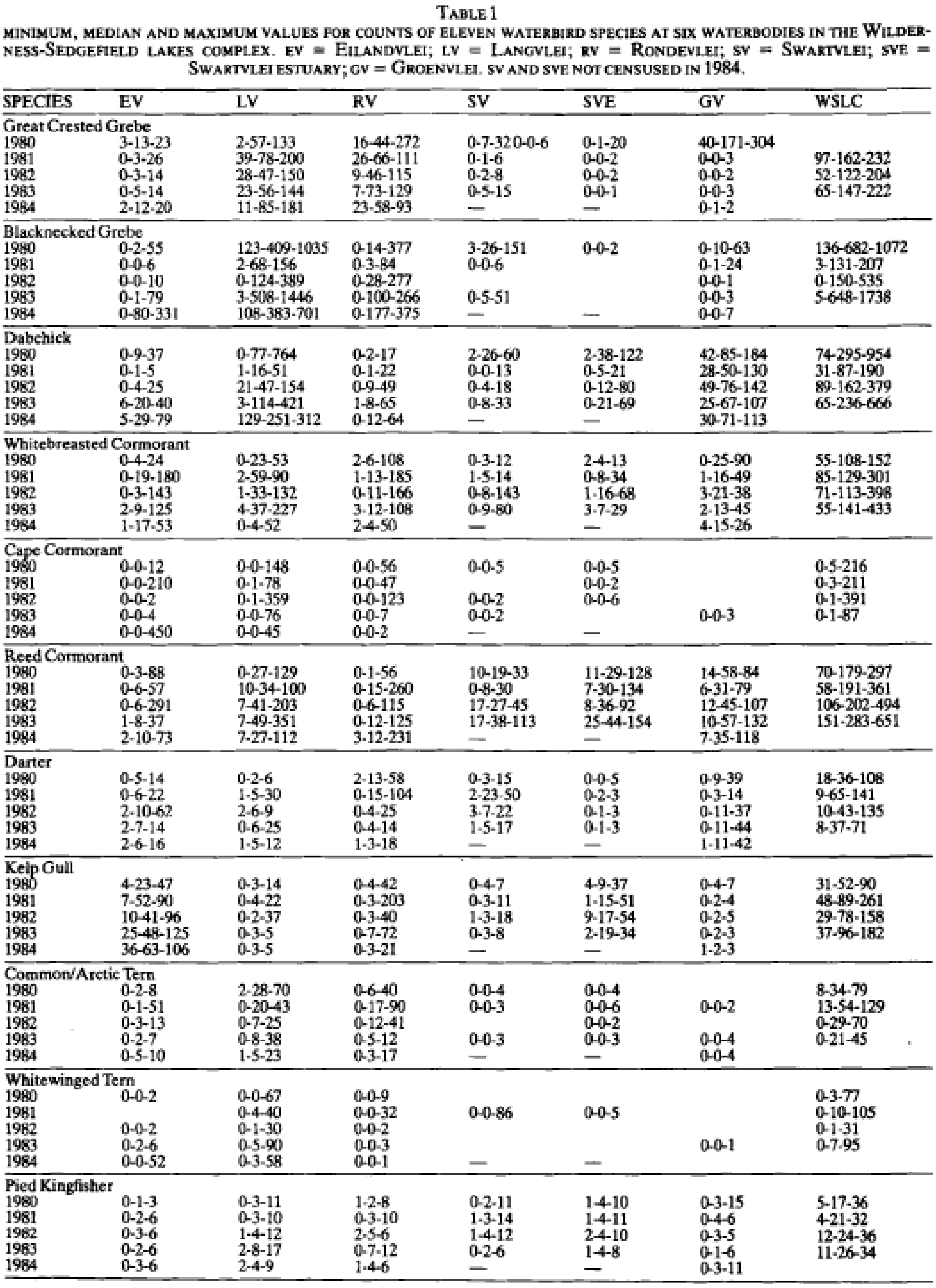


TABLE 1

MINIMUM, MEDIAN AND MAXIMUM VALUES FOR COUNTS OF ELEVEN WATERBIRD SPECIES AT SIX WATERBODIES IN THE WILDERNESS-SEDGEFIELD LAKES COMPLEX. EV = EILANDVLEI; LV = LANGVLEI; RV = RONDEVLEI; SV = SWARTVLEI; SVE = SWARTVLEI ESTUARY; GV = GROENVLEI. SV AND SVE NOT CENSUSED IN 1984.

