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ORANGE-SENQU WATER RESOURCES QUALITY JOINT BASIN SURVEY 2 (JBS 2) – FINAL REPORT

AQUATIC ECOSYSTEM HEALTH AND WATER QUALITY MONITORING IN 2015

November 2015

ORASECOM

The Joint Basin Survey 2 undertaken in 2015 was commissioned by the Secretariat of the Orange-Senqu River Commission (ORASECOM) with technical and financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ) in delegated cooperation with the UK Department for International Development (DFID) and the Australian Department of Foreign Affairs and Trade (DFAT). The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) implemented the support.

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EXECUTIVE SUMMARY

Background

The Orange-Senqu River basin is the third largest in Africa, after the Congo and Zambezi Basins. The Orange-Senqu River originates in the Lesotho Highlands, from where it flows in a westerly direction until it reaches the Atlantic Ocean at Alexander Bay/Oranjemund. The Orange River confluences with two major tributaries on its journey to the sea, namely the Vaal River near the town of Douglas and the Fish River near Klipheuwel. The Orange-Senqu River basin itself covers more than 1,000,000 km^{2,} and has shared zones with four countries Botswana, Lesotho, Namibia and South Africa, of which 64% is located within the borders of South Africa. As the Orange-Senqu basin a) has a footprint that is wider than its geographical extent, b) is vital to the economy of the Southern African Development Commission (SADC) region and c) itself is subject to a multitude of impacts, the political and ecological management of the entire system is particularly complex. The riparian states prioritised the basin for the establishment of a joint basin commission following the adoption of the SADC protocol on shared watercourses. As one of the first multilateral basin commissions established under the Revised SADC Shared Watercourses Protocol, the Orange-Senqu Commission (ORASECOM) faces considerable challenges in terms of managing the water resources in the basin. Between 2008 and 2011 the EU had recognised these challenges and has agreed to support SADC to strengthen ORASECOM especially in light of the numerous bilateral agreements which exist within in the broader water sharing arrangements between countries in the region. A monitoring programme that was developed (ORASECOM, 2009a) proposed that a basin wide survey of aquatic ecosystem health (using a wide range of biomonitoring protocols) be carried out every 5 years, with monitoring of ecosystem health (using just SASS5) to be conducted by individual member states on an annual basis. In 2010, EU, GIZ and UNDP-GEF support to ORASECOM allowed for the piloting of the first of these five-yearly assessments in the form of the first Joint Basin Survey (JBS1). The second Joint Basin Survey (JBS2) took place in July 2015 and the results of the Aquatic Ecosystem Health component of the survey are the focus of this report.

Methods

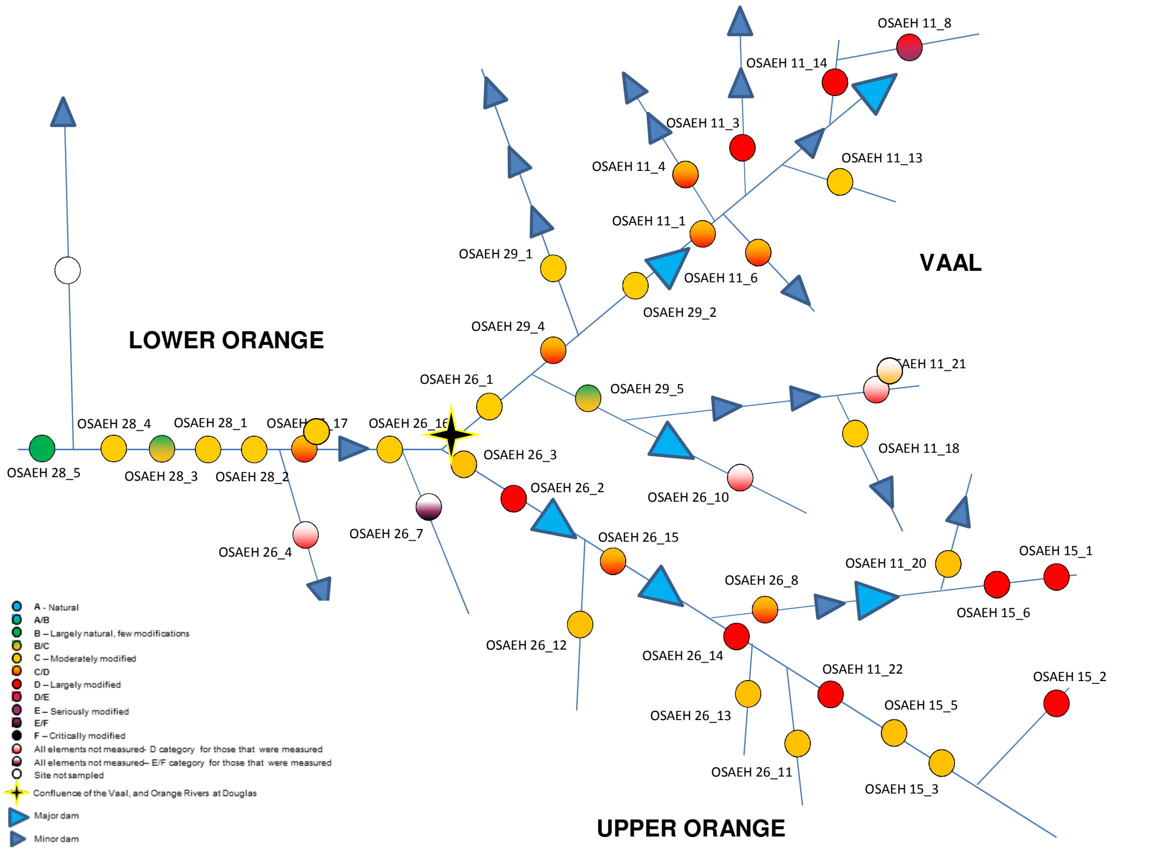
For the purposes of this study, the Orange-Senqu River Basin was divided into three sub-areas/catchments which consisted of the:

- **Vaal River Catchment** – From the origins of the Vaal River to downstream of Douglas Weir in the Northern Cape Province. This includes the Upper, Middle and Lower Vaal Water management Areas (WMAs).
- **Upper Orange Catchment** – Includes the Senqu River from its origins in the Lesotho Highlands to the South African border as well as the Upper Orange River and tributaries up to the confluence with the Vaal River below Douglas in the Northern Cape Province.
- **Lower Orange Catchment** – From the Vaal River confluence to the Orange River mouth.

To ensure a relatively wide spatial survey was undertaken in the basin, three teams were assembled to undertake aquatic assessments within the Vaal, Upper Orange and Lower Orange catchments. Teams sampled sites in parallel over a two week period, with field teams comprising of four members - one team leader/key expert and three non-key experts. In total, **39 sites**, supplied by the ORASECOM secretariat in the tender documentation, were sampled for Aquatic Ecosystem Health (AEH). Furthermore, six **groundwater sites**, selected for sampling based on their importance as transboundary water resources, were sampled by a separate groundwater team in parallel with the AEH sampling. Groundwater sites occurred in Namibia, Botswana and South Africa respectively. A suite of robust biomonitoing tools that have been approved, adopted and widely utilised by the South African Department of Water and Sanitation (DWS) (namely, EcoStatus tools), water authorities and consultants across South Africa was utilised to provide a comprehensive measure of aquatic ecosystem health at selected sampling sites within the Orange/Senqu basin. The tools used in the survey covered assessments of macroinvertebrate (SASS and MIRAI), water quality, fish (FRAI), diatoms (SPI), riparian vegetation (VEGRAI) and habitat integrity (IHI).

Results

A summary of the integrated AEH results obtained during the JBS2 survey is provided in the map below while the accompanying table shows the results of the separate AEH components in JBS1 compared to JB2. Colour coding of the sites is according to the EcoStatus classification.



Map representing the AEH sites sampled in JBS2 in the Orange-Senqu River Basin. The star denotes the confluence of the Orange and the Vaal Rivers.

Summary of EcoStatus Category scores for AEH components in JBS1 and JBS2. * Denotes sites where certain AEH components could not be measured - overall EcoStatus scores for these sites are not true indicators of overall EcoStatus

Catchment	Site Number	River	Diatoms JBS1	Diatoms JBS2	Fish JBS1	Fish JBS2	Inverts JBS1	Inverts JBS2	Instream JBS1	Instream JBS2	Rip Veg JBS1	Rip Veg JBS2	Overall Ecostatus JBS1	Overall Ecostatus JBS2
Vaal	OSAEH_11_8	Blesbokspruit	C/D	F	D	D/E	D/E	E	D/E	E	D	D	D	D/E
Vaal	OSAEH_11_14	Suikerbosrant	C	B/C	C	C	C	C/D	C	C/D	B/C	D	B/C	D
Vaal	OSAEH_11_13	Kromellenboogspruit	C	D/E	C	C	C	D	C	C/D	C	C	C	C
Vaal	OSAEH_11_3	Mooi	D	C	D	C/D	D	C/D	D	C/D	E	E	E	D
Vaal	OSAEH_11_6	Renoster	C	D/E	C	D	C	C	C	D	C	C	C	C/D
Vaal	OSAEH_11_4	Skoonspruit	D/E	F	C	C	C	D	C	C/D	C	C	C	C/D
Vaal	OSAEH_11_1	Vaal	C	D/E	C	B/C	C	E	C	D	C	D	C	D
Vaal	OSAEH_29_2	Vaal		B/C		C		C		C		C		C
Vaal	OSAEH_29_1	Harts	C	B/C	D	C	C/D	C	D	C	D	D	D	C
Vaal	OSAEH_29_4	Vaal	C	B	D	C	C/D	D	C	C	D	D	C	C/D
Vaal	OSAEH_11_21	Korannaspruit	C	D	C	C	D	-	C	E	B	C	C	C*
Vaal	OSAEH_11_18	Modder	C	D	C	C	D	C/D	C	C	B	C	C	C
Vaal	OSAEH_26_10	Riet	C	E	C	C/D	C	-	C	E	B	B/C	C	D*
Vaal	OSAEH_29_5	Riet	B/C	B/C	C	C/D	C	B/C	C	C	B	B	C	B/C
Vaal	OSAEH_26_1	Vaal	B/C	B	C	C/D	C/D	D	C	D	B/C	B/C	C	C
Upper Orange	OSAEH_15_2	Matsoku		B		E	D	C/D		D		E	C	D
Upper Orange	OSAEH_15_3	Senqu		C		D		C		C		C/D		C
Upper Orange	OSAEH_15_5	Senqu		B		D		C		C/D		B		C
Upper Orange	OSAEH_11_22	Orange		C/D		D		D		D		D		D
Upper Orange	OSAEH_26_11	Kraai	C	B	C	D	C	B/C	C	C	C	D	C	C
Upper Orange	OSAEH_26_13	Stormbergspruit		C		C		C/D		C		C		C
Upper Orange	OSAEH_26_14	Orange		C		D		D		D		C/D		D
Upper Orange	OSAEH_15_1	Caledon	B	B/C	D	C/D	C	B/C	D	C	C	E	C	D
Upper Orange	OSAEH_15_6	Caledon		F		E		D		D		D		D
Upper Orange	OSAEH_11_20	Leeu	C	C/D	C	D	C	C	C	C/D	B	C	C	C
Upper Orange	OSAEH_26_8	Caledon	C	D	D	C	D	D	D	C/D	B	C/D	C	C/D
Upper Orange	OSAEH_26_15	Orange		C		C/D		C/D		C/D		D		C/D
Upper Orange	OSAEH_26_12	Seekoei		C		D		C/D		C/D		A		C
Upper Orange	OSAEH_26_2	Orange	B	B	C/D	D	C	D	C	D	B/C	D	C	D
Upper Orange	OSAEH_26_3	Orange		B/C		C		D		C/D		B/C		C
Lower Orange	OSAEH_26_7	Brak		-		-		-		-		E/F		F*
Lower Orange	OSAEH_26_16	Orange		B		C		D		C/D		C		C
Lower Orange	OSAEH_26_17	Orange	B/C	B/C	B/C	C	B	C	B/C	C	D	D	C	C
Lower Orange	OSAEH_26_4	Hartbees		-		-		-		-		D		E*
Lower Orange	OSAEH_28_2	Orange	C	C	C	C	C	C	C	C	C	C	C	C
Lower Orange	OSAEH_28_1	Orange		C/D		C		C		C		C/D		C
Lower Orange	OSAEH_28_3	Orange		C		B/C		B/C		B/C		B		B/C
Lower Orange	OSAEH_28_4	Orange	C	B/C	C	C	C	B/C	C	C	C	C	C	C
Lower Orange	OSAEH_28_5	Orange	C	B	B/C	B/C	B/C	B/C	B/C	B/C	B	B	B/C	B

In general, results revealed that much of the **Vaal Catchment** was in an impacted to highly impacted condition, C-C/D category. The Upper Vaal WMA was particularly impacted with sites in a C/D-D category and the uppermost site OSAEH 11_8 (just south of Nigel and the East Rand) in a seriously modified condition (D/E). The major impacts to the sites within the system include: a large number of dams (altering temperature and flow regimes), extensive mining operations and agriculture (land use change, habitat destruction and water quality impacts) as well as cumulative water quality impacts from industries and densely populated area's (elevated nutrients and salts).

The **Upper Orange/Senqu Catchment** also showed extensive modification, with much of the system in a C-D category. Surprisingly the sites located in the upper reaches of the Senqu and Caledon Rivers (OSAEH 15_1 and 15_2) were in a largely modified condition, likely owing to extensive land use change and agricultural practices leading to sedimentation and riparian degradation. Sites on the lower reaches of the upper orange upstream of the confluence with the Vaal were notably affected by irrigation and hydropower releases from major upstream dams (Gariep and Vanderkloof), in conjunction with surrounding agriculture and WWTW's effluent releases.

Results from sites on the Lower Orange revealed that overall EcoStatus condition improved with downstream distance. Sites in the upper reaches of the system were generally in a C category (moderately modified), likely owing to the effects of intensive agriculture and upstream dam releases (modification of natural thermal and hydrological regimes). Sites on the lower reaches of the system were in B-B/C-C categories (largely natural condition to moderately modified condition). Sites exhibiting largely natural conditions (B-B/C) likely reflect that the fact that: a) less intensive agriculture occurs in the arid lower reaches of the Orange River, b) population densities are low with fewer major towns and c) more intact ecological infrastructure exists in the form of protected areas (such as the Richtersveld National Park) and low density livestock farming areas.

Trends

In JBS2, only one site (OSAEH 28_5 – the most downstream site on the Lower Orange) was in an Overall EcoStatus Category of B (largely natural, with few modifications). Two sites were in a B/C category (OSAEH 29_5 on the Riet River a tributary of the Lower Vaal, and OSAEH 28_3 a site on the Lower Orange). The majority of sites were in an overall EcoStatus category of a C (n=16) (moderately modified), while seven were in a C/D category. Eight sites were in a D category (largely modified). Of these sites two occurred in the Upper Vaal WMA - Vaal catchment and surprisingly six occurred within the Upper Orange/Senqu catchment. The site with the lowest overall EcoStatus Category (D/E) (seriously modified) was OSAEH 11_8 (on the Blesbokspruit)-the most upstream site in the Vaal catchment.

Compared to the sites reported on in JBS1, seven sites remained in a C category, while 11 showed deterioration in EcoStatus category. Of the sites that showed deterioration, one changed from a D to a D/E (OSAEH 11_8), six changed from a C to C/D, one site (OSAEH 11_14) from a B/C to D and three sites from a C to D category. Of concern is that these results indicate a general decline in the overall EcoStatus for the sites that were measured in both

JBS1 and JBS2. **Only three improvements in overall EcoStatus score from JBS1 were noted.** OSAEH 11_3 improved from an E to a D category, OSAEH 29_1 improved from a D to a C category and OSAEH 28_5 improved from a B/C to B category. With only two surveys available to compare trends- confidence in the observed trends is low. Future surveys will be necessary to determine if these trends are consistent.

Management Recommendations for the Orange-Senqu Basin

From the outcomes of JBS2 and the assessment of the primary drivers of change/impact within the Orange -Senqu River basin, the following key management recommendations are highlighted:

- The correct **management of hydropower and irrigation releases** (particularly in the Orange River) as per recommendations emanating from Instream Flow Requirement (IFR) studies and Reserve studies
- The **controlling and monitoring of sediment loads** emanating from overgrazing, crop and cattle farming (particularly high impact within the Upper Orange/Senqu)
- Managing the **condition of riparian zones** with particular impacts related to adjacent land uses, buffer zones and loss of ecological infrastructure
- **Inetensify water quality monitoring** and pollution control (especially the Vaal and Caledon Rivers)
- Assessment of **Waste Water Treatments Works**, along with **effluent toxicity compliance** and management. This should entail a survey to assess the number of WWTW's within the basin and determine their individual Green Drop status scores. If Green Drop scores for certain WWTW's are found to be below national guideline limits then enquiries should be made with local authorities to a) assess problems with those WWTW's and b) rectify the issues,
- **Investigation of acid mine drainage** and industry releases, including addressing the following questions;
    - How many mines and industries are located in riparian zones?
    - What is the nature of their effluents?
    - Investigate whether stricter monitoring by local authorities is needed?
- Investigate the **impacts of weirs, barrages and dams** on migration and habitat connectivity.

To aid in achieving the above recommendations and to contribute to the effective collection of data, which will in turn inform management of the Orange-Senqu River basin, the following suggestions regarding monitoring are proposed:

- The responsible parties from the **member states should undertake quarterly to bi-annual monitoring of some of the components of aquatic ecosystem health** (e.g. macroinvertebrates, diatoms and water chemistry) at key and/or strategic sites within their jurisdiction. The frequency of monitoring will be dependent on the biological component monitored. Water chemistry and Diatoms can be monitored quarterly to determine integrated water quality, while fish and macroinvertebrates can be monitored bi-annually to determine ecosystem health.

- In order to ensure that data is collected in a standardised manner across the Orange-Senqu River basin it is recommended that **ORASECOM promote the use of EcoStatus** assessment methods in member states and provide capacity building/training opportunities to the designated parties to undertake these assessments. It is further strongly recommended that an external review by personnel of the funders to the Joint Basin Surveys be undertaken subsequent to the termination of the following survey. This external review is to ensure that the basin management recommendations are being attended and adhered to, and will provide motivation of the responsible parties to improve and maintain on the effective management of the water resources within the basin.

Of crucial importance to the future sustainable management of the catchment is the **dissemination of the information generated during the Joint Basin Surveys**, by ORASECOM. This is in order to create awareness amongst the land owners, farmers, industries etc. as to the impacts, drivers and management needs within the Orange-Senqu Basin, and how water and land users can play a role.

General Recommendations for Future Joint Basin Surveys

Through undertaking the JBS2, the following recommendations are made specifically with respect to logistical planning of future surveys:

- It is important to plan the survey such that the fieldwork component can be undertaken within the **optimal season** for sampling. It is suggested that this may be spring or autumn, where flows are more favourable and vegetation sampling can be undertaken to greater effect. This is particularly crucial with regards to the ephemeral systems present in the basin and therefore, it is recommended that the responsible parties in the member states sample when surface water flow is present in these systems. This will aid in creating a database of the biota that inhabit/utilise these ephemeral systems and will inform their management in the basin.
- **Continuity in sampling, data gathering and record keeping** is important across subsequent surveys, to best assess changes and inform management actions. Consistent sampling of the same sites at the same periods and through the same suite of assessments is important to achieve this. Detailed record keeping and the development and maintenance of databases which cover all surveys is of importance. These data must be made available during the planning and proposal stages of subsequent surveys in order to facilitate continuity of sampling and efficiency of operations and costs.
- **Project timeframes** must be planned to allow adequate time for effective project implementation. Additional time is suggested for logistical planning, reporting and fieldwork. For example:
    - **Lead time** to organise work visas for the neighbouring countries is approximately 3 months; and
    - Lead time needed for organising **access permits** for Sperregebiet, Namdeb diamond mine area near Alexander Bay is one to two weeks (if all forms and supporting documentation is provided). However, police clearance, which is also required to access the site, can take 2-3 months to obtain in respective

countries. Access to this area is strictly controlled by Namdeb Diamond Corporation and the Namibian Ministry of Mining and Energy. As such, if this site is to be considered in future surveys, the application process for **work permits** should be initiated with Namdeb Diamond Corporation timeously and police clearance to obtain access to Alexander Bay must occur at least five months prior to the date of sampling.

- It should be noted that the JBS project co-ordinator from ORASECOM should apply for necessary **work visas** on behalf of the sampling teams in conjunction with negotiating a diplomatic agreement with the relevant governmental departments of participating member states at least three to four months prior to the date of sampling. The diplomatic agreements should be arranged by ORASECOM (at higher levels than the project co-ordinator) well in advance of sampling.
- The **ILB program** sampling should be undertaken separately from the JBS AEH survey. As an alternative approach, member state personnel could collect samples from the sites in their respective countries, which are then couriered to participating states. A second option is to utilise the SABS Proficiency Testing Scheme (PTS), which is already operational, is accredited and operated independently. While several labs already participate in the SABS PTS, those laboratories could offer to disclose their results every five years to a water quality expert (as part of the Joint Basin Survey team) who could compile a laboratory comparison report, based on the SABS PTS results rather than collected field samples. Laboratories in the member states not currently participating in the SABS PTS could aim to join the scheme over the next five years before JBS3 is conducted.
- A final protocol for the **site nomenclature** should be developed for the Joint Basin Surveys. (could either continue to use OSAEH nomenclature or change it to JBS site names) They recommended this in JBS1 but the sites they used were EWR and IFR sites (they assigned JBS site names to these sites in their recommendations) but many of these sites were not used in JBS2.
- For JBS2, all of the **final sites selected proved suitable and accessible**. The sampling manual will highlight sites with specific access requirements.
- For further JBS's it is imperative that the designated consultants **utilise the JBS1 and JBS2 documentation** to determine sampling sites. This will entail filtering of recommended sites from JBS1 and JBS2 **during the tender process**. In addition, the Orange-Senqu Aquatic Ecosystem Health Monitoring Programme (ORASECOM, 2009a) should be reviewed to identify sample sites.

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LIST OF ACRONYMS AND ABBREVIATIONS

Full text	**Abbreviation/Acronym**
Aquatic Ecosystem Health	AEH
Department of Water Affairs	DWA
Department of Water Affairs and Forestry	DWAF
Department of Water and Sanitation	DWS
Deutsche Gesellschaft für Internationale Zusammenarbeit	GIZ
Dissolved Oxygen	DO
Ecological Water Reserve	EWR
EcoStatus	Ecological Status
European Union	EU
Fish Response Assessment Index	FRAI
Index of Habitat Integrity	IHI
Instream Flow Requirements	IFR
Instream Index of Habitat Integrity	IIHI
Inverts	Macroinvertebrates
Joint Basin Survey	JBS
Latitude	Lat
Longitude	Long
Macroinvertebrate Response Assessment Index	MIRAI
Orange-Senqu Aquatic Ecosystem Health	OSAEH
Orange-Senqu Commission	ORASECOM
Orange-Senqu Surface Water Quality	OSSWQ
Present Ecological State	PES
Rip Veg	Riparian Vegetation
Riparian Index of Habitat Integrity	RIHI
River Health Programme	RHP
South African National Standard	SANS
Southern African Development Commission	SADC
Specific Pollution Sensitivity Index	SPI
Suspended Solids	SS
Total Dissolved Solids	TDS
Total Inorganic Nitrogen	TIN
United Nations Development Program-Global Environment Facility	UNDP-GEF
Vegetation Response Assessment Index	VEGRAI
Water Management Area	WMA
Water Quality	WQ
World Health Organisation	WHO

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1. INTRODUCTION

1.1 Background

The Orange-Senqu River Basin is the third largest in Africa, after the Congo and Zambezi Basins. The Orange-Senqu River originates in the Lesotho Highlands, from where it flows in a westerly direction until it reaches the Atlantic Ocean at Alexander Bay/Oranjemund. The Orange River confluences with two major tributaries on its journey to the sea, namely the Vaal River near the town of Douglas and the Fish River near Klipheuwel. The Orange-Senqu River Basin itself covers more than 1,000,000 $km^{2,}$ and has shared zones with four countries Botswana, Lesotho, Namibia and South Africa, of which 64% is located within the borders of South Africa.

South Africa is the primary user of water from the system and the water is critical to driving the industrial and economic hub of the country around Gauteng. Lesotho, while being one of the smallest users of water from the river system (only 3% of the total basin area) is also the country which contributes the highest stream flow (over 40%) and is located entirely within the upper reaches of the Basin. The broader Orange-Senqu River Basin is utilised in several inter-basin water-transfer schemes and has a large number of dams located on the main stem rivers and associated larger tributaries, which collectively have a marked effect on natural flow regimes in the system. In South Africa the Orange-Senqu system receives water from the Inkomati and Usutu River systems – shared by South Africa with Mozambique and Swaziland – and also the Tugela system. Water from the Orange-Senqu River Basin is transferred to the Limpopo River system – shared by South Africa with Botswana, Mozambique and Zimbabwe – and also the Eastern Cape Province in South Africa.

Groundwater contributions play an important role in the portion of the Orange-Senqu River Basin that is located within southern Botswana and eastern Namibia, where surface water run-off is scarce – particularly that which is linked to the Orange-Senqu system itself. Concerns have been raised about the gradually increasing levels of salinity in the region which over the long term could impact on the use of the groundwater for drinking and crop irrigation purposes.

The middle to lower reaches of the Orange River are predominantly impacted on by the high demands of water for irrigation purposes both in South Africa and Namibia. In the lower reaches specifically, the levels of water abstraction for irrigation further compound the problems of maintaining environmental flows to the estuary – the estuary itself is recognised as one of the most important wetlands in southern Africa, a Ramsar site and one which is placed on the Montreux record. Owing to the continued abstraction of water from the river, destruction of estuarine and riparian habitats both at the estuary and upstream, as well as the alteration of flow regimes (through dam/hydropower releases), the ecosystem functioning of the Orange River estuary/wetland is at risk.

As the Orange-Senqu River Basin a) has a footprint that is wider than its geographical extent, b) is vital to the economy of the Southern African Development Commission (SADC) region and c) itself is subject to a multitude of impacts, the political and ecological management of the entire system is particularly complex. The riparian states prioritised the Basin for the establishment of a joint basin commission following the adoption of the SADC protocol on shared watercourses. As one of the first multilateral basin commissions established under the Revised SADC Shared Watercourses Protocol, the Orange-Senqu Commission (ORASECOM) faces considerable challenges in terms of managing the water resources in the Basin. Between 2008 and 2011 the EU had recognised these challenges and has agreed to support SADC to strengthen ORASECOM especially in light of the numerous bilateral agreements which exist within in the broader water sharing arrangements between countries in the region.

The Revised SADC Protocol on Shared Watercourses, to which all Parties, including member states of ORASECOM are signatory, stipulates various requirements relating to the importance of maintaining aquatic ecosystem functioning, as well as ensuring the sustainable utilisation of water resources in each of the Basin States. ORASECOM was therefore founded on principles of using shared water resources a) within an Integrated Water Resources Management paradigm, b) to address poverty and food security and c) to foster greater intra- and inter-regional cooperation and integration.

Article 5.2.5 of the Orange-Senqu River Commission (ORASECOM) Agreement[1] provides the mandate to develop standardised forms of collecting, processing and disseminating data or information with regard to all aspects of the River System. Article 7.12 requires the Parties to individually and jointly take all measures that are necessary to protect and preserve the River System from its sources and headwaters to its common terminus. ORASECOM was thus given the mandate and responsibility to develop an aquatic ecosystem health monitoring programme. In 2009, such a monitoring programme was developed (ORASECOM, 2009a) in order to satisfy some of the requirements of the Revised SADC Protocol on Shared Watercourses. Furthermore the monitoring programme necessitated that the Parties of ORASECOM would need to be advised on the state of aquatic ecosystems throughout the Basin.

The monitoring programme that was developed (ORASECOM, 2009a) proposed that a basin wide survey of aquatic ecosystem health (using a wide range of biomonitoring protocols) be carried out every 5 years, with monitoring of ecosystem health (using just SASS5) to be conducted by individual member states on an annual basis. In 2010, EU, GIZ and UNDP-GEF support to ORASECOM allowed for the piloting of the first of these five-yearly assessments in the form of the first Joint Basin Survey (JBS1).

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[1] The ORASECOM Agreement establishes the Council as the highest body of ORASECOM. Council is made up of four Delegations, one from each of the Parties. Council must meet at least once a year, but may meet more frequently if required. Delegations must be made up of no more than three Commissioners, who may be supported by no more than three technical advisors. This helps ensure that the Council cannot be dominated by any one nation. The ORASECOM Council can establish its own operating procedures, and has established a number of Task Teams to support its functioning. (ORASECOM, 2008)

1.2 Joint Basin Survey 1 (JBS1 2010)

During October 2010 to March 2011, the 1st Joint Orange-Senqu River Water Resources Quality Basin Survey (JBS1) was conducted. The purpose of JBS1 was two-fold in that:

1) it was intended to undertake the first baseline monitoring of aquatic ecosystem health in the Orange-Senqu River System against which ORASECOM could monitor impacts/trends of any basin wide measures taken through future 5 yearly intensive monitoring programmes; and

2) it was used to define appropriate sampling sites, based on site visits and local knowledge, that could be used in future surveys.

Several key river health and water resource quality components were focused on in the first survey: Aquatic Ecosystem Health (AEH), Persistent Organic Pollutants (POPs), Chemical and Microbial Water Quality, Inter-laboratory benchmarking, and Public & Schools Events (stakeholder participation). A separate study was initiated to survey POPs and heavy metals at selected sites within the Basin. This study was intended to start from December 2014 and continue through to May 2015.

In the first Joint Basin Survey in 2010, 16 sites were physically sampled and ground-truthed while a further 26 sites across the Basin were reported on using information summarised from various Ecological Reserve (environmental flow) studies that were commissioned from 2007 to 2010.

Broadly speaking the results of JBS1 indicated that much of the Vaal catchment (including the upper, middle and lower reaches of the Vaal River main stem as well as main tributaries) was in a C-D (moderately modified to seriously modified) overall EcoStatus Category, with a few tributaries (Klip and Wilge Rivers) in a B category (largely natural with few modifications) and others (namely the Rhenoster and Suikerbosrand Rivers) in a B/C category. While much of the upper reaches of the Orange River main stem was not sampled in JBS1, the lower reaches of the upper Orange River (below Vanderkloof Dam) indicate a C (moderately modified) overall EcoStatus category. Similarly the sites sampled on the Caledon River also indicated a C overall EcoStatus category. The four sites sampled on the lower reaches of the main stem of the Orange River (from below Boegoeberg Dam to Sendelingsdrif) all indicated a C overall EcoStatus category, barring the site at Sendelingsdrif (located in the Richtersveld National Park) which was a B/C.

A summary of the findings of the JBS1 technical report is available online at: www.orasecom.org and an electronic copy can be requested from the ORASECOM secretariat.

1.3 Purpose of this Assignment: Joint Basin Survey 2 (JBS2 2015)

GroundTruth, Water, Wetlands and Environmental Engineering were appointed as the consultants to conduct the second of the five-yearly intensive monitoring programme established for the Orange-Senqu River Basin – JBS2. The primary focus of JBS2 was to successfully implement the required AEH, chemical and water quality sampling in 2015 (in conjunction with the inter-laboratory benchmarking) in a similar manner to that of JBS1, whilst learning from and building on the foundations and recommendations laid out in the first survey. This included a detailed assessment of aquatic ecosystem health indicators, including the impacts that affected these systems. The assignment aimed to build on the results from JBS1 in order to establish preliminary trends where possible and to make recommendations not only for management but for future surveys.

1.3.1 Outcomes and deliverables emanating from this assignment

As per the Terms of Reference (ToR) for this assignment the report presented here has been informed by the outcomes of several prior deliverables including: a stakeholder inception workshop held with the ORASECOM Secretariat and members of the Water Resource Quality Working Group from participating member states, as well as a detailed inception report outlining the sampling programme and methods to be applied. All of the outputs/deliverables associated with this assignment are summarised below in Table 1.1.

Table 1.1 List of outcomes and deliverables associated with the ORASECOM Joint Basin Survey 2 (2015).

Component	Description	Date
Inception Report	Provided detailed information regarding the sampling programme and also the sampling protocols that would be applied at each site.	Draft 28 May 2015 Finalised 7 July 2015
Inception Planning Workshop	The sampling programme was presented at the ORASECOM JBS2 planning workshop held in Windhoek, Namibia	2-3 June 2015
Groundwater monitoring programme	Provided the itinerary and sampling points proposed for sampling	6 July 2015
JBS2 AEH Sampling	Aquatic Ecosystem Health sampling including Fish, Macroinvertebrates, Vegetation, Water Quality and Diatoms conducted by three field teams over 2 weeks in co-ordination with member state personnel. Sampling for Inter-laboratory benchmarking procedure was conducted in parallel.	13-29 July 2015
JBS2 Groundwater sampling	Water quality sampling at groundwater sites in Namibia, Botswana and South Africa conducted in co-ordination with member state personnel	19-25 July 2015
Water quality resources monitoring report (this report)	Provides detailed results of the aquatic ecosystem health monitoring and the groundwater results	Aug 2015
Inter-laboratory benchmarking report	Provides a comparison of water quality samples collected from 11 sites analysed by 8 laboratories within the participating member states (including an independent and accredited laboratory)	Aug 2015 – dependent on receipt of results from participating laboratories
Sampling Manual	Provides an overview of the sampling programme and provides site-specific information such as site co-ordinates, site access, procedures conducted at each site and site suitability.	Aug/Sept 2015

1.4 Purpose of this Report

This report serves to summarise the results of the Orange-Senqu Aquatic Ecosystem Health (OSAEH) Joint Basin Survey 2 sampling undertaken over the period 13-29th July 2015 at a total of 51 sites. Only those sites used for AEH and groundwater sampling are reported on here in detail. The coordinates of sites used for the inter-laboratory benchmarking exercise are provided here, but a separate report will detail the outcomes, procedures and recommendations of the Inter-laboratory benchmarking exercise component.

Summarised information provided in this report includes:

- Site description.
- Present Ecological State (PES) of each biological component
- Water quality results in terms of fitness for use (for groundwater sites only)
- Main impacts on the site.
- EcoStatus results for the site.
- Trend analysis (where applicable)
- Recommendations.

1.5 Report Outline

The main outline of this report is provided below:

Introduction (Section 1)

This section – includes background information regarding ORASECOM and the JBS survey, purpose of the assignment and the report as well as the report outline.

Methods (Section 2)

Includes summary information of sites surveyed, maps, geographical information, and assessment methods applied (EcoStatus tools, sampling protocols)

Results (Section 3)

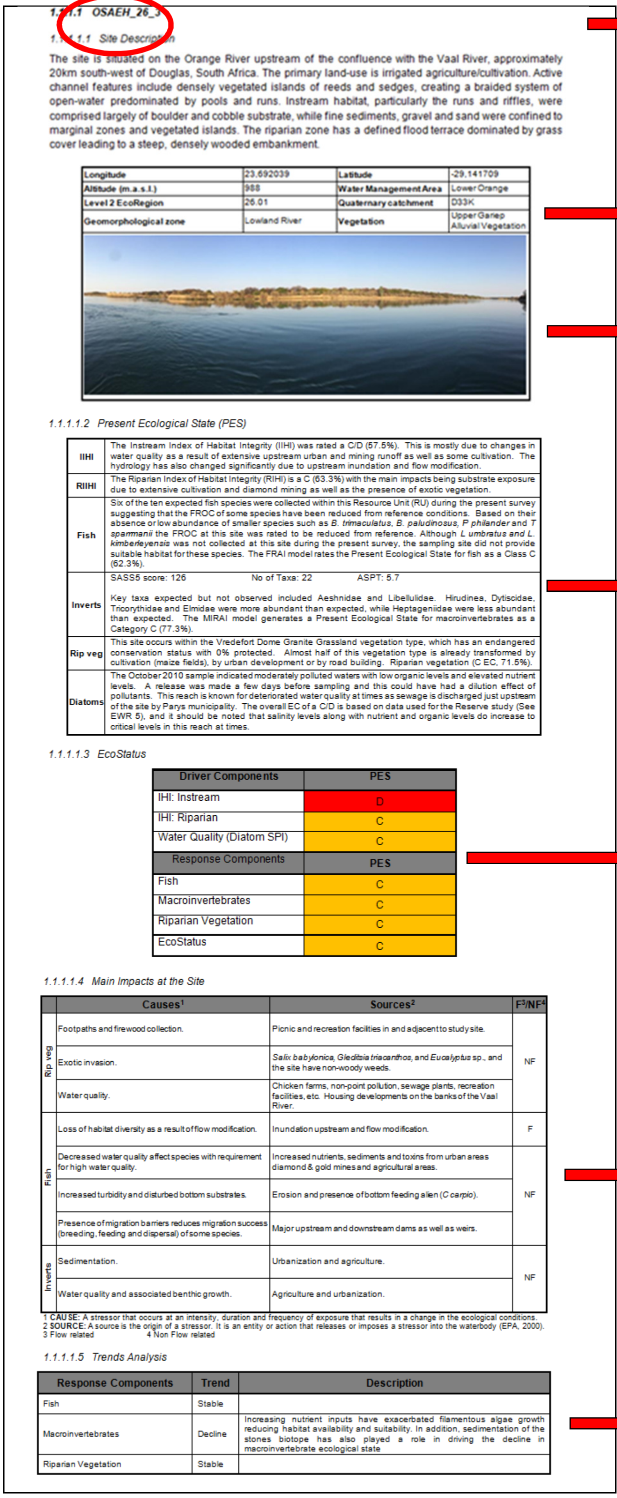
Results are presented for AEH sites first and groundwater sites last. AEH sites are reported on according to main catchment and then to water management area (WMA) in the following order: Vaal Catchment (Upper/Middle/Lower WMAs), Upper Orange/Senqu Catchment (Lesotho/Upper Orange WMA), Lower Orange Catchment (Lower Orange WMA). For each main catchment sites are presented according to the location of the site in relation to the main stem river in that catchment (upstream to downstream). Where a tributary confluences with the main stem river, sites on that tributary are reported on in order from upstream to downstream, before sites on the main stem downstream of that tributary are reported on. In doing this, cumulative water quality impacts effecting sites can logically be discussed. Site descriptions, contextual geographical information, Present Ecological State (PES), major impacts at the sites and trend analyses (where applicable) are provided.

Summary Observations, Conclusions and Recommendations (Section 4)

A broad overview of the catchments, including summary information regarding hydrology, diatoms, fish and water quality as well as general trends in EcoStatus. Broad management recommendations are provided per primary catchment as well as practical/logistical recommendations to be considered for future surveys.

1.6 Reporting Structure for AEH Results

The general structure used to present results from each of the AEH sampling sites is indicated below in the annotated Figure1.1. A slightly modified version has been used for groundwater sites.



1.1.1.1 OSAEH_26_3

1.1.1.1.1 Site Description

The site is situated on the Orange River upstream of the confluence with the Vaal River, approximately 20km south-west of Douglas, South Africa. The primary land-use is irrigated agriculture/cultivation. Active channel features include densely vegetated islands of reeds and sedges, creating a braided system of open-water predominated by pools and runs. Instream habitat, particularly the runs and riffles, were comprised largely of boulder and cobble substrate, while fine sediments, gravel and sand were confined to marginal zones and vegetated islands. The riparian zone has a defined flood terrace dominated by grass cover leading to a steep, densely wooded embankment.

Longitude	23.692039	**Latitude**	-29.141709
Altitude (m.a.s.l.)	988	**Water Management Area**	Lower Orange
Level 2 EcoRegion	26.01	**Quaternary catchment**	D33K
Geomorphological zone	Lowland River	**Vegetation**	Upper Gariep Alluvial Vegetation

1.1.1.1.2 Present Ecological State (PES)

IIHI	The Instream Index of Habitat Integrity (IIHI) was rated a C/D (57.5%). This is mostly due to changes in water quality as a result of extensive upstream urban and mining runoff as well as some cultivation. The hydrology has also changed significantly due to upstream inundation and flow modification.
RIIHI	The Riparian Index of Habitat Integrity (RIHI) is a C (63.3%) with the main impacts being substrate exposure due to extensive cultivation and diamond mining as well as the presence of exotic vegetation.
Fish	Six of the ten expected fish species were collected within this Resource Unit (RU) during the present survey suggesting that the FROC of some species have been reduced from reference conditions. Based on their absence or low abundance of smaller species such as *B. trimaculatus*, *B. paludinosus*, *P philander* and *T sparrmanii* the FROC at this site was rated to be reduced from reference. Although *L umbratus and L. kimberleyensis* was not collected at this site during the present survey, the sampling site did not provide suitable habitat for these species. The FRAI model rates the Present Ecological State for fish as a Class C (62.3%).
Inverts	SASS5 score: 126 No of Taxa: 22 ASPT: 5.7 Key taxa expected but not observed included Aeshnidae and Libellulidae. Hirudinea, Dytiscidae, Tricorythidae and Elmidae were more abundant than expected, while Heptageniidae were less abundant than expected. The MIRAI model generates a Present Ecological State for macroinvertebrates as a Category C (77.3%).
Rip veg	This site occurs within the Vredefort Dome Granite Grassland vegetation type, which has an endangered conservation status with 0% protected. Almost half of this vegetation type is already transformed by cultivation (maize fields), by urban development or by road building. Riparian vegetation (C EC, 71.5%).
Diatoms	The October 2010 sample indicated moderately polluted waters with low organic levels and elevated nutrient levels. A release was made a few days before sampling and this could have had a dilution effect of pollutants. This reach is known for deteriorated water quality at times as sewage is discharged just upstream of the site by Parys municipality. The overall EC of a C/D is based on data used for the Reserve study (See EWR 5), and it should be noted that salinity levels along with nutrient and organic levels do increase to critical levels in this reach at times.

1.1.1.1.3 EcoStatus

Driver Components	PES
IHI: Instream	D
IHI: Riparian	C
Water Quality (Diatom SPI)	C
Response Components	**PES**
Fish	C
Macroinvertebrates	C
Riparian Vegetation	C
EcoStatus	C

1.1.1.1.4 Main Impacts at the Site

	Causes[1]	Sources[2]	F[3]/NF[4]
Rip veg	Footpaths and firewood collection.	Picnic and recreation facilities in and adjacent to study site.	NF
	Exotic invasion.	*Salix babylonica*, *Gleditsia triacanthos*, and *Eucalyptus* sp., and the site have non-woody weeds.	
	Water quality.	Chicken farms, non-point pollution, sewage plants, recreation facilities, etc. Housing developments on the banks of the Vaal River.	
Fish	Loss of habitat diversity as a result of flow modification.	Inundation upstream and flow modification.	F
	Decreased water quality affect species with requirement for high water quality.	Increased nutrients, sediments and toxins from urban areas diamond & gold mines and agricultural areas.	NF
	Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien (*C carpio*).	
	Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Major upstream and downstream dams as well as weirs.	
Inverts	Sedimentation.	Urbanization and agriculture.	NF
	Water quality and associated benthic growth.	Agriculture and urbanization.	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the waterbody (EPA, 2000).
3 Flow related 4 Non Flow related

1.1.1.1.5 Trends Analysis

Response Components	Trend	Description
Fish	Stable	
Macroinvertebrates	Decline	Increasing nutrient inputs have exacerbated filamentous algae growth reducing habitat availability and suitability. In addition, sedimentation of the stones biotope has also played a role in driving the decline in macroinvertebrate ecological state
Riparian Vegetation	Stable	

Site code (circled in red) – the prefix OSAEH stands for Orange-Senqu Aquatic Ecosystem Health the first number denotes the level 1 ecoregion, the second denotes the site number) – followed by a brief **description of the site** including geographical context, in-stream and riparian habitat

Site geographical information (GPS co-ordinates, water management area, catchment, geomorphological zone, altitude

Site photo

Table summarising **the Present Ecological State** for each AEH component measured. The components include: Instream Index of Habitat Integrity (IIHI), Riparian Index of Habitat Integrity (RIHI), Fish using the Fish Response Assessment Index (FRAI) tool, Macroinvertebrates using the Macro-invertebrate Response Assessment Index (MIRAI) tool and the South African Scoring System (SASS5), Riparian Vegetation using the Vegetation Response Assessment Index (VEGRAI), Diatoms using the (Specific Sensitivity and Pollution Index) SPI score and Water Quality using historical data gathered from departmental monitoring points

Individual EcoStatus model results and the integrated overall **site EcoStatus category.** Colour coding is per the EcoStatus category where A=Unmodified/Natural (Blue), B=Largely Natural with Few Modifications (Green), C=Moderately Modified (Yellow), D=Largely Modified (Red), E=Seriously Modified (Purple) and F=Critically Modified.

Summary table of the **main impacts at the site** for each AEH component. An indication of the key/primary causes and sources of the impacts is provided along with an indication of whether the impact is Flow related (F) or Non- Flow related (NF).

Summary table of the **trend analyses** for each AEH response component when compared to JBS1 data or available historical data. The trend is described in a linear fashion as showing either an incline, a decline or remaining stable. This is followed by a description of the likely reasons for the observed trend

Figure 1.1 Reporting structure used to present results from each of the AEH sampling sites.

2. METHODS

2.1 Site Selection

As part of the Terms of Reference (ToR) of the tender documentation for JBS2 the ORASECOM Secretariat provided a list of 56 potential sampling sites for the survey based on the Orange-Senqu Aquatic Ecosystem Health Monitoring Programme developed in 2009 as a desktop study (ORASECOM, 2009a). Of these 56 possible sites, 16 were sampled and ground-truthed as part of JBS1 and therefore formed a core selection of sites that were sampled, as a minimum, during JBS2. A further 23 AEH sites located across the broader Orange-Senqu River Basin) were sampled in JBS2. In total, 39 sites were sampled for AEH and five out of the 39 sites were also used as sites of transboundary importance in the inter-laboratory benchmarking exercise (surface water quality samples collected). A further six sites of transboundary importance were sampled for surface water quality only, also for the purposes of the inter-laboratory benchmarking exercise. Six additional sites, located in Namibia, Botswana and South Africa were sampled for groundwater only (only water quality samples were collected).

The sites sampled in JBS2 therefore allowed for a comprehensive survey of ecosystem health across the Basin and also allowed for necessary ground-truthing of the large majority of the sites originally proposed by the secretariat (i.e. those that were included in the AEH monitoring programme (ORASECOM, 2009a) and the water quality monitoring programme and data management framework document (ORASECOM, 2011). Groundwater sites were selected based on those identified in the groundwater review of the Molopo-Nossob Basin (ORASECOM, 2009b).

For the purposes of this study, the entire study area (comprising all 56 possible sites) was divided into three sub-areas/catchments which consisted of the:

- **Vaal River Catchment** – From the origins of the Vaal River to downstream of Douglas Weir in the Northern Cape Province. This includes the Upper, Middle and Lower Vaal Water management Areas (WMAs).
- **Upper Orange Catchment** – Includes the Senqu River from its origins in the Lesotho Highlands to the South African border as well as the Upper Orange River and tributaries up to the confluence with the Vaal River below Douglas in the Northern Cape Province.
- **Lower Orange Catchment** – From the Vaal River confluence to the Orange River mouth.

Table 2.1 provides a summary of the geographic information relating to the sites sampled in JBS2, while Figure 2.1 gives an indication of the spread of sites across the larger Orange-Senqu River Basin and in relation to the main water management areas and sub areas allocated to the field teams.

See Appendix A for a table containing a summary of the site nomenclature, geographic information and AEH results from JBS1 compared to JBS2.

Table 2.1 Sites sampled as part of JBS2 2015. AEH = Aquatic Ecosystem Health (all EcoStatus tools), ILB = Inter-laboratory benchmarking (water sample only)

JBS2 Site Code	Site Type	Major River/Tributary	Level 1 Ecoregion	Level 1 Ecoregion Name	Member State	Lat	Long
OSAEH_11_01	AEH (Fish intensive)	Vaal	11	Highveld	South Africa	-27.51606	26.20999
OSAEH_11_03	AEH (Fish intensive)	Vaal	11	Highveld	South Africa	-26.68437	27.09980
OSAEH_11_04	AEH	Vaal/Mooi	11	Highveld	South Africa	-26.93451	26.66428
OSAEH_11_06	AEH	Vaal/Skoonspruit	11	Highveld	South Africa	-27.04099	26.99638
OSAEH_11_08	AEH	Vaal/Rhenoster	11	Highveld	South Africa	-26.47759	28.42692
OSAEH_11_13	AEH (Fish intensive)	Vaal/Blesbokspruit	11	Highveld	South Africa	-26.81117	27.57442
OSAEH_11_14	AEH	Vaal/Kromellenboogspruit	11	Highveld	South Africa	-26.68119	28.04964
OSAEH_11_18	AEH	Vaal/Modder/(Suikerbosrand)	11	Highveld	South Africa	-29.16067	26.57225
OSAEH_11_20	AEH	Riet/Modder	11	Highveld	South Africa	-29.51769	27.12968
OSAEH_11_21	AEH (Fish intensive)	Modder/Karonnaspruit	11	Highveld	South Africa	-29.08584	26.63384
OSAEH_11_22	AEH (Fish intensive)	Orange	11	Highveld	South Africa	-30.48755	27.21398
OSAEH_15_01	AEH	Caledon	15	Eastern Escarpment Mountains	South Africa	-28.72313	28.15575
OSAEH_15_02	AEH	Malibamatso/Matsuko	15	Eastern Escarpment Mountains	Lesotho	-29.23410	28.56182
OSAEH_15_03	AEH	Senqu	15	Eastern Escarpment Mountains	Lesotho	-30.06558	28.40896
OSAEH_15_05	AEH	Malibamatso	15	Eastern Escarpment Mountains	Lesotho	-30.02106	28.18295
OSAEH_15_06/OSSWQ 11_01	AEH/ILB	Caledon/Mohokare	15	Eastern Escarpment Mountains	Lesotho	-29.37106	27.40529
OSAEH_26_01	AEH (Fish intensive)	Vaal	26	Nama Karoo	South Africa	-29.05503	23.82103
OSAEH_26_02	AEH (Fish intensive)	Orange	26	Nama Karoo	South Africa	-29.64356	24.21554
OSAEH_26_03/OSSWQ 26_02	AEH/ILB	Orange	26	Nama Karoo	South Africa	-29.14207	23.69191
OSAEH_26_04	AEH	Orange/Hartbees	26	Nama Karoo	South Africa	-28.85738	20.64283
OSAEH_26_07	AEH	Orange/Brak	26	Nama Karoo	South Africa	-29.62299	23.01667
OSAEH_26_08	AEH	Caledon	26	Nama Karoo	South Africa	-30.42757	26.30501
OSAEH_26_10	AEH	Riet	26	Nama Karoo	South Africa	-29.57528	25.70805
OSAEH_26_11	AEH	Orange/Kraai	26	Nama Karoo	South Africa	-30.69007	26.74157
OSAEH_26_12	AEH	Orange/Seekoei	26	Nama Karoo	South Africa	-30.37358	25.00095
OSAEH_26_13	AEH	Orange/Stormbergspruit	26	Nama Karoo	South Africa	-30.65017	26.46516
OSAEH_26_14	AEH	Orange	26	Nama Karoo	South Africa	-30.57142	26.45166
OSAEH_26_15	AEH	Orange	26	Nama Karoo	South Africa	-30.50378	25.24003
OSAEH_26_16	AEH	Orange	26	Nama Karoo	South Africa	-29.65519	22.74464
OSAEH_26_17	AEH (Fish intensive)	Orange	26	Nama Karoo	South Africa	-28.43735	21.40106
OSAEH_28_01/OSSWQ 28_02	AEH	Orange	28	Orange River Gorge	South Africa	-28.95826	19.17281
OSAEH_28_02/OSSWQ 28_01	AEH/ILB	Orange	28	Orange River Gorge	South Africa	-28.51060	20.17190
OSAEH_28_03	AEH (Fish intensive)	Orange	28	Orange River Gorge	South Africa	-28.89773	18.39148
OSAEH_28_04	AEH/ILB	Orange	28	Orange River Gorge	South Africa	-28.76204	17.72510
OSAEH_28_05/OSSWQ 28_03	AEH/ILB (Fish intensive)	Orange	28	Orange River Gorge	South Africa	-28.07772	16.94431
OSAEH_29_01	AEH (Fish intensive)	Vaal/Harts	29	Southern Kalahari	South Africa	-28.37928	24.30178
OSAEH_29_02	AEH	Vaal	29	Southern Kalahari	South Africa	-28.11180	24.81138
OSAEH_29_04	AEH (Fish intensive)	Vaal	29	Southern Kalahari	South Africa	-28.70310	24.07428
OSAEH_29_05	AEH (Fish intensive)	Riet	29	Southern Kalahari	South Africa	-29.02696	24.51292
OSSWQ_15_01	ILB	Mohokare	15	Eastern Escarpment Mountains	Lesotho	-28.91251	27.89076
OSSWQ_15_02	ILB	Mohokare	15	Eastern Escarpment Mountains	Lesotho	-28.68582	28.36762
OSSWQ_15_03	ILB	Makhaleng	15	Eastern Escarpment Mountains	Lesotho	-30.08881	27.43446
OSSWQ_15_04	ILB	Senqu	15	Eastern Escarpment Mountains	Lesotho	-30.36438	27.57665
OSSWQ_26_01	ILB	Vaal	26	Nama Karoo	South Africa	-29.05697	23.69077
OSSWQ_26_03	ILB	Orange at Irene	26	Nama Karoo	South Africa	-29.18915	23.56933
WW39840	Groundwater	Borehole near Blumfelde	-	-	Namibia	-23.64748	18.38873
WW40960	Groundwater	Borehole near Stampriet	-	-	Namibia	-26.46936	20.61719
BH5229	Groundwater	Borehole near Two Rivers	-	-	Botswana	-26.46936	20.61719
BH9087	Groundwater	Borehole near Tsabong	-	-	Botswana	-25.76361	22.37459
BH1255	Groundwater	Borehole near Mokatako	-	-	Botswana	-25.76361	25.22608
42477	Groundwater	Borehole near Tswalu	-	-	South Africa	-27.28592	22.48868

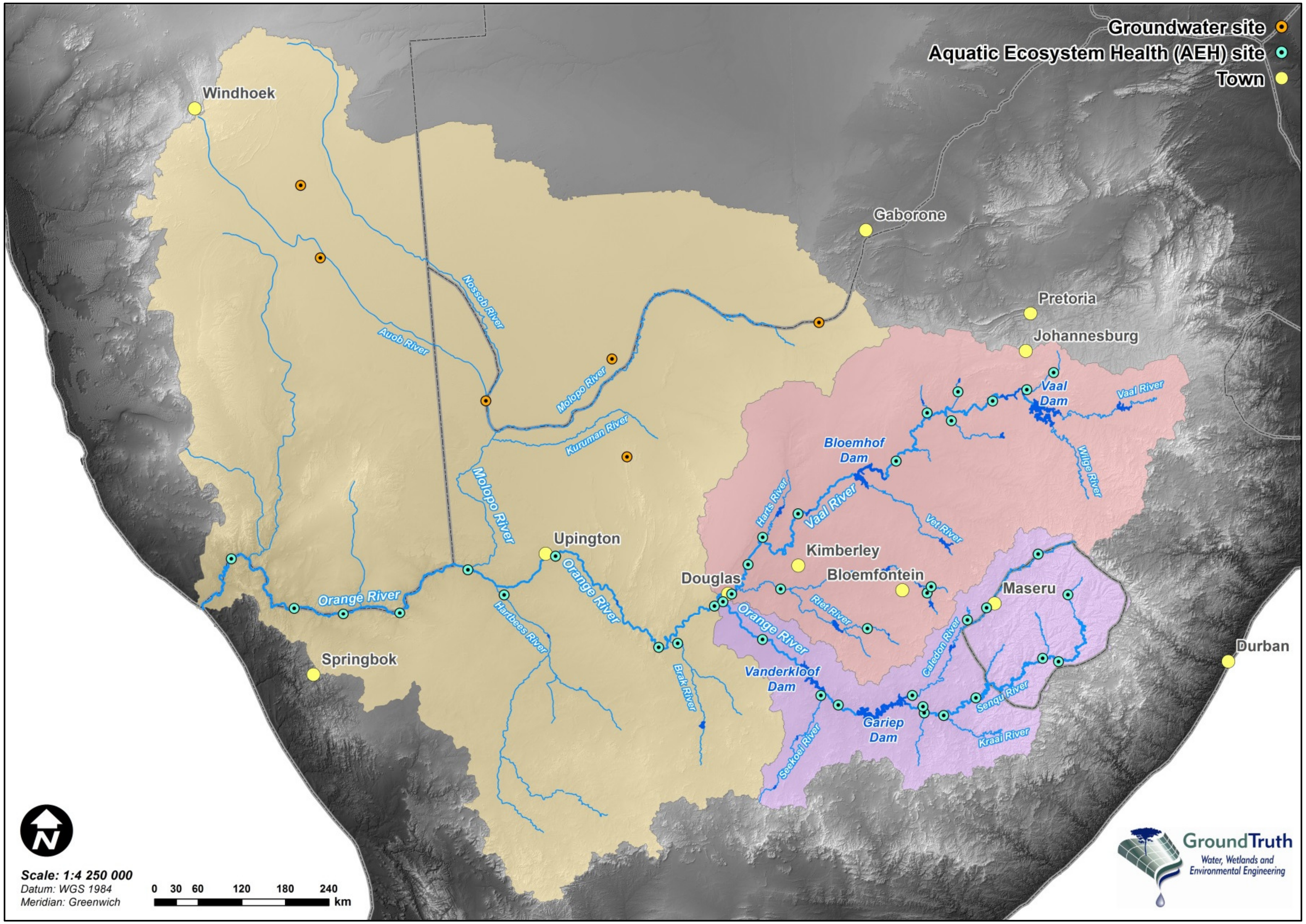


Figure 2.1 **Map of the study area indicating the spread of the Aquatic Ecosystem Health (AEH) sites sampled in JBS2 within the broader Orange-Senqu River Basin as well as the main Water Management Areas (WMA's) within the Basin.**

As part of the outcomes from JBS1 recommendations were provided regarding the suitability of sites considered in the first survey. Several EWR and IFR sites were included in JBS1 but not physically sampled by the field team. They are presented in Appendix B. These EWR and IFR sites were not included in the original list of 56 sites provided in the tender documentation and thus were not included in JBS2 but they should, however, be considered for JBS3. Where applicable, information/data collected from these EWR and IFR sites (specifically PES and EcoStatus scores) were used to inform the reference conditions for sites included in JBS2.

In addition to the sites in Appendix B several recommendations were provided in JBS1 regarding sampling of sites located along the Fish River in Namibia. These recommendations are summarised below:

- Surveys should be undertaken at site B2 near OSAEH 26_18 during late February – March as it seems that this is when the Fish River has the greatest potential for flow.
- The only instream indicator that is recommended for long-term monitoring is fish species composition and fish habitats.
- Particular attention should focus on naturally perennial pools, as these are ecologically important areas that are sensitive to sedimentation and predicted long-term downstream impacts of the dam.
- The baseline data collected on benthic diatoms from the Fish River during this study indicate that the results are too variable for diatoms to be appropriate indicators.
- Similarly, flows in the Fish River are too variable for aquatic invertebrates to provide appropriate or reliable indicators of ecological conditions.

Barring the fact that the sampling during JBS2 took place during winter (July – low flow period) and would likely have resulted in the ephemeral Fish River site being dry (with perhaps some pools present), sampling of the site was nevertheless planned as part of JBS2. Technical difficulties associated with obtaining work visas, however, prevented the site from being sampled in JBS2. Its inclusion in JBS3 should be considered taking into account the time of year of the survey and logistics.

Difficulties associated with obtaining work permits also prevented the ILB site OSSWQ_28_4 near Alexander Bay being sampled.

2.2 EcoRegional Context of Sites

AEH sites within the broader Orange-Senqu River Basin are located within different EcoRegions. Each ecoregion has been delineated according to specific characteristics, such as underlying geology, dominant vegetation type, soil characteristics and rainfall. As such, the EcoRegions themselves can be used to: a) provide a broad ecological/geological context for each of the sites, and b) aid the interpretation of results of the AEH survey presented here. Short descriptive summaries taken from Kleynhans *et al. (*2005) for each of the EcoRegions, in which the AEH sites were located, are provided below.

2.2.1 EcoRegion 11- Highveld

Plains with a moderate to low relief, as well as various grassland vegetation types (with moist types present towards the east and drier types towards the west and south), define this high lying region. Several large rivers have their sources in the region, e.g. Vet, Modder, Riet, Vaal, Olifants, Steelpoort, Marico, Crocodile (west), Crocodile (east) and the Great Usutu. Mean annual precipitation varies between 400 to 1000mm decreasing from East to West and rainfall seasonality being early to late summer. The average altitude varies between 1100 to 2100 m.a.s.l. Major threats to the ecoregion include land conversion to agriculture and mining.

2.2.2 EcoRegion 15 - Eastern Escarpment Mountains

This high lying region is characterized by closed hills, mountains with moderate and high relief with prominent escarpments towards the east. The vegetation consists of a range of grassland types with Afro Mountain and Alti Mountain Grassland being the defining types. Several major South African rivers have their sources in this region, e.g. Orange, Caledon, Wilge, Thukela, Buffalo, Mooi, Mzimkulu, Mzimvubu, Mgeni and Mkomazi,. Mean annual precipitation varies from 400 to 1000mm, with rainfall seasonality being early to late summer. Altitudes vary between 1100 and 3100 m.a.s.l. Threats to the ecoregion include widespread land use change from natural grasslands to agricultural crop lands and grazing pastures.

2.2.3 EcoRegion 26 - Nama Karoo

Topography is diverse but plains with a moderate to high relief and lowlands, hills and mountains with moderate to high relief are dominant. Vegetation consists almost exclusively of Nama Karoo types (low-shrub vegetation adapted to climatic extremes). Perennial rivers that traverse this region are the Riet and Orange. Rivers draining extensive parts of the region, such as the Hartbees, are seasonal. Mean annual precipitation varies from 0 to 500mm, with rainfall seasonality being very late summer to winter. Altitudes vary between 300 and 1900 m.a.s.l. major threats to the EcoRegion include land use change to pastoralism, mining, agriculture and exotic vegetation.

2.2.4 EcoRegion 28 - Orange River Gorge

This largely arid region is characterised by closed hills and mountains with a moderate to high relief topography. Orange River Nama Karoo is the dominant vegetation type along with Upland Succulent Karoo. This ecoregion is situated along the lower section of the Orange River. No perennial streams rise in this region. Mean annual precipitation varies from 0 to 100mm with rainfall seasonality being very late summer to winter. Altitude varies from 0 to 1100 m.a.s.l.

2.2.5 EcoRegion 29 - Southern Kalahari

Terrain morphological types consist of plains with low to moderate relief in the east, and open hills, lowlands and mountains with moderate to high relief in the west. The western part of the region consists of dune hills. The lower part of the Vaal River flows through the region, while others such as the Harts, Molopo, Kuruman and Nossob are seasonal. Vegetation consists of a variety of Kalahari Bushveld types. This region receives moderate/low precipitation in the east but becomes arid in the west. Rainfall seasonality is mid to very late summer, with mean annual precipitation ranging from 0-500. Altitude varies from 500-1900 m.a.s.l.

2.3 Sampling Teams

Sampling in the three sub-areas/catchments (i.e. Vaal, Upper Orange and Lower Orange) was carried out in parallel, over a two week period, by three separate field teams comprising of four members - one team leader/key expert and three non-key experts. Each team member was responsible for sampling a particular AEH component (i.e. Macroinvertebrates - SASS and MIRAI, Fish - FRAI, Vegetation - VEGRAI, Diatoms/water quality and IHI). Field teams were structured in such a way so as to comprise key experts and non-key expert members with overlapping skill sets, this in order to act as a built-in back-up system should a team member have fallen ill during field sampling. The key experts on each team served as the team leaders and co-ordinated sampling with the project co-ordinators. In addition, at least two SASS5 accredited practitioners were included per team in order to speed up identification per site and to provide built-in redundancy, should the assigned macro-invertebrate specialist be unable to perform the sampling.

Field teams were supported by admin staff who co-ordinated a) the accommodation reservations/payments and b) the collection and delivery of water quality samples for AEH analysis and also inter-laboratory benchmarking – this was done in conjunction with the courier company. In addition two experts (Dr Jonathan Taylor – diatoms, and Kim Hodgson – water quality) who were not involved with field sampling directly helped with the interpretation of water quality and diatom data, as well as the associated reporting thereof. The structure and composition of field teams for JBS2 is indicated in Table 2.2.

Table 2.2 Personnel comprising field teams and key experts/team leaders highlighted in boldface with an asterisk

Component	Team 1 – Upper Orange	Team 2 – Vaal	Team 3 – Lower Orange
Fish	Byron Grant	Andrew Husted	**Dr Gordon O'Brien***
Macroinvertebrates	**Dr Mark Graham***	**Peter Kimberg***	Dr Vere Ross-Gillespie
Vegetation	Andrew de Villiers	Lorainmari den Boogert	Gary de Winnaar
IHI, Water Quality, Diatoms	Juan Tedder	Christian Fry	Mahomed Desai

2.4 Sampling Programme

Prior to commencing sampling, the three sampling teams met near Douglas to participate in a one-day pre-sampling coordination workshop. The purpose of this co-ordination workshop was to standardise sampling protocols, check all sampling equipment and finalise logistics. Sampling protocols were practiced by each team at a single site on the Orange River. The following day, teams conducted sampling at sites located near Douglas in the Vaal system, independently of each other, after which they returned to Douglas to discuss problems encountered (i.e. with equipment, sampling protocol, logistics). The objective of this process was to standardise sampling protocols and procedures, eliminate technical issues and share information. On average, teams sampled a site per day for two weeks; however, where distances between sites were short two sites could be sampled in a day. Sites that required intensive fish sampling (owing to their importance) required a whole day to be effectively sampled, with nets deployed over-night.

2.5 Aquatic Ecosystem Health Sampling Protocols

The sampling protocols utilised in the survey represent the most up-to-date set of tools that have been approved, adopted and widely utilised by the South African Department of Water and Sanitation (DWS), water authorities and consultants across South Africa. The combination and application of these tools provided a comprehensive measure of aquatic ecosystem health at selected sampling sites within the Orange/Senqu River Basin. The tools used in the survey covered assessments of macroinvertebrate, water quality, fish, diatoms, riparian vegetation and habitat integrity. A brief overview of the different AEH components sampled and the assessment methods applied is provided in the following sections.

2.5.1 Macroinvertebrates

Macroinvertebrate families vary in their pollution tolerances. This makes them ideal indicators of water quality in freshwater ecosystems. In addition, macroinvertebrates react quickly to pollution events and are able to colonise previously disturbed/polluted habitats if conditions improve. Additionally they integrate water quality conditions over time and account for synergistic and additive effects of different water quality parameters.

The South African Scoring System version 5 (SASS5) (Dickens and Graham, 2002) was developed as a rapid technique for determining aquatic ecosystem health using aquatic macroinvertebrates as bio-indicators. The SASS5 technique has been accredited to ISO 17025 standards and forms part of one of the DWS river eco classification models for EcoStatus determination. The disadvantage of the aforementioned method is that certain instream habitat types must ideally be present for the method to accurately measure river health. Habitat types include stones (in current and out of current), GSM (gravel, sand and mud) and vegetation (aquatic and marginal). Reliability of the results is reduced if one or more of these three key biotopes are absent. In JBS2 standard SASS5 sampling procedures were performed by accredited SASS5 practitioners at all selected sampling sites. Sampling was undertaken at the sites dependent on whether appropriate conditions prevailed for sampling (e.g. availability of biotopes, flowing not stagnant water, not flood conditions, wadeable water depth, etc.). The SASS5 data collected were used to perform desktop analyses using the DWA EcoStatus tool – MIRAI (Macro-invertebrate Response Assessment Index) (Thirion, 2008).

2.5.2 Fish

The DWS approved river eco classification model for EcoStatus determination - Fish Response Assessment Index (FRAI) (Kleynhans, 2008) was used to model fish responses at each of the selected sampling sites. In accordance with the procedure, fish populations were sampled using an electroshocking device, as well as cast nets, fyke nets and seine nets, where applicable. Data were then compared to reference conditions.

Given that fish sampling incurs greater logistical concerns than other aspects, sampling sites were ranked according to their importance. Accordingly, a stratified sampling approach of these sites was adopted. In this regard it was decided that ***intensive fish sampling*** (using fyke nets, active cast-and seine-netting, concentrated electro-shocking) would only be undertaken at important sites. In ranking sites, the South African National Freshwater Ecosystem Priority Areas (NFEPA) and individual river profiles were considered and areas that comprised reference sites, fish corridors and/or fish support areas were prioritised.

The remainder of the sites were sampled using standard sampling techniques for a period of approximately two hours. Furthermore, at sites where electroshocking was not possible (e.g. owing to high flows, deep channels), a hybrid sampling approach was adopted which was tailored to best suit the specific conditions present at the sampling sites.

2.5.3 Diatoms

Benthic diatoms are present in all watercourses in South Africa. They are generally not limited by habitat availability because of their microscopic nature. South Africa has a good record of diatom species and their individual water quality tolerances. This makes them useful for inferring integrated water quality conditions and river health classes. Diatoms are also useful for determining historical water quality conditions as their silica frustules (shells) remain behind once they die, leaving a record of past conditions.

Sampling of diatoms was done according to prescribed protocols in Taylor *et al.* (2005). Results from samples were interpreted according to the Specific Pollution sensitivity Index (SPI; CEMAGREF, 1982) to determine river “health status”. The percentage of pollution tolerant valves (% PTV), in other words the proportion of pollution tolerant diatoms in the sample was calculated, giving a further indication of water quality conditions at each site. Diatoms were collected from all sites, where suitable substrate for sampling existed.

Diatom samples along with water chemistry samples were couriered in batches to the relevant laboratories for analyses during the course of the sampling period.

2.5.4 Riparian vegetation

Riparian vegetation performs a critical role in maintaining lotic ecosystem health. The objective of implementing VEGRAI (Vegetation Response Assessment Index) was to assess the change in riparian vegetation condition from a reference/natural state. Procedures for assessing riparian vegetation using VEGRAI Level 3 as detailed by Kleynhans *et al.* (2007) were undertaken at each of the monitoring sites.

Assessments included the minimum requirements for riparian vegetation assessments in fulfilling the South African national RHP as outlined by DWAF (2008). Assessments therefore included the:

- Condition of different vegetation zones within the riparian zone and the principle drivers of degradation if any;
- Description of native woody and non-woody vegetation; and
- Determination of introduced/exotic vegetation.

The results from the riparian vegetation surveys were used to determine the PES/current condition of respective sites based on the VEGRAI (Vegetation Response Assessment Index) model.

2.5.5 Habitat integrity

The requirements for assessing habitat integrity are similar to those required for riparian vegetation assessments; however, habitat integrity surveys were conducted in order to assess indicators of instream and riparian habitat modification. This was done at each site using the Index of Habitat Integrity (IHI) method as prescribed in Kleynhans *et al.* (2008). IHI assessments essentially consider the deviations/changes of habitat from natural conditions with reference to intensity and extent of human-induced impacts that have affected habitat integrity within river catchments. The assessments were achieved through determining the condition of each site by incorporating biological responses to driver changes (e.g. hydrological, geomorphological, physic-chemical, etc.) as well as through an integration of driver state or condition.

2.5.6 In situ water quality and water chemistry

2.5.6.1 Water Quality Parameters Analysed

In line with standard bio-assessment protocols and following the recommendations made in the Orange-Senqu Aquatic Ecosystem health Monitoring Programme (ORASECOM, 2009a), a suite of ancillary *in situ* water quality indicators was assessed at every site sampled. These indicators included; dissolved oxygen, pH, electrical conductivity and water temperature.

In addition to the *in situ* water quality measurements that were taken from each site, water chemistry samples were collected from all AEH sites as part of the chemical sampling component of JBS2. These samples were analysed at a single SABS approved water quality laboratory (WaterLab). Samples were couriered in batches, during the course of the sampling, from accommodation points used by each of the AEH teams. The water chemistry determinands that were analysed for AEH sites included: Total Dissolved Solids (TDS), Suspended Solids (SS), Conductivity, pH, Turbidity, Total alkalinity, Chloride, Sulphate, Fluoride, Nitrate, Nitrite, Total Phosphate, Orthophosphate, Chlorophyll-*a*, Kjeldahl nitrogen, Free and Saline Ammonia, Sodium, Potassium, Calcium, Magnesium, Silicon.

2.5.6.2 Key Water Quality Parameters for Ecosystem Health

Several key water quality parameters were selected to illustrate the water quality within the Basin in terms of their importance and/ or influence to biota and hence overall ecosystem health. These parameters included dissolved oxygen, pH, SS, TDS and nutrients (Total Inorganic Nitrogen (TIN) and orthophosphate). These parameters were analysed in relation to the DWAF (1996) target water quality guidelines for Aquatic Ecosystems. Where a determinand was found to be above the chronic effect value (DWAF 1996) for aquatic biota he determinand was deemed non-compliant (marked red), whereas if the determind was found to be lower than the chronic effect value it was considered compliant (marked green). Where insufficient data was available to determine the current value in relation to historic/background values, or where the laboratory detection limits were too low to provide meaningful results, the determinand was marked white.

The influence of these key parameters to freshwater ecosystem health is described in the sections below. All information has been sourced from Dallas and Day (2004).

2.5.6.2.1 Suspended Solids

The effects of elevated suspended solids and deposition of fine sediments has been well documented. In water with excess SS light penetration is reduced impeding photosynthesis and therefore the primary production of the system. This reduces food availability for higher trophic organisms. Increased suspended matter and its eventual deposition negatively affects macroinvertebrates by:

- Altering substrate composition and suitability for particular taxa;
- Increasing drift due to substrate instability;
- Clogging respiratory structures; and
- Reducing feeding rates by decreasing food density and impeding filter feeding.

The negative impact of excessive SS for fish includes:

- Impairment of gill functions;
- Reduced foraging efficiency and therefore growth; and
- The siltation or smothering of spawning areas.

The DWAF (1996) chronic effect value for SS is a change (negative or positive) of 10% (mg/l) from the historical background value (taken as the average over the last 5 years).

2.5.6.2.2 pH

As freshwater biota are adapted to maintain ionic and osmotic balance within narrow limits, unnatural/extreme or rapid changes to pH levels can prove detrimental. A change in pH can alter the rate and type of ion exchange across body surfaces, particularly gills. It is possible that lowering the pH can be directly detrimental, especially in water with a low buffering capacity, as hydrogen ions compete with larger cations that control physiological pathways. However, it is not necessarily the direct alterations to physiological functioning (driven by rapid or extreme pH changes) that are the primary cause of organism detriment but rather the physiological stress by increasing energy requirements to maintain osmotic and ionic balance. Such an increase in energy expenditure can lead to reduced fitness by slowing growth rates which in turn can result in a lower fecundity and therefore a reduction in the overall population size. In addition, pH levels can influence the mobilisation and hence bio-availability of toxic substances.

The DWAF (1996) chronic effect value for pH is a change (negative or positive) of 0.5 pH units from the historical background value (taken as the average over the last 5 years).

2.5.6.2.3 Total Dissolved Solids

TDS can be regarded as one of the primary environmental variables determining the composition, structure and health of communities of organisms living within an aquatic ecosystem. TDS may act as an antagonist or synergist in relation to a variety of pollutants. Species inhabiting the middle to lower reaches of a river are likely to be less sensitive to increases in salinity than those living in reaches with naturally low TDS, such as mountain streams. However, for the former, juvenile stages tend to be more sensitive to increased TDS levels than adults. The rate of change in TDS is also critical (as opposed to the final salinity) as many organisms are able to adjust to slow changes in salinity through physiological acclimation but not to rapid changes in salinity. It is important to note that this is mainly applicable to organisms inhabiting the middle/lower reaches of a river, while organisms inhabiting the upper reaches would be largely intolerant of increases in TDS. Unfortunately, information of tolerance limits to increased TDS by upper-reach biota is lacking.

The DWAF (1996) chronic effect value for TDS is a change (negative or positive) of 15% (mg/l) from the historical background value (taken as the average over the last 5 years).

2.5.6.2.4 Dissolved Oxygen

The maintenance of adequate DO concentrations is critical for the survival of the majority of aquatic organisms. The significance of DO depletion to biota depends on the frequency, timing and duration of the depletion. Continuous exposure to saturation levels of less than 80% is likely to have acute effects, while repeated exposure to reduced DO concentrations may cause physiological and behavioural stress effects. Furthermore, in low oxygen environments biota may increase their rate of respiration which, when pollutants are present in the system, can lead to an increased chance of pollutant uptake via respiratory mechanisms. It is for this reason that many species tend to avoid anoxic zones.

The DWAF (1996) chronic effect value for DO is a 7-day moving average less than 60% saturation. In JBS2 a 7-day moving average could not be measured, owing to time limitations for sampling. A single point at each site was thus taken and if it was below 60% saturation it was deemed to be non-compliant.

2.5.6.2.5 Nutrients (Total Inorganic Nitrogen and Orthophosphate)

TIN (the cumulative term for ammonia, nitrate and nitrite) occurs abundantly in nature and is an essential constituent of many biochemical processes. Un-ionized ammonia (NH_3) is toxic to aquatic organisms and its toxicity increases as pH and temperature increase. Nitrite is an intermediate in the conversion of ammonia to nitrate, and is also toxic to aquatic organisms.
Nitrate is the least toxic of the inorganic nitrogenous compounds and is rapidly converted to organic nitrogen in by plants and algae.

Orthophosphate is the soluble, reactive form of phosphorous that is utilised by plants and algae.

Excessive quantities of both TIN and Orthophosphate can lead to eutrophication (cyanobacteria blooms) of the aquatic environment, thereby drastically reducing oxygen levels and increasing toxic compounds found within the cyanobacteria. In addition, ammonia, nitrite and nitrate are toxic as they interfere with the metabolic pathways of organisms and lead to several acute and chronic diseases.

The DWAF (1996) chronic effect value for total inorganic nitrogen (calculated as nitrite+nitrate+free/saline ammonia) is greater than 2.5 mg/l. For orthophosphate the chronic effect value is greater than 0.025 mg/l. In JBS2 the detection limit for Orthophosphate as determined by WaterLab was only 0.2 mg/l, this low resolution resulted in low confidence being placed in the orthopsphate values calculated, specifically in relation to Aquatic Ecosystem health guidelines, and in most cases the determinand was marked white.

2.5.7 Groundwater

As per recommendations in Section 2.3.3.2 of the tender dossier, groundwater quality sampling was included as part of the JBS2 sampling programme. Six sites, in key locations in Namibia, Botswana and South Africa, were proposed for sampling based on previous ORASECOM documentation (ORASECOM, 2008; ORASECOM, 2009b) (see Table 2.1 for localities). A separate two man team comprising staff from GroundTruth and DWS travelled in parallel to the AEH teams and collected groundwater samples from the specified sites together with member state personnel. This arrangement helped to minimise the amount of time spent in the field by AEH teams and allowed more time for AEH data to be analysed and reported on – upon completion of the field work. It is important to note that the personnel from member states, who aided in the collection of groundwater samples, provided necessary equipment to purge and or pump boreholes where they were required. Determinands analysed for groundwater samples included: alkalinity, Arsenic, Calcium, Chloride (soluble), electrical conductivity, Fluoride, Iron, Total hardness, Magnesium, Manganese, Sodium, Ammonia (soluble), Nitrate (soluble), pH, Selenium, Sulphate (soluble) and turbidity.

2.6 Data Collation

As far as possible the reference data required for each AEH site in order to run the various DWS EcoStatus models was obtained, before sampling commenced, by the relevant specialists in each field team. This reference data was used to populate separate EcoStatus model spreadsheets for each site before sampling commenced. In doing so, data obtained from field sampling could then be captured electronically directly into the EcoStatus model spreadsheets, for a given site, on a daily basis while teams were in the field. Upon completion of sampling, the teams collated the sampling data collected during the survey and ensured that all necessary EcoStatus models were performed. All data and EcoStatus model results were e-mailed to GroundTruth for integration into the final report. All data collected and generated during JBS2 were submitted to ORASECOM for inclusion in their database and for future reference.

2.7 Data Interpretation and Reporting

Data interpretation and reporting here follows the recommendations provided in the manual for the Orange-Senqu Aquatic Ecosystem Health Monitoring Programme (ORASECOM, 2009a) and the general formatting provided in JBS1. Where possible results generated from the EcoStatus models used in JBS2 have been compared to historical data and the results obtained in JBS1 to establish preliminary trends for aquatic ecosystem health components at each site. In order to interpret Diatom SPI scores in terms of Ecological Category and EcoStatus 4 classification the conversions between SPI and EC provided in Table 2.3 were used. The EcoStatus indices calculated for each site were integrated using the DWS EcoStatus 4 tool (the same metric in RIVDINT) into six categories which were used to rank and represent the overall site EcoStatus from an A- representing a natural condition to an F- representing a critically modified condition (see Table 2.4)[2]. Importance scores and weights were not applied to fish and aquatic invertebrate ecological categories. This was because individual EcoStatus models inherently account for the natural diversity fish and invertebrates in relation to flow and velocity requirements, water quality requirements, biotopes, depth and cover.

The same confidence ratings were applied to all sites for fish (3), macroinvertebrates (4) and riparian vegetation (3) as each team experienced similar limitations with regards to the collation of historical data.

Table 2.3 Interpretation of Diatom SPI scores in terms of Ecologial Category and Ecostatus classification

Interpretation of index scores		
Ecological Category (EC)	**Class**	**Index Score (SPI Score)**
A	High quality	18 - 20
A/B		17 - 18
B	Good quality	15 - 17
B/C		14 - 15
C	Moderate quality	12 - 14
C/D		10 - 12
D	Poor quality	8 - 10
D/E		6 - 8
E	Bad quality	5 - 6
E/F		4 - 5
F		<4

[2] It is important to note that the scores and their associated categories for the individual EcoStatus components were extracted directly from the individual EcoStatus model output. However, Table 2.4 was used to derive the overall PES category for each site, obtained from the EcoStatus 4 output values.

Table 2.4 Ecological categories, category names and associated meanings used to interpret Ecological Category (adapted from Kleynhans, 1998)

Ecological Category	Generic Description Of Ecological Conditions	Arbitrary Guideline Score (% of Maximum Theoretical Total)
A	Unmodified/natural, close to natural or close too predevelopment conditions within the natural variability of the system drivers: hydrology, physico-chemical and geomorphology. The habitat template and biological components can be considered close to natural or to pre-development conditions. The resilience of the system has not been compromised.	**>92 - 100**
A/B	The system and its components are in a close to natural condition most of the time. Conditions may rarely and temporarily decrease below the upper boundary of a B category.	**>88 - <= 92**
B	Largely natural with few modifications. A small change in the attributes of natural habitats and biota may have taken place in terms of frequencies of occurrence and abundance. Ecosystem functions and resilience are essentially unchanged.	**>82 - <=88**
B/C	Close to largely natural most of the time. Conditions may rarely and temporarily decrease below the upper boundary of a C category.	**>78 - <=82**
C	Moderately modified. Loss and change of natural habitat and biota have occurred in terms of frequencies of occurrence and abundance. Basic ecosystem functions are still predominantly unchanged. The resilience of the system to recover from human impacts has not been lost and it is ability to recover to a moderately modified condition following disturbance has been maintained.	**>62 - <=78**
C/D	The system is in a close to moderately modified condition most of the time. Conditions may rarely and temporarily decrease below the upper boundary of a D category.	**>58 - <=62**
D	Largely modified. A large change or loss of natural habitat, biota and basic ecosystem functions have occurred. The resilience of the system to sustain this category has not been compromised and the ability to deliver ecological goods and services has been maintained.	**>42 - <=58**
D/E	The system is in a close to largely modified condition most of the time. Conditions may rarely and temporarily decrease below the upper boundary of an E category. The resilience of the system is often under severe stress and may be lost permanently if adverse impacts continue.	**>38 - <=42**
E	Seriously modified. The change in the natural habitat template, biota and basic ecosystem functions are extensive. Only resilient biota may survive and it is highly likely that invasive and problem (pest) species may dominate. The resilience of the system is severely compromised as is the capacity to provide ecological goods and services. However, geomorphological conditions are largely intact but extensive restoration may be required to improve the system's hydrology and physico-chemical conditions.	**22 - <=38**
E/F	The system is in a close to critically modified condition most of the time. Conditions may rarely and temporarily decrease below the upper boundary of a F category.	**18-<=22**
F	Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete change of the natural habitat template, biota and basic ecosystem functions. Ecological goods and services have largely been lost This is likely to include severe catchment changes as well as hydrological, physico-chemical and geomorphological changes. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible. Restoration of the system to a synthetic but sustainable condition acceptable for human purposes and to limit downstream impacts is the only option.	**<18**

3. RESULTS

3.1 Aquatic Ecosystem Health Overview

A summary of the AEH results obtained during the JBS2 survey is provided in Figure 3.1 below and Table 3.1. The results of separate AEH components (macroinvertebrates, fish, diatoms and riparian vegetation) are integrated to show the overall EcoStatus Category for the sites in each of the main catchments of the Orange-Senqu River Basin. Colour coding of the sites is according to Table 2.4, transitions between the categories are also shown (Fig 3).