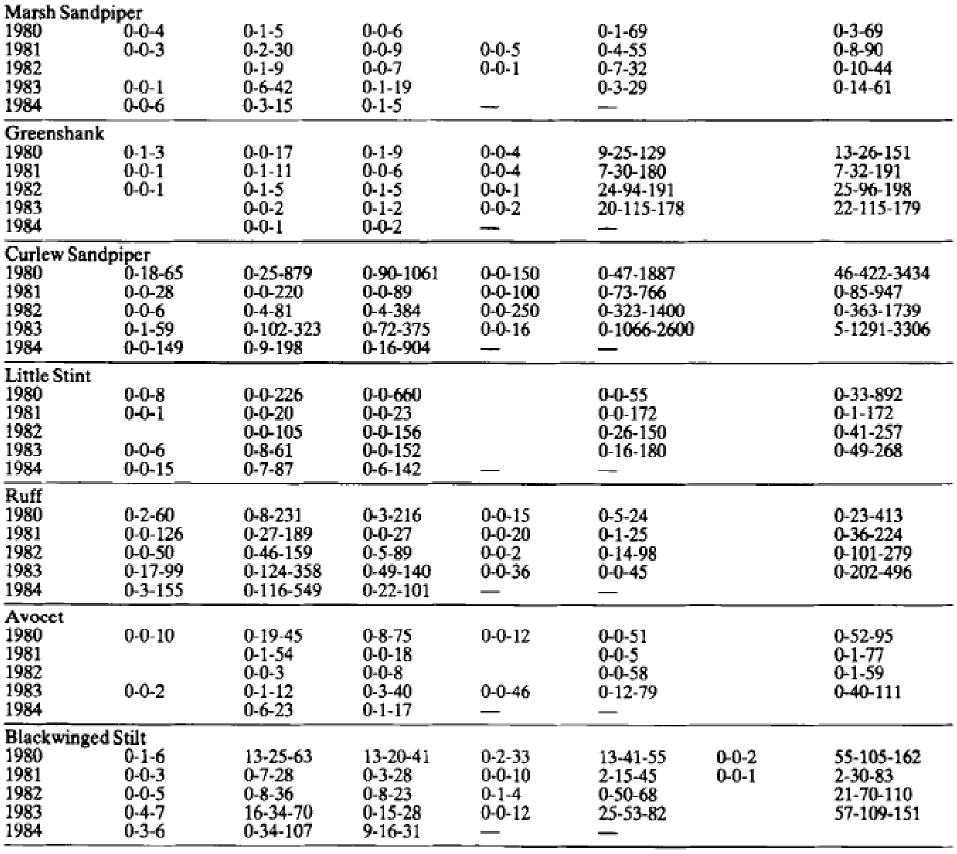
SPECIES	EV	LV	RV	SV	SVE	GV	WSLC
Great Crested Grebe							
1980	3-13-23	2-57-133	16-44-272	0-7-320-0-6	0-1-20	40-171-304	
1981	0-3-26	39-78-200	26-66-111	0-1-6	0-0-2	0-0-3	97-162-232
1982	0-3-14	28-47-150	9-46-115	0-2-8	0-0-2	0-0-2	52-122-204
1983	0-5-14	23-56-144	7-73-129	0-5-15	0-0-1	0-0-3	65-147-222
1984	2-12-20	11-85-181	23-58-93	—	—	0-1-2	
Blacknecked Grebe							
1980	0-2-55	123-409-1035	0-14-377	3-26-151	0-0-2	0-10-63	136-682-1072
1981	0-0-6	2-68-156	0-3-84	0-0-6		0-1-24	3-131-207
1982	0-0-10	0-124-389	0-28-277			0-0-1	0-150-535
1983	0-1-79	3-508-1446	0-100-266	0-5-51		0-0-3	5-648-1738
1984	0-80-331	108-383-701	0-177-375	—	—	0-0-7	
Dabchick							
1980	0-9-37	0-77-764	0-2-17	2-26-60	2-38-122	42-85-184	74-295-954
1981	0-1-5	1-16-51	0-1-22	0-0-13	0-5-21	28-50-130	31-87-190
1982	0-4-25	21-47-154	0-9-49	0-4-18	0-12-80	49-76-142	89-162-379
1983	6-20-40	3-114-421	1-8-65	0-8-33	0-21-69	25-67-107	65-236-666
1984	5-29-79	129-251-312	0-12-64	—	—	30-71-113	
Whitebreasted Cormorant							
1980	0-4-24	0-23-53	2-6-108	0-3-12	2-4-13	0-25-90	55-108-152
1981	0-19-180	2-59-90	1-13-185	1-5-14	0-8-34	1-16-49	85-129-301
1982	0-3-143	1-33-132	0-11-166	0-8-143	1-16-68	3-21-38	71-113-398
1983	2-9-125	4-37-227	3-12-108	0-9-80	3-7-29	2-13-45	55-141-433
1984	1-17-53	0-4-52	2-4-50	—	—	4-15-26	
Cape Cormorant							
1980	0-0-12	0-0-148	0-0-56	0-0-5	0-0-5		0-5-216
1981	0-0-210	0-1-78	0-0-47		0-0-2		0-3-211
1982	0-0-2	0-1-359	0-0-123	0-0-2	0-0-6		0-1-391
1983	0-0-4	0-0-76	0-0-7	0-0-2		0-0-3	0-1-87
1984	0-0-450	0-0-45	0-0-2	—	—		
Reed Cormorant							
1980	0-3-88	0-27-129	0-1-56	10-19-33	11-29-128	14-58-84	70-179-297
1981	0-6-57	10-34-100	0-15-260	0-8-30	7-30-134	6-31-79	58-191-361
1982	0-6-291	7-41-203	0-6-115	17-27-45	8-36-92	12-45-107	106-202-494
1983	1-8-37	7-49-351	0-12-125	17-38-113	25-44-154	10-57-132	151-283-651
1984	2-10-73	7-27-112	3-12-231	—	—	7-35-118	
Darter							
1980	0-5-14	0-2-6	2-13-58	0-3-15	0-0-5	0-9-39	18-36-108
1981	0-6-22	1-5-30	0-15-104	2-23-50	0-2-3	0-3-14	9-65-141
1982	2-10-62	2-6-9	0-4-25	3-7-22	0-1-3	0-11-37	10-43-135
1983	2-7-14	0-6-25	0-4-14	1-5-17	0-1-3	0-11-44	8-37-71
1984	2-6-16	1-5-12	1-3-18	—	—	1-11-42	
Kelp Gull							
1980	4-23-47	0-3-14	0-4-42	0-4-7	4-9-37	0-4-7	31-52-90
1981	7-52-90	0-4-22	0-3-203	0-3-11	1-15-51	0-2-4	48-89-261
1982	10-41-96	0-2-37	0-3-40	1-3-18	9-17-54	0-2-5	29-78-158
1983	25-48-125	0-3-5	0-7-72	0-3-8	2-19-34	0-2-3	37-96-182
1984	36-63-106	0-3-5	0-3-21	—	—	1-2-3	
Common/Arctic Tern							
1980	0-2-8	2-28-70	0-6-40	0-0-4	0-0-4		8-34-79
1981	0-1-51	0-20-43	0-17-90	0-0-3	0-0-6	0-0-2	13-54-129
1982	0-3-13	0-7-25	0-12-41		0-0-2		0-29-70
1983	0-2-7	0-8-38	0-5-12	0-0-3	0-0-3	0-0-4	0-21-45
1984	0-5-10	1-5-23	0-3-17	—	—	0-0-4	
Whitewinged Tern							
1980	0-0-2	0-0-67	0-0-9				0-3-77
1981		0-4-40	0-0-32	0-0-86	0-0-5		0-10-105
1982	0-0-2	0-1-30	0-0-2				0-1-31
1983	0-2-6	0-5-90	0-0-3			0-0-1	0-7-95
1984	0-0-52	0-3-58	0-0-1	—	—		
Pied Kingfisher							
1980	0-1-3	0-3-11	1-2-8	0-2-11	1-4-10	0-3-15	5-17-36
1981	0-2-6	0-3-10	0-3-10	1-3-14	1-4-11	0-4-6	4-21-32
1982	0-3-6	1-4-12	2-5-6	1-4-12	2-4-10	0-3-5	12-24-36
1983	0-2-6	2-8-17	0-7-12	0-2-6	1-4-8	0-1-6	11-26-34
1984	0-3-6	2-4-9	1-4-6	—	—	0-3-11	