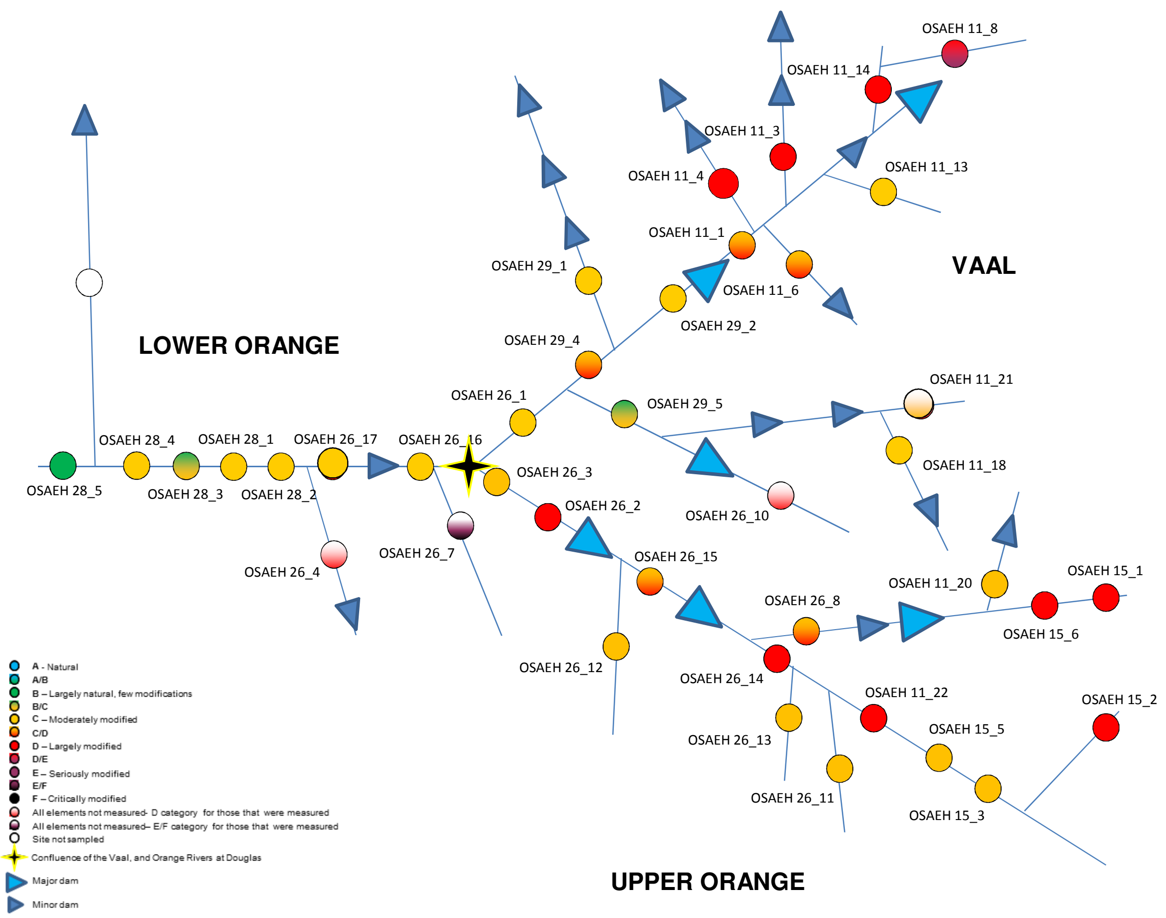


Figure 3.1.1. Map representing the AEH sites sampled in JBS2 in the Orange-Senqu River Basin. Sites are colour coded according to overall EcoStatus Category. Vaal = connected sites to the upper right of the black star, Upper Orange = connected sites to the lower right of the black star and the Lower orange = connected sites to the left of the black star.

Detailed results obtained from the sampling and subsequent EcoStatus models performed for each AEH component, for each site, are discussed in the following sections:

- Section 3.1.1 Vaal - connected sites OSAEH 11_8 to OSAEH 26_1
- Section 3.1.2 Upper Orange - connected sites OSAEH 15_2 to OSAEH 26_3
- Section 3.1.3 Lower Orange - connected sites OSAEH 26_16 to OSAEH 28_5
- Section 3.1.4 Groundwater sites

Table 3.1 **Summary of EcoStatus Category scores for AEH components in JBS1 and JBS2. * Denotes sites where certain AEH components could not be measured - overall EcoStatus scores for these sites are not true indicators of overall EcoStatus**

Catchment	Site Number	River	Diatoms JBS1	Diatoms JBS2	Fish JBS1	Fish JBS2	Inverts JBS1	Inverts JBS2	Instream JBS1	Instream JBS2	Rip Veg JBS1	Rip Veg JBS2	Overall Ecostatus JBS1	Overall Ecostatus JBS2
Vaal	OSAEH_11_8	Blesbokspruit	C/D	F	D	D/E	D/E	E	D/E	E	D	D	D	D/E
Vaal	OSAEH_11_14	Suikerbosrant	C	B/C	C	C	C	C/D	C	C/D	B/C	D	B/C	D
Vaal	OSAEH_11_13	Kromellenboogspruit	C	D/E	C	C	C	D	C	C/D	C	C	C	C
Vaal	OSAEH_11_3	Mooi	D	C	D	C/D	D	C/D	D	C/D	E	E	E	D
Vaal	OSAEH_11_6	Renoster	C	D/E	C	D	C	C	C	D	C	C	C	C/D
Vaal	OSAEH_11_4	Skoonspruit	D/E	F	C	D/E	C	D	C	C/D	C	C	C	D
Vaal	OSAEH_11_1	Vaal	C	D/E	C	B/C	C	E	C	D	C	D	C	D
Vaal	OSAEH_29_2	Vaal		B/C		C		C		C		C		C
Vaal	OSAEH_29_1	Harts	C	B/C	D	C	C/D	C	D	C	D	D	D	C
Vaal	OSAEH_29_4	Vaal	C	B	D	C	C/D	D	C	C	D	D	C	C/D
Vaal	OSAEH_11_21	Korannaspruit	C	D	C	C	D	-	C	E	B	C	C	C*
Vaal	OSAEH_11_18	Modder	C	D	C	C	D	C/D	C	C	B	C	C	C
Vaal	OSAEH_26_10	Riet	C	E	C	C/D	C	-	C	E	B	B/C	C	D*
Vaal	OSAEH_29_5	Riet	B/C	B/C	C	C/D	C	B/C	C	C	B	B	C	B/C
Vaal	OSAEH_26_1	Vaal	B/C	B	C	C/D	C/D	D	C	D	B/C	B/C	C	C
Upper Orange	OSAEH_15_2	Matsoku		B		E	D	C/D		D		E	C	D
Upper Orange	OSAEH_15_3	Senqu		C		D		C		C		C/D		C
Upper Orange	OSAEH_15_5	Senqu		B		D		C		C/D		B		C
Upper Orange	OSAEH_11_22	Orange		C/D		D		D		D		D		D
Upper Orange	OSAEH_26_11	Kraai	C	B	C	D	C	B/C	C	C	C	D	C	C
Upper Orange	OSAEH_26_13	Stormbergspruit		C		C		C/D		C		C		C
Upper Orange	OSAEH_26_14	Orange		C		D		D		D		C/D		D
Upper Orange	OSAEH_15_1	Caledon	B	B/C	D	C/D	C	B/C	D	C	C	E	C	D
Upper Orange	OSAEH_15_6	Caledon		F		E		D		D		D		D
Upper Orange	OSAEH_11_20	Leeu	C	C/D	C	D	C	C	C	C/D	B	C	C	C
Upper Orange	OSAEH_26_8	Caledon	C	D	D	C	D	D	D	C/D	B	C/D	C	C/D
Upper Orange	OSAEH_26_15	Orange		C		C/D		C/D		C/D		D		C/D
Upper Orange	OSAEH_26_12	Seekoei		C		D		C/D		C/D		A		C
Upper Orange	OSAEH_26_2	Orange	B	B	C/D	D	C	D	C	D	B/C	D	C	D
Upper Orange	OSAEH_26_3	Orange		B/C		C		D		C/D		B/C		C
Lower Orange	OSAEH_26_7	Brak		-		-		-		-		E/F		F*
Lower Orange	OSAEH_26_16	Orange		B		C		D		C/D		C		C
Lower Orange	OSAEH_26_17	Orange	B/C	B/C	B/C	C	B	C	B/C	C	D	D	C	C
Lower Orange	OSAEH_26_4	Hartbees		-		-		-		-		D		E*
Lower Orange	OSAEH_28_2	Orange	C	C	C	C	C	C	C	C	C	C	C	C
Lower Orange	OSAEH_28_1	Orange		C/D		C		C		C		C/D		C
Lower Orange	OSAEH_28_3	Orange		C		B/C		B/C		B/C		B		B/C
Lower Orange	OSAEH_28_4	Orange	C	B/C	C	C	C	B/C	C	C	C	C	C	C
Lower Orange	OSAEH_28_5	Orange	C	B	B/C	B/C	B/C	B/C	B/C	B/C	B	B	B/C	B

3.1.1 Vaal River Catchment

In general, results revealed that much of the Vaal Catchment was in an impacted to highly impacted condition, C-C/D category. The Upper Vaal WMA was particularly impacted with sites in a C/D-D category and the uppermost site OSAEH 11_8 (just south of Nigel and the East Rand) in a seriously modified condition (D/E). The major impacts to the sites within the system include: a large number of dams (altering temperature and flow regimes), extensive mining operations and agriculture (land use change, habitat destruction and water quality impacts) as well as cumulative water quality impacts from industries and densely populated area's (elevated nutrients and salts).

AEH sites located in the Vaal catchment are shown in Figure 3.2, while overall EcoStatus condition of the sites is represented in Figure 3.3.

Results of the water chemistry analyses from samples collected at all AEH sites in the Orange-Senqu River Basin are provided in Appendix C. These data were analysed in relation to DWAF (1996) chronic effect values for aquatic ecosystems and used to inform the compliance for AEH sites.

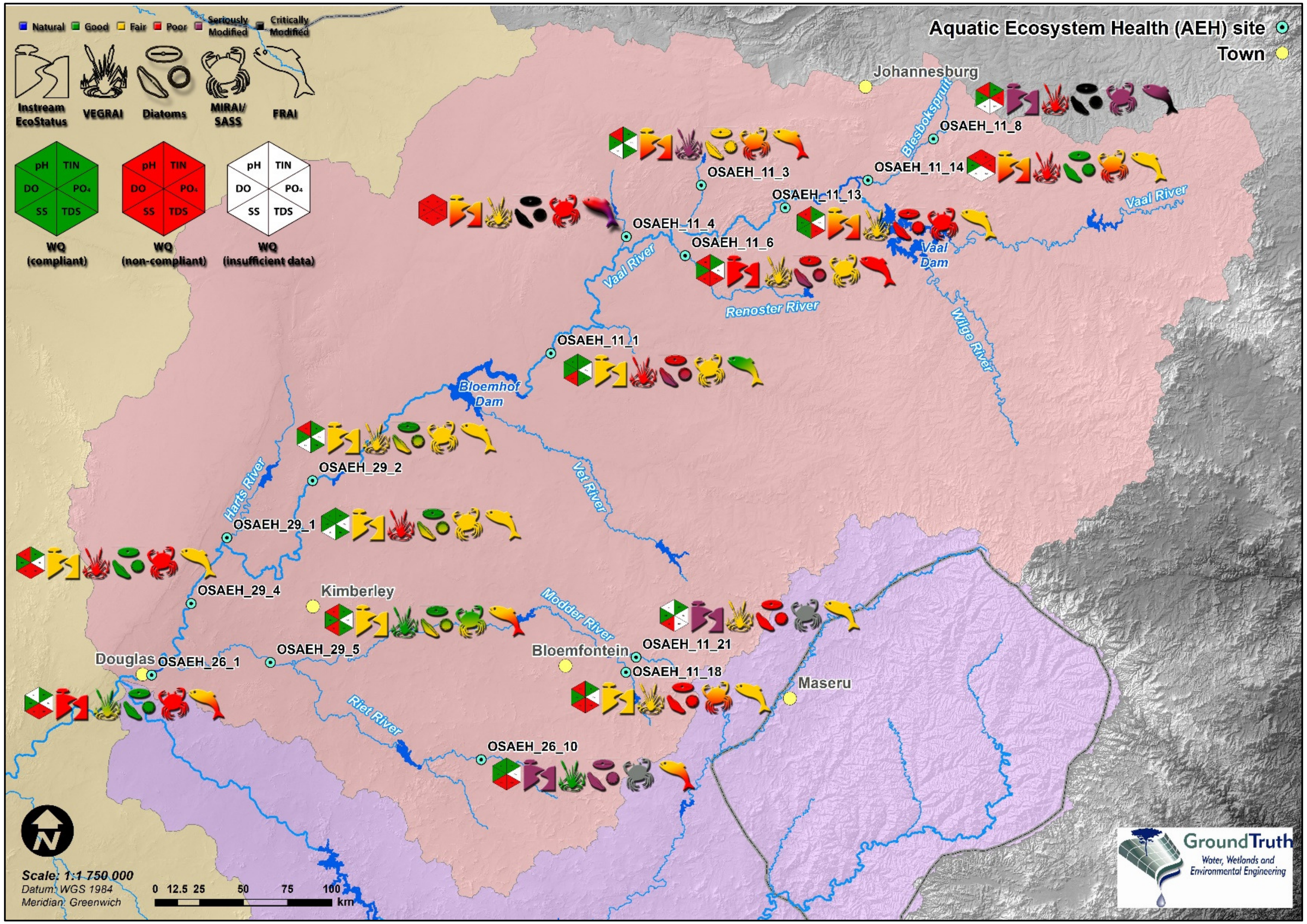


Figure 3.2 **Study sites within the Vaal catchment. AEH components are colour coded according to EcoStatus categories (grey symbols indicate that the component was not sampled). Water quality (WQ) determinands are colour coded according to compliance with the DWAF (1996) chronic effect values for aquatic ecosystems.**

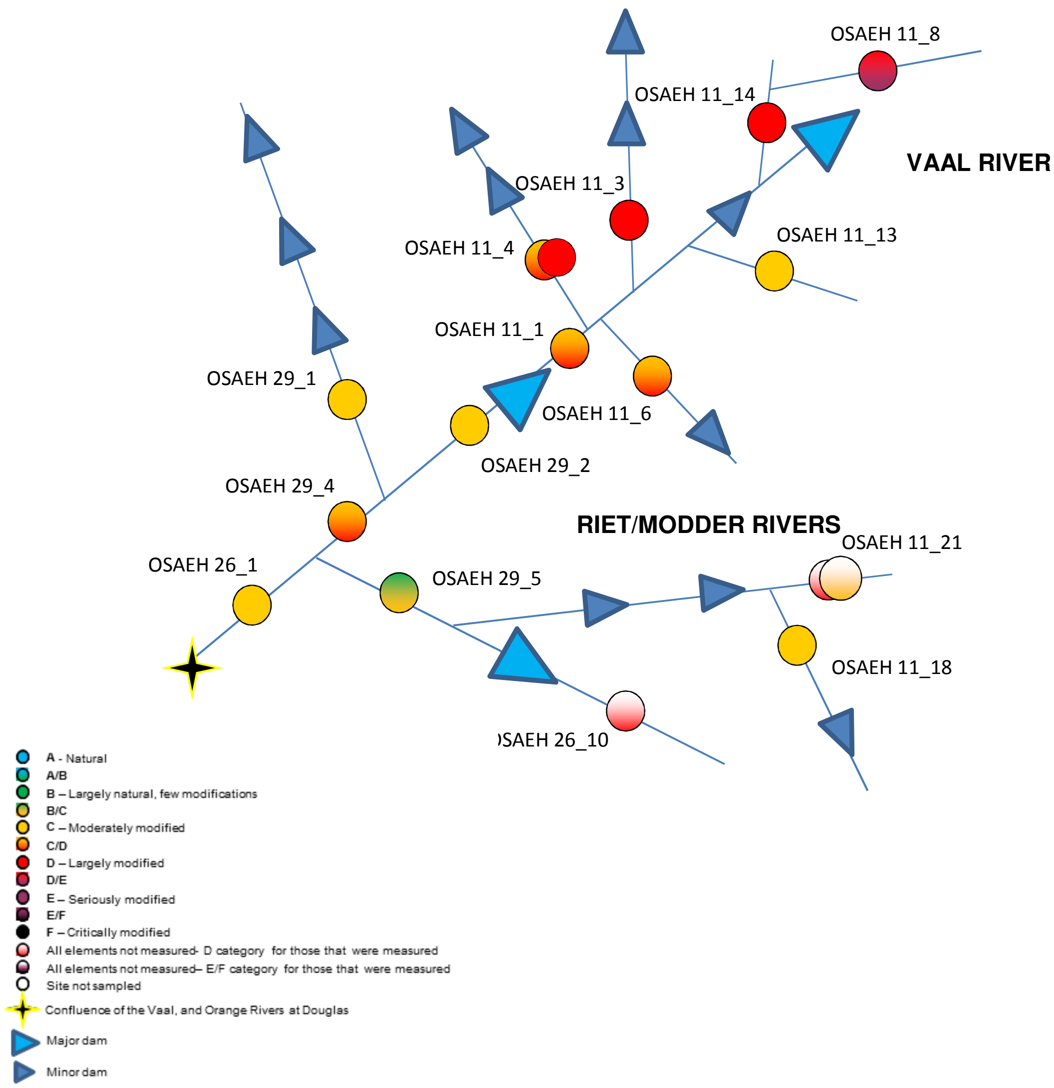


Figure 3.3 Map representing the AEH sites sampled in JBS2 in the Vaal catchment. Sites are colour coded according to overall EcoStatus Category

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3.1.1.1 OSAEH_11_08 - Blesbokspruit at Heidelberg

3.1.1.1.1 Site Description

The site is situated in the Blesbokspruit between Nigel and Heidelberg. The active channel comprises a series of riffles and runs and is dominated by bedrock and boulder substrate. The Stones-In-Current (SIC) biotope was abundant but was limited by the size of the boulders as well as the extensive growth of aquatic macrophytes which has a smothering effect on all biotopes. Marginal vegetation cover was moderate and gravel, sand and mud substrates (GSM) were limited.

Longitude	28.426916°	**Latitude**	-26.477589°
Altitude (m.a.s.l.)	1533	**Water Management Area**	Upper Vaal
Level 2 EcoRegion	11.03	**Quaternary catchment**	C21F
Geomorphological zone	Lower foothills	**Vegetation**	Soweto Highveld Grassland

Upstream | **Downstream**

3.1.1.1.2 Present Ecological State (PES)

IIHI	Integrity Score: 41 Integrity Category: D/E Key impacts were changes to water quality as a result of upstream run-off from urban areas, discharge from a WWTW, poultry farms and mining activities within the adjacent catchments. Instream habitat was covered in algae and aquatic macrophytes (watercress and *Potamogeton pectinatus*). Flow modifications were due to mine and WWTW effluents increasing basal flows. Some litter was observed at the site.

RIHI	Integrity Score: 39 Integrity Category: D/E The main impacts were vegetation removal due to fires, overgrazing, and trampling. The livestock activities have cause bank erosion and channel modification. Increased flows have resulted in wider channels and bank erosion. A number of exotic species were observed at the site.
Rip veg	EcoStatus: D (47.6%) **Marginal zone: Sedge and reed dominated** Right and left bank: A recent fire event adversely affected vegetative cover. Grazing pressure was excessive and vegetative cover very low on both banks. Invasive grass species *Bromus catharticus* present in high abundance. Marginal zone also contains *Phragmites australis*, *Typha capensis, Cyperus* and *Juncus effusus. Gomphostigma virgatum* is present. Impacts: Wastewater and run-off input due to sewerage treatment, mining, agriculture and other urban related activities as the town of Nigel is upstream of the site. The aquatic weed *Nasturtium officinale* present in high abundance. **Non marginal zone: Grass herb dominated** Right bank and left bank: A recent fire event large impact on vegetative cover. Exotic invasion of herbaceous species is high. Invasive grass species *Bromus catharticus* is present at the bridge. Woody invasive species includes scattered individuals of *Acacia mearnsii* as well as *Sesbania punicea.* Some interspersed patches of *Phragmites australis, Cyperus* and *Juncus effusus* species present. Upper zone: Characterised by grassland species, but high abundance of *Seriphium plumosum* indicative of overgrazing. Woody species are minimal. Loss of indigenous species due to overgrazing. Impacts: Bridge crossing present upstream. Invasive species both woody and herbaceous present. Trampling and grazing pressure should be lower under reference conditions.
WQ	The water quality at this site was poor. Dissolved oxygen saturation was unsatisfactory at 63% (6.32 mg/l), and dissolved salt concentrations were elevated, with TDS (498 mg/l) and sulphate (118 mg/l) recorded in the JBS 2 data. Nutrient enrichment is also apparent at this site, with elevated nitrate and phosphorus concentrations recorded in the JBS 2 data (nitrate 1.5 mg/l, total phosphorus 0.8 mg/l, orthophosphate 0.7 mg/l). The historical data from DWS site C2H185 also indicated significant nutrient enrichment at times, with the 95-percentile statistic for nitrate, ammonia and orthophosphate recorded as 2.0, 2.1 and 0.7 mg/l respectively. The historical data from DWS site C2H185 also indicates microbiological contamination with a 95-percentile of 21 000 *E. coli* per 100 ml.
Diatoms	The diatom assessment indicated that integrated water quality was critically modified. The specific sensitivity pollution index (SPI) score was a low 3.2 (out of a maximum of 18). A relatively low number of 13 species were identified from the 400 diatom cell-count with approximately 11.5% of the cells being deformed.
Inverts	Jul 2015: SASS5 score: 25 No of Taxa: 8 ASPT: 3.1 Feb 2014: SASS5 score: 31 No of Taxa: 9 ASPT: 3.4 Oct 2013: SASS5 score: 30 No of Taxa: 9 ASPT: 3.3 Jun 2012: SASS5 score: 22 No of Taxa: 7 ASPT: 3.1 Apr 2008: SASS5 score: 61 No of Taxa: 16 ASPT: 3.8 Aug 2007: SASS5 score: 57 No of Taxa: 14 ASPT: 4.1 Aquatic macroinvertebrate diversity was far lower than expected. No taxa with a moderate or high sensitivity to water quality impairment were present at the site confirming that water quality has a limiting effect on the assemblage. Taxa diversity was lower than expected across the range of flow and habitat preferences. The July 2015 SASS results showed that the site has remained in a similarly impaired state since 2012.based on a comparison with the River Health Programme (RHP) results. Based on the MIRAI results the Present Ecological State (PES) of the aquatic macroinvertebrate community was rated as a Category E (27.5%).
Fish	The fish community wellbeing evaluation resulted in a largely modified (D/E (41.3%)) ecological state. Only two of the expected nine fishes were collected at the site which was sampled extensively using active electrofishing and limit cast netting methods. Only a single individual of the *Clarias gariepinus*

	(Sharptooth catfish) and the *Pseudocrenilabrus philander* (Southern mouthbrooder) were sampled. Although the more common species such as *Labeo capensis* (Orange River mudfish), *Labeo umbratus* (Moggel), *Tilapia sparrmanii* (Banded tilapia), *Barbus anoplus* (Chubbyhead barb) and *Barbus paludinosus* (Straightfin barb) were expected to occur in the reach, albeit with limited frequency, these were not collected. Drivers of change identified to be affecting the wellbeing of the fish communities included flow alterations, notably increased base flows. The discharge and pumping of mine workings has increased the base flows of the system, this has also impacted on the water quality of the system. The extensive algae growth across the reach is evident of eutrophication of this system; this has also impacted on the water quality of the system. The increased flows and algae growth has also impacted on the quality and quantity of habitat availability. The overall impact of these drivers of change at this site has been considered to be large/serious as the fish community was evaluated to occur in a largely modified/seriously modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.1.3 EcoStatus

Driver Components	PES
IHI: Instream	D/E
IHI: Riparian	D/E
Water Quality (Diatom SPI)	F
Response Components	**PES**
Riparian Vegetation	D
Macroinvertebrates	E
Fish	D/E
EcoStatus	D/E

3.1.1.1.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	D/E	Alteration of flows	Effluent from WWTW, mines and storm water run-off	F
		Water quality deterioration	Effluent from WWTW, mines and storm water run-off and agriculture	NF
RIHI	D/E	Channel modification	Increased flows has re-shaped channel from upstream sources	F
		Bank erosion	Excessive cattle trampling and overgrazing	NF
Rip veg	D	Loss of marginal zone vegetation.	Increased flows	F
		Loss of riparian habitat.	Erosion from bridge, localized effect	NF

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Loss of indigenous species.	High grazing pressure and trampling in lower and upper zones	
		Aquatic exotic invasive species	*Nasturtium officinale* highly abundant due to nutrient enrichment	
WQ	F	Diatoms dominated by taxa tolerant of highly degraded water quality	Effluent from WWTW, mines, agriculture and storm water run-off	NF
		High dissolved salt concentrations	Point sources (mine water decants) and diffuse run-off from mining-related activities.	
		Significant nutrient enrichment and elevated *E. coli* levels at times.	Urban run-off from formal and informal settlements and from areas with inadequate wastewater infrastructure.	
Inverts	E	Flow modification especially increased base flows	Decant from mines, effluent releases from WWTW and well as run-off from urban and industrial areas.	F
		Decreased water quality	Decant from mines, effluent releases from WWTW and well as run-off from urban and industrial areas	NF
		Limited habitat availability	Smothering of habitat by alien invasive macrophytes due to nutrient enrichment	
Fish	D/E	Loss of habitat diversity as a result of flow modification.	The discharge and pumping of mining areas upstream of the catchment. The development of the catchment area and increased storm water run-off	F
		Altered velocity-depth habitats notably increased base flows.		
		Impaired water quality.	Discharge and pumping from mine workings, and also surrounding agricultural activities.	NF
		Decreased water quality affects species with requirements for high water quality.	Increased nutrients, sediments and toxins from urban areas	
		Loss of habitat	Excessive algae growth (eutrophication)	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.1.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	The VEGRAI category remained unchanged at D from JBS1 to JBS2. The following impacts require attention to prevent the deterioration of riparian vegetation. Nutrient input likely to increase due to urban sprawl and mining activities. Frequent fires and high grazing pressure alters vigour and resilience of riparian vegetation.
Water Quality	Decline	2010 – current:

Response Components	Trend	Description
		Increasing trend in Nitrate + Nitrite concentration noted at C2H185
Macroinvertebrates	Decline	THE PES of aquatic macroinvertebrate communities decreased from a D/E during JBS1 to an E during JBS2.
Fish	Decline	The FRAI Class decreased from a Class D during JBS1 to a D/E during JBS2

3.1.1.2 OSAEH_11_14 – Suikerbosrand at Vereeniging

3.1.1.2.1 Site Description

The site is situated in the lower reach of the Suikerbosrand River downstream of the R54 road bridge, approximately 14 km from the confluence with the Vaal. Habitat at the site consisted of a long cobble dominated riffle. Stones-In-Current (SIC) and marginal vegetation biotopes were abundant while GSM was limited. Active channel features include densely vegetated islands of reeds and sedges, creating a braided system of open-water predominated by pools and runs. Instream habitat, particularly the runs and riffles, were comprised largely of boulder and cobble substrate, while fine sediments, gravel and sand were confined to marginal zones and vegetated islands. The riparian zone has a defined flood terrace dominated by grass cover leading to a steep, densely wooded embankment.

Longitude	28.04964°	**Latitude**	-26.68119°
Altitude (m.a.s.l.)	1437	**Water Management Area**	Upper Vaal
Level 2 EcoRegion	11.01	**Quaternary catchment**	C21G
Geomorphological zone	Lowland	**Vegetation**	Soweto Highveld Grassland

Upstream	Downstream

3.1.1.2.2 Present Ecological State (PES)

IIHI	Integrity Score: 63 Integrity Category: C Impacts included changes in water quality as a result of urban run-off and upstream WWTW (sewage and soapy odour and extensive algae coverage instream). Extensive dumping occurred at the site, with large amounts of litter and rubble observed. Some channel modification and erosion was observed due to scouring. Some sedimentation was observed in slow moving and standing pools. Minor hydrological changes were present, due to WWTW upstream, as well as fallen trees and debris causing minor inundation.
RIHI	Integrity Score: 43 Integrity Category: D The main impacts were encroachment of the riparian zone by exotic vegetation (*Eucalyptus sp.*, *Salix babylonica* and honeysuckle bush). Vegetation removal was evident due to trampling and rubbish dumping. An additional impact was bank erosion.
Rip veg	EcoStatus: D (53.2%) **Marginal zone: Reed and tree dominated** Right and left bank: *Phragmites australis* and *Salix babylonica* were the dominant species within marginal zone. Areas underneath *Salix babylonica* were mostly sparsely vegetated. *Schoenoplectus* and *Persicaria* species were present with pockets of *Typha capensis*. Scouring of marginal zone was more prominent on right bank. Islands: *Phragmites australis.* Impacts: Dam present upstream of R23 has changed the natural hydrological regime. Irrigation activities upstream affect water quality. Small patch of the aquatic weed *Eichhornia crassipes* was present. Livestock trampling in marginal zone. Nutrient input due to sewerage treatment and release. **Non marginal zone: Tree dominated with vast open patches under tree canopy** Right bank and left bank: Dominant tree species includes *Celtis africana*, *Salix babylonica* and *Gleditsia tracanthos* with interspersed patches of *Phragmites australis and Schoenoplectus* species. *Eucalyptus camaldulensis* was present. Dominant understorey was *Cynodon dactylon* and *Asparagus laricinus.* Islands: Stands of *Phragmites australis* and the alien invasive tree *Gleditsia tracanthos.* Upper zone: Contains most of the tree species present in the lower zone but the canopy cover decreases and the amount of terrestrial grasses increase. Impacts: Trees are more abundant due to less frequent flood events. Grazing and trampling is more extensive. Erosion of banks as a result of high grazing pressure and sparse cover under tree canopy. Rubbish dumping extensive.
WQ	Elevated levels of dissolved salts, with TDS measured at 446 mg/l and Sulphate at 96 mg/l at the time of sampling. Elevated nutrient concentrations, with Nitrate 3.2 mg/l, Total Phosphorus 0.6 mg/l and Orthophosphate 0.5 mg/l, indicating eutrophic conditions at the time of JBS 2 sampling. The historical data measured at DWS site S2H004 concurs with the JBS 2 data, showing significant nutrient enrichment.

Diatoms	The diatom assessment indicated that integrated water quality was rated as good. The SPI score was a high 14.1 (out of a maximum of 18). A total of 22 species were identified from a 400 cell count with a 1.5% proportion possessing deformities.
Inverts	**SASS Results for OSAEH_11_14** Jul 2015: SASS5 score: 75 No of Taxa: 16 ASPT: 4.7 **SASS Results for EWR10 (C2SUIK-BADFO)** Oct 2013: SASS5 score: 49 No of Taxa: 11 ASPT: 4.5 Jun 2012: SASS5 score: 22 No of Taxa: 3 ASPT: 7.3 Apr 2008: SASS5 score: 85 No of Taxa: 15 ASPT: 5.7 Sep 2007: SASS5 score: 64 No of Taxa: 13 ASPT: 4.9 Jan 2007: SASS5 score: 101 No of Taxa: 10 ASPT: 5.3 Sep 2002: SASS5 score: 71 No of Taxa: 16 ASPT: 4.4 Apr 2002: SASS5 score: 85 No of Taxa: 17 ASPT: 5.0 Sep 2001: SASS5 score: 60 No of Taxa: 16 ASPT: 3.8 The SASS results for site OSAEH_11_14 were in a similar range to those to that were measured at EWR10 during the JBS1 surveys. Based on an assessment of the long-term River Health Programme (RHP) data for site EWR10 (C2SUIK-BADFO) biotic integrity in the Suikerbosrand River decreased to its lowest level in June 2012, improved in October 2013 and returned to its 2007 and 2008 levels in 2015. Taxa expected but not observed were generally those that are highly or moderately sensitive to water quality changes including Perlidae, Heptageniidae and Helodidae (Scirtidae). The aquatic macroinvertebrate community was primarily composed of those taxa with little to no sensitivity to water quality impairment indicating the limiting effect of water quality on the community. Based on the MIRAI results the Present Ecological State (PES) of the aquatic macroinvertebrate community was rated as a Category C/D (59.2)
Fish	The fish community wellbeing evaluation resulted in a moderately modified (C (62.7%)) ecological state. Only five of the expected eleven fishes were collected at the site which was sampled extensively using active electrofishing methods. Only single individuals of *L. capensis* (Orange River mudfish) and *P. philander* (Southern mouthbrooder) were sampled for the survey, but the frequency is expected to be high. The remaining fish species that were sampled and considered to have a high frequency include *T. sparrmanii* (Banded tilapia), *B. paludinosus* (Straightfin barb) and *Labeobarbus aenus* (Orange-Vaal smallmouth yellowfish). Although none of the remaining fish species expected to occur at the site were collected, including the more common species such as *B. anoplus* (Chubbyhead barb), *C. gariepinus* (Sharptooth catfish) and *L.umbratus* (Moggel), these species are expected to occur in the reach, albeit with moderate frequency. The more cryptic fish species expected to occur at the site were not collected; this is with reference to *Austroglanis sclateri* (Rock catfish). The health of the fishes collected was good; however, there were notable signs of external abnormalities (deformities, ulcers, lesions and wounds) but no parasitic infections. Drivers of change identified to be affecting the wellbeing of the fish communities includes flow alterations, caused by weirs within the upper catchment. The significance of the negative impact caused by these structures is considered to be moderately low, with vary velocity-depth scenarios being recorded, this included fast-shallow and fast deep sections. The surrounding land uses are associated with agricultural activities, with urban development in the upper catchment areas; these are expected to impact on the water quality of the system. The overall impact of these drivers of change at this site has been considered to be moderate as the fish community was evaluated to occur in a moderately modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.2.3 EcoStatus

Driver Components	**PES**
IHI: Instream	C
IHI: Riparian	D
Water Quality (Diatom SPI)	B/C
Response Components	**PES**
Riparian Vegetation	D
Macroinvertebrates	C/D
Fish	C
EcoStatus	D

3.1.1.2.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	C	Water quality deterioration	Urban run-off and WWTW effluent	NF
		Bed modification	Benthic algae growth and sedimentation	
		Habitat degradation	Rubbish dumping	
RIHI	D	Exotic vegetation	Disturbance by rubbish dumping and trampling	NF
		Bank erosion	Increase in flow from WWTW and soil exposure	F/NF
Rip veg	D	Altered species composition	High abundance of trees present marginal and non-marginal zone forming a dense canopy which decreases light availability to the understory and significantly alters species composition	NF
		Reduction in lower and upper zone species cover and composition	Abundant presence of woody and herbaceous alien invasive species	
		Aquatic exotic invasive species	Irrigation and sewerage treatment and release	
WQ	B/C	Elevated Conductivity, TDS and Sulphates	Point and diffuse sources associated with mining activities and urban run-off	NF
		Excessive nutrient enrichment	Agriculture, urbanisation and inadequately treated sewage.	
Inverts	C/D	Habitat transformed (slow habitats transformed to fast habitats)	Increased base flows	F

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Decreased water quality, including increased conductivity and nutrient enrichment	Effluent discharges from various industries including mines Waste Water Treatment Works (WWTW) as well as run-off from urban areas and agriculture	NF
Fish	C	Loss of habitat diversity and changes to habitat composition as a result of flow modification	Inundation of selected reaches caused by small weirs. Also increased flows and a changing hydrological regime	F
		Increased turbidity and disturbed bottom substrates	Increased nutrients, notably from a WWTW. Extensive algal growth on substrates	NF
		Decreased water quality affects species with requirements for high water quality	Increased nutrients, sediments and toxins from agricultural areas	
		Loss of habitat, including overhanging vegetation and sedimentation of the substrate	Grazing & agricultural encroachment, and also water level fluctuations. Erosion of the banks and sedimentation caused by land uses	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species	Dams and various weirs. Also farm dams in tributaries reduce refuge areas	
		Decreased water quality, including increased conductivity and nutrient enrichment	Effluent discharges from various industries including mines Waste Water Treatment Works (WWTW) as well as run-off from urban areas and agriculture	NF

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.2.5 Trends Analysis

Response Components	Trend	Description
Water Quality	Decline	2010 – current: Increasing trend in Nitrate + Nitrite concentration noted at C2H004
Riparian Vegetation	N/A	No assessment of trends is possible as a different site situated approximately 21 km upstream was sampled during the JBS1 survey
Macroinvertebrates	Stable	Based on a comparison of the 2015 SASS scores with the long-term RHP data for site EWR10, SASS scores decreased to its lowest level in June 2012 when only 3 taxa were collected. The SASS score showed some improvement in October 2013 and returned to its 2007 and 2008 levels in 2015.
Fish	N/A	No assessment of trends is possible as a different site situated approximately 21 km upstream was sampled during the JBS1 survey

During JBS1 an alternative site EWR10, situated approximately 22 km upstream of OSAEH_11_14 was reported. Direct comparison between the results of the surveys should therefore be undertaken with caution.

3.1.1.3 OSAEH_11_13 – Kromelmboogspruit at Parys (C2KROM-AVAAL)

3.1.1.3.1 Site Description

The site is situated downstream of a road bridge on the Kromelmboogspruit, a tributary of the Vaal River that originates to the north-east of Heilbron. From there it flows in a north-westerly direction to its confluence with the Vaal River. Flow in the Kromelmboogspruit was very low and therefore habitat consisted primarily of pools with muddy and sandy substrates. Limited stones habitat was present directly downstream of the bridge but marginal vegetation biotope was adequate. The extensive growth of the invasive aquatic weed *Azolla filiculoides* (Red water fern) and filamentous algae were indicative of increased nutrient concentrations in the water. A large dairy operation is situated in close proximity to the river approximately 2 km upstream of the site and may be contributing to the enriched state of the water.

Longitude	27.57442°	**Latitude**	-26.81117°
Altitude (m.a.s.l.)	1424	**Water Management Area**	Upper Vaal
Level 2 EcoRegion		**Quaternary catchment**	C23B
Geomorphological zone	Foothills	**Vegetation**	Soweto Highveld Grassland

Upstream	Downstream

3.1.1.3.2 Present Ecological State (PES)

IIHI	Integrity Score: 17 Integrity Category: F The principle impact at the site was the presence of weirs, bridges and small farm dams influencing flow conditions, thereby causing inundation and an accumulation of debris and sediment within the channel. Impacted water quality was a result of agricultural run-off and livestock waste driving a relatively high abundance of *Azolla filiculoides*.
RIHI	Integrity Score: 34 Integrity Category: E

	The main impacts were substrate exposure and bank erosion due to extensive cultivation, livestock trampling and overgrazing. The presence of the bridge altered the channel structure.
Rip veg	EcoStatus: C (66.2%) **Marginal zone: Sedge and tree dominated** Right and left bank: Marginal zone - *Schoenoplectus, Cyperus* and *Salix babylonica* were dominant within marginal zone. Areas underneath *Salix babylonica* were sparsely vegetated. Some pockets of *Phragmites australis* and *Persicaria* sp. were present. The left bank was steep but vegetative cover was still high. Right bank more gradual transition into non marginal zone. Impacts: Irrigation activities upstream affected water quality thereby influencing vegetation structure. The aquatic weed *Azolla filiculoides* present in high abundance. Livestock trampling in marginal zone had reduced cover and abundance. **Non marginal zone: Grass tree dominated** Right bank and left bank: Grass species include *Imperata cylindrica* and *Cynodon dactylon.* Dominant tree species include *Salix babylonica, Gleditsia tracanthos* and *Eucalyptus camaldulensis.* Some interspersed patches of *Phragmites australis, Cyperus* and *Schoenoplectus* species were present. The woody *Asparagus laricinus* was abundantly present. Islands: Severely grazed and trampled and dominated by *Cynodon dactylon.* Upper zone: Contains a mixture of terrestrial shrubs and grass species. Impacts: Bridge crossing present upstream reducing cover and abundance. Invasive woody and herbaceous species were present. Trampling and grazing pressure would have been lower under reference conditions.
WQ	JBS 2 data indicated dissolved oxygen saturation unsatisfactory at 6.02 mg/l. Turbidity was also noted as elevated (25 NTU) considering a mid-winter sample. Moderate levels of dissolved salts were noted – the Kromelmboogspruit as a tributary of the Vaal River, had significantly lower dissolved salt concentrations compared to the historical data measured at DWS site C2H140. Nutrients were noted to be elevated at times, with JBS 2 data recording free and saline ammonia at 0.3 mg/l. The historical data, while not directly representative as it is on the main Vaal River at DWS site C2H140, also indicated significant nutrient enrichment, with 95-percentile statistics for nitrate+nitrite at 3.9 mg/l, orthophosphate at 0.49 mg/l.
Diatoms	The diatom assessment indicated water quality at the site was largely modified. The SPI score was 6.7 (out of a maximum of 18). Thirty nine species of diatoms were identified with a 1.3% occurrence of deformed individuals.
Inverts	July 2015: SASS5 score: 65 No of Taxa: 17 ASPT: 3.8 Nov 2012: SASS5 score: 66 No of Taxa: 15 ASPT: 4.4 Sep 2012: SASS5 score: 53 No of Taxa: 12 ASPT: 4.4 May 2012: SASS5 score: 66 No of Taxa: 14 ASPT: 4.7 Dec 2011: SASS5 score: 54 No of Taxa: 11 ASPT: 4.9 Key taxa expected but not observed were generally those that are highly or moderately sensitive to water quality changes including Atyidae, Leptophlebiidae, Veliidae, Elmidae and Hydrometridae. The majority of the taxa that were present at the site were those with no sensitivity to modified water quality. Based on the MIRAI results the Present Ecological State (PES) of the aquatic macroinvertebrate community was rated as a Category D (46.0%).
Fish	The fish community wellbeing evaluation resulted in a moderately modified (C (75.5%)) ecological state. Only three of the expected ten fishes were collected at the site which was sampled extensively using active electrofishing methods. Only a single individual of *L. capensis* (Orange River mudfish) and *T. sparrmanii* (Banded tilapia) were sampled. A high frequency of *P. philander* (Southern mouthbrooder) was recorded for the sampled reach. Although none of the remaining fish species expected to occur at the site were collected, including the more common species such as *L. aenus* (Orange-Vaal smallmouth yellowfish), and also the barb species including *B. anoplus* (Chubbyhead barb) and *B. paludinosus* (Straightfin barb), these species are expected to occur in the reach, albeit with moderate frequency. *Cyprinus carpio* (Carp) was also sampled during the survey; this species is expected to impact on habitat and refugia for fish species. The health of the fishes collected was poor,

	with notable signs of external abnormalities (deformities, ulcers, lesions and wounds) and some parasitic infections. Drivers of change identified to be affecting the wellbeing of the fish communities includes flow alterations, caused by poorly maintained causeways and agricultural dams. The reach is characterised by slow-deep sections, with limited fast flowing water. The inundation of these reaches has resulted in habitat being lost and a uniform velocity-depth scenario across the reach. The presence of Red water fern (*Azolla filiculoides*) will impact on the functioning of the system, primarily due to a reduction in light penetration and the lack of atmospheric oxygen exchange with the water surface. The overall impact of these drivers of change at this site has been considered to be moderate as the fish community was evaluated to occur in a moderately modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.3.3 EcoStatus

Driver Components	PES
IHI: Instream	F
IHI: Riparian	E
Water Quality (Diatom SPI)	D/E
Response Components	**PES**
Riparian Vegetation	C
Macroinvertebrates	D
Fish	C
EcoStatus	C

3.1.1.3.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	F	Inundation and flow modifications	Weirs, farm dams and bridge	F
		Bed modification	Weirs and bank erosion	F/NF
RIHI	E	Bank erosion	Livestock trampling and over-grazing and exotic vegetation	NF
Rip veg	C	Reduction in lower and upper zone species cover and composition.	Abundant presence of woody and herbaceous alien invasive species	NF
		Aquatic exotic invasive species	Irrigation and nutrient enrichment	
WQ	D/E	Diatom community was dominated by taxa tolerant of largely modified water quality	Nutrient enrichment from agriculture	NF
		Low dissolved oxygen concentrations and elevated nutrient concentrations	Agricultural inputs and sewage discharges	
Inverts	D	Loss of habitat diversity as a result of flow modification	Inundation of selected reaches caused by small dams, also restricting flows downstream during dry periods	F
		Decreased water quality affects species with requirements for high water quality.	Increased nutrients and sediment from agricultural run-off	NF
Fish	C	Loss of habitat diversity as a result of flow modification	Inundation of selected reaches caused by small dams, also restricting flows downstream during dry periods	F
		Loss of substrate as a result of surrounding land uses and weirs / dams	The sedimentation of the catchment, and scouring of the banks and channel	F/NF

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Decreased water quality affects species with requirements for high water quality.	Increased nutrients and sediment from agricultural run-off	NF
		Loss of fish nurseries and refugia due to the presence of *C. carpio*	Presence of habitat modifying alien fish species	
		Water quality and associated growth of algae and invasive aquatic weeds.	Agricultural activities in the catchment including	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.3.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	N/A	Site not surveyed during JBS1
Water Quality	Decline	2010 – current: Increasing trend in Nitrate + Nitrite concentration noted at C2H140 (main Vaal River, not Kromelmboogspruit)
Macroinvertebrates	N/A	Site not surveyed during JBS1
Fish	N/A	Site not surveyed during JBS1

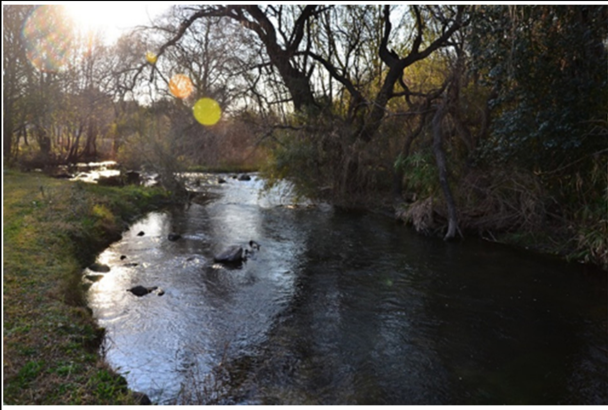
During JBS1 the location of OSAEH_11_13 was changed to the Vaal River at Parys in order to coincide with a PR event. During the July 2015 JBS2 survey the location of OSAEH_11_13 reverted to its original location of the Kromelmboogspruit. Therefore the results from JBS1 and JBS2 are not comparable.