Table 1

Minimum, median and maximum values for counts of twenty waterbird species at six waterbodies in the Wilderness-Sedgefield lakes complex. EV = Eilandvlei; LV = Langvlei; RV = Rondevlei; SV = Swartvlei; SVE = Swartvlei estuary; GV = Groenvlei. SV and SVE not censused in 1984.

SPECIES	EV	LV	RV	SV	SVE	GV	WSLC
Grey Heron							
1980	0-1-5	1-6-19	6-10-17	0-1-6	0-4-10		8-24-36
1981	0-1-5	2-6-9	2-11-22	0-1-4	1-7-10		12-26-37
1982	0-1-4	3-6-27	0-5-10	0-1-3	3-9-13	0-0-1	11-23-33
1983	1-3-7	3-10-17	0-4-12	1-1-8	6-9-13		16-28-44
1984	0-2-5	3-7-21	0-4-8	—	—	0-0-1	
Purple Heron							
1980	0-0-5	0-1-9	0-0-2	0-0-2	0-0-2	0-0-6	0-3-11
1981	0-0-1	0-1-6	0-0-8	0-0-1	0-0-4	0-0-4	1-5-12
1982	0-1-5	0-4-13	0-0-7	0-0-2	0-0-1	0-1-5	2-8-19
1983	0-1-11	0-6-16	0-2-4	0-0-1		0-1-4	1-13-20
1984	0-1-2	0-5-12	0-1-3	—	—	0-0-5	
Little Egret							
1980	0-1-5	3-46-84	0-5-22	0-0-5	2-7-21		19-64-117
1981	0-1-3	0-8-22	1-8-49	0-2-5	0-4-14		6-31-61
1982	0-2-5	0-19-34	1-9-24	0-2-3	4-11-50	0-0-3	12-44-88
1983	0-1-6	2-19-53	0-6-73	0-1-4	2-10-28	0-0-3	5-47-122
1984	0-3-6	0-7-18	0-5-27	—	—	0-0-4	
African Spoonbill							
1980	0-0-8	0-0-28	0-0-5		0-0-7		0-1-32
1981		0-0-22	0-0-10	0-0-9		0-0-1	0-2-26
1982	0-0-3	0-1-41	0-0-6	0-0-8	0-0-10		0-2-48
1983	0-0-5	0-10-72	0-1-13	0-0-6	0-0-15		0-18-81
1984	0-0-15	0-3-16	0-0-43	—	—	0-0-1	
Greater Flamingo							
1980		0-0-11	0-0-5	0-0-28			0-0-28
1981			0-0-10				0-0-10
1982		0-0-23	0-0-3	0-0-2			0-0-23
1983		0-0-15	0-0-25	0-0-56	0-0-15		0-3-56
1984		0-0-280	0-32-138	—	—		
Ringed Plover							
1980	0-0-10	0-0-8	0-0-145		0-0-50		0-0-211
1981		0-0-11			0-0-80		0-5-80
1982		0-0-12	0-0-4		0-10-120		0-18-130
1983	0-0-1	0-0-6	0-0-14		0-28-110		0-37-127
1984	0-0-3	0-1-11	0-0-27	—	—		
Whitefronted Plover							
1980	0-0-5	0-0-22	0-1-22		0-0-1		0-1-25
1981	0-0-2				0-0-12		0-0-14
1982	0-0-3	0-0-1	0-0-4		0-4-27		0-8-27
1983	0-0-3	0-0-2			0-0-15		0-2-15
1984	0-0-4		0-0-1	—	—		
Kittlitz's Plover							
1980	0-0-3	0-4-37	0-10-24		0-1-17		0-24-52
1981		0-0-37	0-0-1		0-1-83		0-3-88
1982	0-0-3	0-3-14	0-1-38	0-0-1	0-4-81		0-27-85
1983	0-0-11	0-9-13	0-3-26		0-3-27		2-19-47
1984	0-0-4	0-7-17	0-6-13	—	—		
Threebanded Plover							
1980	0-4-35	0-0-12	0-0-52	0-0-1	0-2-35	0-0-1	0-10-122
1981	0-0-6	0-0-3		0-0-1	0-1-9		0-2-9
1982	0-0-1	0-1-11	0-0-14	0-0-2	0-3-26		0-6-33
1983	0-2-9	0-3-24	0-1-49		0-3-46		0-11-108
1984	0-2-7	0-3-20	0-1-55	—	—	0-0-1	
Grey Plover							
1980			0-0-2		0-0-15		0-0-17
1981					0-0-2		0-0-2
1982			0-0-4		0-0-35		0-0-39
1983			0-0-9		0-10-21		0-10-28
1984				—	—		
Blacksmith Plover							
1980	0-5-10	3-6-21	3-10-23	0-0-10	6-16-25	0-0-4	20-36-65
1981	0-5-9	6-11-23	0-5-27	0-2-14	4-13-22	0-0-1	23-32-76
1982	0-2-14	2-10-14	0-6-23	0-0-2	8-12-16		16-29-58
1983	0-4-6	4-12-24	1-8-16	0-2-24	4-9-26	0-0-2	21-37-61
1984	1-4-22	6-10-19	3-10-26	—	—	0-2-2	
Common Sandpiper							
1980	0-0-3	0-0-7		0-0-2	0-0-23		0-1-29
1981	0-0-1	0-0-2	0-0-1	0-0-1	0-1-9		0-2-11
1982	0-0-2	0-0-2	0-1-2	0-0-1	0-3-10		0-4-14
1983		0-0-3	0-0-2	0-0-2	0-2-10		0-3-11
1984		0-0-1		—	—		
Wood Sandpiper							
1980	0-0-11	0-1-8	0-0-2	0-0-3	0-1-20		0-1-35
1981	0-0-3	0-2-14	0-0-5		0-1-5		0-5-20
1982	0-0-2	0-2-10	0-1-6		0-1-7	0-0-1	0-4-20
1983	0-1-5	0-4-42	0-0-1	0-0-2	0-0-3		0-6-49
1984	0-1-4	0-5-24	0-0-2	—	—		

TABLE 1 (CONT.)