3.1.1.4 OSAEH_11_03 – Mooi River at Potchefstroom Dam

3.1.1.4.1 Site Description

The site is situated in the Mooi River approximately 1.6 km downstream of Potchefstroom Dam in close proximity to the RHP site C2MOOI-MEULS. The Mooi River originates on the southern slopes of the Magaliesburg, near to Boons and Derby. From there the river flows in a southerly direction towards its confluence with the Vaal River just south of Potchefstroom. The site is situated in park, in a residential suburb of Potchefstroom. The site is characterised by riffles, runs and pools and primarily has a rocky substrate. Stones-In-Current (SIC) and marginal vegetation biotopes were abundant, while gravel, sand and mud habitats were present but limited. The riverbanks are dominated by exotic trees, primarily *Salix babylonica* which would be expected to form a dense canopy over the site during the wet season. The channel is incised but appears to be stable with evidence of erosion. At the downstream end of the site the river passes below the R501 road bridge.

Longitude	27.0998°	**Latitude**	-26.68437°
Altitude (m.a.s.l.)	1393	**Water Management Area**	Upper Vaal
Level 2 EcoRegion	11.01 & 11.08	**Quaternary catchment**	C23H
Geomorphological zone	Foothills	**Vegetation**	Rand Highveld Grassland



Upstream	**Downstream**

3.1.1.4.2 Present Ecological State (PES)

IIHI	Integrity Score: 54 Integrity Category: D The principle impacts were due to changes hydrology and flow modification, due to upstream dams and discharge upstream. Impacted water quality was as a result of urban run-off. Litter observed at the site.
RIHI	Integrity Score: 10 Integrity Category: F The main impacts were vegetation removal as a result of levelling for a recreational park, abundant exotic vegetation including poplars, syringa and kikuyu.
Rip veg	EcoStatus: E (22.2%) **Marginal zone: Tree grass dominated** Right and left bank: Narrow, incised and mostly open due to extensive shading from alien woody species, especially taller trees such as *Salix babylonica* and *Populus alba*. Mostly open fine alluvium or dominated by exposed roots. Some clumps of *Typha capensis and Cyperus* species were present. Undercut banks are abundant. Impacts: Excessive littering by pedestrians. Nutrient enrichment and altered flow regime. **Non marginal zone: Tree grass dominated** Right and left bank: Tree layer contains mainly invasive species such as *Populus alba* and *Salix babylonica*. *Pennisetum clandestinum was* the dominant grass in the lower zone and it is mowed extensively. Upper zone: Dominated by *Pennisetum clandestinum* with planted alien trees which cause intense shading, Left bank mostly alien species, especially *Ligustrum* species, but also with *Celtis africana,*

	Searsia pyroides, Sersia lancea and some open grassed areas on the terrace with a healthy population of *Crinum bulbispermum* present Impacts: Woody invasion by *Populus alba* and *Salix babylonica*.
WQ	Elevated TDS and sulphate concentrations were noted at 494 and 104 mg/l respectively. While nutrient levels of the data collected during JBS 2 were moderate to low, historical water quality data collected from site C2H001 indicates intermittent nutrient enrichment.
Diatoms	The diatom assessment resulted in a C ecological category. At this site the SPI score was a moderate 13.8 (out of maximum of 18). At this site the 400 diatoms evaluated included 39 species with a low deformity percentage of 1.0%.
Inverts	Jul 2015: SASS5 score: 122 No of Taxa: 23 ASPT: 5.3 Oct 2010: SASS5 score: 97 No of Taxa: 20 ASPT: 4.9 Key taxa expected but not observed were generally those that are highly or moderately sensitive to water quality changes, such as Heptageniidae, Perlidae, Aeshnidae and Atyidae. This indicates that water quality impairment was a limiting factor of aquatic macroinvertebrate diversity in the Mooi River. Only 13% of the expected taxa with a high preference for the marginal vegetation biotope were recorded at the site. Based on the MIRAI results the Present Ecological State (PES) of the aquatic macroinvertebrate community was rated as a Category C/D (60.9%).
Fish	The fish community wellbeing evaluation resulted in a largely modified (C/D (60.1%)) ecological state. Four of the five expected fish species were collected at the site. Common fish species included *C. gariepinus* (Sharptooth catfish), *Barbus trimaculatus* (Threespot barb) and the cichlids including *T. sparrmanii* (Banded tilapia) and *P. philander* (Southern mouthbrooder). *B. anoplus* (Chubbyhead barb) that was expected to occur at the site, but with limited frequency and was not sampled during the survey. The health of the fishes collected were generally good with no serious external abnormalities (deformities, ulcers, lesions and wounds) or any parasitic infections. Drivers of change identified to be affecting the wellbeing of the fish communities included flow alterations resulting from the upstream impoundment, urbanisation of the catchment and storm water structures within the system. The water quality of the system has deteriorated as a result of nutrient and toxicant inputs from the urban development, this was evident with the extensive algal growth within the reach. The changes in flows and the extensive algal growth have collectively altered the habitat structure and quality of the system, with selected habitat units being lost. The presence of *Gambusia affinis* (Mosquito fish), which preys on fish eggs and larvae, will also negatively impact on the fish species present in the system. *Micropterus salmoides* (Largemouth bass) was also recorded and will pose a threat to the smaller fish species and juveniles. The overall impact of these drivers of change at this site has been considered to be large as the fish community was evaluated to occur in a largely modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.4.3 EcoStatus

Driver Components	PES
IHI: Instream	D
IHI: Riparian	F
Water Quality (Diatom SPI)	C
Response Components	**PES**
Riparian Vegetation	E
Macroinvertebrates	C/D
Fish	C/D
EcoStatus	D

3.1.1.4.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	D	Flow modifications	Upstream dams and WWTW	F
		Water quality	Urban run-off, WWTW effluent, agriculture and mines	NF
RIHI	F	Exotic vegetation	Recreational area and disturbance	NF
Rip veg	E	Change in vegetation structure	Shading effect from *Populus alba* decreases vegetative cover below the dense canopy formed in the marginal and non-marginal zone	NF
		Reduced cover		
		Altered species composition	*Populus alba* present in marginal and non-marginal zones. Decreased diversity in species composition due to shading. Grass cover also altered due the addition of *Pennisetum clandestinum* especially in the lower zone	
WQ	C	Diatom community dominated by taxa tolerant of poor water quality	Urban run-off, WWTW effluent and agriculture	NF
		Elevated dissolved salt concentrations	Impact of mining and industrial activities as well as irrigation return flows	NF
		Nutrient enrichment	Agriculture and urbanisation, including wastewater inputs	
		Altered temperature and dissolved oxygen regimes	Releases from upstream Boskop and other impoundments	F
Inverts	C/D	Modification of flow regime resulting in modification of instream habitat	Site is situated downstream of a large impoundment	F
		Poor water quality	Urbanization of the catchment	NF
Fish	C/D	Loss of habitat diversity as a result of flow modification.	Large dams in the upper catchment and increased storm water run-off	F

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Decreased water quality affects species with requirements for high water quality.	Increased nutrients, sediments and toxins from urban areas	NF
		Increased turbidity and disturbed bottom substrates.	Extensive algal growth and the embedding of substrates. Lower natural floods and flushes of the system. Erosion of banks causes sedimentation of the system, caused by urban development.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Major upstream dams	
		Decreased species diversity and abundance due to presence of *G. affinis* and *M. salmoides.*	Presence of alien predatory species	
		Poor water quality	Urbanization of the catchment	NF

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2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.4.5 Trends Analysis

Response Components	Trend	Description
Water Quality	Decline	2010 – current: Slight increasing trend in Conductivity at C2H001 Slight increasing trend in Total Inorganic Nitrogen at C2H001
Riparian Vegetation	Stable	No change in VEGRAI category from JBS1. However it is recommended that *Populus alba* should be removed to increase light moving through this dense tree canopy
Macroinvertebrates	Stable	Slight increase in the MIRAI category from a D in JBS1 to a C/D in JBS2. This increase is believed to be within the natural range of variation inherent in any ecosystem.
Fish	Stable	Slight increase in FRAI category from a D in JBS1 to a C/D in JBS2.

3.1.1.5 OSAEH_11_06 – Rhenosterspruit at Viljoenskroon (C5RENO-R501B)

3.1.1.5.1 Site Description

Site is situated in the Rhenosterspruit, a tributary of the Vaal River approximately 18 km upstream of the confluence with the Vaal. The Rhenosterspruit originates to the north of Petrus Steyn in the Northern Free State and flows in a north westerly direction to its confluence with the Vaal. Flow at the site was low during the July 2015 survey. The site consisted of a series of small pools linked by very shallow marshy areas. One small riffle was present in the upper reaches of the site. Active channel features include densely vegetated islands of reeds and sedges, creating a braided system of open-water predominated by pools and runs. Instream habitat, particularly the runs and riffles, were comprised largely of boulder and cobble substrate, while fine sediments, gravel and sand were confined to marginal zones and vegetated islands. The riparian zone has a defined flood terrace dominated by grass cover leading to a steep, densely wooded embankment.

Longitude	26.99638°	**Latitude**	-27.04099°
Altitude (m.a.s.l.)	1308	**Water Management Area**	Middle Vaal
Level 2 EcoRegion	11.08	**Quaternary catchment**	C70J
Geomorphological zone	Lowland	**Vegetation**	Rand Highveld Grassland

Upstream **Downstream**

3.1.1.5.2 Present Ecological State (PES)

IIHI	Integrity Score: 31 Integrity Category: E The degradation of instream habitat integrity was mostly due to changes in water quality as a result of extensive upstream discharge from a WWTW. Instream habitat was covered in algae and free-floating algae were observed. Sediment input has resulted in bed modification (formation of sand islands) and channel modification. Water abstraction and release due to agriculture and WWTW. A number of deep pools appear to be excavations.
RIHI	Integrity Score: 11 Integrity Category: F The main impacts were bank erosion and channel modification due to livestock trampling, discharge from WWTW and water fluctuations. Numerous woody and herbaceous exotic plants were observed.
Rip veg	EcoStatus: C (64.7%) **Marginal zone: Sedge grass dominated state.** Right and left bank: Channel was wide with several sub-channels with most of them dry. Many sedge clumps dominated by *Schoenoplectus* and *Cyperus* occurred in sub-channels. Woody species included *Salix mucronata* and *Gomphostigma virgatum*. Impacts consisted mainly of erosion in the form of bank-slumping and exotic vegetation. There was good cover and abundance but exotic pioneer species were present. Nutrient enriched water possibly contributed to excessive growth of vegetation. *Phragmites australis* was present in a pool further downstream. Impacts: Trampling and grazing. Nutrient enrichment and altered flow regime. Presence of aquatic *Nasturtium officinale*. **Non marginal zone: Grass and shrub dominated** Right and left bank: Grass layer contains the pioneer species *Cynodon dactylon* as well as *Setaria sphacelata* and also some terrestrial grasses such as *Themeda triandra*. Shrub layer dominated by

	Asparagus spp. Woody invasive species include *Gleditsia tracanthos* and *Eucalyptus camaldulensis.* Indigenous woody species include *Salix mucronata*, *Ziziphus mucronata* and *Sersia lancea*. *Phragmites australis* present in non-marginal zone especially in close proximity to pool downstream. Herbaceous weeds common and include species such as *Tagetes minuta*, *Bidens bipinnata* and *Verbena bonariensis.* Upper zone: Contains mainly woody and terrestrial grasses. Impacts: Woody invasion. Trampling and grazing.
WQ	The water quality at this site was moderate at the time of sampling for JBS 2. Slightly elevated nitrate concentrations were recorded in JBS 2 (0.6 mg/l), and occasional high nitrate and ammonia results were observed in the historical data (C7H006). In addition, the historical data record reflected elevated intermittent orthophosphate concentrations.
Diatoms	The diatom evaluation resulted in a D/E or seriously modified ecological category for this site. The specific sensitivity pollution index score for this site was 7.9 (out of 18). At this site the 400 diatoms evaluated included 51 species with a low deformity percentage of 2.0%.
Inverts	**Site OSAEH_11_06** Jul 2015: SASS5 score: 88 No of Taxa: 20 ASPT: 4.4 Oct 2010: SASS5 score: 127 No of Taxa: 27 ASPT: 4.7 **Site C7RENO-R501B** Nov 2012: SASS5 score: 58 No of Taxa: 15 ASPT: 3.9 Sep 2012: SASS5 score: 19 No of Taxa: 6 ASPT: 3.2 May 2012: SASS5 score: 65 No of Taxa: 14 ASPT: 4.6 Dec 2011: SASS5 score: 127 No of Taxa: 27 ASPT: 4.7 Key taxa expected but not observed were generally those that are highly or moderately sensitive to water quality changes, such as Perlidae, Heptageniidae and Hydropsychidae >2spp. This indicated that water quality impairment was a limiting factor of aquatic macroinvertebrate diversity in the Rhenosterspruit. Based on the MIRAI model the Present Ecological State (PES) of the aquatic macroinvertebrate community was in a Category C (65.1%).
Fish	The fish community wellbeing evaluation resulted in a largely modified (category D (45.4%)) ecological state. Three of the expected nine fish species were collected at the site which was sampled extensively using active electrofishing methods. Common fishes included the Chubbyhead barb (BANO) and the cichlids including *T. sparrmanii* (Banded tilapia) and *P. philander* (Southern mouthbrooder). None of the cryptic fishes expected to occur at the site were collected, including *Labeobarbus kimberleyensis* (Orange-Vaal largemouth yellowfish) and *A. sclateri* (Rock catfish). *C. gariepinus* (Sharptooth catfish), *L. aenus* (Orange-Vaal smallmouth yellowfish) and the two mudfish, namely *L. capensis* (Orange River mudfish) and *L.umbratus* (Moggel) were expected to be present at the site, but in spite of these species not being recorded during the survey, they are expected to occur with a moderately low frequency. The health of the fishes collected was generally good, with no parasitic infections observed. Drivers of change identified to be affecting the wellbeing of the fish communities include flow alterations that are the result of agricultural dams within the catchment. The upper reaches are characterised by slow-deep systems with barely perceptible flow, with the sample reach being characterised as slow-shallow. The discharge from a WWTW has impacted on the water quality of the system; this is evident with the extensive algae growth in the reach. The changes in flows and effects of impaired water quality have resulted in changes to the available habitat structures within the reach. The overall impact of these drivers of change at this site has been considered to be large as the fish community was evaluated to occur in a largely modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.5.3 EcoStatus

Driver Components	PES
IHI: Instream	E
IHI: Riparian	F
Water Quality (Diatom SPI)	D/E
Response Components	**PES**
Riparian Vegetation	C
Macroinvertebrates	C
Fish	D
EcoStatus	C/D

3.1.1.5.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	E	Water quality deterioration	Releases from WWTW and upstream agriculture	NF
		Bed modification	Excessive benthic algae growth and sedimentation	
RIHI	F	Bank erosion	Cattle trampling and access paths and WWTW release	F/NF
		Channel modification	Discharge from upstream WWTW	F
		Exotic vegetation	Disturbance and excessive nutrient input	NF
Rip veg	C	Terrestrialisation	Burning regime out of control. Annual burns enhance the encroachment of terrestrial species into the riparian zone.	NF
		Exotic invasion	*Gleditsia triacanthos*, and *Eucalyptus* spp., and herbaceous weeds.	
		Presence of aquatic weeds	Nutrient enrichment due to Waste Water Treatment Works present upstream of site as well as agricultural activities.	
WQ	D/E	The diatom community evaluated at this site was dominated by species that are tolerant to altered water quality states and are particular indicators of elevated salt and nutrient contaminations.	Upstream agricultural activities, non-point surfaces and WWTW effluent	NF

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Nutrient enrichment		
Inverts	D	Low flow conditions	Abstraction for agriculture	
		Decreased water quality	Return flows from agriculture resulting in nutrient enrichment	
Fish	D	Decreased habitat diversity as a result of flow modification.	Inundation of selected reaches caused by small dams, also restricting flows downstream during dry periods	F
		Increased turbidity and disturbed bottom substrates	Increased nutrients, notably from a WWTW. Extensive algal growth on substrates	NF
		Decreased water quality affects species with requirements for high water quality.	Increased nutrients, sediments and toxins from agricultural areas.	
		Decreased water quality	Return flows from agriculture resulting in nutrient enrichment	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.5.5 Trends Analysis

Response Components	Trend	Description
Water Quality	Stable	No significant change in water quality
Riparian Vegetation	Stable	The VEGRAI category remained unchanged between JBS1 and JBS2. The following impacts should however receive attention to prevent deterioration in riparian vegetation. Likely increase in woody invasive species is expected. If these invasive woody species are not controlled it is likely that they will spread and further alter species composition and vegetation structure especially in the non-marginal zone. Continual nutrient enrichment from upstream sewerage works and presence of aquatic weed expected to increase if no mitigation measures are applied.
Macroinvertebrates	Stable	The MIRAI category remained unchanged between JBS1 and JBS2. Based on a comparison of SASS5 scores for site C7RENO-R501B, biotic integrity in the Rhenosterspruit decreased sharply between Dec 2011 and Sep 2012 reaching its lowest level during the latter survey. Biotic integrity increased after Sep 2012 but hadn't reached the Oct 2010 or Dec 2011 levels during the current survey.
Fish	Stable	Although the FRAI category decreased from a C in October 2010 to a D in July 2015 the same 3 fish species were recorded at the site.

3.1.1.6 OSAEH_11_04 – Skoonspruit at Kanana (C2SKOO-URANI)

3.1.1.6.1 Site Description

The Skoonspruit is a tributary of the Vaal River that originates to the north of Ventersdorp and flows mostly in a southerly direction to its confluence with the Vaal River south west of Orkney. The site is situated between Klerksdorp and Orkney, approximately 10 km upstream of the confluence with the Vaal River. The substrate at the site consisted primarily of cobble that was blanketed by extensive algal growth indicating that excess nutrients are present in the system. The habitat comprised a mixture of riffles and runs. Stones-In-Current, marginal vegetation and aquatic macrophyte biotopes were abundant although smothered by filamentous algae. The GSM biotope was limited. The water at the site had a distinctive sewage odour.

Longitude	26.66428°	**Latitude**	-26.93451°
Altitude (m.a.s.l.)	1293	**Water Management Area**	Middle Vaal
Level 2 EcoRegion	11.08	**Quaternary catchment**	C24H
Geomorphological zone	Foothills	**Vegetation**	Vaal-Vet Sandy Grassland

Upstream	**Downstream**

3.1.1.6.2 Present Ecological State (PES)

IIHI	Integrity Score: 37 Integrity Category: E The principle impact was due to changes in water quality as a result of extensive upstream discharge from waste water treatment works and urban runoff. The hydrology has also changed significantly due to frequent discharge from the WWTW.
RIHI	Integrity Score: 8 Integrity Category: F The main impacts being vegetation removal due to infilling, rubbish dumping, trampling and pedestrians. A number of woody and herbaceous exotic species were observed at the site. The WWTW has impacted largely on the flow and physico-chemical state.
Rip veg	EcoStatus: C (63.9%)

	Marginal zone: Grass and reed dominated state. Right and left bank: Substrate rocky and *Phragmites australis* dominant along marginal zone clumps of *Typha capensis* and *Scheonoplectus* species present. Woody invasive *Salix babylonica* present in marginal zone but more abundant in non-marginal zone. Some bare patches occur due to shading effect of *Salix babylonica*. Exotic pioneers occur. *Persicaria* species present but inflorescence absent and foliage discoloured therefore unable to determine species and invasion status. Islands: *Phragmites australis* dominant along marginal zone with interspersed clumps of *Typha capensis* present Impacts: Excessive littering by pedestrians and black bags filled with domestic waste present. Trampling and grazing. Nutrient enrichment and altered flow regime. **Non marginal zone: Tree shrub dominated** Right and left bank: Tree layer contains mainly invasive species such as *Salix babylonic* and *Gleditsia tracanthos. Gleditsia tracanthos* forms a dense thicket with *Asparagus* species. Dense clumps of *Phragmites australis* and *Typha capensis* present in the absence of woody thicket. Invasion is severe and includes the following herbaceous species *Tagetes minuta*, *Bidens bipinnata* and *Verbena bonariensis.* Upper zone: Contains mainly woody and terrestrial grasses. *Gleditsia tracanthos* still present in upper zone. Impacts: Woody invasion. Trampling and grazing.
WQ	The water quality at this site was poor. Oxygen saturation was low (<50%), and dissolved salt concentrations were elevated, with Conductivity (112 mS/m), TDS (818 mg/l), Sodium (110 mg/l) and Sulphate (205 mg/l) recorded in the JBS 2 survey. Similar to the results recorded in JBS 1, nutrient enrichment is problematic at this site, with excessively high nitrogen concentrations recorded (Nitrate 1.2 mg/l, Nitrite 0.4 mg/l and Ammonia 30 mg/l). Phosphorus concentrations were also significantly elevated (Total Phosphorus 5 mg/l, Orthophosphate 4.7 mg/l), indicating hypertrophic conditions. It was, however, noted that while the JBS 2 data was comparable to JBS 1 data, these data were of significantly poorer water quality compared to the historical data measured at DWS site C2H084.
Diatoms	The diatom evaluation resulted in an F or critically modified ecological category for this site. The specific sensitivity pollution index score for this site was 3.29 (out of 18).
Inverts	July 2015: SASS5 score: 17 No of Taxa: 6 ASPT: 2.8 North West River Health Results: SASS5 score: 55, No of Taxa: 13, ASPT: 4.2 Oct 2010: SASS5 score: 47 No of Taxa: 13 ASPT: 3.6 Taxa diversity was very low with only 6 taxa recorded. Taxa that were expected but that weren't recorded included: Potamonautidae, Atyidae, Baetidae, Coenagrionidae, Belostomatidae, Gerridae, Hydropsychidae, Gyrinidae and Ceratopogonidae. The aquatic macroinvertebrate community at the site was composed entirely of taxa with no sensitivity to water quality impairment. No moderately or highly sensitive taxa were present at the site confirming that water quality impairment was most likely the main limiting factor at the site. Although riffle and run habitats over cobble would generally be regarded as good habitat for aquatic macroinvertebrate communities, in this case colonization of the substrate by aquatic macroinvertebrates is restricted by the dense algal growth. Based on the MIRAI model the Present Ecological State (PES) of the aquatic macroinvertebrate community was in a Category D (53.3%).
Fish	The fish community wellbeing evaluation resulted in a moderately modified (D/E) ecological state. Only a single specimen was sampled, namely *T. sparrmanii* (Banded tilapia). The remaining two expected fish species, *B. anoplus* (Chubbyhead barb) and *P. philander* (Southern mouthbrooder) were not sampled. The health of the sampled individual appeared to be generally good with no serious external abnormalities (deformities, ulcers, lesions and wounds) and low parasitic infections. Drivers of change identified to be affecting the wellbeing of the fish communities includes flow alterations that have resulted from weirs within the upper catchment, storm water from the urban developments and a Waste Water Treatment Works. In addition to this, these have also contributed to the deterioration of water quality, with the increased nutrient and toxins input resulting in excessive algae growth. The changes to flows and the effects of impaired water quality have also resulted in the

	quality and quantity of habitat being affected. The overall impact of these drivers of change at this site has been considered to be large as the fish community was evaluated to occur in a largely modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.6.3 EcoStatus

Driver Components	PES
IHI: Instream	E
IHI: Riparian	F
Water Quality (Diatom SPI)	F
Response Components	**PES**
Riparian Vegetation	C
Macroinvertebrates	D
Fish	D/E
EcoStatus	D

3.1.1.6.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	E	Water quality deterioration	Releases from WWTW and upstream agriculture	NF
		Bed modification	Excessive benthic algae growth and sedimentation	
RIHI	F	Bank erosion	Cattle trampling and access paths and WWTW release	F/NF
		Channel modification	Discharge from upstream WWTW	F
		Exotic vegetation	Disturbance and excessive nutrient input	NF
Rip veg	C	Change in vegetation structure from reference state	Woody invasive species *Salix babylonic* and *Gleditsia tracanthos*	NF
		Change in species composition	Nutrient enrichment due to sewerage works and farming related activities.	
		Change in species composition	More frequent fires and removal.	

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
WQ	F	The diatom community evaluated at this site was dominated by species that are tolerant to altered water quality states and are particular indicators of elevated salt and nutrient contaminations.	Upstream agricultural activities, non-point surfaces and WWTW effluent	NF
		Poor oxygen saturation, high dissolved salt concentrations and excessive nutrient enrichment		
Inverts	D	Decreased water quality resulting in changes in aquatic macroinvertebrate community	Increased nutrients, sediments and toxins from urban areas, but notably for an upstream WWTW	NF
		Smothering of habitat by nuisance growth of filamentous algae limits habitat availability for aquatic macroinvertebrate taxa	Increased nutrients associated with the effluent from an upstream WWTW	
Fish	D/E	Loss of habitat diversity as a result of flow modification.	Weirs in the upper catchment and storm water from the urban developments	F
		Loss of habitat notably loss of substrate due to eutrophication and waste	Increased nutrients, sediments and toxins from urban areas, but notably for an upstream WWTW	NF
		Decreased water quality affects species with requirements for high water quality.		

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.6.5 Trends Analysis

Response Components	Trend	Description
Water Quality	Stable	2010 – current: No definite trends noted at C2H084
Riparian Vegetation	Stable	No change in VEGRAI category from JBS1
Macroinvertebrates	Decline	Based on a comparison of the July 2015 results with those from October 2010 the SASS results have decreased further.
Fish	Decline	Based on the FRAI results the PES of the fish community decreased from a Class C in October 2010 to a Class D/E during the July 2015 survey. Only a single fish was recorded at the site during the electrofishing survey despite adequate habitat.

3.1.1.7 OSAEH_11_01 – Vaal River at Commandodrift

3.1.1.7.1 Site Description

The site is located approximately 25 km downstream of the Wolwespruit Nature Reserve. The river at this point is approximately 130 m wide and the channel straight, deep and uniform with a muddy substrate. Habitat for fish sampling was primarily slow (< than 0.6 m/s and deep) whereas the invertebrate sampling habitat was limited to the shallow muddy substrate immediately adjacent to the riverbank. The riverbanks are steep and muddy with no marginal vegetation. It is believed that fluctuations in flow level due to releases from upstream impoundments has contributed to the absence of marginal vegetation and the encroachment of alien invasive weeds most notably *Xanthium spinosum* in the marginal zone.

The site surveyed during JBS1 was situated in the Wolwespruit Nature Reserve and comprised extensive runs over mainly a cobble substrate. The site surveyed during JBS2 was situated approximately 25 km downstream of the original site due to a discrepancy in the GPS coordinates provided. The site consisted of a deep, uniform channel with limited sampling habitat. Therefore the results cannot be directly compared to the JBS1 site.

Longitude	26.20999°	**Latitude**	-27.51606°
Altitude (m.a.s.l.)	1242	**Water Management Area**	Middle Vaal
Level 2 EcoRegion	11.08	**Quaternary catchment**	C24J
Geomorphological zone	Lowland River	**Vegetation**	Highveld Alluvial Vegetation and Vaal-Vet Sandy Grassland

Upstream **Downstream**

3.1.1.7.2 Present Ecological State (PES)

IIHI	Integrity Score: 20 Integrity Category: E/F Key impacts were hydrological changes such as flow modification (abstraction and water input) and inundation due to Bloemhof dam downstream of the site. Large bed modification was observed due to heavy sedimentation of the system.

RIHI	Integrity Score: 8 Integrity Category: F The main impacts were disturbance of the marginal zone due to vegetation removal and over grazing. Fluctuating water levels have modified the channel extensively. Abundant exotic vegetation was observed.
Rip veg	EcoStatus: D (47.4%) **Marginal zone: Mostly open with interspersed herbs present** Right and left bank: Narrow and mostly open due to fluctuating water levels. Only a few herbaceous pioneer species such as *Cyperus longus* and *Cyperus marginatus* were present. *Salix babylonica* present in marginal zone. Impacts: Fluctuating water levels. Trampling by livestock for watering and grazing. Nutrient enrichment by irrigation as well as sewerage treatment and release. Undercut banks were associated with the presence of *Salix babylonica.* **Non marginal zone: Tree grass dominated** Right and left bank: Open patches were present due to grazing and trampling leading to bank erosion. Dominant species were mostly invasive and included *Xanthium spinosum*, *Salix babylonica*, *Sesbania punicea*, *Tagetes minuta*, *Bidens pilosa* and *Verbena bonariensis*. Upper zone: Dominated by a tree layer containing mostly indigenous species such as *Ziziphus mucronata* and *Vachellia karroo*. Impacts: Changes in hydrological regime. High grazing pressure and associated trampling. Nutrient enrichment altering species composition and exacerbating growth.
WQ	The JBS 2 data indicate elevated TDS and sulphate concentrations at 462 and 147 mg/l respectively. In terms of nutrients, elevated nitrate concentrations were recorded at 0.7 mg/l and a resultant very high chlorophyll *a* concentration of 85 µg/l, indicating eutrophication. The historical water quality data measured at DWS site C2H061 confirmed the episodic elevated nutrient (both nitrogen and phosphorus) concentrations.
Diatoms	The wellbeing of the diatom component at this site was observed to be in a D/E ecological category. At this site the specific sensitivity pollution index score was a low 6.2 (out of maximum of 18). At this site the 400 diatoms evaluated included 29 species with a low deformity percentage of 1.3%.
Inverts	SASS5 score: 27 No of Taxa: 10 ASPT: 2.7 Key expected taxa that were not observed included Caenidae, Corbiculidae, Gomphidae and Sphaeridae. The aquatic macroinvertebrate community consisted primarily of taxa with a tolerant of impaired water quality. Very few taxa with a moderate or high requirement for unimpaired water quality were observed at the site indicating that water quality impairment may be a limiting factor at the site. Despite mud being the dominant biotope only one taxa that favours this biotope was present at the site. Based on the MIRAI model the Present Ecological State (PES) of the macroinvertebrate community at the site was classified as a Category E (31.3%).
Fish	The fish community wellbeing evaluation resulted in a B/C (77.5%) ecological state. Four of the expected eleven fishes were collected at the site which was sampled extensively using active electrofishing and seine netting methods. Common fishes included *C. gariepinus* (Sharptooth catfish), *B. trimaculatus* (Threespot barb), *L. capensis* (Orange River mudfish) and the cichlids including *T. sparrmanii* (Banded tilapia) and *P. philander* (Southern mouthbrooder). None of the cryptic fishes expected to occur at the site were collected, including *L. kimberleyensis* (Orange-Vaal largemouth yellowfish) and *A. sclateri* (Rock catfish), the barbs and *L. aenus* (Orange-Vaal smallmouth yellowfish), but these species with the exception of *A. sclateri* are expected to be present at the site. The health of the fishes collected were generally good, however, parasitic anchor worm was recorded for some of the *B. trimaculatus* specimens. Drivers of change identified to be affecting the wellbeing of the fish communities includes the loss of habitat as a result of inundation of the sample reach, with the site being upstream of Bloemhof Dam. The water quality of the system has decreased as a result of increased nutrients, sediments and toxins from the upstream urban developments and adjacent agricultural activities. The presence of the Bloemhof Dam and Vaal Barrage are two barriers that would impact on the fish migration across the

	catchment. The presence of Crap (CCAR) will also impact on the availability and quality of habitat and breeding areas for selected fish species. The overall impact of these drivers of change at this site has been considered to be moderately low as the fish community was evaluated to occur in a moderately modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.7.3 EcoStatus

Driver Components	PES
IHI: Instream	E/F
IHI: Riparian	F
Water Quality (Diatom SPI)	D/E
Response Components	**PES**
Riparian Vegetation	D
Macroinvertebrates	E
Fish	B/C
EcoStatus	D

3.1.1.7.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	E/F	Altered natural hydrological cycles	Water abstraction and increase in flows from releases	F
		Inundation	Bloemhof Dam downstream	
		Bed modification	Sedimentation from over-grazing and bank erosion	NF
RIHI	F	Exotic vegetation	Disturbance and creation of open areas from over-grazing	NF
		Vegetation removal	Over-grazing and trampling	
Rip veg	D	Vegetation removal	Flow fluctuation as well as high grazing pressure	F/NF
		Exotic vegetation	Specifically in lower zone *Xanthium spinosum, Salix babylonica, Sesbania punicea, Tagetes minuta, Bidens pilosa and Verbena bonariensis*	NF
		Bank undercutting and scouring	Substrate of site consists out of sand and alluvial material. Due to dynamics of aggradation and degradation habitat change is constant. Bank instability and the impact of trampling and exotic vegetation among others, contribute towards bank erosion	F
WQ	D/E	Diatom community was dominated by species tolerant of seriously modified water quality	Non-point source agricultural activities, mining activities, urbanization and inadequately treated wastewater	NF
		High dissolved salt concentrations		

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Nutrient enrichment and associated elevated chlorophyll concentrations		
		Altered temperature and dissolved oxygen regimes anticipated	Releases from upstream impoundments	F
Inverts	E	Loss of habitat diversity	Fluctuations in flow levels	F
		Decreased water quality	Agriculture, mining and urbanization	NF
Fish	B/C	Loss of habitat diversity as a result of flow modification	Inundation of the sample reach, and modified flows	F
		Decreased water quality affects species with requirements for high water quality	Increased nutrients, sediments and toxins from urban areas, diamond and gold mines and agricultural areas	NF
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien species (CCAR)	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species	Major upstream (Vaal Barrage) and downstream dams (Bloemhof Dam)	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.7.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	N/A	Different site sampled during JBS1, therefore insufficient data available to comment on trend
Water Quality	Stable	2010 – current: Decreasing trend in Orthophosphate at C2H061 Increasing trend in Total Inorganic Nitrogen at C2H061
Macroinvertebrates	N/A	Different site sampled during JBS1, therefore insufficient data available to comment on trend
Fish	N/A	Different site sampled during JBS1, therefore insufficient data available to comment on trend

The EcoStatus of the site was rated as a Class C/D. Although this represents a decrease in EcoStatus compared to site OSAEH_11_01 during JBS1 the results cannot be directly compared as the JBS1 site was situated approximately 25 km upstream with very different instream habitat.

3.1.1.8 OSAEH_29_02 – Vaal River at Warrenton

3.1.1.8.1 Site Description

The site is situated in the Vaal River approximately 4 km downstream of the RHP site C9VAAL-WARRE. The river at this point is approximately 200 m wide, relatively shallow (< 1 m) and bedrock dominated. The river is impounded just upstream of Warrenton to form Vaalharts Dam, from where water is diverted via canal to the Vaal-Harts Irrigation Scheme. There is also extensive irrigation along the section of the Vaal River between Christiana and Warrenton.

Longitude	24.81138°	**Latitude**	-28.1118°
Altitude (m.a.s.l.)	1190	**Water Management Area**	Lower Vaal
Level 2 EcoRegion	29.02	**Quaternary catchment**	C91D
Geomorphological zone	Lower foothills	**Vegetation**	Kimberley Thorn Bushveld

Upstream

Downstream

3.1.1.8.2 Present Ecological State (PES)

IIHI	Integrity Score: 54 Integrity Category: D The key impact was changes in flow modification due to Vaalharts Dam. Further impacts include water quality deterioration as a result of urban and agriculture run-off as evident by large amount of algae and the presence of water hyacinth in low abundance.
RIHI	Integrity Score: 73 Integrity Category: C The main impacts were channel modification and vegetation removal due to trampling, grazing and flow modifications. A number of exotic species were observed, including Eucalyptus and numerous herbaceous species (*Xanthium spinosum*)
Rip veg	EcoStatus: C (63.7%)

	Marginal zone: Sedge and reed dominated Right and left bank - Mainly shrub and reed dominated. *Salix mccronata* was present in the marginal zone. Islands: Very abundant within the main channel. Mainly rocky with some sandy patches. Contains a mix of *Phragmites australis, Schoenoplectus* spp and *Juncus* spp. Impacts: Altered hydrology due to the presence of Bloemhof Dam upstream is the dominant driver with minor impacts from alien plant invasion and water quality. The aquatic weed *Eichhornia crassipes* was present in low abundance between islands. **Non marginal zone: Grass and herbs dominated** Right bank - *Eucalyptus camaldulensis* was present further downstream. Dominant grass species was *Cynodon dactylon. Searsia lancea* present in lower zone. Upper zone contains mostly indigenous trees such as *Searsia lancea, Vachellia karroo, Ziziphus mucronata*. Left bank - Woody alien invasive species are more prominent. *Searsia lancea* present in lower zone. Grazing and trampling is more extensive on the left bank. Erosion of banks as a result of high grazing pressure. Upper zone contains mainly indigenous woody species such as *Searsia lancea, Vachellia karroo* and *Ziziphus mucronata*. Woody invasives included *Sesbania punicea* and *Eucalyptus camaldulensis* present. Impacts: Reduced flood frequency resulted in altered species composition, particularly woody species. Herbaceous invasive species formed a dense cover and included species such as *Bidens bipinnata, Tagetus minuta* and *Conyza spp, Sesbania punicea* and *Eucalyptus camaldulensis* were the dominant invasive woody species.
WQ	Moderately elevated salts, notably sulphate at 94 mg/l. The free and saline ammonia concentration measured during JBS 2 was elevated at 0.3 mg/l. Furthermore, review of the historical water quality data measured at site C9H008 indicated episodic nutrient enrichment (particularly nitrogen).
Diatoms	The wellbeing of the diatom component at this site was observed to be in a B/C ecological category. At this site the SPI score was a 14.9 (out of maximum of 18). At this site the 400 diatoms evaluated included 26 species with a relatively high deformity percentage of 5.3%.
Inverts	**Site OSAEH_29_02** Jul 15 SASS5 score: 138 No of Taxa: 24 ASPT: 5.8 **Site C9VAAL-WARRE** July 2015: SASS5 score: 101 No of Taxa: 19 ASPT: 5.3 Aug 2013: SASS5 score: 87 No of Taxa: 16 ASPT: 5.4 May 2013: SASS5 score: 78 No of Taxa: 15 ASPT: 5.2 Oct 2009: SASS5 score: 76 No of Taxa: 15 ASPT: 5.1 Aug 2009: SASS5 score: 66 No of Taxa: 15 ASPT: 4.4 Oct 2005: SASS5 score: 99 No of Taxa: 20 ASPT: 5.0 Sep 2005: SASS5 score: 90 No of Taxa: 19 ASPT: 4.7 Mar 2005: SASS5 score: 66 No of Taxa: 12 ASPT: 5.5 Oct 2004: SASS5 score: 83 No of Taxa: 12 ASPT: 6.9 Key taxa expected but not observed included Aeshnidae, Athericidae, Corbiculidae, Dixidae, Dytiscidae, Gomphidae, Gerridae, Libellulidae, Perlidae, Physidae, Tipulidae and Tricorythidae. The diversity of taxa with a preference for marginal vegetation biotope was lower than expected along with the taxa with a preference for standing water despite adequate habitat availability. Taxa with a moderate to high requirement for unmodified water quality were well represented suggesting that water quality remains moderate to good. Taxa that were present that have a high requirement for unmodified water quality included Heptageniidae and Hydropsychidae >2spp. The MIRAI model generates a Present Ecological State for macroinvertebrates as a Category C (76.6%).
Fish	Two fish species, namely *B. anolus* and *B. paludinosus*, were recorded in addition to the expected reference fish species list for the sample reach. A reference list of seven (7) fish was expected for the reach. The Frequency of Occurrence (FROC) of some species has been increased from reference conditions due to these species being sampled. The FROC of *A. sclateri* has been reduced due to this species not being sampled, however, the species is expected to be present at the sample reach.

	The fish community wellbeing evaluation resulted in a moderately modified (C (65.7%)) ecological state. A total of seven of the expected nine fishes were collected at the site which was sampled extensively using a range of active electrofishing and netting methods. The moderately common fishes that were sampled include *L. capensis* (Orange River mudfish), *C. gariepinus* (Sharptooth catfish), *L. aenus* (Orange-Vaal smallmouth yellowfish). The remaining more cryptic fishes expected to occur at the site that were collected, include the barbs *B. paludinosus* (Straightfin barb) and *B. anoplus* (Chubbyhead barb) and *T. sparrmanii* (Banded tilapia). *A. sclateri* (Rock catfish) and *L.umbratus* (Moggel) were two cryptic fish species that were not sampled, but still expected to be present within the reach. The health of the fishes collected was generally good with some external abnormalities (deformities, ulcers, lesions and wounds) and expected parasitic infections. Drivers of change identified to be affecting the wellbeing of the fish communities includes flow alterations associated with the inter-basin water transfer scheme and Vaalharts Dam in the upper catchment. Resulting in an increased base flow, impacting on habitat availability, velocity-depth scenarios and also water quality impacts. The sample reach is characterised by fast-shallow and fast-deep velocity-depth scenarios, The overall impact of these drivers of change at this site has been considered to be moderate as the fish community was evaluated to occur in a moderately modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.8.3 EcoStatus

Driver Components	PES
IHI: Instream	D
IHI: Riparian	C
Water Quality (Diatom SPI)	B/C
Response Components	**PES**
Riparian Vegetation	C
Macroinvertebrates	C
Fish	C
EcoStatus	C

3.1.1.8.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	D	Flow modification	Bloemhof Dam	F
		Water quality modification	Urban and agricultural run-off	NF
RIHI	C	Vegetation removal	Livestock grazing and trampling	NF
WQ	B/C	Diatom community dominated by taxa tolerant of altered water quality	Return flows and run-off from large-scale agricultural activities as well as urban and industrial activities in the catchment.	NF
		Elevated salts and episodic nutrient enrichment		

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Altered temperature and dissolved oxygen regimes anticipated	Releases from upstream impoundments	F
Rip veg	C	Sparse vegetative cover	Mainly high grazing pressure and associated trampling by livestock.	NF
		Change in species composition	Encroachment of exotic invasive species both woody and herbaceous.	
		Aquatic exotic invasive species.	Increased nutrients input likely from sewerage treatment and releases.	
Inverts	C	Modified flow resulting in increased baseflows during the dry season. Unnatural fluctuations in flow level.	Vaalharts Dam and abstraction for irrigation	F
		Decreased water quality	Return flows from large-scale agricultural activities as well as urban and industrial activities in the catchment	NF
Fish	C	Loss of habitat diversity as a result of flow modification (especially during natural low flow periods).	Inter-basin transfer and Vaalharts Dam	F
		Increased flows, notably increased baseflows during the dry period		
		Decreased water quality affects species with a preference for good water quality.	Return flow from agriculture	NF
		Increased turbidity and disturbed bottom substrates.	Sedimentation of the system and algal growth.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Vaalharts Dam is a permanent barrier upstream of the reach.	
		Decreased water quality	Return flows from large-scale agricultural activities as well as urban and industrial activities in the catchment	NF

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.8.5 Trends Analysis

Response Components	Trend	Description
Water Quality	Stable	2010 – current: Decreasing trend in orthophosphate noted at C9H008 but no significant changes
Fish	N/A	Not assessed in JBS1 therefore insufficient data available to comment on trend
Macroinvertebrates	Increase	Site was not sampled during JBS1, however, based on a comparison of the SASS5 scores with site C9VAAL-WARRE biotic integrity may have improved. The SASS score measured during the July 2015 survey represents the highest SASS5 score, number of invertebrate taxa and ASPT score
Riparian Vegetation	N/A	Not assessed in JBS1 therefore insufficient data available to comment on trend

3.1.1.9 OSAEH_29_01 – Harts River at Delportshoop (C3HART-DELPO)

3.1.1.9.1 Site Description

The site is situated in the Harts River downstream of the Vaalharts Irrigation Scheme, approximately 60 km downstream of Spitskop Dam and approximately 5 km upstream of the confluence with the Vaal River at Delportshoop. The site is also known as the RHP site C3VAAL-EUR17. The Vaalharts Irrigation Scheme is considered to be one of the largest irrigation schemes in the world. The scheme diverts water from the Vaal River at Warrenton via a series of canals and provides water for furrow irrigation as well as for various industrial uses. The return flows occur via the Harts River

The banks are composed of bedrock and appear to be extensively disturbed by earlier alluvial diamond mining activities and overgrazing. This has resulted in extensive erosion of the banks. Fish and aquatic macroinvertebrate habitat appears to be moderate but is limited by the extensive growth of aquatic weeds including *Stuckenia pectinata* which has a smothering effect. Flow modification which originates from the irrigation scheme and is exacerbated by releases from Spitskop Dam is expected to result in unnatural habitat fluctuations. The site is situated immediately upstream and downstream of a Department of Water and Sanitation (DWS) gauging weir called Lloyds weir. Instream habitats comprised limited Stones-In-Current biotopes, while marginal vegetation, aquatic vegetation and mud habitats were extensive.

Longitude	24.30178°	**Latitude**	-28.37928°
Altitude (m.a.s.l.)	1114	**Water Management Area**	Lower Vaal
Level 2 EcoRegion	29.02	**Quaternary catchment**	C33C
Geomorphological zone	Lower Foothills	**Vegetation**	Kimberley Thorn Bushveld

Upstream

Downstream

3.1.1.9.2 Present Ecological State (PES)

IIHI	Integrity Score: 21 Integrity Category: E/F The site was heavily disturbed due to excavation/mining activities. Right bank consisted of rubble and eroded banks Site is downstream of two large bridges and a large pool which appears to have been excavated. Flow modification is extensive due to the Vaal-Harts Transfer Scheme and river bed is seriously modified due to sedimentation and excavation. Water quality is in an impacted state due to eutrophication (abundance of algae and invasive aquatic vegetation) and high electrical conductivity.
RIHI	Integrity Score: 28 Integrity Category: E The main impacts were substrate exposure and vegetation removal due to excavation/mining activities and bank erosion. Abundant exotic vegetation was observed at the site.
Rip veg	EcoStatus: D (53.6%) The area is currently considerably degraded due to the old mining activities and the construction of the bridge that have disturbed much of the riparian vegetation and the introduction of a number of exotic species. Aquatic weeds included *Stuckenia pectinata* which was highly abundant throughout the reach. Scouring of the marginal zone was evident. Vegetative cover in the lower zone was sparse. Bare patches were present and can be attributed to the high grazing pressure as well as disturbance related to old mining activities.
WQ	Significantly elevated dissolved salt concentrations were recorded at the time of sampling for JBS 2, with very high conductivity and TDS levels (110 mS/m, 968 mg/l) and sodium, chloride and sulphate concentrations (155, 202 and 238 mg/l respectively), associated with irrigated agricultural return flows. JBS 2 dissolved salt concentrations were aligned to the historical water quality data measured at DWS site C3H016. Turbidity and suspended solids concentrations were moderately elevated (37 NTU and 44 mg/l), possibly due to upstream mining impacts. Nutrient concentrations measured during JBS 2 were low to moderate, but the historical data from site C3H016 indicated limited episodic nutrient enrichment.
Diatoms	The wellbeing of the diatom component at this site was observed to be in a B/C ecological category. At this site the SPI score was a 14.9 (out of maximum of 18). At this site the 400 diatoms evaluated included 26 species with a relatively deformity percentage of 1%.
Inverts	Jul 15 SASS5 score: 110 No of Taxa: 23 ASPT: 4.5 May 15 SASS5 score: 116 No of Taxa: 18 ASPT: 5.9 Aug 13: SASS5 score: 54 No of Taxa: 13 ASPT: 4.2 Apr 08 SASS5 score: 61 No of Taxa: 16 ASPT: 3.8 Sep 07 SASS5 score: 91 No of Taxa: 21 ASPT: 4.3 Key taxa expected but not observed included Potamonautidae, Aeshnidae, Libellulidae and Belostomatidae. The observed aquatic macroinvertebrate assemblage included taxa with a wide range of velocity and habitat preferences but was primarily composed of taxa with a low or no

	requirement for unmodified water quality, confirming that water quality was the primary limiting factor of diversity. The July 2015 SASS5 results represent an improvement in the SASS5, No of taxa and ASPT scores when compared to the results generated during the Lower Vaal Reserve Determination. The MIRAI model generates a Present Ecological State for macroinvertebrates as a Category C (71.6%).
Fish	The fish community wellbeing evaluation resulted in a moderately modified (C (76.0%)) ecological state. A total of six of the expected ten fishes were collected at the site which was sampled extensively using a range of active electrofishing and netting methods. The moderately common fishes that were sampled include *L. capensis* (Orange River mudfish), *C. gariepinus* (Sharptooth catfish) and the cichlids including *T. sparrmanii* (Banded tilapia) and *P. philander* (Southern mouthbrooder). *B. trimaculatus* (Threespot barb) is the only fish species considered to have a low frequency that was sampled. The remaining more cryptic fishes expected to occur at the site that was not collected included *B. paludinosus* (Straightfin barb), *L. kimberleyensis* (Orange-Vaal largemouth yellowfish) and *A. sclateri* (Rock catfish). The health of the fishes collected were generally good with some external abnormalities (deformities, ulcers, lesions and wounds) and low parasitic infections. Drivers of change identified to be affecting the wellbeing of the fish communities includes flow alterations associated with the inter-basin water transfer scheme. Resulting in an increased base flow, impacting on habitat availability, velocity-depth scenarios and also water quality impacts. The extensive algal growth within the sample reach is evident of the eutrophication of the system, The overall impact of these drivers of change at this site has been considered to be moderate as the fish community was evaluated to occur in a moderately modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.9.3 EcoStatus

Driver Components	PES
IHI: Instream	E/F
IHI: Riparian	E
Water Quality (Diatom SPI)	B/C
Response Components	**PES**
Riparian Vegetation	D
Macroinvertebrates	C
Fish	C
EcoStatus	C

3.1.1.9.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	E/F	Bed modification	Mining activity	NF
		Rubbish dumping		
		Flow modification	Vaal-Harts Transfer Scheme	F

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
RIHI	D	Vegetation removal	Mining activity	NF
		Bank erosion		
WQ	B/C	Diatom community dominated by taxa tolerant of altered water quality	Agricultural and mining impacts	NF
		High dissolved salts	Irrigated agricultural return flows	
		Episodic increased turbidity and nutrient levels	Agricultural and mining impacts	
		Altered temperature and dissolved oxygen regimes anticipated	Flow modification due to Vaal/Harts water transfer scheme and Spitskop Dam	F
Rip veg	D	Sparse vegetative cover	Scouring of marginal zone, old mining activities and current high pressure grazing and trampling	NF
		Homogenous vegetative composition	Encroachment of terrestrial exotic invasive species	
		Aquatic exotic invasive species.	Increased nutrients input through the Vaalharts Irrigation Scheme	
Inverts	C	Water quality has a limiting effect on taxa that have a high and moderate preference for unmodified water quality.	Agricultural return flows from upstream agriculture	NF
		Extensive growth of algae and invasive aquatic macrophytes	Nutrient input from agriculture	
Fish	C	Loss of habitat diversity as a result of flow modification	Flow modification due to Vaal/Harts water transfer scheme and Spitskop Dam	F
		Increased flows, notably increased baseflows during the dry period		
		Decreased water quality affects species with a preference for good water quality.	Run-off from agriculture	NF
		Increased turbidity and disturbed bottom substrates.	Sedimentation of the system and algal growth.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Spitskop Dam is a significant upstream migration barrier breaking the link between the Vaal and Harts River catchments.	
		Extensive growth of algae and invasive aquatic macrophytes	Although some SIC habitat was present the habitat is limited by the nuisance growth of aquatic macrophytes and algae	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.9.5 Trends Analysis

Response Components	Trend	Description
Water Quality	Unclear	2010 – current: Decreasing trend in nutrients noted at C3H016

Response Components	Trend	Description
Riparian Vegetation	Stable	No change in overall VEGRAI category from The Lower Vaal Reserve surveys. However the following impacts require attention and could lead to degradation of the riparian vegetation. Grazing pressure remains too high. No rehabilitation of old mining activities has been initiated. Continual nutrient enrichment increases the amount of aquatic weeds present.
Macroinvertebrates	Stable	Although the MIRAI Category improved from a Class C/D during the Lower Vaal Reserve Determination to a Class C during the July 2015 assessment some variation is inherent and expected in natural systems. The same limiting factors apply to the site and the aquatic macroinvertebrate community is still composed of taxa with a tolerance for impaired water quality. When compared to the RHP results for Aug 2013 the SASS5 score showed a substantial improvement and the number of taxa increased from 13 to 23
Fish	Stable	Although the FRAI Category improved from a Class D during the Lower Vaal Reserve Determination to a Class C during the July 2015 assessment this is believed to be due to natural variation in the system. The fish community at the site remains largely unchanged although some species were present in higher abundances other species such as *L. umbratus* were still present in lower than expected frequencies and some external anomalies were noted indicting that the fish community may be experiencing increased physiological stress due to decreased water quality.

3.1.1.10 OSAEH_29_04 – Vaal River at Schmidtsdrif (C9VAAL-SCHMI)

3.1.1.10.1 Site Description

The site is located downstream of Bloemhof dam and the Vaal/Harts irrigation scheme and is also known as the RHP site C9VAAL-EUR19. The site consists of a deep, wide (approximately 100 m), uniform, channel with a muddy substrate. This habitat is representative of the lower Vaal from the confluence with the Harts River downstream to the confluence with the Orange. Due to the depth the site is non-wadeable except along the banks. Habitat diversity for fish and aquatic macroinvertebrate sampling is limited. Fish habitat consisted primarily of slow deep (SD) habitats and marginal vegetation comprising reeds, riparian trees and grass. Aquatic macroinvertebrate habitats consisted primarily of marginal vegetation along with sand, mud and some stones out of current. Impacts noted in the vicinity included grazing, and diamond mining. The dense water grass (*Potamogeton* and *Ceratophyllum)* that was present at the site during the previous surveys was absent during the current assessment.

Longitude	24.07428°	**Latitude**	-28.70310°
Altitude (m.a.s.l.)	1239	**Water Management Area**	Lower Vaal
Level 2 EcoRegion	29.02	**Quaternary catchment**	C92B
Geomorphological zone	Lower Foothills	**Vegetation**	Kimberley Thorn Bushveld

Upstream | Downstream

3.1.1.10.2 Present Ecological State (PES)

IIHI	Integrity Score: 38 Integrity Category: E The key impacts were changes in hydrology due to inundation and flow modification as a result of dams and weirs. The system possessed substantial bed modification through excessive sedimentation.
RIHI	Integrity Score: 30 Integrity Category: E The main impacts were bank erosion and channel modification due to scouring of the right bank. Flow modification has altered seasonal flows, preventing flushing of the system.
Rip veg	EcoStatus: C/D (58.2%) Mining activities do occur in the upper zone and the terrestrial areas above the Vaal River. Grazing and trampling as well as use of the river for recreation as well as fishing for sustenance have all lead to very sparse vegetative cover. The upper zone contains a dense stand of woody vegetation with no cover under the canopy of these trees and shrubs. The lower zone comprised of mainly grass and herbaceous weeds whilst the marginal zone contained mainly reeds and grass. Grazing pressure is high in the lower zone. No aquatic weeds or plants were observed. It is however noted that the invasive species *Myriophyllum spicatum* was recorded at the JBS1 site which was further downstream. The spread of this species should be monitored. The area has been impacted by construction of bridges, mining activities, grazing and invasive species.
WQ	High salt concentrations were recorded during JBS 2, notably TDS 474 mg/l and sulphate 111 mg/l, associated with mining impacts in the area. Nutrient results from JBS 2 were recorded as less than the analytical detection limit. Nutrient levels in the historical data from C9H024 were also mostly low, but did indicate periodic elevated nitrogen and particularly phosphorus concentrations at times.
Diatoms	The wellbeing of the diatom component at this site was observed to be in a B ecological category. At this site the SPI score was a 15.3 (out of maximum of 18). At this site the 400 diatoms evaluated included 39 species with a relatively deformity percentage of 1.5%.

Inverts	Jul 2015: SASS5 score: 57 No of Taxa: 14 ASPT: 4.1 May 2015: SASS5 score: 70 No of Taxa: 16 ASPT: 4.4 May 2014: SASS5 score: 73 No of Taxa: 14 ASPT: 5.2 Aug 2013: SASS5 score: 93 No of Taxa: 19 ASPT: 4.9 Oct 2009: SASS5 score: 72 No of Taxa: 16 ASPT: 4.5 Aug 2009: SASS5 score: 65 No of Taxa: 12 ASPT: 5.4 May 2009: SASS5 score: 63 No of Taxa: 12 ASPT: 5.3 Dec 2008: SASS5 score: 71 No of Taxa: 16 ASPT: 4.4 Aug 2008: SASS5 score: 72 No of Taxa: 14 ASPT: 5.1 Apr 2008: SASS5 score: 74 No of Taxa: 17 ASPT: 4.4 Sep 2007: SASS5 score: 33 No of Taxa: 9 ASPT: 3.7 Taxa expected but not observed included Aeshnidae, Pleidae, Dytiscidae and Naucoridae. However, the latter two taxa were recorded during May 2015. Overall taxa richness was far lower than expected. This was related to changes in flow regime and impacts on water quality. The aquatic macroinvertebrate community was comprised almost entirely of taxa with a high tolerance for decreased water quality. The MIRAI model generates a Present Ecological State for macroinvertebrates as a Category D (57.1%).
Fish	The fish community wellbeing evaluation resulted in a moderately modified (C (72.3%)) ecological state. A total of five of the expected ten fish species were collected at the site which was sampled extensively using active electrofishing and netting methods. The more common fish species expected to be sampled, and sampled for the survey include *L. capensis* (Orange River mudfish), *L.umbratus* (Moggel) and the two cichlids *T. sparrmanii* Banded tilapia (TSPA) and *P. philander* (Southern mouthbrooder). Some of the fishes expected to occur at the site that were not collected, included the cyprinids *B. paludinosus* (Straightfin barb), *B. trimaculatus* (Threespot barb) and *L. aenus* (Orange-Vaal smallmouth yellowfish. Furthermore, the two cryptic species *L. kimberleyensis* (Orange-Vaal largemouth yellowfish) and *A. sclateri* (Rock catfish) were not recorded. The health of the fishes collected were generally good with no serious external abnormalities (deformities, ulcers, lesions and wounds) and no signs of parasitic infections. Drivers of change identified to be affecting the wellbeing of the fish communities includes flow alterations associated with the water quantity management activities upstream of the site, notably larger dams in the upper reaches, and the resulting modified habitat, cover and water quality impacts. The surrounding land uses is associated with agricultural activities, but the impacts to the water quality are expected to be low. The overall impact of these drivers of change at this site has been considered to be moderate as the fish community was evaluated to occur in a moderately modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.10.3 EcoStatus

Driver Components	PES
IHI: Instream	E
IHI: Riparian	E
Water Quality (Diatom SPI)	B
Response Components	**PES**
Riparian Vegetation	C/D
Macroinvertebrates	D
Fish	C
EcoStatus	C/D

3.1.1.10.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	E	Flow modification	Upstream dams	F
		Bed modification	Excessive sedimentation	NF
RIHI	E	Bank erosion	Mining activity	NF
		Vegetation removal		
WQ	B	High dissolved salt levels.	Mining activities and impacts.	NF
		Intermittent nutrient enrichment	Upstream agricultural activities	
		Altered temperature and dissolved oxygen regimes anticipated	Extensive flow modification due to Bloemhof Dam	F
Rip veg	C/D	Reduced cover of indigenous species.	Mining activities, grazing and trampling.	NF
		Altered species composition	Invasive species such as *Xanthium spinosum*, *Argemone mexicana* and *Nicotiana glauca* specifically in the lower zone.	
		Water quality.	Agriculture and livestock farming	
Inverts	D	Modification of natural flow regime including increased low flows and decreased high flows	Release strategies from upstream dams	F
		Water quality and associated benthic growth.	Eutrophication associated with upstream farming activities, especially the Vaalharts irrigation scheme. As well as alluvial mining activities.	NF
Fish	C	Loss of habitat diversity as a result of flow modification.	Extensive flow modification due to Bloemhof Dam	F
		Decreased water quality affect species with requirement for high water quality.	Increased nutrients and sediment due to agriculture and bank erosion. Diamond mine downstream of site. .	NF
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien (*C. carpio*).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Major upstream dam (Bloemhof) and the presence of weirs.	
		Water quality and associated benthic growth.	Upstream farming activities, especially the Vaalharts irrigation scheme. As well as alluvial mining activities.	

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2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.10.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	No change from JBS1 in terms of VEGRAI category. High grazing pressure is resulting in low vegetative cover. If grazing pressure is not reduces erosion will likely follow.
Water Quality	Unclear	2010 to current:

		Very limited data indicates a decreasing trend in salinity noted at C9H024 (low confidence)
Macroinvertebrates	Stable	Although a slight decrease in PES category was noted when compared to JBS1, comparison with previous SASS5 results shows that the SASS score measured during Jul 2015 represents the lowest SASS score for the site since Sep 2007. The ASPT shows a similar pattern. The SASS5 results showed relatively little variation between Apr 2008 and May 2014
Fish	Stable	The current PES represents a slight improvement when compared to the JBS1 results; however, it matches that of the 2007 – 2008 Lower Vaal Reserve Study. The fish community is therefore determined to be stable

3.1.1.11 OSAEH_11_21 - Korannaspruit

3.1.1.11.1 Site Description

The site was located on the Korannaspruit, which is a non-perennial tributary of the Modder River that reaches its confluence with the Modder River approximately 14 km downstream of this site. The RHP site C5KORA-MOCK2 is approximately 6 km downstream. During the July 2015 survey there was no flow in the Korannaspruit however large pools with muddy and sandy substrates and abundant marginal vegetation provided adequate habitat for sampling. Depth in the pools ranged from 10 to 60 cm. The average width of the river was 2 to 3 m. Marginal vegetation comprised reeds, sedges and overhanging trees.

Longitude	26.633841°	**Latitude**	-29.08584°
Altitude (m.a.s.l.)	1350	**Water Management Area**	Upper Orange
Level 2 EcoRegion	11.03	**Quaternary catchment**	C52C
Geomorphological zone	Foothills	**Vegetation**	Moist Cool Highveld Grassland

Upstream

Downstream

3.1.1.11.2 Present Ecological State (PES)

IIHI	Integrity Score: 66 Integrity Category: C The principle impacts are hydrological changes due to a number of weirs and small dams within the reach. This has resulted in inundation and flow modification of the system. Excess nutrients and impacted water quality has resulted in abundant *Azolla sp*. Dead livestock were observed in the system downstream of the site.
RIHI	Integrity Score: 66 Integrity Category: C The main impacts at the site are bank erosion and inundation of the marginal and riparian zones. Vegetation removal due to overgrazing and livestock footpaths.
Rip veg	EcoStatus: C (69.3%) **Marginal zone: Sedge grass dominated** Right and Left bank: *Schoenoplectus* species dominated the marginal zone. *Salix mucronata* present in marginal zone along reach. Islands: *Schoenoplectus* species dominant Impacts: Grazing and trampling evident. Less frequent flood events and lower basal flows due to farm dam present upstream. Scouring of marginal zone has led to bank erosion **Non-marginal zone: Tree grass dominated.** Right bank: Woody tree *Leucosidea sericea* present in lower zone. Pioneer grass *Cynodon dactylon* dominant with interspersed clumps of *Schoenoplectus* species. Left bank: Alluvial deposits with dense and tall stands of *Salix mucronata. Gomphostigma virgatum* were present along bedrock areas. The alien invasives *Bidens bipinnata* and *Datura stramonium* were very abundant. Islands: *Gomphostigma virgatum* present along with *Schoenoplectus* species. Upper zone contains a mixture of woody trees with dense canopy cover and limited ground cover. Impacts: High grazing pressure, invasive species and lower basal flow due to farm dam upstream with no release during winter.
WQ	While the water quality at the time of sampling was generally satisfactory, the percentage dissolved oxygen saturation was 76% (7.21 mg/l). While JBS2 data indicated nitrogen and phosphorus concentrations less than the analytical detection limits, JBS 1 data indicated nutrient enrichment, notably with elevated phosphorus concentrations. Unfortunately, there is no representative historical water quality data available for comparison.
Diatoms	The wellbeing of the diatom component at this site was observed to be in a D or largely modified ecological category. At this site the specific sensitivity pollution index score was a low 9.7 (out of maximum of 18). At this site the 400 diatoms evaluated included 40 species with a low deformity percentage of 1.3%.
Inverts	**Site OSAEH_11_21** Oct 2010: SASS5 score: 55 No of Taxa: 15 ASPT: 3.7 **Site C5KORA-MOCK2** Nov 2012: SASS5 score: 32 No of Taxa: 8 ASPT: 4.0 Sep 2012: SASS5 score: 56 No of Taxa: 13 ASPT: 4.3 May 2012: SASS5 score: 41 No of Taxa: 8 ASPT: 5.1 Dec 2011: SASS5 score: 71 No of Taxa: 17 ASPT: 4.2 As there was no flow at the site during the Jul 2015 survey a MIRAI score could not be calculated
Fish	The fish community wellbeing evaluation resulted in a moderately modified (C (70.6%)) ecological state. A total of four of the expected five fishes were collected at the site which was sampled extensively using active electrofishing and numerous netting methods. The more common fish species expected to be sampled, and sampled for the survey include *L. capensis* (Orange River mudfish), *L. aenus* (Moggel), *C. gariepinus* Sharptooth catfish (CGAR) and *B. anoplus* (Chubbyhead barb). The more common *L. aenus* (Orange-Vaal smallmouth yellowfish) that was expected to occur at the site was not collected. The health of the fishes collected was good, with no notable signs of external abnormalities (deformities, ulcers, lesions and wounds) and no parasitic infections. Drivers of change identified to be affecting the wellbeing of the fish communities is notably flow alterations, caused by weirs within the catchment area. At the time of the survey, no flow was evident within the reach, with extensive sections of the reach completely dry. Areas upstream of the weirs

	were inundated, thus the only habitat available was characterised by slow-deep and slow-shallow areas. The overall impact of these drivers of change at this site has been considered to be moderate as the fish community was evaluated to occur in a moderately modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.11.3 EcoStatus

Driver Components	PES
IHI: Instream	C
IHI: Riparian	C
Water Quality (Diatom SPI)	D
Response Components	**PES**
Riparian Vegetation	C
Fish	C

3.1.1.11.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	C	Flow modification	Dams and weirs	F
		Water quality impacts	Excessive nutrient inputs	NF
RIHI	C	Inundation	Weirs	F
		Bank erosion	Over-grazing and excessive trampling	NF
Rip veg	C	Reduced cover of indigenous riparian obligate species, especially in the marginal and lower zones.	High trampling pressure around pools, with associated grazing.	NF
	C	Altered species composition.	Low cover and presence of alien species, but trampling and grazing pressure also reduces grass cover which caters for an increase in sedge density and cover.	NF
		Reduced vegetation cover, especially in marginal and lower zone.	Altered base flows due to farm dams upstream	F
Fish	C	Loss of habitat diversity as a result of flow modification. Loss of flows during the dry season.	Weirs causing inundation, and obstructing flows. Abstraction of water.	F
		Altered velocity-depth scenarios, notably slow-shallow (pools) and slow-deep areas remaining.		
		Loss of cover, notably the water column due to limited (no) flow conditions. Lower breeding and recruitment successes.	Dry season conditions have reduced the extent of cover. Modified flows and loss of flows entirely, compounded by weirs and dams.	NF
		Impaired water quality, with negligible impact.	Limited agricultural (crop) areas primarily used for grazing. Livestock trampling likely to contribute.	

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Increased turbidity. Erosion of the banks and sedimentation of the system resulting in deterioration of substrate for habitat.	Erosion of the catchment and sedimentation of the system.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Weirs and farm dams in tributaries reduce refuge areas.	

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2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.11.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	No change in VEGRAI category from JBS1. No further vegetative response to changes in flow expected. Grazing pressure not excessive.
WQ	N/A	No data available
Macroinvertebrates	Stable	Based on a comparison of JBS1 results with those from site C5KORA-MOCK2 biotic integrity in the Korannaspruit is stable
Fish	Increase	The FRAI Score increased from 35.4% in October 2015 to 70.6% in July 2015 contributing to an improvement in Class from and E to a C. Four of the 5 expected fish species were recorded at the site during the July 2015 survey It should be noted that conditions in o-perennial rivers can be quite variable dependant how long ago there was flow.

3.1.1.12 OSAEH_11_18 – Modder River at Sannaspos (C5MODD-SANA)

3.1.1.12.1 Site Description

The site is situated in the Modder River, a tributary of the Riet River that reaches its confluence with the Riet River near to Ritchie. The site is situated approximately 13 km downstream of Rustfontein Dam at a Department of Water and Sanitation (DWS) gauging weir. Current land uses in the catchment include agricultural activities (primarily irrigated crops), urbanisation, mining and industrial activities. The Modder River supplies water to several urban areas including Bloemfontein, Botshabelo (upstream) and Thabu Nchu although this is supplemented to a large degree by water from the Caledon River via the Caledon - Modder River Government Water Scheme (CMRGWS).

This site is bedrock-dominated with good marginal vegetation comprising sedges and overhanging vegetation. The river width varies from 2 m to 15 m in places. Some sedimentation is present with filamentous algae on the rocks at the river's edge. The instream habitat consists of pools, riffles and runs, with some boulders, cobbles, gravel and sand present.

Longitude	26.57225°	**Latitude**	-29.16067°
Altitude (m.a.s.l.)	1346	**Water Management Area**	Upper Orange
Level 2 EcoRegion	11.03	**Quaternary catchment**	C52B

Geomorphological zone	Foothills	**Vegetation**	Highveld

Upstream	**Downstream**

3.1.1.12.2 Present Ecological State (PES)

IIHI	Integrity Score: 19% Integrity Category: E/F The poor instream habitat rating was due to flow modification due to a large weir, dams and a number of bridges within the reach. The bed was seriously modified due to concrete structures and settled construction rubble downstream of the site. The weir caused a large amount of inundation upstream of the site and has altered the channel significantly. During the July 2015 survey the highway bridge was in the process of being upgraded which had resulted in extensive modification of the Modder River.
RIHI	Integrity Score: 29% Integrity Category: E The Riparian Index of Habitat Integrity is an E with the main impacts being vegetation removal due to bridge construction and footpaths. The weir has caused channel modification, flow modification. Bank erosion and water abstraction were evident. A number of *Populus alba* specimens were observed at the site.

Rip veg	EcoStatus: C (66.0%) **Marginal zone: Sedge tree dominated** Right and left bank: Large amounts of fine alluvial deposits present. *Gomphostigma virgatum* and *Cyperus marginatus* dominated the marginal zone. *Salix mucronata* present in marginal zone along reach. Impacts: Construction activities due to upgrade of bridge downstream. Inundation due to weir. Grazing and trampling evident. Change in hydrological regime due to Krugersdrift Dam decreasing natural flood frequency and increasing basal flows. **Non-marginal zone: Tree grass dominated.** Right bank and left bank: Presence of *Populus alba* above weir. *Salix mucronata* dominant woody species below weir. Pioneer grass *Cynodon dactylon* dominant grass and herbaceous weeds such as *Bidens bipinnata*, *Nicotiana glauca*, *Datura stramonium* etc. Upper zone: Alluvial terraces dominated by grasses with woody patches woody species woody patches containing *Searsia pyroides*, *Vachellia karroo* and *Lycium hirsutum.* Impacts: Construction activities due to upgrade of bridge downstream. Invasive woody present upstream of weir. Trampling and grazing evident. Change in hydrological regime due to Rustfontein Dam decreasing natural flood frequency and increasing basal flows.
WQ	While the water quality at the time of sampling for JBS 2 was satisfactory with no specific determinands indicating concern, the historical data (C5H003) and JBS 1 data indicate episodic nutrient enrichment, with elevated nitrogen and phosphorus levels.
Diatoms	The diatom evaluation resulted in a D or largely modified ecological category for this site. The specific sensitivity pollution index score for this site was 9.4 (out of 18). At this site the 400 diatoms evaluated included 37 species with a very low deformity percentage of 0.5%.
Inverts	Jul 2015: SASS5 score: 36 No of Taxa: 9 ASPT: 4.0 Sep 2014: SASS5 score: 75 No of Taxa: 16 ASPT: 4.7 Nov 2012: SASS5 score: 54 No of Taxa: 12 ASPT: 4.5 Sep 2012: SASS5 score: 22 No of Taxa: 6 ASPT: 3.7 May 2012: SASS5 score: 46 No of Taxa: 9 ASPT: 5.1 Dec 2011: SASS5 score: 73 No of Taxa: 17 ASPT: 4.3 Oct 2010: SASS5 score: 95 No of Taxa: 21 ASPT: 4.5 Overall taxa diversity was lower than expected with key taxa expected but not observed including: Aeshnidae, Atyidae, Belostomatidae, Caenidae, Dytiscidae, Gerridae and Gyrinidae. Taxa with a moderate and high sensitivity to water quality impacts were entirely absent from the community indicating that water quality was the primary limiting factor at the site. Although marginal and aquatic vegetation was abundant only 6% of the taxa with a preference for this biotope were present at the site. Despite the impoundment created by the weir taxa with a preference for standing water were largely absent from the site with only 5% of the expected taxa recorded. The MIRAI model generates a Present Ecological State for macroinvertebrates as a Category C/D (58.2%).

Fish	The fish community wellbeing evaluation resulted in a moderately modified (C (75.5%)) ecological state. A total of five of the expected six fishes were collected at the site which was sampled extensively using active electrofishing and netting methods. The more common fish species expected to be sampled, and sampled for the survey include *L. capensis* (Orange River mudfish), *L.umbratus* (Moggel), *C. gariepinus* (Sharptooth catfish) and the two barbs, *B. paludinosus* (Straightfin barb) and *B. anoplus* (Chubbyhead barb). The more cryptic fish species, *L. kimberleyensis* (Orange-Vaal largemouth yellowfish) that was expected to occur at the site was not collected. The health of the fishes collected was good, with no notable signs of external abnormalities (deformities, ulcers, lesions and wounds) and no parasitic infections. Drivers of change identified to be affecting the wellbeing of the fish communities includes flow alterations, caused by weirs within the catchment area. At the time of the survey, the river was being diverted to accommodate the construction of a new bridge. This has resulted in large reaches being inundated, resulting in the loss of habitat, and also reducing water flow velocities across the reach. The surrounding land uses are associated with agricultural activities; this is expected to impact on the water quality of the system. The overall impact of these drivers of change at this site has been considered to be moderate as the fish community was evaluated to occur in a moderately modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.12.3 EcoStatus

Driver Components	PES
IHI: Instream	E/F
IHI: Riparian	E
Water Quality (Diatom SPI)	D
Response Components	**PES**
Riparian Vegetation	C
Macroinvertebrates	C/D
Fish	C
EcoStatus	C

3.1.1.12.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	E/F	Flow modification	The presence of upstream dams and local weirs	F
		Channel modification	Presence of the weir	NF
		Bed modification	Concrete structures and construction rubble	NF

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
RIHI	E	Vegetation removal	Bridge and access paths	NF
		Inundation	Construction of the weir	F
		Bank Erosion	Vegetation removal for access paths and the bridge	NF
WQ	D	Diatom community was dominated by species tolerant of largely modified water quality	Agricultural run-off, fertiliser usage and urbanisation.	NF
		Nutrient enrichment		
		Altered temperature and dissolved oxygen regimes anticipated	Releases from upstream impoundments	F
Rip veg	C	Reduced cover of indigenous riparian obligate species.	Construction activities. Moderate to high trampling and grazing pressure with bank destabilization and erosion, also minimal wood cutting.	NF
		Altered species composition.	Woody species including *Populus alba* and *Eucalyptus camaldulensis.* Variety of herbaceous invasive species including *Nicotiana glauca*, *Tagetes minuta, Bidens bipinnata and Datura stramonium.*	
		Altered species composition.	Reduced maintenance flows and small floods promote and increase in woody vegetation and sedges in the marginal and lower zone, especially when coupled with high grazing pressure.	F
Inverts	C/D	Decreased water quality	Run-off from Botshabelo which is situated on the Klein-Modder River which confluences with the Modder upstream of the site.	NF
		Modification of habitat due to flow modification	Rustfontein Dam and the gauging weir at the site	F
Fish	C	Loss of habitat diversity as a result of flow modification.	Weirs causing inundation, and obstructing flows. Construction of a new bridge requiring the diversion of flows.	F
		Altered velocity-depth scenarios, notably increased slow-deep reaches.		
		Impaired water quality.	Livestock farming in the catchment area. Livestock trampling likely to contribute.	NF
		Increased turbidity. Erosion of the banks and sedimentation of the system resulting in deterioration of substrate for habitat.	Erosion of the catchment and sedimentation of the system.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Weirs reduce refuge and nursery areas.	
		Modification of habitat due to flow modification	Rustfontein Dam and the gauging weir at the site	F

F1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.12.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Decline	From JBS1 VEGRAI category decreased from a B to a C. This is attributed to current construction activities associated with the upgrade of the bridge that will continue to deteriorate the riparian vegetation. Rehabilitation of the disturbed area is recommended.
Water Quality	Decline	2010 – current: Increasing trend nitrogen enrichment noted at C5H003
Macroinvertebrates	Decline	The MIRAI Class decreased from a Class C in October 2010 to a C/D in July 2015. When SASS5 results are assessed for the period 2010 – 2015 it is seen that biotic integrity decreased between Oct 2010 and Sep 2012 reaching its lowest level during the later survey. The SASS5 scores showed a steady improvement between Sep 2012 and Sep 2014 but again decreased between that survey and the Jul 2015 survey
Fish	Stable	The FRAI Score increased between JBS1 and JBS2 although the PES Class remained unchanged in a Class C. The fish assemblage remained unchanged.

3.1.1.13 OSAEH_26_10 – Riet River at Austin's Post (C5RIET-IFR03)

3.1.1.13.1 Site Description

The site is situated in the upper reaches of the Riet River, a tributary of the Vaal that originates in the south eastern Free State and flows in a western direction and confluences with the Vaal just north of Douglas. The catchment is rural in nature with irrigated agriculture as the primary land use. The habitat at the site comprised isolated pools with no surface flow. The substrate at the site is dominated by bedrock with limited fine substrate. Marginal vegetation was abundant and comprised reeds, grasses and sedges. Although there are no large dams on the Rietspruit upstream of the site several small weirs do impede the flow. The surrounding vegetation is largely untransformed and used primarily for grazing with limited agriculture also evident.

Longitude	25.70805°	**Latitude**	-29.57528°
Altitude (m.a.s.l.)	1273	**Water Management Area**	Lower Orange
Level 2 EcoRegion	26.01	**Quaternary catchment**	C51F
Geomorphological zone	Foothills	**Vegetation**	Eastern Mixed Nama Karoo

Upstream	Downstream

3.1.1.13.2 Present Ecological State (PES)

IIHI	Instream Integrity: 94 Integrity Category: A Minor impacts were due to flow modifications from the presence of weirs upstream of the site. A number of alien macrophytes were observed (*Azolla filiculoides*).
RIHI	Instream Integrity: 87 Integrity Category: B There was limited bank erosion and flow modification being the main impacts. Abundant exotic vegetation was present but was comprised only herbaceous species.
Rip veg	EcoStatus: B/C (80.8%) **Marginal zone: Reed dominated with large open patches** Right bank: Narrow patches of *Phragmites australis. Limosella major* was present in patches along edges of the remainder of pools. *Schoenoplectus* spp. was associated with sunny areas with some exposed bedrock. Left bank: Alluvial deposits with dense and tall stands of *Salix mucronata. Gomphostigma virgatum was* also present along bedrock areas. Impacts: Grazing and trampling evident. **Non-marginal zone: Grass herb dominated with open patches.** Right bank: Pioneer grass *Cynodon dactylon* was dominant with interspersed clumps of *Schoenoplectus* spp. Left bank: Alluvial deposits with dense and tall stands of *Salix mucronata. Gomphostigma virgatum* was also present along bedrock areas. Alien invasive *Bidens bipinnata* and *Datura stramonium* were very abundant. Upper zone contains a mixture of *Searsia pyroides* and *Lycium* species as dominant woody species interspersed with terrestrial grasses. Left bank has lower vegetative cover in the upper zone. Impacts: High grazing pressure, invasive species and regulated flow conditions.
WQ	Significantly elevated dissolved salt concentrations were recorded at the time of sampling for JBS 2, with very high conductivity and TDS levels (185 mS/m, 1584 mg/l) and sodium and chloride concentrations (393 and 690 mg/l respectively); these results were notably higher than JBS 1 and historical water quality samples (C5H012).