Marsh Sandpiper							
1980	0-0-4	0-1-5	0-0-6		0-1-69		0-3-69
1981	0-0-3	0-2-30	0-0-9	0-0-5	0-4-55		0-8-90
1982		0-1-9	0-0-7	0-0-1	0-7-32		0-10-44
1983	0-0-1	0-6-42	0-1-19		0-3-29		0-14-61
1984	0-0-6	0-3-15	0-1-5	—	—		
Greenshank							
1980	0-1-3	0-0-17	0-1-9	0-0-4	9-25-129		13-26-151
1981	0-0-1	0-1-11	0-0-6	0-0-4	7-30-180		7-32-191
1982	0-0-1	0-1-5	0-1-5	0-0-1	24-94-191		25-96-198
1983		0-0-2	0-1-2	0-0-2	20-115-178		22-115-179
1984		0-0-1	0-0-2	—	—		
Curlew Sandpiper							
1980	0-18-65	0-25-879	0-90-1061	0-0-150	0-47-1887		46-422-3434
1981	0-0-28	0-0-220	0-0-89	0-0-100	0-73-766		0-85-947
1982	0-0-6	0-4-81	0-4-384	0-0-250	0-323-1400		0-363-1739
1983	0-1-59	0-102-323	0-72-375	0-0-16	0-1066-2600		5-1291-3306
1984	0-0-149	0-9-198	0-16-904	—	—		
Little Stint							
1980	0-0-8	0-0-226	0-0-660		0-0-55		0-33-892
1981	0-0-1	0-0-20	0-0-23		0-0-172		0-1-172
1982		0-0-105	0-0-156		0-26-150		0-41-257
1983	0-0-6	0-8-61	0-0-152		0-16-180		0-49-268
1984	0-0-15	0-7-87	0-6-142	—	—		
Ruff							
1980	0-2-60	0-8-231	0-3-216	0-0-15	0-5-24		0-23-413
1981	0-0-126	0-27-189	0-0-27	0-0-20	0-1-25		0-36-224
1982	0-0-50	0-46-159	0-5-89	0-0-2	0-14-98		0-101-279
1983	0-17-99	0-124-358	0-49-140	0-0-36	0-0-45		0-202-496
1984	0-3-155	0-116-549	0-22-101	—	—		
Avocet							
1980	0-0-10	0-19-45	0-8-75	0-0-12	0-0-51		0-52-95
1981		0-1-54	0-0-18		0-0-5		0-1-77
1982		0-0-3	0-0-8		0-0-58		0-1-59
1983	0-0-2	0-1-12	0-3-40	0-0-46	0-12-79		0-40-111
1984		0-6-23	0-1-17	—	—		
Blackwinged Stilt							
1980	0-1-6	13-25-63	13-20-41	0-2-33	13-41-55	0-0-2	55-105-162
1981	0-0-3	0-7-28	0-3-28	0-0-10	2-15-45	0-0-1	2-30-83
1982	0-0-5	0-8-36	0-8-23	0-1-4	0-50-68		21-70-110
1983	0-4-7	16-34-70	0-15-28	0-0-12	25-53-82		57-109-151
1984	0-3-6	0-34-107	9-16-31	—	—		

TABLE 1

MINIMUM, MEDIAN AND MAXIMUM VALUES FOR COUNTS OF FOURTEEN WATERBIRD SPECIES AT SIX WATERBODIES IN THE WILDERNESS-SEDGEFIELD LAKES COMPLEX. EV = EILANDVLEI; LV = LANGVLEI; RV = RONDEVLEI; SV = SWARTVLEI; SVE = SWARTVLEI ESTUARY; GV = GROENVLEI. SV AND SVE NOT CENSUSED IN 1984.

SPECIES	EV	LV	RV	SV	SVE	GV	WSLC
Spurwinged Goose							
1980	0-0-15	0-0-15		0-0-18		0-0-15	0-0-32
1981		0-0-19		0-0-35		0-0-18	0-1-35
1982	0-0-2	0-0-1	0-0-25	0-0-44	0-0-1	0-0-6	0-2-45
1983	0-0-1	0-0-11	0-0-6	0-0-5		0-1-29	0-3-29
1984		0-0-4	0-0-1	—	—	0-0-61	
Egyptian Goose							
1980	0-2-48	0-0-10	4-12-108	0-0-6	0-0-2	0-0-2	8-22-113
1981	0-2-6	0-4-28	2-10-50	0-1-11	0-0-1	0-0-7	8-21-60
1982	0-0-5	0-2-18	1-14-53	0-12-75	0-0-9	0-0-2	16-27-115
1983	0-4-12	0-5-19	0-21-58	0-3-10	0-0-4	0-0-4	11-32-63
1984	0-3-12	0-5-31	2-17-66	—	—	0-0-6	
Yellowbilled Duck							
1980	9-40-191	43-217-796	17-65-125	7-26-142	11-65-227	3-18-35	159-410-1294
1981	4-20-62	43-70-155	6-16-234	0-13-87	2-36-387	0-10-39	106-187-659
1982	0-25-52	55-112-413	11-42-266	2-18-109	22-86-283	0-6-33	134-305-934
1983	12-64-175	55-155-722	16-69-470	12-38-123	4-59-258	1-9-20	133-362-1555
1984	44-70-193	95-313-700	64-257-660	—	—	2-8-27	
Cape Teal							
1980	0-0-2	2-11-36	0-4-25	0-0-2	0-1-4		7-19-39
1981	0-0-1	0-6-14	0-0-10		0-1-9		0-10-24
1982		2-8-28	0-1-11	0-0-2	0-3-5	0-0-2	2-9-39
1983		0-9-43	0-4-14	0-0-2	0-0-7		2-16-51
1984	0-0-2	3-9-41	0-2-13	—	—		
Hottentot Teal							
1982		0-0-2				0-0-3	0-0-3
1983		0-0-2				0-0-6	0-0-8
1984	0-0-5	0-0-7	0-1-13	—	—	0-0-4	
Redbilled Teal							
1980	0-0-1	0-10-39	0-1-5	0-0-3		0-0-1	0-11-44
1981	0-0-2	0-1-14	0-0-2			0-0-1	0-2-14
1982	0-0-8	0-2-7	0-0-6				0-3-13
1983	0-0-12	0-1-26	0-0-9	0-0-2	0-0-3	0-0-3	0-4-37
1984	0-0-5	0-7-31	0-0-4	—	—	0-0-1	
Cape Shoveller							
1980	0-3-77	59-195-470	0-30-157	0-0-13	0-20-151	0-1-10	188-320-642
1981	0-3-12	7-96-231	0-5-199	0-1-13	0-4-47	0-0-6	7-125-435
1982	0-5-18	4-54-494	0-7-153	0-1-24	0-12-40	0-0-5	4-95-703
1983	0-12-80	76-258-798	2-12-193	0-1-20	0-3-32	0-0-4	99-290-1011
1984	5-27-61	213-354-490	10-65-318	—	—	0-0-2	
Southern Pochard							
1980	0-3-26	3-317-1233	0-136-1650	0-3-1485	0-0-19	0-6-1093	11-1257-2795
1981	0-1-82	0-154-1395	0-19-741	0-0-17	0-0-5	0-4-664	1-356-2201
1982	0-4-92	7-151-994	0-153-1396	0-0-8		0-5-578	7-765-2174
1983	0-29-212	29-382-1064	0-114-1161	0-0-23		0-5-178	42-868-1799
1984	0-8-20	0-91-583	0-43-339	—	—	0-1-30	
Maccoa Duck							
1980		0-37-140	0-1-36			0-54-913	38-143-915
1981		0-44-213	0-2-17			0-9-41	6-63-240
1982		12-54-263	0-7-20			0-8-63	19-61-326
1983	0-0-2	0-95-851	0-4-34			0-1-4	0-107-853
1984	0-0-1	13-116-409	0-1-9	—	—	0-0-2	
Whitebacked Duck							
1980	0-0-2	0-0-5		0-0-1		0-5-45	0-5-45
1981		0-1-2	0-0-1				0-1-2
1982		0-1-8	0-0-2				0-1-8
1983	0-0-2	1-15-89	0-0-2			0-0-6	1-18-93
1984	0-0-3	0-25-77		—	—	0-0-2	
Mute Swan							
1980			0-0-1	0-0-1	0-0-2	7-12-22	7-14-23
1981		0-0-2		0-0-1	0-0-2	0-4-10	1-5-10
1982	0-0-1	0-0-1		0-0-1		0-0-3	0-1-4
Purple Gallinule							
1980	0-4-7	2-4-19	1-3-12	0-3-10		0-1-3	9-18-30
1981	0-1-4	2-5-13	1-3-17	0-1-3		0-0-2	4-11-26
1982	0-1-3	1-5-11	0-0-2	0-1-7		0-0-2	3-9-18
1983	0-1-9	3-6-18	0-1-3	0-2-6		0-0-2	3-12-30
1984	1-3-7	1-8-19	0-2-5	—	—	0-1-7	
Moorhen							
1980	0-6-13	0-5-14	0-10-18	0-0-2		0-2-5	3-19-47
1981	0-0-2	0-3-10	0-1-5			0-0-1	0-5-14
1982	0-2-7	1-6-30	0-1-3	0-0-1	0-0-2	0-1-5	2-13-33
1983	1-7-20	3-16-86	0-1-6	0-0-3		0-1-13	4-30-98
1984	3-18-40	9-23-67	0-1-10	—	—	0-1-8	
Redknobbed Coot							
1980	188-460-2037	40-52-1551	9-29-103	420-970-3057	489-767-1673	465-965-2412	2628-4760-6688
1981	215-373-876	416-1949-3307	37-116-410	11-64-709	265-557-873	124-300-525	1794-3516-5118
1982	301-550-754	716-1631-6020	127-618-1413	263-765-2489	13-381-890	109-453-605	2733-4508-9730
1983	505-966-1380	1713-3029-7237	487-1478-3316	1720-3983-8255	1-239-627	174-745-1690	6423-10506-18698
1984	557-1334-2043	2997-3843-6327	542-1316-2360	—	—	206-606-860	