	Suspended solids and turbidity were also elevated at 85 mg/l and 43 NTU, particularly considering that the sample was taken in mid-winter. Furthermore, fluoride concentrations were high (2.9 mg/l). The percentage saturation for dissolved oxygen was not satisfactory at 69.5% (6.69 mg/l). Historical data from DWS site C5H012 indicates episodic nutrient enrichment (notably phosphorus).
Diatoms	The diatoms assessment at this site resulted in an E or severely altered ecological category. The specific sensitivity pollution index score was a very low 5 (out of maximum of 18). At this site the 400 diatoms evaluated included 24 species with a very low deformity percentage of 1.5%.
Inverts	Oct 2012: SASS5 score: 40 No of Taxa: 9 ASPT: 4.4 Sep 2012: SASS5 score: 66 No of Taxa: 14 ASPT: 4.7 May 2012: SASS5 score: 31 No of Taxa: 7 ASPT: 4.4 Dec 2011: SASS5 score: 40 No of Taxa: 9 ASPT: 4.4 Oct 2010: SASS5 score: 74 No of Taxa: 16 ASPT: 4.6 As there was no flow at the site during the Jul 2015 survey a MIRAI score could not be calculated
Fish	The fish community wellbeing evaluation resulted in a moderately modified (C/D (61.8)) ecological state. A total of two of the expected seven fishes were collected at the site which was sampled extensively using active electrofishing methods. The more common fish species recorded included *C. gariepinus* (Sharptooth catfish) and *B. anoplus* (Chubbyhead barb). The more cryptic fishes expected to occur at the site that were not collected, included *L. aenus* (Orange-Vaal smallmouth yellowfish), *L. capensis* (Orange River mudfish) and *L.umbratus* (Moggel) and the cichlids including *T. sparrmanii* (Banded tilapia) and *P. philander* (Southern mouthbrooder). The health of the fishes collected were generally good with no serious external abnormalities (deformities, ulcers, lesions and wounds) and no parasitic infections. Drivers of change identified to be affecting the wellbeing of the fish communities is notably flow alterations, caused by weirs within the catchment area. At the time of the survey, no flow was evident within the reach, with extensive sections of the reach completely dry. Pools, considered to be shallow and moderate in extent were sampled. Areas upstream of the sample reach were inundated, primarily due to low flows and natural bedrock features. The only habitat available was characterised by shallow areas, with no flow. The overall impact of these drivers of change at this site has been considered to be moderate as the fish community was evaluated to occur in a moderately modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.13.3 EcoStatus

Driver Components	PES
IHI: Instream	A
IHI: Riparian	B
Water Quality (Diatom SPI)	E
Response Components	**PES**
Riparian Vegetation	B/C
Fish	C/D

3.1.1.13.4 Main Impacts at the Site

<table>
<tr><th></th><th>PES</th><th>Causes[1]</th><th>Sources[2]</th><th>F[3]/NF[4]</th></tr>
<tr><td rowspan="4">WQ</td><td rowspan="4">E</td><td>The high dominance of diatom species that are indicative of altered water quality conditions at this site suggest that the site is negative affected by high nutrient and or salt loads.</td><td>Agricultural activities south of Bloemfontein.</td><td rowspan="4">NF</td></tr>
<tr><td>Very high dissolved salts</td><td>Irrigated agricultural return flows.</td></tr>
<tr><td>Elevated turbidity and suspended solids</td><td>Erosion and agricultural run-off</td></tr>
<tr><td>Episodic nutrient enrichment</td><td>Agricultural run-off and fertiliser usage.</td></tr>
<tr><td rowspan="4">Rip veg</td><td rowspan="4">B/C</td><td>Reduced cover of indigenous riparian obligate species, especially in the marginal and lower zones.</td><td>High trampling pressure around pools, with associated grazing.</td><td rowspan="2">NF</td></tr>
<tr><td>Altered species composition.</td><td>Low cover and presence of alien species, but trampling and grazing pressure also reduces grass cover which caters for an increase in sedge density and cover.</td></tr>
<tr><td>Reduced vegetation cover, especially in marginal and lower zone.</td><td>Altered base flows due to farm dams upstream</td><td>F</td></tr>
<tr><td>Poor water quality and associated benthic growth</td><td></td><td></td></tr>
<tr><td rowspan="6">Fish</td><td rowspan="6">C/D</td><td>Loss of habitat diversity as a result of no flow conditions.</td><td rowspan="3">Dry season survey, only isolated pools present.</td><td>F</td></tr>
<tr><td>Loss of cover, notably the complete absence of the water column</td><td rowspan="5">NF</td></tr>
<tr><td>Loss of species diversity and abundances due to loss of habitat availability and diversity.</td></tr>
<tr><td>Lower breeding success and recruitment for fish.</td><td>Lower, less and/or no natural flushes and smaller floods, with the presence of weirs contributing to this impact.</td></tr>
<tr><td>Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.</td><td>The presence of weirs, this compounded with limited water availability.</td></tr>
<tr><td>Poor water quality and associated benthicgrowth.</td><td></td></tr>
</table>

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.13.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	Slight decrease in VEGRAI category between JBS1 and JBS2. No further vegetative response to changes in flow expected. Grazing pressure not excessive.

Response Components	Trend	Description
Water Quality	Unclear	2010 to current: Decreasing trend in orthophosphate noted at C5H012
Macroinvertebrates	Stable	Based on an assessment of the RHP dataset the SASS5 scores decreased after the JBS1 survey in Oct 2010 to their lowest level in May 2012. Following that, the SASS5 scores fluctuated with an increase in Sep 2012 and a decrease in Oct 2012
Fish	Stable	Slight decrease in PES class from a C in October 2015 to a C/D in July 2015 believed to represent natural variation. No further decreases in water quality or habitat integrity expected.

3.1.1.14 OSAEH_29_05 – Riet River at Mokala National Park (C5VAAL-EUR18)

3.1.1.14.1 Site Description

The site is situated on the Riet River downstream of the Vanderkloof-Riet and Riet River canals, bordering Mokala National Park. The left-hand bank is in the park, with the right-hand bank on private farm land. The site is largely natural, with minor grazing impacts on the right-hand bank and algal mats in the instream channel (presumably the result of increased nutrients from crop farming operations upstream).

Longitude	24.513009°	**Latitude**	-29.027495°
Altitude (m.a.s.l.)	1080m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	29.02	**Quaternary catchment**	C51L
Geomorphological zone	Lower Foothills	**Vegetation**	Kimberley Thornveld

Upstream

Downstream

3.1.1.14.2 Present Ecological State (PES)

IIHI	Integrity Score: 88 Integrity Category: B A minor increase in nutrients (leading to increased benthic algal growth and concomitant reduction in available benthic habitat for invertebrates) from upstream farming practices and minor changes in flow due to upstream dams were the only impact at the site.
RIHI	Integrity Score: 95 Integrity Category: A The riparian habitat was also in a good condition with almost no impacts barring minor impacts from grazing on the right-hand bank
Rip veg	EcoStatus: B (87%) The marginal zone was characterised by a mosaic of vegetation and habitat types: predominantly reed beds and bedrock slabs. Increased nutrients from upstream agricultural activities are likely to be responsible for the presence of algal and aquatic vegetation mats. The non-marginal zone was characterised by a mosaic of vegetation and habitat types: predominantly localised bedrock slabs, grasses and opportunistic woody terrestrial woody species (associated with a Kimberley Thornveld (Mucina and Rutherford, 2006) environment) that ingress into the non-marginal zone. The reference state marginal and non-marginal zones would have been largely similar to the present state.
WQ	This site indicated moderate to high dissolved salt concentrations and the historical data record at DWS site C5H014 indicated excessive nutrient enrichment at times (both nitrogen (particularly ammonia) and phosphorus) likely to be associated with agricultural return flows and diffuse sources of pollution.
Diatoms	The diatoms assessment at this site resulted in a B/C or largely natural ecological category. The SPI score was a good to moderate 14.1 (out of maximum of 18). At this site the 400 diatoms evaluated included 33 species with a few deformities (1.8%). Overall the water quality was regarded as moderate to good.
Inverts	Jul 2015: SASS5 Score: 121 No of Taxa: 20 ASPT: 6.05 Oct 2012: SASS5 Score: 87 No of Taxa: 15 ASPT: 5.80 Aug 2012: SASS5 Score: 54 No of Taxa: 10 ASPT: 5.40 May 2012: SASS5 Score: 92 No of Taxa: 15 ASPT: 6.13 Dec 2011: SASS5 Score: 78 No of Taxa: 15 ASPT: 5.20 Water quality was the main driver for this site, with agriculture and settlements upstream contributing to the decline in quality. Eutrophication was evident in algal growth upon the bedrock and boulder habitats and filamentous algae growth in the water column. The moderately sensitive taxa, Heptageniidae, Athericidae, Elmidae and Leptophlebiidae were found at the site. Cobbles habitat was the preferred substrate of most of the expected reference taxa but due to the algal growth on the limited cobble habitat, only half of the expected taxa were found. The MIRAI EC was calculated as B/C (77.59%).
Fish	With the exception of *Pseudocrenilabrus philander* (Southern Mouthbrooder), *Tilapia sparmanii* (Banded Tilapia) and *Labeobarbus kimberleyensis* (Vaal-Orange Largemouth Yellowfish), all species expected to occur at the site were present in reduced frequencies of occurrence or absent. During the present study, significant growth of invasive aquatic macrophytes within the channel was noted, which reduced habitat access and availability for utilisation within the shallow reaches by fish species having a preference for such habitats or seeking cover from predation by indigenous piscivorous fish species (such as *L. kimberleyensis*) which were confirmed within the deeper water habitats. In addition, increased algal growth on rocks present within the shallow water habitat (attributed to agricultural return flows in the upper catchment) was noted to render such habitat structures unsuitable for *Austroglanis sclateri* (Rock Catfish). Further, abstraction from upstream dams (Krugersdrift and Kalkfontein) was expected to reduce baseflows and decrease spring flushes and moderate flood events, thus decreasing migratory cues for indigenous species present within the catchment and subsequently decreasing recruitment. Accordingly, a FRAI score of 60.9% (Ecological Category C/D) was obtained for the site.

3.1.1.14.3 EcoStatus

Driver Components	PES
IHI: Instream	B
IHI: Riparian	A
Water Quality (Diatom SPI)	B/C
Response Components	**PES**
Riparian Vegetation	B
Macroinvertebrates	B/C
Fish	C/D
EcoStatus	B/C

3.1.1.14.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	B	Minor nutrient enrichment	Upstream farming practices	NF
		Water quantity	Reduced baseflows due to abstraction and upstream Krugersdrif and Kalkfontein dams. However, there is potential for increased flows due to upstream transfers from Vanderkloof Dams.	F
RIHI	A	None	None	-
Rip veg	B	Water quality	Indications of slight changes to the water quality within the system were present (e.g. algal growth and aquatic vegetation). This is likely the result of agricultural run-off from the farming activities upstream of the site.	NF
		Water quantity	Slight changes to the water quantity available within the system were present. This was likely the result of abstraction for irrigation and impoundments in the upstream catchment.	F
		Vegetation removal	Vegetation removal at the site was minor. This was a result of livestock grazing on the right-hand bank.	NF
WQ	B/C	Moderate to high salinity	Agricultural activities and return flows	NF/F
		Nutrient enrichment		
		Altered temperature and dissolved oxygen regimes anticipated	Releases from upstream impoundments	F
Inverts	B/C	Water quality	Nutrient enrichment from upstream farming activities and town.	NF
Fish	C/D	Decreased habitat access and lateral connectivity	Significant growth of invasive aquatic macrophytes	NF
		Decreased habitat suitability	Agricultural return flow and nutrient enrichment, leading to increased algal growth	

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Reduction in seasonal migration cues	Krugersdrif and Kalkfontein Dams, and abstraction	F

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3 Flow related 4 Non Flow related

3.1.1.14.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	This reach was sampled in JBS1 (site code OSAEH 29 5 and C5RIETIFR01). It was also assessed as part of the Lower Vaal Reserve study, during 2007-2008. The riparian vegetation ecological condition improved from a C/D to a B between 2008 and 2010, with conditions remaining stable between 2010 and 2015. It is therefore predicted that the system will remain in a stable condition if no additional impacts are introduced into the system.
Water Quality	Decline	2010 to current: Increasing trend in ammonia noted at C5H014
Macroinvertebrates	Stable	Similar to previous scores
Fish	Stable	In general, habitat diversity present as well as upstream impacts have remained relatively unchanged to those identified during JBS1. Further, although differences in the expected and observed species lists and frequencies of occurrence were noted between the surveys, similar species were collected at comparable frequencies, resulting in a stable trend between JBS1 and JBS2. However, it should be noted that trend analysis is based on two points, namely results from JBS 1 and results obtained during JBS 2. Further, the models used under JBS1 and JBS2 represent different versions, and as such inherent differences in the values obtained may be present. As such, trends presented should be interpreted with caution.

3.1.1.15 OSAEH_26_01 – Vaal River at St. Claire's

3.1.1.15.1 Site Description

Site is on the Vaal River approximately 14 km upstream of the confluence with the Orange River. The macro-channel forms an extensive floodplain system comprising large islands with established terrestrial vegetation on the upper reaches. Braids between islands provide a diversity of instream habitats including riffles, runs, pools and back-waters. The site is immediately downstream of the diversion weir (C9H007) on the lower reaches of the Vaal River system. Extensive filamentous algae define the benthic layer, reflecting water quality impacts from the broader catchment. The riparian zone has dense reed/sedge vegetation along the marginal zone extending into the non-marginal zone where there is a higher occurrence of woody vegetation. Large *Eucalyptus* trees dominate the upper zone.

Longitude	23.821032°	**Latitude**	-29.055032°
Altitude (m.a.s.l.)	1093	**Water Management Area**	Lower Vaal
Quaternary catchment	C92C	**Level 2 EcoRegion**	26.01
Geomorphological zone	Lowland river	**Vegetation**	Upper Gariep Alluvial Vegetation

Upstream	Downstream

3.1.1.15.2 Present Ecological State (PES)

IIHI	Integrity Score: 63 Integrity Category: C The principle impacts are flow modification from LHDA transfers and bed modification due to the extensive filamentous algae growth. Other impacts include water quality modifications from upstream influences, invasive macrophytes and water abstraction.
RIHI	Integrity Score: 66 Integrity Category: C The principle impacts are the high infestation of invasive alien plants with disturbances in the riparian zone from artisanal mining of alluvial soils on the flood bench. Channel modification through livestock trampling. Initial disturbance by livestock trampling had de-stabilised a portion of the channel bar. This has now stabilised but has modified the shape of the channel.
Rip veg	EcoStatus: B/C (80.6%) **Marginal zone:** Narrow and dominated by herbaceous vegetation. The marginal zone is extensive due to the numerous islands and backwaters that occur throughout the macro-channel. Dense patches of *Phragmites australis* occur on the smaller islands and along the banks, extending well into the non-marginal zone in areas. *Cynodon dactylon* also dominates the non-marginal zone and forms a mosaic with sedges (e.g. *Cyperus eragrostis* and *Pseudoschoenus inanis*) and exotic herbs. The shrub *Gomphostigma virgatus* has formed dense stands in certain areas. **Non-marginal zone:** Ranges between 50 and 100 metres-wide with dense reed beds of *P. australis* leading to heavily wooded thickets on the upper banks. *Salix mucronata*, *Searsia lancea* and *Ziziphus mucronata* dominate the woody component along with large, well-established *Eucalyptus* (exotic) trees. Other invasive alien plants that dominate include *Medicago polymorpha* and *Melilotus indicus* within the marginal and non-marginal zones, and the aquatic macrophyte *Myriophyllum aquaticum*, which occurs largely in backwaters.
WQ	Water quality was generally satisfactory at this site based on the data collected during JBS 2. Nitrate concentrations were moderately elevated at 0.5 mg/l. Concurring with this, historical data from C9R003 indicated elevated nutrient concentrations at times, particular nitrogen species.

	Dissolved salt concentrations were deemed moderate. The impact of elevated nutrient and salt concentrations is mitigated by elevated flows at this sample point.
Diatoms	The diatoms assessment at this site resulted in a B or largely natural ecological category. The specific sensitivity pollution index score was a high 15.4 (out of maximum of 18). At this site the 400 diatoms evaluated included 32 species with a very low deformity percentage of 0.8%. The dominance of diatom species that are intolerant to water quality alterations suggests that the water quality at this site is in a good state. This is surprising as other components suggest that there are nutrient contamination issues at this site.
Inverts	Jul 2015: SASS5 Score: 115 No of Taxa: 24 ASPT: 4.8 Aug 2013: SASS Score: 41 No of Taxa: 12 ASPT: 3.4 Oct 2010: SASS5 Score: 128 No of Taxa: 28 ASPT: 4.6 For JBS1 the MIRAI EC at this site was calculated as a C/D (61.4%) - driven largely by the absence of taxa that were sensitive to water quality changes such as Hydropsychidae (>2 species), Aeshnidae, Atyidae, Chlorocyphidae, Dixidae, Ecnomidae, Gerridae, Hydrometridae, Philopotamidae, Tricorythidae and Veliidae/ Mesoveliidae. In JBS 2 key taxa that were expected but not observed were those with a preference for moderate to fast flows, cobble and water column habitat and also moderate to high water quality preference. Taxa absent from the site included various mayflies - Baetidae, Caenidae, Leptophlebiidae, Heptageniidae and Tricorythidae- many of the Odonata and most of the Hemiptera as well as various Diptera barring Chironomidae. Ecnomidae, Hydropsychidae (>2 species) and Leptoceridae were also unexpectedly all absent from sampling. In general these results are in line with the results from JBS1, but with fewer taxa recorded. The results indicate water quality impacts to invertebrates at the site, followed by modification of natural flows. The biotopes present at the site as well as the diversity of available habitats (velocity and depth) was good. MIRAI EC was calculated as D (55.3%)
Fish	The fish community wellbeing evaluation resulted in a moderately modified to largely modified ecological state (Class C/D (58.1%)). At this site eight of the expected eleven fishes were collected at the site which was sampled extensively using a range of active electrofishing and netting methods. Common fishes included *L. capensis* (Orange River mudfish) and the cichlids including *T. sparrmanii* (Banded tilapia) and *P. philander* (Southern mouthbrooder). Although some of the cryptic fishes expected to occur at the site were collected such as *L. kimberleyensis* (Vaal-Orange largemouth yellowfish) were collected. At this site no *A. sclateri* (Rock catfishes) and *L. umbratus* (Moggel) were sampled which is unexpected. The health of the fishes collected at this site was generally poor with only a few external abnormalities (deformities, ulcers, lesions and wounds) and very high parasitic infections. The overall impact of the drivers of change at this site have are considered to be moderate to large as the fish community was evaluated to occur in a moderately modified/largely modified state. These outcomes are based on a low confidence once-off assessment which included inferences to existing information pertaining to the study area.

3.1.1.15.3 EcoStatus

Driver Components	PES
IHI: Instream	C
IHI: Riparian	C
Water Quality (Diatom SPI)	B
Response Components	**PES**
Riparian Vegetation	B/C
Macroinvertebrates	D
Fish	C/D
EcoStatus	C

3.1.1.15.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	C	Alteration of flows	LHDA inter-basin transfers and the Orange-Douglas Transfer	F
		Bed modification from excessive filamentous algae	Increase in nutrient concentrations from upstream activity	NF
		Extensive growth of alien invasive aquatic macrophytes	Increase in nutrients exacerbate aquatic invasive growth	NF
RIHI	C	Extensive alien invasive plants	Disturbance to the site allows invasive alien vegetation to establish	NF
		Channel modification	Artisanal mining and livestock trampling	NF
		Bank erosion	Artisanal mining	NF
WQ	B	Sporadic nutrient enrichment	Agricultural activities.	NF
Rip veg	B/C	Increase in herbaceous vegetation cover	More continuous baseflows and reduced seasonality due to flow regulation by large impoundments upstream	F
		Establishment of dense woody vegetation	Less frequent flooding by medium to large return period events due to flood attenuation by large impoundments upstream	F
		Change in plant species composition	Infestation by invasive alien plants, notably *Eucalyptus camuldensis*	NF
Inverts	D	Water quality deterioration	Mining, agriculture, urban sewage and industries with associated waste upstream	NF
		Algal and benthic growth	Mining, agriculture, urban sewage and industries with associated waste upstream	NF
		Increased sedimentation	Mining, agriculture, urban sewage and industries with associated waste upstream	NF

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Increased base flows	Inter basin transfer, dam releases, return flows from sewer works and mines	F
		Loss of instream habitat	Flow modification due to weirs and abstraction for agriculture	
Fish	C/D	Flow alterations associated with the water quantity management activities upstream of the site (Vaal-Harts Irrigation Scheme), and the flow alteration associated habitat, cover and water quality (dilution) impacts were observed.	Vaal-Harts irrigation scheme and other quantity impacts associated with upstream dams (Bloemhof Dam etc.)	F
		Water quality impacts including: nutrient enrichment impacts associated with upstream agricultural activities (including Vaal-Harts scheme). The agricultural activities usually also have pesticide impacts that may accumulate into the fish through the food chain and affect fish wellbeing (not considered in this assessment). Additional water quality impacts associated with salinization impacts associated with agriculture and regional mining activities were also observed.	Vaal-Harts Irrigation scheme and upstream alluvial diamond mining activities in the Vaal River (consider new activities at Rooipoort nature reserve).	F/NF
		Habitat alteration impacts associated with infrastructure developments, mining activities, water quality (nutrient enrichment has resulted in excessive growth of filamentous algae which changes habitats) and flows affecting habitats were observed.	Upstream weirs, bridges, mining activities and agriculture activities.	
		Competition with alien fishes *G. affinis* (Mosquito fish, observed), C. *idella* (Grass carp, inferred to occur with comments from stakeholders/historical data) and *C. carpio* (Common carp, inferred to occur) is limited but may have a slight impact on the wellbeing of the indigenous fishes. Other alien fishes including *M. salmoides* (Largemouth bass) may be actively preying on the indigenous fishes.	Alien invasive fishes	NF

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.1.15.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Decline	The VEGRAI score declined from a B (82.4%) to a B/C (80.6%) but differences were not substantial
Water Quality	Stable	2010 to current: no significant changes at C9R003
Macroinvertebrates	Decline	The MIRAI scores declined from a C/D (61.4%) to a D (55.3%)
Fish	Decline	The FRAI scores declined from a C (68.7%) to a C/D (58.1%)

3.1.2 Upper Orange/Senqu River Catchment

The Upper Orange/Senqu Catchment also showed extensive modification, with much of the system in a C-D category. Surprisingly the sites located in the upper reaches of the Senqu and Caledon Rivers (OSAEH 15_1 and 15_2) were in a largely modified condition, likely owing to extensive land use change and agricultural practices leading to sedimentation and riparian degradation. Sites on the lower reaches of the upper orange upstream of the confluence with the Vaal were notably affected by irrigation and hydropower releases from major upstream dams (Gariep and Vanderkloof), in conjunction with surrounding agriculture and WWTW's effluent releases.

AEH sites located in the Upper Orange/Senqu Catchment are shown in Figure 3.4, while overall EcoStatus condition of the sites is represented in Figure 3.5.

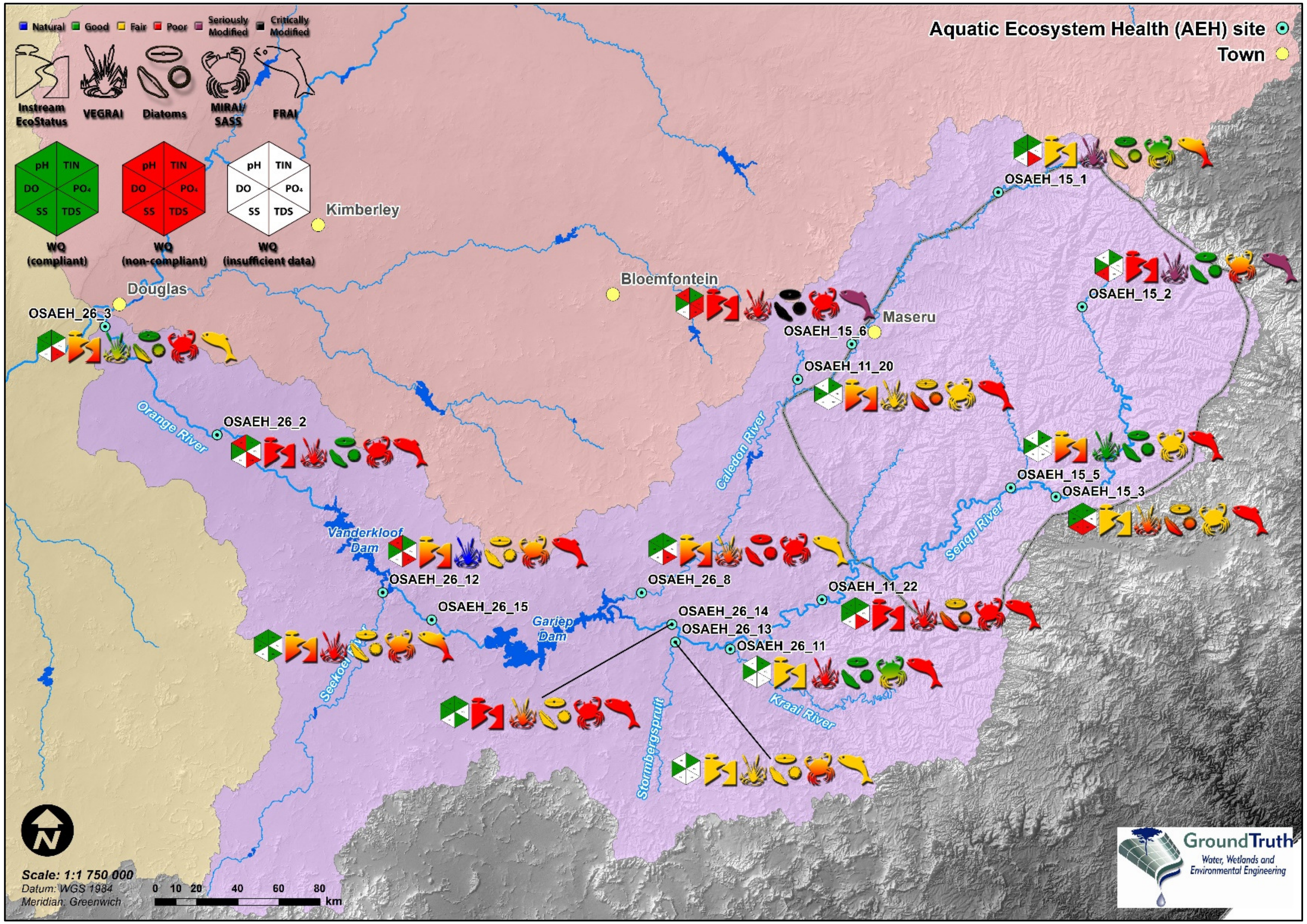

Figure 3.4 **Study sites within the Upper Orange catchment. AEH components are colour coded according to EcoStatus categories (grey symbols indicate that the component was not sampled). Water quality (WQ) determinands are colour coded according to compliance with the DWAF (1996) chronic effect values for aquatic ecosystems.**

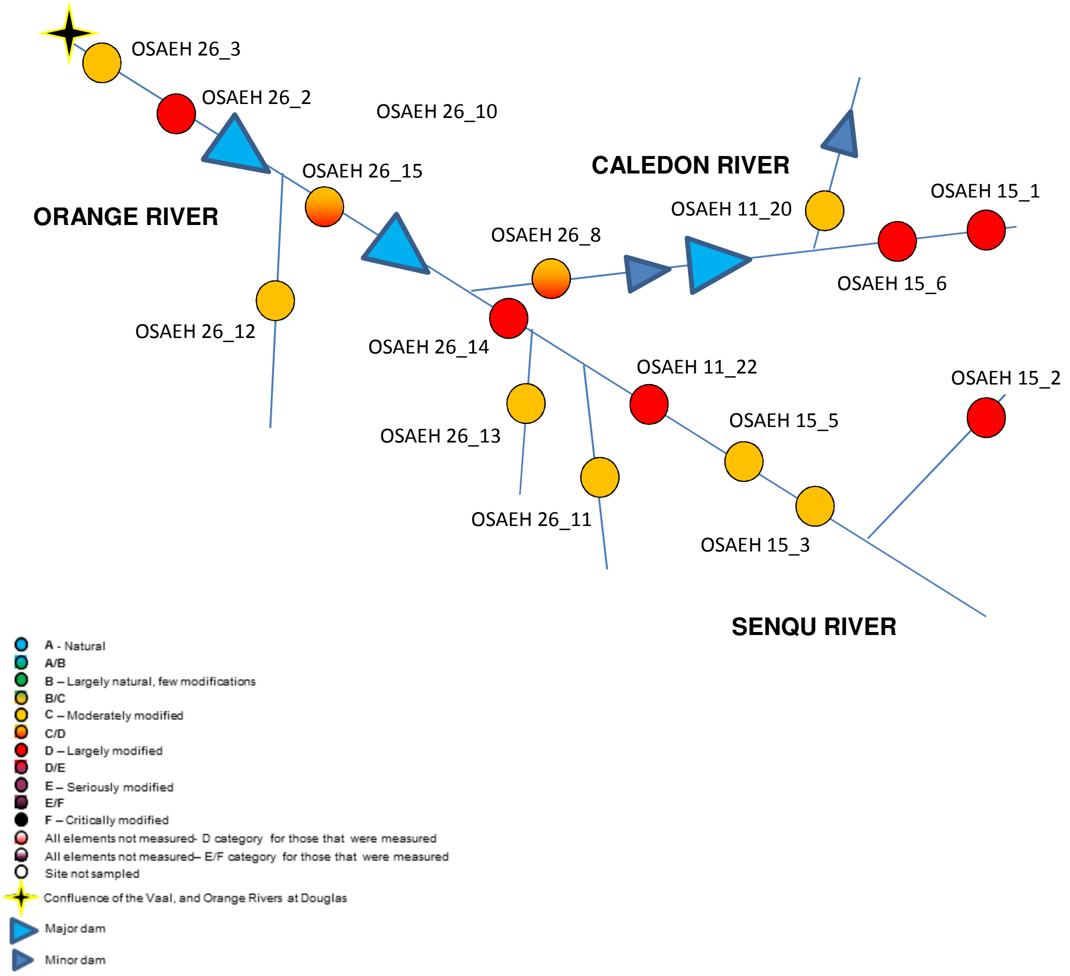

Figure 3.5 Map representing the AEH sites sampled in JBS2 in the Upper Orange catchment. Sites are colour coded according to overall EcoStatus Category.

3.1.2.1 OSAEH_15_02 – Matsoku River

3.1.2.1.1 Site Description

The site is located on the Matsoku River approximately 4km upstream of the confluence with the Liseleng River and downstream of the Matsuko weir, Lesotho. The primary land use within the upstream catchment includes subsistence farming and livestock grazing. The site is represented by a pool downstream of the weir with the substrate dominated by fine sediment and embedded substrate, as well as riffle/rapid habitat dominated by boulders. Riparian elements associated with the site include the presence of the alien invasive tree: *Salix fragilis*. The site is subject to run-off from snow-melt during the winter months.

Longitude	28.56182297°	**Latitude**	-29.23409804°
Altitude (m.a.s.l.)	2092	**Water Management Area**	Lesotho
Level 2 EcoRegion	15.02	**Quaternary catchment**	D11H
Geomorphological zone	Lower Foothill	**Vegetation**	Lesotho Highland Basalt Grassland

Upstream

Downstream

3.1.2.1.2 Present Ecological State (PES)

IIHI	Integrity Score: 81 Integrity Category: B/C This score was mostly related to flow and bed modification. Abstraction of water from upstream has led to lower flows and an increase in sediment deposits (as well as surrounding agricultural practices),

	which have altered the instream habitat availability and water quality. Solid refuse in the channel and catchment run-off have also had an impact on the water quality at the site
RIHI	Integrity Score: 46 Integrity Category: D The main impacts being substrate exposure, with related bank erosion. This is due to over grazing and excessive livestock hoof action. In addition, the presence of exotic vegetation has also reduced the natural vegetation cover.
Rip veg	EcoStatus: D/E (38.6%) The marginal zone was characterised by heavily overgrazed sandy banks. Marginal vegetation abundance and cover was low, with a deep silt layer covering areas between rocks. The non-marginal zone was characterised by overgrazed sandy banks with extensive alien invasive tree (*Salix fragilis*) abundance and cover. In the reference state, the marginal zone would have been classified as a grass and sedge dominated system, interspersed with rocks and bedrock outcrops; and the non-marginal zone as a grass dominated system in a Lesotho Highland Basalt Grassland (Mucina and Rutherford, 2006) environment.
WQ	No representative historical DWS data exists for this site. JBS 1 data indicates low concentrations of dissolved salts and turbidity, but a high nitrate concentration at 6.7 mg/l. This single result requires confirmation.
Diatoms	The diatoms were observed to be in a B or largely natural ecological category at this site. The specific sensitivity pollution index score was a high 16.5 (out of maximum of 18). At this site the 400 diatoms evaluated included 15 species with a moderate deformity percentage of 3.8%. The dominance of diatom species that are known to be highly intolerant to altered water quality suggests the water quality at this site is ideal.
Inverts	Jul 2015: SASS5 Score: 93 No of Taxa: 19 ASPT: 4.89 Increased suspended solids/sedimentation and reduced flows had impacted negatively upon the flow and habitat metrics' of the invertebrate community. However, the accumulative impact was most noticeable in the water quality metric, which showed the largest impact on the macroinvertebrate community. The highly or moderately sensitive taxa Perlidae, Heptageniidae, Oligoneuridae, Polymitarcyidae, Prosopistomatidae, Aeshnidae, Gerridae, Hydrometridae, Veliidae, Ecnomidae, Elmidae, Hydraenidae and Athericidae were all expected but were absent from the site. Only Leptophlebiidae and Tricorythidae were present of the taxa considered to be highly or moderately sensitive to water quality. The taxa present at the site, were generally those with no or low requirements for unmodified water quality, and with preferences for faster flowing water, cobbles or GSM. The MIRAI EC was calculated as a C (61.76%).
Fish	Fish collection records from the study area indicate the historic presence of *Pseudobarbus quathlambae* (Maloti Minnow) at the selected site, while *Austroglanis sclateri* (Rock Catfish) was expected to occur at regular frequencies under natural conditions. Other species expected to occur at the site included *Labeobarbus aeneus* (Vaal-Orange Smallmouth Yellowfish) and *Labeo capensis* (Orange River Mudfish), albeit at reduced frequencies relative to *P. quathlambae* and *A. sclateri*. During the present study, no fish species were collected at the site, while the predatory alien species *Oncorhynchus mykiss* (Rainbow Trout) was expected to be present and preying on *P. quathlambae* and *A. sclateri*, as well as on smaller *L. aeneus* and *L. capensis* cohorts, thus resulting in the site being classified as seriously modified in terms of fish with a FRAI value of 33.5% (Ecological Category E). Drivers of change identified to be affecting the wellbeing of the fish communities included sediment run-off and infilling of available habitat as a result of overgrazing and agricultural practices within the catchment, as well as the likely presence of the alien species *O. mykiss* (Rainbow Trout). In addition, the abstraction of water upstream of the weir for transfer to Katse Dam is likely to have decreased baseflows within the Matsoku River downstream of the weir, further supporting the deposition of sediments and decreasing available habitat.

3.1.2.1.3 EcoStatus

Driver Components	PES
IHI: Instream	B/C
IHI: Riparian	D
Water Quality (Diatom SPI)	B
Response Components	**PES**
Riparian Vegetation	E
Macroinvertebrates	C/D
Fish	E
EcoStatus	D

3.1.2.1.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	B/C	Water quantity	Abstraction and transfer to Katse Dam resulting in reduced baseflows	F
RIHI	D	Vegetation removal and exotic vegetation	Extensive over grazing and alien vegetation invasion	NF
Rip veg	D/E	Vegetation removal	Overgrazing in the riparian zone resulting in reduced cover and abundance of indigenous vegetation in both the marginal and non-marginal zones.	NF
		Exotic vegetation	Woody alien invasive vegetation (*Salix fragilis*) infesting the riparian zone resulting in a change in species composition in the system.	NF
		Habitat modification	High levels of sedimentation changed the substrate composition and stability in the system in certain areas of the marginal zone. Furthermore, bank collapse and incision (prevalent on the left-hand bank) resulted in reduced habitat availability and stability for the riparian vegetation.	
		Water quantity	Changes in baseflows from the water transfer upstream of the site to Katse Dam had a minor impact on riparian vegetation community integrity. Certain sections of instream habitat were available for colonisation, which may not have been present in the reference.	F
WQ	B	Elevated nitrate and phosphate concentrations as well as increased turbidity and TDS	Subsistence agricultural practices and overgrazing leading to increased erosion and sediment run-off and siltation of the instream habitats	NF
Inverts	C	Reduced baseflows	Abstraction and transfer to Katse Dam	F

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Loss of habitat	Over grazing and trampling reduced the vegetation habitat extensively. The loss of vegetation in the surrounding areas and upper catchment has led to increased deposits of fine sediment.	NF
Fish	E	Decreased substrate quality and sedimentation	Extensive overgrazing and agricultural practices in catchment	NF
		Increased turbidity	Catchment run-off	
		Decreased species diversity and abundance	Presence of predatory alien fish species (*O. mykiss*)	
		Reduced baseflows	Abstraction and transfer to Katse Dam	F

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2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.1.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	Vegetation has already been largely negatively impacted
Water Quality	Unclear	Inadequate data to determine trends
Macroinvertebrates	Decline	Increasing sedimentation from catchment processes (largely overgrazing) negatively impacting on available habitats within the stream and hence biota
Fish	N/A	Due to the fact that the site was not assessed as part of JBS1, no trend analysis for the fish component could be established.

3.1.2.2 OSAEH_15_03 – Senqu River at Seapa

3.1.2.2.1 Site Description

The site is located on the Senqu River at LHDA IFR Site 5 approximately 150km downstream of Katse Dam and approximately 40km upstream of the confluence with the Sequnyane River, Lesotho. Whitehills weir, located on the Senqu River, is approximately 15km upstream of the site. The primary land use within the upstream catchment includes subsistence farming and livestock grazing. The site was characterised by the presence of a large cobble bar with deeper pools, dominated by highly mobile alluvium (gravel) upstream and downstream. A large run was present upstream. Embedded boulders with evidence of fine sediment particulates were noted to be present within the channel upstream of the riffle habitat. In addition, algal growth was noted on rocks and boulders within the riffle habitat. Boulders were present on the left hand bank downstream of the riffle habitat, limiting bank erosion and protecting road infrastructure.

Longitude	28.408956	**Latitude**	-30.06557998
Altitude (m.a.s.l.)	1566	**Water Management Area**	Lesotho
Level 2 EcoRegion	15.06	**Quaternary catchment**	D17L
Geomorphological zone	Lower Foothill	**Vegetation**	Senqu Montane Shrubland

Upstream	Downstream

3.1.2.2.2 Present Ecological State (PES)

IIHI	Integrity Score: 69 Integrity Category: C Impacts relating to Katse Dam included reduced base flows/flow regulation and bed modification due to sedimentation. The accumulation of algal growth on substrate in lower flow areas also infers nutrient enrichment and a lack of scouring from freshets.
RIHI	Integrity Score: 68 Integrity Category: C Vegetation removal, through over grazing and invasion of alien vegetation were the main drivers.
Rip veg	EcoStatus: C/D (62%) The marginal zone was characterised by sandy banks, cobble outcrops and limited marginal vegetation cover. The non-marginal zone was characterised by a mosaic of vegetation and habitat types. Impacts included localised sand-mining, increased sedimentation from upstream catchment-scale overgrazing and localised grazing in the riparian zone. In the reference state, the marginal zone would have been characterised by a mosaic of vegetation and habitat types. Grass and sedge cover would have been higher than what they were in the present state. The non-marginal zone would have been characterised by a mosaic of vegetation (predominantly grassland with sedges and woody vegetation interspersed) and habitat types (cobble and boulder outcrops and sand bars) in a Senqu Montane Shrubland (Mucina and Rutherford, 2006) environment.
WQ	Temperature effects are anticipated since this site is downstream of a significant impoundment. In addition, low dissolved oxygen concentrations (0.1 and 1.38 mg/l) were recorded in the very limited Lesotho historical data set. However, the sample collected during JBS 2 reflected good dissolved oxygen saturation at 99 % (9.42 mg/l) saturation. Dissolved salt concentrations were generally low. There was some evidence of intermittent nutrient enrichment (both nitrogen (nitrate and ammonia) and phosphorus) from the limited historical data available from Lesotho. The limited DWS historical

	data collected at D1H035 also indicated sporadic nutrient enrichment (particular nitrate+nitrite, as orthophosphate results were low with the exception of a single occurrence).
Diatoms	The diatom assessment at this site resulted in a C or moderately modified ecological category. The specific sensitivity pollution index score was a low 13.8 (out of maximum of 18). At this site the 400 diatoms evaluated included 23 species with a high deformity percentage of 5.8%.
Inverts	Jul 2015: SASS5 Score: 87 No of Taxa: 15 ASPT: 5.8 Jul 2013: SASS% Score: 71 No of Taxa: 12 ASPT: 5.9 The main drivers affecting the macroinvertebrate community were changes in water quality and loss of habitat. The following taxa which are sensitive to water quality were expected at the site but were not found, *Oligoneuridae*, *Heptageniidae* and *Prosopistomatidae.* Of the 17 taxa with a preference for cobble habitats expected at the site only *Perlidae*, *Leptophlebiidae*, *Hydropsychidae* and *Simuliidae* were present. Deposition of sediments and algal growth on and amongst the cobbles appears to be the main factors influences in the reduced number of taxa. The taxa present at the site generally had a preference for faster flowing water, cobbles or GSM and had low preferences for unmodified water quality. The MIRAI EC was calculated as C (63.56%)
Fish	Fish species expected to occur at the site under natural conditions at high frequencies included *Austroglanis sclateri* (Rock Catfish), *Labeobarbus aeneus* (Vaal-Orange Smallmouth Yellowfish) and *Labeo capensis* (Orange River Mudfish), while *Clarias gariepinus* (Sharptooth Catfish) was expected at a moderate frequency. Species with a low expectation of occurrence at the site included *Barbus anoplus* (Chubbyhead Barb), *Labeobarbus kimberleyensis* (Vaal-Orange Largemouth Yellowfish) and *Labeo umbratus* (Moggel). During the present study, *A. sclateri*, *L. aeneus* and *L. capensis* were sampled at lower than expected frequencies, while *C. gariepinus* was expected to occur infrequently. No *L. kimberleyensis*, *L. umbratus* or *B. anoplus* individuals were sampled during the present study, nor were any expected to occur based on the habitat structure. In addition, the presence of the predatory alien species *Oncorhynchus mykiss* has been confirmed during previous studies conducted on the reach in question, and was likely preying on *A. sclateri* and smaller cohorts of other expected species. As a result, the site was classified as largely modified in terms of fish with a FRAI value of 52.5% (Ecological Category D). Drivers of change identified to be affecting the wellbeing of the fish communities included sedimentation and infilling of habitat (most notably pools), the presence of an abrasive environment during high flows as a result of the significant gravel depositions, and the presence of alien *O. mykiss* which will predate on indigenous species. In addition, the presence of algal growth on stable substrate present suggested some degree of nutrient enrichment (likely from catchment run-off and livestock grazing).