APPENDIX I: COMMENTS AND RESPONSE REGISTER

Section	Report Statement	Comments	Addressed in Report?	Author Comment
Comments: Dr Andrew Gordon (DWS) dated 12 May 2015				
8.2	EcoSpecs	No EWRs and Ecospecs have been proposed for alternate Ecological Category scenarios	No	In terms of the Estuary methods (DWAF, 2008) and ToR for this preliminary Reserve study, EcoSpecs will only be provided for REC
8.2	EcoSpecs	Phrase "Resource Quality Objective" is used to describe what I think are actually Ecospecs	Yes	RQOs changed to EcoSpecs throughout report
8.3	Monitoring programme	Recommended monitoring programmes for the estuaries are beyond the current capabilities of the DWS/CMA. Is it possible to suggest a monitoring plan that is phased in over a number of years so that the managing agency has a chance to build capacity	Yes, mostly	Priority components in the monitoring programme has been identified. Also the monitoring was split between baseline surveys and long-term monitoring.
8.2	EcoSpecs: Fish	EcoSpecs for fish need to be more explicit	Yes	Uncertainly in EcoSpecs for fish was changed (see Section 8.2)
Comments: Dr Angus Paterson (external reviewer, SAIAB) dated May 2015				
Entire report	Entire report	Editorial corrections pointed out in his report	Yes	Editorial corrections were made through out report
9	References	Referencing in the report is not comprehensive. In some instances references in main report are listed in Appendices	Yes	References were check and consolidated (i.e. removed from individual Appendices) in the Reference section (see Section 9)
4 and 7	Colour coding of Abiotic States in Tables and Graphs	A colour legend should be included with each of the figures in these sections for the various abiotic state	Yes, mostly	To include a legend in each of the graphs and figures would result in major repetition. The colour legend is first described in Table 3.2. Therefore in the legend of each table and figure, the reader is referred to Table 3.2 (see Sections 4.1 and 7.1).

Section	Report Statement	Comments	Addressed in Report?	Author Comment
1.1	Introduction	The introduction to all the reports should include more detail on the rationale of the RDM analysis level applied to that system.	Yes, this was been included	This has been included (see Section 1.1, paragraph 2). The sections referred to in the Inception report provides the level of EWR studies for those estuaries not included in this study)
1.4	Assumptions and Limitations	The assumptions and limitations of each study must be clearly outlined and should be linked to the Data Availability Tables. Specifically any data requirement that is not met in the Data Availability Tables but is prescribed as being required in the 2008 Methods, must be discussed even if it is to indicate that an omission will have negligible bearing on the confidence or outcome of the Reserve	Yes	The Assumptions and Limitation sections has been updated accordingly (see Section 1.4)
1.4	Use of study data	The reports must include a more comprehensive guideline on how the different reports should be used by DWS. These guidelines are available in the 2008 methods but should be included in each report and customised to that particular system.	Yes	The Assumptions and Limitation sections has been updated accordingly (see Section 1.4, last bullet)
2.2	Human activities affecting estuary	This section in all the reports is not comprehensively covered, yet in many systems these non-flow drivers are very important	Yes, mostly	Where possible and information was readily available these tables were amended. Care was specifically taken to make sure that the important pressures that impact in a particular system were included (see Section 2.2)
5.3	Confidence	Low confidences – It is suggested that in Sections which end up having a low or Very Low confidence, the low confidence be explained in the narrative on that section and/or specifically discussed . If it is data that was limiting or inconclusive this then needs to be linked to the limitations and assumptions section as per comment 5.6 above.	Yes, mostly	Components with low data availability were highlighted in Section 5.3 on confidence. Section 1.2 also explains the different levels of confidence (including low and very low confidence

Section	Report Statement	Comments	Addressed in Report?	Author Comment
4 and 7	Water quality tables	The Water Quality tables used in the Reports e.g. Gouritz 4.12; 4.13 and 7.18 do not have a colour legend or colour explanation	No	Unlike for abiotic states the colour coding in the WQ tables do not have any explicit meaning other than to alert the reader to changes in concentration, mostly arbitrary.
8.3	Monitoring programme	The resource monitoring programmes should be divided into two discreet sections namely Baseline surveys and Long term compliance monitoring. In terms of long term monitoring a priority system should be included	Yes	The monitoring was split into baseline survey and long-term programmes. Priorities were also defined (see Tables 8.2 and 8.3)
Appendices A-H	Data availability for all Specialist studies	The Specialist reports vary in the manner in which Available information and Data Requirements are reported on. It is important that the reports clearly outline: a) data required for the level of Reserve being undertaken and b) the availability of the prescribed data and if it will be collected in this study. Key missing data should be indicated in Limitations and Assumptions section of the Report.	Yes, mostly	Rapid level assessments do not have data limitation, but avaialbel data sources was discussedin the Specialist summaries
Appendices A-H	Station numbering	Stationing numbering should be distance from mouth as per methods	Yes, mostly	As far as possible distance from mouth was provided.
1.4	Assumptions and limitations	Management of this system has been problematic in the past when trying to balance ecological versus social demands. It is advised that this section is further unpacked with respect to the low confidence in the hydrology, breaching levels and mouth closure. The rationale for undertaking a reserve at a rapid level for this system also needs to be clearly articulated	Yes	Bullet was added to Assumption and limitation list (see Section 1.4)
Table 3.2	Areas of zones	Why is the area of the Serpentine still unclear?	Yes	Corrected text

Section	Report Statement	Comments	Addressed in Report?	Author Comment
Table 4.7 & 4.8	Physical habitat	Bullet numbering needs checking.	Yes	Corrected
6.1	Estuarine importance	Check wording around the Estuary importance score in relation to Table 6.3.	Yes	Text amended
6.2	REC	Why are recommendations contained in this section as they are then repeated in Section 8?	Yes	Amended, recommendation now only in Section 8
Table 7.3	Floods	Artefact of Model: This needs to be explained to the reader. Does this have any material implication?	Yes	Footnote to Table amended
Tables 7.19, 7.20 & 7.31	Scenario consequences	Check for completeness.	Yes	Table amended
8	Recommendations	The report needs to clearly outline any additional studies required around the mouth condition, hydrology and breaching levels. This is an issue of critical importance to the management of the system.	Yes	Highlighted in text on Baseline surveys (see Section 8.3)
Appendix A	Hydrodynamics	Given the importance of mouth management to the operation and health of the system is the available information which is based mainly on Fijen 1995 of sufficient detail and confidence. If not what additional studies should be done wrt managing water levels and mouth breaching?	Yes	Fijen (995) not sufficient for comprehensive understanding, therefore additional requirements have been listed in baseline surveys (see Table 8.2)
Appendix B	Sediment dynamics	Given the dearth of information available what specialist studies are required if an intermediate or comprehensive Reserve were to be undertaken?	Yes	Additional baseline survey, as well as long-term monitoring action have been provided see (Tables 8.2 and 8.3)
Appendix C	Water quality	Some Figures are out of focus	Partly	Some figures had to be scanned and are therefore not of best quality
Appendix F	Invertebrates	Tables need border	Yes	Amended
Comments: Barbara Weston (DWS) dated September 2015 as presented in Gouritz Report in track changes				
Entire report	Entire report	Editorial corrections made in track changes	Yes	Editorial corrections were made through out report, where also applicable to Duiwenhoks study

Section	Report Statement	Comments	Addressed in Report?	Author Comment
Entire report	Salinity	Add units for salinity	No	Salinity is unitless (IS units)