3.1.2.2.3 EcoStatus

Driver Components	PES
IHI: Instream	C
IHI: Riparian	C
Water Quality (Diatom SPI)	C
Response Components	**PES**
Riparian Vegetation	C/D
Macroinvertebrates	C
Fish	D
EcoStatus	C

3.1.2.2.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	C	Flow reduction	Katse Dam	F
		increased sediments and nutrients	Localized sand mining and catchment related agricultural practices	NF
RIHI	C	Vegetation removal and exotic vegetation	Over grazing and alien plant invasion	NF
Rip veg	C/D	Vegetation removal	Vegetation removal was serious at a localised scale as a result of sand mining in the non-marginal zone. Moderate removal of vegetation throughout most of the site was the result of overgrazing in the riparian zone.	NF
		Exotic vegetation	A moderate level of exotic vegetation infestation (both woody and non-woody) was present within the site. This resulted in a change in a change in species composition in the system.	
		Water quantity	Katse Dam upstream of the site altered the flooding regime and base flows in the system. Certain sections of instream habitat were available for colonisation, which may not have been present in the reference.	F
		Habitat modification	High levels of sedimentation changed the substrate composition and stability in the system in certain areas of the marginal zone and lower sections of the non-marginal zone. Furthermore, bank collapse and incision (prevalent on the left-hand bank) resulted in reduced habitat availability and stability for the riparian vegetation.	NF
WQ	C	Altered temperature and dissolved oxygen regimes downstream of impoundments	Alteration of flow regime from upstream Katse Dam.	F
		Intermittent nutrient enrichment	Run-off from subsistence farming, livestock grazing	NF
		High percentage of deformed diatoms	Various environmental stresses s such as: reduced flows/velocities, temperature increases, herbicides, heavy metals	NF/F
Inverts	C	Decrease in habitat availability	Increased sediment deposits resulting from catchment over grazing, covering and embedding available habitat.	NF
		Water quality	Increase in nutrients leading to excessive algal growth on cobble and bedrock substrates.	
		Water quantity	Reduced flows due to Katse Dam upstream of the site, limit potential flood events which could assist in scouring the cobble habitats and flushing sediments	F
Fish	D	Decreased species abundance	Presence of predatory alien fish species (*O. mykiss*)	NF
		Reduced baseflows	Katse Dam (upstream)	F
		Deterioration of potential spawning habitat and migratory cues	Unnatural releases from Katse Dam	F
		Decreased FROC of species with a preference for fast-deep and slow-deep habitats	Infilling of pools	NF

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Decreased substrate quality	Extensive overgrazing and agricultural practices in catchment leading to increased sediment input and possible nutrient enrichment	

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3 Flow related 4 Non Flow related

3.1.2.2.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	The site was in a C condition during surveys for the LHDA Phase II project (2014). The slight deterioration in the ecological condition can be attributed to the winter sampling period i.e. (i) low confidence as it is not the right time of year for vegetation samples; and (ii) overgrazing and alien impacts more notable during the high stress dry season.
Water Quality	Stable	Limited data but no obvious trends evident
Macroinvertebrates	Stable	Similar to 2013 scores
Fish	N/A	Due to the fact that the site was not assessed as part of JBS1, no trend analysis for the fish component could be established.

3.1.2.3 OSAEH_15_05 – Senqunyane River at Nkaus

3.1.2.3.1 Site Description

The site is located on the Senqunyane River approximately 1.5km upstream of the confluence with the Senqu River, Lesotho, at LHDA IFR Site 8 upstream of the road bridge. The site was characterised by a large shallow pool immediately upstream of two riffle habitats separated by a cobble bar, a run, and a boulder rapid located below the bridge. Substrate within the reach was dominated by highly mobile alluvium (gravel) downstream of the riffle habitat, while finer sediments dominated the substrate of the pool located upstream of the riffle habitat. The presence of some algal growth on the boulders present within the channel underneath the bridge suggested some degree of nutrient enrichment. Boulders and overhanging grassland vegetation was limited and confined to the right hand bank downstream of the riffle habitat. A demarcated pedestrian crossing point (demarcated by means of a signboard and depth markers located in with bank) was noted at the top of the riffle habitat. Primary land use within the immediate upstream catchment includes extensive subsistence farming and livestock grazing, while Mohale Dam is located in the upper reaches of the catchment.

Longitude	28.18295399	**Latitude**	-30.02105699
Altitude (m.a.s.l.)	1519	**Water Management Area**	Lesotho
Level 2 EcoRegion	15.02	**Quaternary catchment**	D17F
Geomorphological zone	Lower Foothill	**Vegetation**	Senqu Montane Shrubland

Upstream | **Downstream**

3.1.2.3.2 Present Ecological State (PES)

IIHI	Integrity Score: 83 Integrity Category: B The instream habitat integrity was impacted marginally by bed modification from increased sedimentation and minor impacts related to flow modification were also noted. Flow modifications were primarily in the form of flow regulation and abstraction from an upstream weir. Water quality impacts included solid refuse in the channel and catchment run-off.
RIHI	Integrity Score: 88 Integrity Category: A/B The riparian habitat integrity was in good condition with vegetation removal due to over grazing being the main driver. Alien vegetation was also present at the site but in a low density.
Rip veg	EcoStatus: B (84.3%) The marginal zone was largely natural and classified as a grass dominated system, with sedges interspersed. Sand bars, from increased sediments in the instream habitat from upstream catchment-scale overgrazing were present. The non-marginal zone was classified as a grass dominated system in a Senqu Montane Shrubland (Mucina and Rutherford, 2006) environment. The right- and left-hand banks were similar. Vegetation was not heavily overgrazed. In the reference state, the marginal zone would have been largely similar to the present state, and classified as a grass dominated system. The non-marginal zone would have also been largely similar to the present state, and classified as a grass dominated system.
WQ	Little water quality data was available for the site, the Senqunyane River upstream of the confluence with the Senqu River, including only the results of the JBS 1 and 2. The water quality appeared good, with low dissolved salt concentrations and turbidity, and most nutrient concentrations reported as less than the analytical detection limit. Temperature and dissolved oxygen impacts are anticipated since this site is downstream of significant impoundments.
Diatoms	The diatoms were observed to be in a B or largely natural ecological category at this site. The specific sensitivity pollution index score was a high 15.4 (out of maximum of 18). At this site the 400 diatoms

	evaluated included 24 species with a moderate deformity percentage of 4.3%. The dominance of diatom species that are known to be intolerant to altered water quality suggests the water quality at this site is good.
Inverts	Jul 2015: SASS5 Score: 96 No of Taxa: 16 ASPT: 6.0 Jul 2013: SASS5 Score: 54 No of Taxa: 9 ASPT: 6.0 This site was impacted similarly by changes, in water quality, flow and habitat modification. Agricultural practices within the catchment and dams and weirs higher up in the system have all impacted on the macroinvertebrate community. Some of the more sensitive taxa expected at the site which were not found included; Heptageniidae, Leptophlebiidae and Tricorythidae. There was no vegetation habitat available due to lower flows dropping the water level below the marginal vegetation. The MIRAI EC was calculated as C (70.13%)
Fish	Fish species expected to occur at the site under natural conditions at high frequencies included *Austroglanis sclateri* (Rock Catfish), *Labeobarbus aeneus* (Vaal-Orange Smallmouth Yellowfish) and *Labeo capensis* (Orange River Mudfish), while *Clarias gariepinus* (Sharptooth Catfish) was expected at a moderate frequency. Species with a low expectation of occurrence at the site included *Barbus anoplus* (Chubbyhead Barb), *Labeobarbus kimberleyensis* (Vaal-Orange Largemouth Yellowfish) and *Labeo umbratus* (Moggel). During the present study, *L. aeneus* was sampled at all habitat within the study area that provided some means of cover, while *A. sclateri* and *L. capensis* were sampled at lower than expected frequencies. Although likely to occur at a moderate frequency within the study reach, *C. gariepinus* was only expected to occur infrequently under current conditions. During the present study, no *L. kimberleyensis*, *L. umbratus* or *B. anoplus* individuals were sampled, nor were any expected to occur based on the habitat structure. In addition, the presence of the predatory alien species *Oncorhynchus mykiss* (Rainbow Trout) was expected within the reach under study based on previous records and suitable habitat structure, and was thus expected to impact on indigenous fish species present. As a result, the site was classified as largely modified in terms of fish with a FRAI score of 49.6% (Ecological Category D). Drivers of change identified to be affecting the wellbeing of the fish communities included sedimentation and infilling of habitat (most notably pools), the presence of a highly mobile substrate which may become abrasive during high flows as a result of the significant gravel depositions, and the presence of the predatory alien *O. mykiss* which will predate on indigenous species. In addition, the presence of algal growth on stable substrate located at the bridge crossing suggested some degree of nutrient enrichment (likely from extensive livestock grazing and catchment run-off).

3.1.2.3.3 EcoStatus

Driver Components	**PES**
IHI: Instream	B
IHI: Riparian	A/B
Water Quality (Diatom SPI)	B
Response Components	**PES**
Riparian Vegetation	B
Macroinvertebrates	C
Fish	D
EcoStatus	C

3.1.2.3.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	B	Reduced base flows	Upstream Mohale dam altering flows	F
		Increased sedimentation	Over grazing and resultant increased sediments in overland run-off. Reduced flows for transporting sediments	F/NF
RIHI	A/B	Vegetation removal	Over grazing and trampling	NF
Rip veg	B	Vegetation removal	Vegetation removal at the site was minor and largely as a result of livestock grazing. This brought about reduced cover and abundance of indigenous vegetation in both the marginal and non-marginal zones.	NF
		Exotic vegetation	A low level of exotic vegetation infestation was present within the site. This resulted in a small change in species composition in the system.	
		Water quantity	Mohale Dam upstream alters the natural hydrograph of the system, with concomitant changes to the riparian vegetation. Certain sections of instream habitat were available for colonisation, which may not have been present in the reference.	F
WQ	B	Temperature and dissolved oxygen impacts downstream of impoundments	Altered flow regime due to releases from upstream Mohale Dam	F
		Moderate percentage of deformed diatoms	Possible changes in temperature regimes/flows, herbicides, heavy metals	NF/F
Inverts	C	Reduced flows	Mohale Dam upstream has altered the hydrological regime	F
		Habitat modification and Water Quality	Sedimentation due to catchment agricultural practices and associated land degradation.	NF
Fish	D	Decreased substrate quality	Extensive overgrazing and agricultural practices in catchment leading to increased sediment input and possible nutrient enrichment	NF
		Decreased species abundance	Presence of predatory alien fish species (*O. mykiss*)	
		Reduced baseflows	Mohale Dam (upstream)	F
		Limited migratory cues	Lack of environmental flow releases from Mohale Dam	
		Decreased FROC of species with a preference for fast-deep and slow-deep habitats	Infilling of pools	NF

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2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.3.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	Compared to LHDA Phase 1
Water Quality	Unclear	Inadequate data to determine trend
Macroinvertebrates	Stable	Similar to 2013 scores

Fish	N/A	Due to the fact that the site was not assessed as part of JBS1, no trend analysis for the fish component could be established.

3.1.2.4 OSAEH_11_22 – Orange River at Skisazana

3.1.2.4.1 Site Description

The site is located on the Orange River near Skisazana. The primary land use in the catchment is subsistence farming and extensive livestock grazing. Localised sand mining was present immediately downstream of the site, with evidence of machines operating within the channel. The site consists of a cobble bar/bed rock shelf with a run up- and downstream of it. The cobble bar/bed rock shelf was relatively embedded from increased sediment deposition from upstream sources. Similarly, the runs, although naturally sandy, had sand bars associated with elevated sediment loading in the system. The riparian habitat was heavily impacted by overgrazing and associated bank collapse.

Longitude	27.216232°	**Latitude**	-30.488857°
Altitude (m.a.s.l.)	1344m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	11.1	**Quaternary catchment**	D12C
Geomorphological zone	Lowland River	**Vegetation**	Zastron Moist Grassland

Upstream

Downstream

3.1.2.4.2 Present Ecological State (PES)

IIHI	Integrity Score: 78 Integrity Category: B/C The main impacts were related to bed modification, mainly sedimentation, from upstream agricultural practices. Some minor alterations due to channel modification (bank collapse and incision) and physico-chemical drivers. Sand mining and catchment related agricultural practices are the main drivers of the impacts.
RIHI	Integrity Score: 69 Integrity Category: C Removal of groundcover, through over-grazing and heavy hoof action, was the main driver. In addition, minor impacts from bank erosion and exotic vegetation were also noted.
Rip veg	EcoStatus: D (44.8%) The marginal zone was characterised by sandy banks. These banks were unstable and whatever vegetation was present, was heavily grazed. The non-marginal zone was classified as a grass dominated system. The banks, particularly the right-hand bank, were heavily overgrazed, with concomitant bank collapse and incision. The left-hand bank had a bedrock control that limited overgrazing in certain areas. The marginal zone would have been classified as a grass dominated system in the reference state. The non-marginal zone would have been classified as a grass dominated system in a Zastron Moist Grassland (Mucina and Rutherford, 2006) environment.
WQ	Low dissolved salts were recorded at this site. However, the suspended solids concentration and turbidity measured during JBS 2 was elevated at 57 mg/l and 64 NTU. Similarly, the historical water quality data collected at site D1H009 indicated notably high turbidity with a 95-percentile statistic of 1907 NTU. Associated with the higher turbidity, the total phosphorus concentration measured in JBS 2 was elevated at 0.5 mg/l, but the orthophosphate was recorded as below the analytical detection limit (<0.2 mg/l)
Diatoms	The wellbeing of the diatom component at this site was observed to be in a C/D or largely modified ecological category. At this site the specific sensitivity pollution index score was a moderate 11.7 (out of maximum of 18). At this site the 400 diatoms evaluated included 36 species with a high deformity percentage of 5.5%.
Inverts	Jul 2015: SASS5 Score: 63 No of Taxa: 11 ASPT: 5.73 Nov 2012: SASS5 Score: 26 No of Taxa: 5 ASPT: 5.2 Sep 2012: SASS5 Score: 28 No of Taxa: 6 ASPT: 4.67 May 2012: SASS5 Score: 46 No of Taxa: 8 ASPT: 5.75 Jan 2011: SASS5 Score: 51 No of Taxa: 8 ASPT: 6.38 Habitat was the most impacted of the drivers at the site. The GSM habitat was dominant at the time of sampling due to increased inputs from catchment erosion. No vegetation was present for sampling due to unstable substrates, heavy grazing impacts and low flows. Oligochaeta and Tabanidae were expected in the GSM but were not found. Taxa expected in the cobbles habitat that were not found included, Potamonautidae, Turbellaria and Libellulidae. The taxa that were present at the site generally had preferences for either cobbles or GSM, fast flows and were tolerant of low water quality conditions. The MIRAI Score was calculated as D (56.74%).
Fish	Under natural conditions, fish species expected to occur at high frequencies included *Labeobarbus aeneus* (Vaal-Orange Smallmouth Yellowfish), *Labeo capensis* (Orange River Mudfish) and *Clarias gariepinus* (Sharptooth Catfish), while *Austroglanis sclateri* (Rock Catfish) and *Labeo umbratus* (Moggel) were expected at moderate frequency of occurrence. *Labeobarbus kimberleyensis* (Vaal-Orange Largemouth Yellowfish) as well as *Barbus anoplus* (Chubbyhead Barb) were only expected to occur infrequently at the site under natural conditions. During the present study, *L. aeneus* was determined to be common within the habitats sampled and representative of perceived natural frequencies of occurrence, while the remaining species occurred at reduced frequencies. This was attributed primarily to the decrease in the slow-deep habitat as a result of infilling by eroded sediment. As such, the fish assemblage at the time of the survey was regarded as representing a largely modified state with a FRAI score of 53.1% (Ecological Category D). In addition, a prevalence of trematode cysts were noted on many of the *L. aeneus* sampled. Drivers of change identified to be associated with the fish communities included sedimentation and infilling of slow-deep habitat as a result of catchment erosions processes brought about by extensive

	overgrazing and agricultural practices which subsequently decrease basal cover, and the presence of a highly mobile substrate which will limit utilization of rocky substrate specialists such as *A. sclateri* and *L. capensis* which utilize such habitat as cover and/or a feeding substrate.

3.1.2.4.3 EcoStatus

Driver Components	PES
IHI: Instream	B/C
IHI: Riparian	C
Water Quality (Diatom SPI)	C/D
Response Components	**PES**
Riparian Vegetation	D
Macroinvertebrates	D
Fish	D
EcoStatus	D

3.1.2.4.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	B/C	Bed modification –substrate removal and increased sediments	Sand mining and erosion	NF
RIHI	C	Vegetation removal	Extensive over grazing and to a lesser degree sand mining operations	NF
Rip veg	D	Vegetation removal	Overgrazing in the riparian zone was severe on the left-hand bank, and moderate on the right-hand bank. This resulted in reduced cover and abundance of indigenous vegetation in both the marginal and non-marginal zones.	NF
		Exotic vegetation	A low level of exotic vegetation infestation was present within the site. This resulted in minor changes in species composition in the system.	
		Habitat modification	High levels of sedimentation changed the substrate composition and stability in the system in certain areas of the marginal zone and lower sections of the non-marginal zone. Furthermore, bank collapse and incision (prevalent on the left-hand bank) resulted in reduced habitat availability and stability for the riparian vegetation.	
WQ	C/D	Elevated turbidity and suspended solids	Erosion associated with subsistence farming and extensive livestock grazing, sand mining	NF
		Deformed diatoms and diatoms species present with tolerance for moderate water quality	Various environmental stresses s such as: reduced flows/velocities, temperature increases, herbicides, heavy metals	NF/F

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
Fish	D	Decreased FROC of species with a preference for slow-deep habitats	Extensive overgrazing and agricultural practices in catchment leading to increased sediment input (primarily from Lesotho)	NF
		Decreased substrate quality (scouring during periods of high flow due to highly mobile substrate)	Extensive overgrazing and agricultural practices in catchment leading to increased sediment input (primarily from Lesotho)	
		Increased sedimentation	Adjacent sand mining	
Inverts	D	Habitat modification	Increased sediment deposition from catchment erosion, embedding or covering other habitats. In addition, vegetation habitat was also reduced due to overgrazing.	NF
		Water quality	Sedimentation, sand mining and upstream communities the larger of which being Blue Gums and Sterkspruit.	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.4.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Decline	This site was not sampled in JBS1, and no baseline is available. However, given the current impacts and their effects on the riparian zone, it is inferred that the ecological condition is in decline.
Water Quality	Stable	No obvious trends evident in key determinands
Macroinvertebrates	Stable	Similar scores achieved since 2011 for sites on this river
Fish	-	Due to the fact that the site was not assessed as part of JBS1, no trend analysis for the fish component could be established.

3.1.2.5 OSAEH_26_11 – Kraai River at Oorlogsfontein

3.1.2.5.1 Site Description

The Kraai River site is located at Oorlogsfontein farm, approximately 3km east of Aliwal North and 3km upstream with its confluence with the Orange River. The prevailing land use in the system is formal agriculture (both crops/centre pivots and livestock). The instream habitat is defined as a bedrock shelf that is bisected by a low level crossing. This crossing has resulted in extensive pooling upstream, with concomitant changes to the instream and riparian habitats. Habitat downstream of the crossing is characterised by a riffle and pools. The riparian habitat has been altered by alien invasive infestation, overgrazing and trampling, and localised intensive sand mining on the left-hand bank below the crossing.

Longitude	26.741607°	**Latitude**	-30.690537°
Altitude (m.a.s.l.)	1303m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	26.03	**Quaternary catchment**	D13M
Geomorphological zone	Lowland River	**Vegetation**	Upper Gariep Alluvial Vegetation

Upstream	Downstream

3.1.2.5.2 Present Ecological State (PES)

IIHI	Integrity Score: 85 Integrity Category: B Bed modification due to increased sediments, related to overgrazing and catchment agricultural practices being the main driver. Localised impacts from picnic area and sand mining of alluvial sediment banks on the left-hand bank. Flow modification was also a minor driver due to a low level crossing point upstream of the site and return flow from irrigation.
RIHI	Integrity Score: 59 Integrity Category: C/D Main drivers included a high density of exotic vegetation, livestock grazing and poor basal cover present in the riparian zone
Rip veg	EcoStatus: D (55.5%) The marginal zone was characterised by a mosaic of vegetation and habitat types. The system up- and downstream of the low level crossing was notably different, with higher vegetation cover upstream of the crossing. The non-marginal zone was characterised by a mosaic of vegetation and habitat types. Localised sand-mining devastated the left-hand bank below the crossing, with overgrazing and alien invasive plants deteriorating the integrity of the rest of the non-marginal zone. A bedrock shelf was a dominant control on the left-hand bank, which was otherwise incised and disturbed. In the reference state, the marginal zone would have been characterised by a mosaic of vegetation communities, particularly reeds, sedges and grasses, with limited woody vegetation. The non-marginal zone would have been classified as a grass dominated system in an Upper Gariep Alluvial Vegetation (Mucina and Rutherford, 2006) environment.
WQ	Dissolved salt concentrations were moderate. Some nutrient enrichment is anticipated due to farming-related activities and fertilizer use, but all nutrient data for JBS 2 was below the analytical detection limit and the turbidity result was low (3.8 NTU). There is no suitable DWS site to assess historical data records.

Diatoms	The diatoms assessment at this site resulted in a B or largely natural ecological category. The specific sensitivity pollution index score was a very high 16.6 (out of maximum of 18). At this site the 400 diatoms evaluated included 36 species with no deformities observed.
Inverts	Jul 2015: SASS5 Score: 133 No of Taxa: 23 ASPT: 5.78 Flow modification and reduced water quality were the main impacts affecting the macroinvertebrate community. Moderately to highly sensitive taxa that were expected but were not found included Atyidae, Corduliidae, Gerridae, Hydracarina and Veliidae. Elevated return flows from irrigation and increased flow velocities due to channel restriction as a result of the low level crossing reduced preferential habitat for several of the expected taxa. In addition, increased nutrients within the system resulted in algal growth which further reduced available habitat. The taxa that were present at the site were generally tolerant of low water quality conditions and had preferences for fast or moderately fast flowing water. The MIRAI EC was calculated as a B/C (77.96%). A possible new distribution record for Prosopistomatidae was noted for this site.
Fish	With the exception of two species, all fish species expected to occur at the site are still present. However, many of the species confirmed to still occur do so at a reduced frequency of occurrence. Only *Labeo capensis* (Orange River Mudfish) was noted to be present at a frequency of occurrence that was representative of reference conditions. The primary drivers responsible for the deterioration of the fish assemblage during the present stud included the deterioration of water quality and elevated base flows as a result of agricultural return flow from adjacent agricultural practices, the deterioration of the substrate availability as a result of increased algal growth, and the impedance of upstream movement as a result of the weir present at the site. Subsequently, a FRAI score of 54.9% was determined for the site (Ecological Category D).

3.1.2.5.3 EcoStatus

Driver Components	PES
IHI: Instream	B
IHI: Riparian	C/D
Water Quality (Diatom SPI)	B
Response Components	**PES**
Riparian Vegetation	D
Macroinvertebrates	B/C
Fish	D
EcoStatus	C

3.1.2.5.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	B	Bed modification	Over grazing and agriculture	NF
		Flow modification	Low level crossing restricting flow path	
RIHI	C/D	Vegetation removal and exotic vegetation	Over grazing and alien plant invasion	NF

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
Rip veg	D	Vegetation removal	Vegetation removal at the site was serious as a result of livestock grazing and localised sand-mining, resulting in reduced cover and abundance of indigenous vegetation (particularly the non-woody vegetation) in both the marginal and non-marginal zones.	NF
		Exotic vegetation	A moderate level of exotic vegetation infestation was present within the site. This resulted in a notable change in species composition in the system.	
		Habitat modification	Bank collapse and incision (prevalent on the left-hand bank) resulted in reduced habitat availability and stability for the riparian vegetation.	
WQ	B	Potential nutrient enrichment	Agricultural activities	NF
Inverts	B/C	Increased seasonal baseflows	Agricultural return flows	F
		Habitat modification	Reduction in slow and standing water habitats due to increased flow velocities. Loss of habitat due to algal growth and sediment deposits	F/NF
Fish	D	Decreased water quality	Agricultural return flows	NF
		Reduced access to diverse local habitats	Presence of a weir	
		Decreased substrate quality related to increased benthic growth	Agricultural return flows	
		Increased deposition of fines upstream of weir	Impoundment of water and bank erosion	
		Increased seasonal baseflows	Agricultural return flows	F

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.5.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	This site was not sampled in JBS1, and no riparian vegetation baseline is available. The sites for EFR K7 and JBS1's OSAEH_26_11 were further upstream of the present site. Riparian vegetation was less impacted (EC=C) at the site upstream. This not likely to be a temporal difference, but rather a spatial and land use difference between JBS1 and JBS2 sites. Therefore, trends cannot be extrapolated between sites. That said, it is interesting to note that JBS1 noted a declining trend in the riparian vegetation health over time. However, given the current impacts and their effects on the riparian zone, it is inferred that the ecological condition is in a relatively stable condition.
Water Quality	Unclear	Inadequate data to determine trends
Macroinvertebrates	Stable	Expected stable trend as catchment processes appear to be relatively established and buffered.
Fish	Decline	Trend analysis is based on two points, namely results from JBS 1 and results obtained during JBS 2. However, the information provided as part of JBS 1 was summarised from WFA (2010a;b), and as such the FRAI models applied at the site assessed during

Response Components	Trend	Description
		JBS 1 were not available to draw comparisons from. In addition, the sites assessed during JBS 1 and JBS 2 were located approximately 25km apart. As such, the assessed trend needs to be interpreted with caution.

3.1.2.6 OSAEH_26_13 – Stormberg River at Kommisecondaryiedrift

3.1.2.6.1 Site Description

The Stormberg River site is situated at the district road bridge approximately 3km upstream of its confluence with the Orange River. The primary land use is formal agriculture (crops/centre pivots and livestock). The instream habitat is controlled by a bedrock shelf on the left-hand bank. Pools (dominated by reeds) and runs are situated upstream of the bedrock control. Dense filamentous algal growth, likely from inputs from crops and the Burgersdorp WWTW upstream, was evident on rocky substrates.

Longitude	26.465192°	**Latitude**	-30.650366°
Altitude (m.a.s.l.)	1290m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	26.03	**Quaternary catchment**	D14H
Geomorphological zone	Lowland River	**Vegetation**	Besemkaree Koppies Shrubland

Upstream

Downstream

3.1.2.6.2 Present Ecological State (PES)

IIHI	Integrity Score: 80 Integrity Category: B/C Bed modification driven by sedimentation from catchment-scale processes (e.g. agricultural practices). Deep sediments were present in pools. Water quality impacts included WWTW return flows from Burgersdorp upstream of the site and potential nutrient inputs from surrounding croplands. Elevated nutrients have likely resulted in the very dense filamentous algal growth observed over most available benthic habitat at the site which occludes benthic organisms. Sedimentation and water quality were the main drivers of the instream habitat integrity PES
RIHI	Integrity Score: 73 Integrity Category: C Localised heavy alien weed infestations (exotic vegetation) and moderate livestock pressures (over grazing) were the main drivers of the Riparian habitat integrity PES
Rip veg	EcoStatus: C (66.2%) The marginal zone was characterised by sandy banks. The stream was braided in sections, with limited marginal vegetation. Reed beds were present in the upstream sections of the site. The non-marginal zone was characterised by a mosaic of vegetation and habitat types. The left-hand bank was largely controlled by a bedrock outcrop. The right-hand bank was infested with a variety of alien invasive species. In the reference state, the marginal zone would have been classified as a grass dominated system, with a braided stream in sand substrate. The non-marginal zone would have been classified as a grass dominated system in a Besemkaree Koppies Shrubland (Mucina and Rutherford, 2006) environment. The left-hand bank would have been controlled by the bedrock outcrop, with the right-hand bank being more gradual with a sandy substrate.
WQ	Data are limited to the single JBS 2 result since this site was not sampled in JBS1 and there is no suitable DWS monitoring site in reasonable proximity to this site. From the single sample collected, water quality at this site appears satisfactory. Confidence in this water quality status is deemed low due as it is based on a single sample. Dissolved salt concentrations were deemed moderate (conductivity 36.5 mS/m and TDS 340 mg/l). In addition, turbidity and suspended solids data were moderate at 17 NTU and 16.7 mg/l suspended solids. All nutrient data collected for JBS 2 were below the analytical detection limit. However, nutrient concentrations may be elevated at times due to the presence of the Burgersdorp WWTW upstream.
Diatoms	The diatoms assessment at this site resulted in a C or moderately modified ecological category. The specific sensitivity pollution index score was a moderate 13.9 (out of maximum of 18). At this site the 400 diatoms evaluated included 23 species with no deformities.
Inverts	Jul 2015: SASS5 Score: 84 No of Taxa: 18 ASPT: 4.67 Water quality had the largest impact on this site followed by limited habitats. Of the expected taxa with requirements for unmodified or largely unmodified water quality; Atyidae, Leptophlebiidae, Corduliidae and Hydracarina were all absent from the site. Mostly taxa with preferences for standing water, water column habitat and low requirements for water quality were present at the site. Sedimentation deposition from erosion and reduced water quality from WWTW's upstream were some of the main drivers impacting the system. The MIRAI EC was calculated as a C/D (61.27%).
Fish	Given the nature of the watercourse, a high abundance of diverse fish species was not expected at the site under reference conditions, with many of the species likely to move into the study area from the Orange River. In addition, the study site is expected to be outside the documented distribution range for cichlids indigenous to the Vaal-Orange system, vis. *Tilapia sparmanii* (Banded Tilapia) and *Pseudocrenilabrus philander* (Southern Mouthbrooder), and as such were excluded for the reference species list. Nevertheless, many of the species expected to occur did so at a reduced frequency of occurrence which was attributed to limited habitat diversity brought about by increased sediment input as a result of decreased basal cover and agricultural practices within the upstream catchment that has led to sediment run-off. The high frequency of occurrence for *Barbus anoplus* (Chubbyhead Barb) observed during the present study was attributed to the presence of favourable velocity-depth classes and cover structure (slow-flowing water with abundant overhanging and marginal vegetation). During the present study, occurrence of one alien fish species, namely *Cyprinus carpio* (Common Carp), was confirmed and was likely contributing to habitat modification and increases in turbidity. As such, a FRAI score of 63.7% (Ecological Category C) was obtained for the site.

3.1.2.6.3 EcoStatus

Driver Components	PES
IHI: Instream	B/C
IHI: Riparian	C
Water Quality (Diatom SPI)	C
Response Components	**PES**
Riparian Vegetation	C
Macroinvertebrates	C/D
Fish	C
EcoStatus	C

3.1.2.6.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	B/C	Bed modification	Fine sediment deposits from overland run-off due to over grazing and trampling.	NF
		Water quality	WWTW upstream leading to decline in water quality	
RIHI	C	Vegetation removal and exotic vegetation	Over grazing and invasion by alien plants	NF
Rip veg	C	Vegetation removal	Vegetation removal at the site was moderate. This was a result of overgrazing and trampling at the site.	NF
		Exotic vegetation	A moderate level of exotic vegetation infestation was present within the site, particularly on the left-hand bank. This resulted in low to moderate changes in species composition in the system.	
WQ	C	Potential for elevated nutrients (nitrates and phosphates) at times	Effluent release from Burgersdorp WWTW	NF
		Diatom community dominated by species tolerant of moderate water quality conditions, no sensitive species present	Water quality deterioration from upstream effluent release from Burgersdorp WWTW	
Fish	C	Decreased FROC for species with a preference for deep water habitat	Sediment input from adjacent agricultural practices, reduced basal cover and erosion within the catchment, resulting in infilling of deep water habitat and increased instream vegetation (*Phragmites* reed beds).	NF
		Increased turbidity, reduction in water clarity	Reduced basal cover and agricultural practices in the catchment, evidence of catchment erosion and confirmed presence of habitat-modifying alien species *C. carpio*.	
		Decreased water quality	Run-off from adjacent and upstream agricultural practices and disturbance of bottom substrate by habitat-modifying *C. carpio*.	
Inverts	C/D	Water quality	WWTW discharges form upstream settlements.	NF

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Habitat loss	Increased sediment deposition due to erosion.	

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2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.6.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	This site was not sampled in JBS1, and no baseline is available. However, given the current impacts and their effects on the riparian zone, it is inferred that the ecological condition is stable.
Water Quality	Unclear	No historical data available to assess trend
Macroinvertebrates	Stable	Currently poor but expected stable due to a relatively large and unchanging catchment. However increased settlement may push the trajectory negative in the longer term.
Fish	N/A	Due to the fact that the site was not assessed as part of JBS1, no trend analysis for the fish component could be established.

3.1.2.7 OSAEH_26_14 – Orange River at Goedemoed

3.1.2.7.1 Site Description

The site is on the Orange River, approximately 5km upstream of Goedemoed prison, and adjacent to the outflow from the weir diversion. The site located on an extensive dolerite shelf providing broad bedrock habitat, overlain with sand sediment bars and islands. A long sandy run is present downstream. This site is the first site upstream of the major Gariep and Vanderkloof dams to be influenced by upper catchment sediment loads. Primary landuse includes livestock grazing. The riparian zone has been invaded by alien invasive species, primarily on the right-hand bank. Increased sediments in the system from upstream catchment processes is evident in the extensive sand bars and embedded cobble habitat.

Longitude	26.450924°	**Latitude**	-30.570859°
Altitude (m.a.s.l.)	1280m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	26.03	**Quaternary catchment**	D14J
Geomorphological zone	Lowland River	**Vegetation**	Upper Gariep Alluvial Vegetation

Upstream

Downstream

3.1.2.7.2 Present Ecological State (PES)

IIHI	Integrity Score: 78 Integrity Category: B/C The PES score is due to several minor impacts consisting of modified flows, water abstraction, water quality and bed modification. Bed modification includes extensive sedimentation (and highly mobile sediments) causing all cobble habitat to be highly embedded.
RIHI	Integrity Score: 81 Integrity Category: B/C The riparian habitat PES was mostly due to exotic vegetation and vegetation removal. Riparian vegetation also virtually absent at this time of year but represented a better age class distribution than sites downstream of the major dams. Large unstable sand banks and with alien vegetation in many areas of the riparian zone. A sediment settling facility caused localised bank scouring.
Rip veg	EcoStatus: C/D (61.3%) The marginal zone was characterised by sandy banks, with limited grass (*Cynodon dactylon*), sedge (*Pseudoschoenus inanis*) and reed (*Phragmites australis*) cover, and Salix roots sticking out from the banks. The non-marginal zone was similar to the marginal zone, with more trees in the upper sections of the zone *Cynodon dactylon* was the dominant non-woody taxon that was present in between large areas of open sand and cobble bars. In the reference state, the marginal zone would have been characterised by a mosaic of vegetation types, primarily grasses, sedges and reeds. Vegetation cover would have been higher. The non-marginal zone would have been classified as a tree dominated system in an Upper Gariep Alluvial Vegetation (Mucina and Rutherford, 2006) environment, with a more heterogeneous grass and forb basal cover than the present state.
WQ	Dissolved salt concentrations were generally low – moderate. Slightly elevated turbidity and suspended solids results were recorded in JBS 2, at 23 NTU and 23 mg/l, and this was aligned to historical data collected at DWS site D1H003 which indicate an average turbidity of 217 NTU and a 95-percentile statistic of 749 NTU. While the sample results for JSB 2 for nitrate, nitrite, ammonia and orthophosphate were all below the analytical detection limit at this site, the historical data does indicate limited intermittent nutrient enrichment.
Diatoms	The diatoms assessment at this site resulted in a C or moderately modified ecological category. The specific sensitivity pollution index score was a moderate 12.9 (out of maximum of 18). At this site the 400 diatoms evaluated included 36 species with a very low deformity percentage of 0.3%.
Inverts	Jul 2015: SASS5 Score: 25 No of Taxa: 5 ASPT: 5.00 This site was highly impacted. There was a large loss of habitat due to sediment deposits, and low flows. This was exacerbated by water abstraction and the return flows from the settling tanks from Goedemoed Prison. From the expected reference conditions, taxa with preferences for cobble habitat were anticipated to be the most abundant however; due to this habitat being highly embedded none were found at the

	site. Only Baetidae, Caenidae, Chironomidae, Gomphidae and Tipulidae were found at the site, these having preferences for GSM habitats. The MIRAI EC was calculated as a D (47.65%)
Fish	During the present study, fish species sampled at the site exhibited a reduced frequency of occurrence relative to the reference condition, including the species expected to be common within the reach such as *Labeobarbus aeneus* (Vaal-Orange Smallmouth Yellowfish), *Clarias gariepinus* (Sharptooth Catfish), *Labeo capensis* (Orange River Mudfish) and *Labeo umbratus* (Moggel), all of which show a preference for the slow-deep velocity-depth class which was noted to have decreased relative to reference conditions. Limited habitat diversity and cover features within the main channel due to the presence of bedrock features (geological feature) and mobile sediment deposits which were likely to act as abrasive features during period of high flows were likely to play a significant role in the reduced abundances of fish species noted to be present. Further, the lack of marginal or instream vegetation and cobble habitat was likely to limit the amount of suitable spawning material available for several expected species that require such material for spawning. Nevertheless, local residents report regularly catching several of the larger expected fish species on conventional angling tackle at the site, although this appears to be in more within the channel associated with the discharge point of the water settling plant on the right hand bank which provides more favourable habitat for fish species. In addition, a decreased freedom of movement for fish species within the reach as a result of a weir immediately upstream of the site was expected to decrease fish abundance within the study area. Diversion of water from the weir for irrigation purposes and water supply to the prison located downstream was also likely to reduce water availability within the main channel, albeit to a minor extent. Although the habitat-modifying alien species *Cyprinus carpio* (Common Carp) was likely to be present, its impact on indigenous fish abundance and diversity was expected to be limited. Accordingly, a FRAI score of 55.1% (Ecological Category D) was obtained for the site.

3.1.2.7.3 EcoStatus

Driver Components	**PES**
IHI: Instream	B/C
IHI: Riparian	B/C
Water Quality (Diatom SPI)	C
Response Components	**PES**
Riparian Vegetation	C/D
Macroinvertebrates	D
Fish	D
EcoStatus	D

3.1.2.7.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	B/C	Bed modification	Sedimentation due to over grazing and return flows from water treatment settling tanks.	NF
		Reduced baseflows	Weir and local abstraction for Goedemoed prison farm.	F
RIHI	B/C	Exotic vegetation and vegetation removal	Alien plant invasion and over grazing	NF
Rip veg	C/D	Vegetation removal	Signs of minor vegetation removal were evident at the site.	NF
		Exotic vegetation	A moderate level of exotic vegetation infestation was present within the site (e.g. *Salix babylonica* and *Populus spp*.). This resulted in moderate changes in species	

			composition in the system (severe in localised areas).	
		Habitat modification	High levels of sedimentation changed the substrate composition and stability in the system in certain areas of the marginal zone and lower sections of the non-marginal zone. Furthermore, bank collapse and incision (prevalent on the right-hand bank) resulted in reduced habitat availability and stability for the riparian vegetation.	
WQ	C	Elevated intermittent turbidity and, at times, nutrient concentrations	Agricultural practices, particularly livestock overgrazing	NF
		Mixed diatom community dominated by species tolerant of moderately modified water quality conditions -two species present which are indicators of elevated nutrients and salts	Intermittent nutrient enrichment from return flows from water treatment settling tanks and catchment run-off	
Fish	D	Reduction on FROC of species with a preference for slow-deep class	Infilling of deep water habitat as a result of sediment run-off from upstream catchment practices (including overgrazing and reduced basal cover in Lesotho)	NF
		Limited habitat diversity and cover features	Abrasive nature of sediment transported from upper catchment and sediment deposition	
		Decreased freedom of movement within the reach	Upstream weir restricting movement both upstream and downstream	
		Limited impact on water abstraction	Abstraction for irrigation and water supply to prison downstream	
Inverts	D	Habitat modification	High levels of sedimentation changed the substrate composition. Reduced flows limited availability of marginal vegetation.	F/NF

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.7.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	This site was not sampled in JBS1, and no baseline is available. However, given the current impacts and their effects on the riparian zone, it is inferred that the ecological condition is stable.
Water Quality	Stable	No obvious trends evident in key determinands
Macroinvertebrates	Stable	Upstream and catchment processes already accounted for in the assessment and unlikely to deteriorate much further
Fish	-	Due to the fact that the site was not assessed as part of JBS1, no trend analysis for the fish component could be established.

3.1.2.8 OSAEH_15_01 – Caledon River

3.1.2.8.1 Site Description

The site is located on a riffle section approximately 3km upstream of the EWR site: D2CALE-EWR03 on the Caledon River. The site was moved upstream due to very poor habitat availability at the EWR site. The primary land uses in the system include livestock grazing and infested banks that act as informal wood lots. Extensive bank collapse and incision have resulted in increased sedimentation in the instream habitat. Cobble habitats are embedded, and sand bar formation was noted up- and downstream of the site.

Longitude	28.155681°	**Latitude**	-28.723170°
Altitude (m.a.s.l.)	1586m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	15.01	**Quaternary catchment**	D21H
Geomorphological zone	Lowland River	**Vegetation**	Eastern Free State Clay Grassland

Upstream | **Downstream**

3.1.2.8.2 Present Ecological State (PES)

IIHI	Integrity Score: 88 Integrity Category: A/B There is extensive agriculture on both sides of the river which has led to some bed modification due to sediments from overland run-off and bank collapses.
RIHI	Integrity Score: 46 Integrity Category: D The riparian habitat was in a poorer condition, with bank collapse, trampling and grazing from livestock, vegetation removal and exotic vegetation impacts resulting in low PES score.
Rip veg	EcoStatus: E (34.7%) The marginal zone was characterised by sandy banks. Sections of the system upstream had small patches of marginal vegetation. The non-marginal zone was characterised by incised sandy banks with extensive alien invasive tree infestation that resulted in bank collapse and limited basal vegetation cover. In the reference state, the marginal zone would have been classified as a grass dominated system, and would have been less regimented and incised than what was observed in the present. The non-marginal zone would have been classified as a grass dominated system in an Eastern Free

	State Clay Grassland (Mucina and Rutherford, 2006) environment. The banks would have been less incised than what was observed in the present state, with an almost complete non-woody basal cover.
WQ	The historical data measured at DWS site D2H012 indicates low dissolved salt concentrations and moderate turbidity levels and nutrient concentrations. No specific determinands of concern are apparent.
Diatoms	The diatoms were observed to be in a B/C or moderately modified to largely natural ecological category at this site. The specific sensitivity pollution index score was a high 14.8 (out of maximum of 18). At this site the 400 diatoms evaluated included 19 species with a moderate deformity percentage of 5.5%. The dominance of diatom species that are known to be intolerant to altered water quality suggests the water quality at this site is good.
Inverts	Jul 2015: SASS5 Score: 112 No of Taxa: 16 ASPT: 7.00 Nov 2012: SASS5 Score: 56 No of Taxa: 9 ASPT: 6.22 Sep 2012: SASS5 Score: 74 No of Taxa: 14 ASPT: 5.29 May 2012: SASS5 Score: 120 No of Taxa: 21 ASPT: 5.71 Dec 2011: SASS5 Score: 66 No of Taxa: 13 ASPT: 5.08 Jul 2010: SASS5 Score: 85 No of Taxa: 16 ASPT: 5.30 The majority of the expected taxa with requirements for unmodified or largely unmodified water quality conditions were present at the site with the exception of *Hydracarina* and *Corduliidae*. The preference group showing the most disparity with the reference were those with no water quality requirements. Water quality was impacted by extensive subsistence and commercial farming upstream and habitat was reduced due to sedimentation from erosion. The MIRAI EC was calculated as B/C (77.59%)
Fish	During the present study, all fish species expected under reference conditions were sampled or inferred at very low frequencies, including those that were expected at high frequencies of occurrence. This was attributed to the reduced abundance and diversity of fish habitats that were expected under reference conditions. Juvenile *Labeobarbus aeneus* (Vaal-Orange Smallmouth Yellowfish) were only collected within the habitat structure provided by the undercut banks, albeit at low frequencies relative the amount of habitat present. Similarly, *Barbus anoplus* (Chubbyhead Barb) was observed at a far lower frequency than expected under reference conditions, and was attributed to the lack of preferable velocity-depth classes, overhanging vegetation and/or aquatic macrophytes. Although present, the cobble/boulder riffle located at the site did not yield many *Austroglanis sclateri* (Rock Catfish) individuals, while undercut banks did not appear to support any. Further, the potential for the presence of the predatory alien species *Oncorhynchus mykiss* (Rainbow Trout) is likely to impact on some of the smaller indigenous fish species expected. Accordingly, a FRAI score of 58.4% (Ecological Category C/D) was obtained for the site.

3.1.2.8.3 EcoStatus

Driver Components	PES
IHI: Instream	A/B
IHI: Riparian	D
Water Quality (Diatom SPI)	B/C
Response Components	**PES**
Riparian Vegetation	E
Macroinvertebrates	B/C
Fish	C/D
EcoStatus	D

Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	A/B	Bed modification	Large scale agriculture on both banks of the river and bank collapses increasing sediment loads	NF
RIHI	D	Vegetation removal, exotic vegetation and bank collapse	Over grazing, alien plant invasion and bank destabilization	NF
Rip veg	E	Vegetation removal	Vegetation removal at the site was severe. This was the result of bank collapse and incision from woody alien invasive species (e.g. *Salix babylonica* and *Populus spp.*) in the non-marginal zone.	NF
		Exotic vegetation	A high level of exotic vegetation infestation was present at the site, resulting in a serious change in indigenous plant abundances, cover and species composition, particularly in non-woody species.	
		Habitat modification	High levels of sedimentation changed the substrate composition and stability in the system in certain areas of the marginal zone and lower sections of the non-marginal zone. Furthermore, bank collapse and incision (prevalent on both banks) resulted in reduced habitat availability and stability for the riparian vegetation.	
WQ	B/C	Moderate turbidity and nutrient concentrations	Erosion and catchment run-off	F/NF
		Moderate percentage of deformed diatoms	Various environmental stresses s such as: reduced flows/velocities, temperature increases, herbicides, heavy metals	
Inverts	B/C	Water quality	Reduction in water quality due to inputs from commercial and subsistence farming in the upstream catchment	NF
		Habitat modification	Increased sediment deposition due to erosion.	
Fish	C/D	Decreased habitat abundance and diversity	Sediment input from adjacent agricultural practices, reduced basal cover and erosion within the catchment as a result of extensive livestock grazing (Lesotho),	NF
		Water quality deterioration	Commercial agriculture (South Africa) and subsistence agriculture (Lesotho)	
		Reduction on FROC of species with a preference for slow-deep class	Sedimentation of pool habitats as a result of increased run-off from catchment	

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2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.8.4 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	This site was not sampled in JBS1, and no riparian vegetation baseline is available. Sites from EFRC5 and JBS1 (OSAEH_15_1)

		were not similar to this site (which was preferred for potential instream habitat availability). Therefore, trends cannot be extrapolated between samples. However, given the current impacts and their effects on the riparian zone, it is inferred that the ecological condition is in a stable, albeit seriously modified condition.
Water Quality	Stable	2010 – current: A decreasing trend in conductivity was noted at D2H012
Macroinvertebrates	Stable	Similar SASS scores to previous samples.
Fish	Increase	Trend analysis is based on two points, namely results from JBS 1 and results obtained during JBS 2. However, the information provided as part of JBS 1 was summarised from WFA (2010a;b), and as such the FRAI models applied at the site assessed during JBS 1 were not available to draw comparisons from. In addition, the sites assessed during JBS 1 and JBS 2 were located approximately 25km apart. As such, the assessed trend needs to be interpreted with caution.

3.1.2.9 OSAEH_15_06 – Caledon River at Maseru

3.1.2.9.1 Site Description

The site is located approximately 8km downstream of the Maseru WWTW on the Caledon River. The primary land use impacting the site includes livestock grazing and impacts from Maseru (most notably very poor water quality from the WWTW). The instream habitat was dominated by sand beds, with minimum marginal vegetation present. The riparian zone was impacted by heavy livestock grazing and bank erosion. Water quality at the site was extremely poor.

Longitude	27.405391°	**Latitude**	-29.370233°
Altitude (m.a.s.l.)	1480m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	15.01	**Quaternary catchment**	D23A
Geomorphological zone	Lowland River	**Vegetation**	Eastern Free State Clay Grassland

Upstream

Downstream

3.1.2.9.2 Present Ecological State (PES)

IIHI	Integrity Score: 55 Integrity Category: D Bed modification in the form of heavy sedimentation from catchment-scale processes and water quality (primarily from the Maseru WWTW upstream) were the main drivers impacting on the instream habitat.
RIHI	Integrity Score: 56 Integrity Category: D Mainly due to vegetation removal, overgrazing in the riparian zone, bank erosion and exotic vegetation drivers.
Rip veg	EcoStatus: D (48.0%) The marginal zone was characterised by sandy banks as a result of heavy overgrazing in the upstream catchment and left-hand bank. The non-marginal zone was classified as a grass dominated system, with woody vegetation on the right-hand bank in the upper sections of the non-marginal zone. The banks, particularly the left-hand side of the river, were heavily overgrazed. In the reference state, the marginal zone would have been classified as a sedge and grass dominated system, with less exposed sand than the present state. The non-marginal zone would have been classified as a grass dominated system in an Eastern Free State Clay Grassland (Mucina and Rutherford, 2006) environment. The upper sections of the right-hand bank would have had largely terrestrial woody vegetation cover that would ingress toward the river between flooding events.
WQ	No historical DWS water quality data is available for this site, and this site was also not sampled for JBS 1. Very limited dataset from Lesotho (between 1 and 3 results per determinand) was used for assess water quality, and confidence is therefore low. A low dissolved concentration of 1.46 mg/l was recorded – this is in contrast to a high concentration measuring during JBS 2 (10.4 mg/l and 109% saturation). Dissolved salt concentrations were moderate, but suspended solids concentrations were significantly elevated under high flow conditions, with one of two results being 680 mg/l. In addition, excessive nutrient enrichment is apparent from the Lesotho data, with both the nitrogen and phosphorus concentrations highly elevated, indicating significant levels of eutrophication.
Diatoms	The diatoms assessment at this site resulted in an F or critically modified ecological category. The specific sensitivity pollution index score was a very low 2.3 (out of maximum of 18). At this site the 400 diatoms evaluated included 26 species with a high deformity percentage of 6.5%.
Inverts	Jul 2015: SASS5 Score: 14 No of Taxa: 4 ASPT: 3.50 Nov 2012: SASS5 Score: 33 No of Taxa : 7 ASPT: 4.71 Sep 2012: SASS5 Score: 27 No of Taxa: 7 ASPT: 3.86 May 2012: SASS5 Score: 38 No of Taxa: 8 ASPT: 4.75 Jan 2012: SASS5 Score: 30 No of Taxa: 6 ASPT: 5.00

	A decline in water quality due to upstream WWTW's and large settlements was the main impact at this site followed closely by changes in habitat availability. The only habitat present for sampling was GSM where only four taxa were present namely, Oligochaeta, Baetidae, Gyrinidae and Chironomidae. No taxa with preferences for high or moderately high water quality were present. The MIRAI EC was calculated as a D (53.84%).
Fish	Under reference conditions, fish species expected to be present at high frequencies of occurrence included *Labeobarbus aeneus* (Vaal-Orange Smallmouth Yellowfish), *Labeo capensis* (Orange River Mudfish) and *Clarias gariepinus* (Sharptooth Catfish), while *Austroglanis sclateri* (Rock Catfish), *Labeo umbratus* (Moggel) and *Barbus anoplus* (Chubbyhead Bard) were expected at moderated frequencies of occurrence. During the present study, a depauperate fish assemblage was determined to be present, with no fish being sampled despite active sampling having occurred. However, three of the seven expected fish species were inferred to occur at a very low frequency of occurrence. This was attribute to a loss of diverse habitat structure (reduction of diverse velocity-flow and cover) due to sedimentation (sediment input from adjacent agricultural practices and upstream catchment practices), as well as significant water quality deterioration as a result of urban run-off from the upstream town of Maseru, and organic pollution from upstream WWTW and likely raw sewage input. In addition, indigenous vegetation removal and agricultural practices within and adjacent to the site were likely to impacting on the fish. As such, a FRAI score of 36.6% (Ecological Category E) was obtained for the site.

3.1.2.9.3 EcoStatus

Driver Components	**PES**
IHI: Instream	D
IHI: Riparian	D
Water Quality (Diatom SPI)	F
Response Components	**PES**
Riparian Vegetation	D
Macroinvertebrates	D
Fish	E
EcoStatus	D

3.1.2.9.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	C	Bed modification	Increased sedimentation due to over grazing and bank collapses	NF
		Water quality	Maseru WWTW upstream	
RIHI	D	Vegetation removal and exotic vegetation	Over grazing, bank collapse and alien plant invasion	NF
Rip veg	D	Vegetation removal	Vegetation removal at the site was moderate. This was largely the result of overgrazing, particularly on the left-hand bank, where overgrazing and trampling were more serious.	NF
		Exotic vegetation	A moderate level of exotic vegetation infestation was present within the site. This occurred whenever bank disturbance had occurred.	

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Water quality	Increased nutrients were present in the river. This altered the marginal zone species composition slightly.	
		Habitat modification	High levels of sedimentation changed the substrate composition and stability in the system in certain areas of the marginal zone and lower sections of the non-marginal zone. Furthermore, bank collapse and incision resulted in reduced habitat availability and stability for the riparian vegetation.	
WQ	F	Excessive nutrient enrichment	Urban run-off (Maseru) and WWTW effluent discharge, and agricultural practices	F/NF
		Elevated suspended solids	Erosion associated with overgrazing and reduced land cover in Lesotho	NF
		Diatoms dominated by species tolerant of critically modified water quality	Effluent from upstream WWTW	F/NF
		High percentage of deformed diatoms	Various environmental stresses s such as: reduced flows/velocities, temperature increases, herbicides, heavy metals	
Inverts	D	Water quality	Upstream settlements as well was poor quality WWTW discharges into the river have reduced the water quality	NF
		Habitat modification	Erosion and sedimentation have eliminated cobbles and vegetation habitats.	
Fish	E	Loss of habitat diversity	Infilling as a result of sediment run-off from adjacent agriculture and upstream catchment practices (including overgrazing and reduced basal cover in Lesotho)	NF
		Water quality deterioration (toxicant input and organic enrichment)	Urban run-off (Maseru), WWTW effluent release, raw sewage input , and adjacent agricultural practices (Lesotho)	

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3 Flow related 4 Non Flow related

3.1.2.9.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	This site was not sampled in JBS1, and no riparian vegetation baseline is available. However, given the current impacts and their effects on the riparian zone, it is inferred that the ecological condition is in a stable, albeit largely modified condition.
Water Quality	Unclear	Inadequate data to determine trends
Macroinvertebrates	Stable	Score slightly lower than those achieved in 2012
Fish	-	Due to the fact that the site was not assessed as part of JBS1, no trend analysis for the fish component could be established.

3.1.2.10 OSAEH_11_20 – Leeu River at Dipelaneng

3.1.2.10.1 Site Description

The site on the Leeu River is located downstream of the farm weir approximately half a kilometre from the R709 and 1km from the R26. It is in close proximity to EWR site D2LEEU-EWR06. The primary land use is formal agriculture (livestock grazing). The site upper section of the site is located on rocky substrate near the weir, with the rest of the site being largely sandy with an extensive pool with a bedrock shelf as control on the right-hand bank.

Longitude	27.129740°	**Latitude**	-29.517629°
Altitude (m.a.s.l.)	1460m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	11.03	**Quaternary catchment**	D23D
Geomorphological zone	Lower Foothills	**Vegetation**	Eastern Free State Clay Grassland

Upstream

Downstream

3.1.2.10.2 Present Ecological State (PES)

IIHI	Integrity Score: 69 Integrity Category: C Flow modification, due to a large weir upstream of the site, and minor impacts from sedimentation, physico-chemical changes and introduced aquatic fauna, were drivers of the PES.
RIHI	Integrity Score: 75 Integrity Category: C The riparian habitat integrity was driven by vegetation removal from over grazing and trampling, along with alien plant invasion
Rip veg	EcoStatus: C (70.0%)

	The marginal zone was classified as a reed, sedge and grass dominated system. Alien invasive woody vegetation (e.g. *S. babylonica* and *Populus spp.*) had invaded this zone, with relatively heavy grazing noticeable (though not as severe as to cause bank collapse). The non-marginal zone was classified as a grass (*Themeda, Sporobolus* and *Panicum spp.*) dominated system. Heavy grazing was observed in this zone (though this was not severe), with the abovementioned alien woody taxa present. In the reference state, the marginal zone would have been classified as a reed, sedge and grass dominated system. The non-marginal zone would have been classified as a grass dominated system in an Eastern Free State Clay Grassland (Mucina and Rutherford, 2006) environment.
WQ	No DWS water quality site was able to be located in reasonable proximity to OSAEH 11_20, and this site was also not sampled in JBS 1. The potential for some water quality deterioration due to agricultural run-off exists. An unsatisfactory dissolved oxygen saturation percentage was recorded in JBS 2 at 70% (6.85 mg/l).
Diatoms	The wellbeing of the diatom component at this site was observed to be in a C/D or largely modified ecological category. At this site the specific sensitivity pollution index score was a low 11.9 (out of maximum of 18). At this site the 400 diatoms evaluated included 27 species with a high deformity percentage of 6.8%.
Inverts	Jul 2015: SASS5 Score: 70 No of Taxa: 19 ASPT: 3.68 Nov 2012: SASS5 Score: 87 No of Taxa : 19 ASPT: 4.58 Sep 2012: SASS5 Score: 64 No of Taxa: 15 ASPT: 4.27 May 2012: SASS5 Score: 81 No of Taxa: 18 ASPT: 4.50 Dec 2011: SASS5 Score: 72 No of Taxa: 16 ASPT: 4.50 Water quality changes were the main impact at the site. Eutrophication was evident by excessive filamentous algal growth. In addition to the water quality flow modification due to weirs and upstream extraction also impacted the site. Heptageniidae, Atyidae and Leptophlebiidae were some of the more sensitive taxa expected under reference conditions but were absent from the site. The taxa found at the site were dominated by those with little or no preferences for unmodified water quality, had preferences for either cobbles or vegetation, and standing water. The MIRAI was calculated as a C (68.80%)
Fish	During the present study, several of the larger indigenous fish expected to occur at the site were confirmed, albeit at a reduced frequency of occurrence. In addition, the presence of the predatory alien *Micropterus salmoides* (Largemouth Bass) was confirmed, while the habitat modifying alien Cyprinus carpio (Common Carp) was expected to occur at a low frequency. While the presence of slow-deep water habitat at the site was considered favourable for the presence of indigenous fish species expected under reference conditions, this habitat also favoured for the alien fish species present. Presence of root wads created by alien riparian elements such as *Salix babylonica* (Weeping Willow) also provided additional cover features that are preferential habitats for the predatory alien *M. salmoides*. Reduced base flows as a result of upstream weir was further expected to further contribute to the decreased abundance of species expected under reference conditions, while favouring the frequency of occurrence for the alien *M. salmoides* within the reach. In addition, the lack of collection of smaller species or cohorts of indigenous species indicates potential impact of predatory alien *M. salmoides* (Largemouth Bass) confirmed at the site, while the presence of juvenile *M. salmoides* indicates successful recruitment of alien fish within the reach. Presence of weir is also expected to decrease the potential for recruitment of indigenous fish species through limiting movement of fish species within the reach and decreasing accessibility to spawning habitat. As such, a FRAI score of 48.7% (Ecological Category D) was obtained for the site.

3.1.2.10.3 EcoStatus

Driver Components	PES
IHI: Instream	C
IHI: Riparian	C
Water Quality (Diatom SPI)	C/D
Response Components	**PES**
Riparian Vegetation	C
Macroinvertebrates	C
Fish	D
EcoStatus	C

3.1.2.10.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	B/C	Flow modification	Upstream weir	NF
		water quality, bed modification,	Over grazing and agriculture	
RIHI	C	Vegetation removal, exotic vegetation	Over grazing, alien plant invasion	NF
Rip veg	C	Vegetation removal	Vegetation removal at the site was moderate. This was largely the result of heavy grazing and trampling in the system on the left-hand bank in localised areas.	NF
		Exotic vegetation	Moderate levels of exotic vegetation infestation were present within the site (most notably *Salix babylonica* and *Populus spp.*).	
WQ	C/D	Low oxygen saturation	Upstream dam affecting flow velocities	F
		Diatom species observed at this site are indicative of high loads of nutrient and or salt contaminants.	Agriculture activities north of Hobhouse, also associated with activities around Armenia Dam	NF
Inverts	C	Water quality	Eutrophication from upstream sources.	NF
		Reduced baseflows	Weirs and abstraction occurring upstream.	F
Fish	D	Loss of smaller species and cohorts of larger species	Presence of predatory alien *M. salmoides*	NF
		Decreased in FROC of species with a preference for fast habitats	Decreased base flows (presence of a weir upstream)	F
		Water quality deterioration	Agricultural run-off	NF
		Reduced fish movement within the reach and loss of access to upstream spawning habitat	Presence of weir acting as a movement barrier	

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2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.10.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	This site was not sampled in JBS1, and no riparian vegetation baseline is available. However, given the current impacts and their effects on the riparian zone, it is inferred that the ecological condition is in a stable condition.
Water Quality	Unclear	Inadequate data to determine trends
Macroinvertebrates	Stable	Similar to 2012 scores
Fish	N/A	Due to the fact that the site was not assessed as part of JBS1, no trend analysis for the fish component could be established.

3.1.2.11 OSAEH_26_08 – Caledon River at Bethel (D2CAL-TUSSE)

3.1.2.11.1 Site Description

The site is situated on a dolerite dyke control near the bridge close to Bethel on the road from the R701 to Aliwal North, approximately 30km upstream from Bethulie. Livestock grazing is the primary land use in the immediate catchment. The site has been heavily impacted by increased sedimentation from the upstream catchment. Signs of heavy grazing and bank erosion were also observed at the site, contributing to local sediment inputs. Rocky substrates were largely embedded.

Longitude	26.305146°	**Latitude**	-30.427646°
Altitude (m.a.s.l.)	1275m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	26.03	**Quaternary catchment**	D24J
Geomorphological zone	Lowland River	**Vegetation**	Upper Gariep Alluvial Vegetation

Upstream	Downstream

3.1.2.11.2 Present Ecological State (PES)

IIHI	Integrity Score: 75 Integrity Category: C The main impact drivers being bed modification, due to increased sedimentation, and poor water quality most likely related to extensive agriculture and Smithfield and Rouxville WWTW's upstream.
RIHI	Integrity Score: 72 Integrity Category: C The main drivers being over grazing and resultant riparian vegetation degradation but also bank incision/collapse and sedimentation.
Rip veg	EcoStatus: C/D (60.3%) The marginal zone was characterised by sandy banks. This was the result of increased sedimentation from upstream catchment-scale overgrazing. These bars and banks are unstable and are only favoured by pioneer species, particularly grasses (e.g. *Cynodon dactylon*). The non-marginal zone was characterised by sandy banks. The left- and right-hand banks were dissimilar. The left-hand bank was heavily grazed and strongly incised. The right-hand bank was more gradual, although this bank was also grazed. In the reference state, the marginal zone would have been classified as a grass dominated system. Reduced sediments in the system would have exposed more rocky substrates and a more variable and stable habitat with concomitant heterogeneous non-woody vegetation community assemblages. The non-marginal zone would have been classified as a grass dominated system in an Upper Gariep Alluvial Vegetation (Mucina and Rutherford, 2006) environment. The banks would have been more stable, with a good basal cover.
WQ	Temperature and dissolved oxygen impacts are anticipated due to releases from the Welbedacht Dam. Dissolved salts concentrations were moderate. JBS 2 results (conductivity 24 mS/m and TDS 218 mg/l) were lower than the average data recorded at DWS site D2H036. At the time of sampling for JBS 2, all nutrient concentrations were less than the analytical detection limit. However, in the historical data measured at D2H036, indicated intermittent elevated nutrient concentrations. While low turbidity levels (4.9 NTU and 3.3 mg/l suspended solids) were recorded, historical data for DWS site D2H036 indicated significantly
Diatoms	The diatoms assessment at this site resulted in a D or largely modified ecological category. The specific sensitivity pollution index score was a very low 9 (out of maximum of 18). At this site the 400 diatoms evaluated included 38 species with a very low deformity percentage of 0.3%.
Inverts	Jul 2015: SASS5 Score: 91 No of Taxa: 16 ASPT: 5.69 Nov 2012: SASS5 Score: 72 No of Taxa : 13 ASPT: 5.54 Sep 2012: SASS5 Score: 62 No of Taxa: 10 ASPT: 6.20 May 2012: SASS5 Score: 62 No of Taxa: 12 ASPT: 5.17 Jan 2012: SASS5 Score: 28 No of Taxa: 6 ASPT: 4.67 Changes in water quality, habitat availability and flow modification all impacted the site. Upstream of the site on tributaries to the Caledon are two WWTW which score less than 5% for their most recent green drop status assessments. In addition, upstream farming practices have added nutrients to the system as well as sediments from erosion. Simuliidae were present at the site in far greater abundance (>1000) than expected under reference conditions (10-100) indicating water quality issues. The other taxa present were also predominantly tolerant of poor water quality conditions. The MIRAI EC was calculated as a D (55.67%)
Fish	During the study, six of seven expected fish species were either sampled or inferred based on habitat diversity present and connectivity with the lower reaches with the Orange River. In addition, several species were noted to be present at the expected frequencies of occurrence, namely *Labeobarbus aeneus* (Vaal-Orange Smallmouth Yellowfish), *Clarias gariepinus* (Sharptooth Catfish) and *Austroglanis sclateri* (Rock Catfish), while the remaining species were noted to be present at lower-than-expected frequencies of occurrence. No clear primary driver of change with regards to the fish assemblage was identified, although water quality deterioration from upstream sources as well as habitat alteration (infilling of pools in the lower reaches and increased algal growth) due to sediment and nutrient input from adjacent agricultural practices was expected to play a role in the reduced frequency of occurrence for many species. In addition, the lack of finer substrate and detritus at the

	site was expected to limit the occurrence of *Labeo umbratus* (Moggel). Nevertheless, a FRAI value of 69.8% (Ecological Category C) was obtained for the site.

3.1.2.11.3 EcoStatus

Driver Components	PES
IHI: Instream	C
IHI: Riparian	C
Water Quality (Diatom SPI)	D
Response Components	**PES**
Riparian Vegetation	C/D
Macroinvertebrates	D
Fish	C
EcoStatus	C/D

3.1.2.11.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	C	Bed modification and water quality	Over grazing and exotic vegetation leading to increased overland run-off.	NF
RIHI	C	Vegetation removal	over grazing and catchment scale agricultural processes.	NF
Rip veg	C/D	Vegetation removal	Vegetation removal at the site was moderate as a result of overgrazing, particularly on the left-hand bank.	NF
		Exotic vegetation	Low levels of exotic vegetation infestation were present at the site.	
		Habitat modification	High levels of sedimentation changed the substrate composition and stability in the system in certain areas of the marginal zone and lower sections of the non-marginal zone. Furthermore, bank collapse and incision (prevalent on the left-hand bank) resulted in reduced habitat availability and stability for the riparian vegetation.	
WQ	D	Altered temperature and dissolved oxygen regimes downstream of impoundment	Bottom releases from Welbedacht Dam	F
		Elevated turbidity levels	Erosion and poor land management, notably overgrazing	NF
		Intermittent elevated nutrients concentrations	Impacts of agricultural activities and upstream urban areas	
		The extremely high dominance of the diatom species that are highly tolerant to altered water quality indicate that there the nutrient and or salt loads at this site are high.	Agriculture activities along the Caledon River.	
Inverts	D	Water quality	Poor water quality discharges from upstream settlements and eutrophication from agricultural practices.	NF
		Habitat modification.	Erosion in the upstream catchment.	

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
Fish	C	Habitat alterations (infilling of pools and loss of fine sediments)	Increased catchment run-off and sediment input	NF
		Deterioration of spawning habitat	Adjacent agricultural activities and catchment run-off (nutrient and sediment input)	
		Decreased water quality and increased algal growth in riffle habitats	Agricultural run-off (nutrient input)	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.11.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	This site was not sampled in JBS1, and no riparian vegetation baseline is available. The sites for EFR C6 and JBS1's OSAEH_26_8 were further downstream of the present site. Riparian vegetation was less impacted (EC=B) at the sites downstream. This not likely to be a temporal difference, but rather a spatial and land use difference between JBS1 and JBS2. Therefore, trends cannot be extrapolated between sites. However, given the current impacts and their effects on the riparian zone, it is inferred that the ecological condition is in a relatively stable condition.
Water Quality	Unclear	Limited data to determine trend
Macroinvertebrates	Stable	Similar to 2012 scores
Fish	Increase	Trend analysis is based on two points, namely results from JBS 1 and results obtained during JBS 2. However, the information provided as part of JBS 1 was summarised from WFA (2010a;b), and as such the FRAI models applied at the site assessed during JBS 1 were not available to draw comparisons from. Accordingly, the assessed trend needs to be interpreted with caution.

3.1.2.12 OSAEH_26_15 – Orange River at Gariep Dam

3.1.2.12.1 Site Description

The site is located on a bedrock shelf approximately 30km downstream of the Gariep Dam and 2.5km upstream of the R717 Bridge over the Orange River. The primary land use and impacts in the catchment affecting the site include the Gariep Dam upstream and agricultural impacts from livestock grazing and crops/centre pivots. The site is bedrock dominated, with a low diversity of marginal vegetation (predominantly taxa tolerant of highly variable flows). Armouring of the substrate has taken place, with bedrock becoming more exposed and dominant at the site than would have been the case in the reference. The flow regime at the site has been heavily modified, with daily releases from the dam for hydroelectric power generation.

Longitude	25.239199°	**Latitude**	-30.503859°
Altitude (m.a.s.l.)	1175m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	26.03	**Quaternary catchment**	D34E
Geomorphological zone	Lowland River	**Vegetation**	Besemkaree Koppies Shrubland

Upstream	Downstream

3.1.2.12.2 Present Ecological State (PES)

IIHI	Integrity Score: 58 Integrity Category: D The main driver being daily fluctuation in flow volumes due to hydro-power release upstream. A loss of sediment, through substrate armouring has occurred resulting in bed modification. Water quality impacts were evident in the form of a biofilm on the bedrock control (possibly the result of increased nutrients from crop farming practices)
RIHI	Integrity Score: D52 Integrity Category: D The main drivers were vegetation removal and temporary inundation from upstream dam releases.
Rip veg	EcoStatus: D (56.0%) The marginal zone was classified as a sedge (predominantly *Pseudoschoenus inanis*) and reed (Phragmites australis) dominated system with bedrock outcrops. Highly variable flows from Gariep Dam releases have resulted in a largely species poor marginal zone. The non-marginal zone was classified as a tree dominated system. The left- and right-hand banks were dissimilar, with the left-hand bank dominated by Pseudoschoenus inanis in the lower sections, with woody cover (Salix, Acacia, Diospyros and Gymnosporia species) dominating the upper sections of the non-marginal zone. The right-hand bank was more dominated by woody vegetation. In the reference state, the marginal zone would have been more heterogeneous and classified as a grass, reed and sedge dominated system. The non-marginal zone would have been classified as a tree dominated system, but with a more in-tact and heterogeneous non-woody basal cover in a Besemkaree Koppies Shrubland (Mucina and Rutherford, 2006) environment.
WQ	Temperature effects are anticipated since this site is downstream of the Gariep impoundment. Moderately elevated turbidity was recorded during JBS 2 (34 NTU), and the historical data collected at D3H013 indicated a 95-percentile statistic of 81 NTU. Dissolved salts were low at this site and also significantly less variable due to the impact of the impoundment, The sample collected during JBS 2 recorded a lower conductivity (12.3 mS/m)

	compared to the recent historical data collected by DWS at D3H013. Limited episodic nutrient enrichment was noted.
Diatoms	The diatoms assessment at this site resulted in a C or moderately modified ecological category. The specific sensitivity pollution index score was a moderate 12.7 (out of maximum of 18). At this site the 400 diatoms evaluated included just 18 species with no deformities.
Inverts	Jul 2015: SASS5 Score: 95 No of Taxa: 17 ASPT: 5.59 Flow modification and altered hydrological regimes due to releases from Gariep dam were the main impacts at the site. Under reference conditions taxa with a preference for standing water would have been the most common at the site, while under current conditions only a quarter of these taxa were present, Some of the more unexpected missing taxa included *Gyrinidae, Gomphidae* and *Atyidae*. Due to the daily fluctuations in water level the taxa with preferences for water column and GSM habitat showed the greatest variation from the reference for habitat preferences. The MIRAI EC was calculated as a C/D (60.17%).
Fish	During the present study, a reduced frequency of occurrence was noted for all species expected to occur at the site. This was attributed to significant unseasonal releases from Gariep Dam during the winter months for the purposes of hydroelectric power generation, which were noted to occur at night during the study period. However, cover features such as deep water and marginal vegetation (*Phragmites* sp.) are present that allows for some degree of refuge for fish species from the increased flows experienced, although the availability of suitable spawning habitat within the reach is likely greatly reduced. Nevertheless, scouring of substrate and bed armouring was noted to be present at the site as a result of the altered hydrology and limited sediment input, with Gariep Dam acting as a sediment trap for sediment originally derived from upstream in the catchment). Further, decreased/loss of natural seasonality in the hydrology of the system and loss of seasonal minor and moderate floods due to the presence of Gariep Dam upstream of the study site was likely to have a detrimental impact on the fish community present within the reach, particularly with regards to seasonal migratory cues where increased flows would initiate upstream migration for the purposes of breeding. The confirmed presence of *Pseudocrenilabrus philander* (Southern Mouthbrooder) at the site during the present study is likely to represent the uppermost limit of the distribution range within the Orange River system for species. As such, a FRAI score of 58.6% (Ecological Category C/D) was obtained for the site.

3.1.2.12.3 EcoStatus

Driver Components	**PES**
IHI: Instream	D
IHI: Riparian	D
Water Quality (Diatom SPI)	C
Response Components	**PES**
Riparian Vegetation	D
Macroinvertebrates	C/D
Fish	C/D
EcoStatus	C/D

3.1.2.12.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	D	Flow modification	hydro-power releases from upstream dam	F
		Unseasonal Inundation	Temporary increased flows due to upstream dam releases	
RI HI	D	Unseasonal inundation	Releases from upstream dam	F

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Vegetation removal	Over grazing and trampling	NF
Rip veg	D	Vegetation removal	Vegetation removal at the site was moderate. This was largely the result of overgrazing and bank slip (particularly on the left-hand bank).	NF
		Exotic vegetation	Low levels of exotic vegetation infestation were present at the site.	
		Water quantity	Water quantity fluctuations were severe, with Department of Water and Sanitation records indicating frequent releases from the Gariep Dam upstream of the site. This altered the marginal zone substrate; and riparian vegetation species composition, abundances and cover in both the marginal and non-marginal zones. Certain sections of instream habitat were not available for colonisation (due to increased baseflows), which would have been present in the reference.	F
WQ	C	Altered temperature and dissolved oxygen regimes downstream of impoundments	Releases from upstream Gariep impoundment - significant unseasonal releases during the winter months associated with hydroelectric power generation	F
		Episodic nutrient enrichment and elevated turbidity	Impact of agricultural activities	F/NF
		Mixed diatom community dominated by species tolerant of moderately modified water quality conditions -two species present which are indicators of elevated nutrients and salts	Intermittent nutrient enrichment from return flows from water treatment settling tanks and catchment run-off	
Inverts	C/D	Flow modification	Daily fluctuation and unseasonal flows due to releases from Gariep Dam.	F
		Habitat loss	Loss of habitat due to regular disturbance from Gariep dam releases	
Fish	C/D	Reduced recruitment as a result of loss of seasonal migration cues	Unseasonal releases from Gariep Dam	F
		Substrate scouring and bed armoring	High magnitude hydroelectric releases from upstream Gariep Dam	
		Reduced recruitment due to decease in suitable spawning habitat and loss of connectivity with suitable spawning habitat upstream	Presence of Gariep Dam upstream of site acting as a movement barrier	NF

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
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3 Flow related 4 Non Flow related

3.1.2.12.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	This site was not sampled in JBS1, and no riparian vegetation baseline is available. However, given the current impacts and their effects on the riparian zone, it is inferred that the ecological condition is in a relatively stable condition.
Water Quality	Stable	Results for most determinands are similar to records from D3H013
Macroinvertebrates	Stable	Upstream and catchment processes already accounted for in the assessment and unlikely to deteriorate much further

Response Components	Trend	Description
Fish	-	Due to the fact that the site was not assessed as part of JBS1, no trend analysis for the fish component could be established.

3.1.2.13 OSAEH_26_12 – Orange River at Doringkloof Nature Reserve

3.1.2.13.1 Site Description

The site on the Seekoei River is located upstream of the Vanderkloof Dam in the Doringkloof Nature Reserve at a low level road crossing. The site is dominated by bedrock and gravels, with pools and good marginal vegetation present. The land use in the catchment is largely natural (inside the reserve). Minor flow modifications from small impoundments upstream have had a small impact on the instream habitat, with almost no impact on the marginal vegetation.

Longitude	25.000667°	**Latitude**	-30.373595°
Altitude (m.a.s.l.)	1180m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	26.03	**Quaternary catchment**	D32K
Geomorphological zone	Lower Foothills	**Vegetation**	Besemkaree Koppies Shrubland

Upstream

Downstream

3.1.2.13.2 Present Ecological State (PES)

IIHI	Integrity Score: 87 Integrity Category: B There were very few impacts at the site. There were some minor impacts with regards to water quantity and quality most likely due to low flows and an upstream low level crossing/weir.
RIHI	Integrity Score: 94 Integrity Category: A Very minor bank erosion being the largest impact.
Rip veg	EcoStatus: A (96.7%) The marginal zone was characterised by a mosaic of vegetation and habitat types, predominately sand bars, bedrock sheets and *Pseudoschoenus inanis* clusters. The non-marginal zone was characterised by a mosaic of vegetation and habitat types in a Besemkaree Koppies Shrubland (Mucina and Rutherford, 2006) environment. The right- and left-hand banks were dissimilar: with the left-hand bank steep with good woody vegetation cover; and the right-hand bank gradual and dominated by a bedrock sheet. Both the marginal and non-marginal zones would have been similar to the present state.
WQ	High dissolved salt concentrations were recorded during JBS 2 (conductivity 58.5 mS/m, 560 TDS mg/l, sodium 95 mg/l, chloride 77 mg/l, and sulphate 95 mg/l). Fluoride was also elevated at 0.5 mg/l. All nutrient data collected for JBS 2 were below the analytical detection limit, but historical data from the DWS site D3H015 indicated that while nutrient concentrations were moderate for the most time, a few elevated results were present in the data record, indicating enrichment at times.
Diatoms	The diatoms assessment at this site resulted in a C or moderately modified ecological category. The specific sensitivity pollution index score was a high 13.4 (out of maximum of 18). At this site the 400 diatoms evaluated included 18 species with a very low deformity percentage of 1.5%.
Inverts	Jul 2015: SASS5 Score: 60 No of Taxa: 33 ASPT: 4.62 This site was on a small river with very low flows and limited habitat at the time of sampling both flow and habitat availability is likely to improve in the wet season. The taxa present were generally tolerant of low water quality and with a preference for the water column habitat. Both *Hydraenidae* and *Hydracarina* were present and require largely unmodified water quality. The available habitat was in a good condition bar some algal growth on the cobbles and in the water column. The MIRAI EC was calculated as a C/D (59.93%)
Fish	Flow modification has occurred as a result of the presence of several weirs within the Seekoeispruit upstream of the site, resulting in the loss of sufficient base flows during winter for maintaining diverse habitat structure and allowing the settling out of fine sediment which was noted to smother available habitat within the main channel. Further, loss of deep water within the reach downstream of the weirs that would otherwise provide cover for larger individuals of the expected species has occurred, resulting in a reduced frequency of occurrence for *Labeo umbratus* (Moggel) and *Labeo capensis* (Orange River Mudfish). The presence of the upstream weirs were further expected to reduced recruitment and spawning success of indigenous fish species due to reduction of migration cues (loss of small to moderate seasonal flows) and loss of connectivity with upper reaches of the watercourse which would provide suitable spawning habitat, while reduced inundation of favourable breeding habitat for species such as *Barbus anoplus* (Chubbyhead Barb) is likely downstream of the weirs. In addition, pushback from Vanderkloof Dam (which is likely to act as an artificial support for larger cyprinids within the system) into the lower reaches of the Seekoeispruit is likely to increase accessibility of the lower reaches of the Seekoeispruit to predatory indigenous fish species such as *Labeobarbus kimberleyensis* (Vaal-Orange Largemouth Yellowfish) which predate *on B. anoplus*, further reducing the species' ability to occur at the expected frequency of occurrence within the reach under study. Accordingly, a FRAI score of 55.3% (Ecological Category D) was obtained for the site.

3.1.2.13.3 EcoStatus

Driver Components	PES
IHI: Instream	B
IHI: Riparian	A
Water Quality (Diatom SPI)	C
Response Components	**PES**
Riparian Vegetation	A
Macroinvertebrates	C/D
Fish	D
EcoStatus	C

3.1.2.13.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	A	water quality	Minor nutrient enrichment due to limited winter flows	F
RIHI	A	Minor bank erosion	Dirt road track crossing river	NF
Rip veg	A	The site was pristine to largely natural, with no significant impacts in the system.	N/A	N/A
WQ	C	High dissolved salt concentrations and nutrient enrichment at times	Impact of upstream agricultural activities and return flows	NF
		Diatom community dominated by species tolerant of moderately modified water quality conditions -three species present which are indicators of elevated nutrients and salts	Intermittent nutrient enrichment from upstream return flows, low winter flows and general catchment run-off	F/NF
Inverts	C/D	Water quality	Minor increase in nutrients due to limited winter flows	F
		Limited habitat	Low winter flows excluding available habitat	
Fish	D	Fine sediment deposition and smothering of available habitat due to loss of baseflows as well as small and moderate seasonal flooding events	Presence of upstream weirs	F
		Loss of movement within the reach	Presence of upstream weirs	NF

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Decreased hydraulic habitat diversity due to loss baseflows	Presence of upstream weirs	F
		Reduced recruitment and spawning success due to reduction of migration cues and loss of connectivity with upper reaches	Presence of weirs acting as an upstream movement barrier	NF

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2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.13.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	This site was not sampled in JBS1, and no riparian vegetation baseline is available. However, given the current impacts and their effects on the riparian zone, it is inferred that the ecological condition is in a stable condition.
Water Quality	Stable	2010 to current: Limited data available at D3H015 indicates an increasing trend in conductivity
Macroinvertebrates	Stable	Upstream and catchment processes already accounted for in the assessment and unlikely to deteriorate much further
Fish	-	Due to the fact that the site was not assessed as part of JBS1, no trend analysis for the fish component could be established.

3.1.2.14 OSAEH_26_02 – Orange River at Hopetown

3.1.2.14.1 Site Description

The site is located approximately 10km upstream of Hopetown, and 1km upstream of the train bridge. Furthermore, it is located approximately 15 to 20 km upstream of the EWR sites D3ORAN-HOPET and D3ORAN-VANDE and The site was characterised by a cobble bar and riparian vegetation that was regularly inundated as a result of releases from Vanderkloof Dam for hydropower generation. These flows fluctuated by approximately 1.5m during the 6 hour intensive sampling period. These flow modifications have resulted in harsh benthic conditions, with loose relatively sterile cobbles present. The riparian habitat was also impacted by the flow fluctuations, increased base flows in the low flow season and extensive impacts from livestock grazing. This site is therefore not a suitable reference site.

Longitude	24.215221°	**Latitude**	-29.643404°
Altitude (m.a.s.l.)	1060m	**Water Management Area**	Upper Orange
Level 2 EcoRegion	26.01	**Quaternary catchment**	D33E
Geomorphological zone	Lowland River	**Vegetation**	Upper Gariep Alluvial Vegetation

Upstream | Downstream

3.1.2.14.2 Present Ecological State (PES)

IIHI	Integrity Score: 64 Integrity Category: C Daily fluctuation in water levels of approximately one meter was the largest driver of changes instream.
RIHI	Integrity Score: 66 Integrity Category: C Daily water level fluctuations and Livestock grazing and trampling are the main drivers of changes in the riparian habitat.
Rip veg	EcoStatus: D (52.9%) The marginal zone was dominated by boulder outcrops and sandbanks with sedge clusters in between. Daily flow releases from Vanderkloof Dam have a notable impact on the system, with few taxa dominating the open habitats available when flows reside. The altered flow regime resulted in increased base lows in the low flow season and an unstable growing environment for vegetation on the banks of the system. The left- and right-hand banks were dissimilar. The non-marginal zone on the left-hand bank was classified as a grass dominated system. The non-marginal zone on the right-hand bank was characterised by a mosaic of vegetation types, with a grass basal cover and trees dominating the upper edges of the non-marginal zone. Banks seemed destabilised, which is the likely impact of highly variable flows with limited vegetation cover. In the reference state, the marginal zone would have been characterised by a mosaic of grass, sedge and forbe vegetation communities that would have responded to season, and not daily, changes in flow. This would have resulted in more stable and heterogeneous vegetation communities. The non-marginal zone would have been characterised by a mosaic of grass, shrub and tree vegetation communities, with grasses being dominant in an Upper Gariep Alluvial Vegetation (Mucina and Rutherford, 2006) type environment. Banks would have been more stable and gradual.
WQ	Temperature and dissolved oxygen impacts are anticipated due to releases from the upstream impoundments as well as twice daily flow fluctuations associated with the hydropower operation from the Vanderkloof Dam. Dissolved salts concentrations were low-moderate.

	Nutrient concentrations were moderate for the most time, but limited intermittent elevated nutrient concentrations, associated with agricultural activities, were apparent in the historical data measured at D3H012. Low to moderate turbidity levels (14 NTU and 6 mg/l suspended solids) were recorded, associated with the trapping of silt in upstream dams.
Diatoms	The diatoms assessment at this site resulted in a B or largely natural ecological category. The SPI score was a high 15.4 (out of maximum of 18). At this site the 400 diatoms evaluated included 27 species with a few deformities (1.8%). Overall the water quality was regarded as good.
Inverts	Jul 2015: SASS5 Score: 57 No of Taxa: 10 ASPT: 5.70 Nov 2012: SASS5 Score: 37 No of Taxa: 8 ASPT: 4.63 Sep 2012: SASS5 Score: 31 No of Taxa: 7 ASPT: 4.43 May 2012: SASS5 Score: 19 No of Taxa: 4 ASPT: 4.75 Dec 2011: SASS5 Score: 24 No of Taxa: 5 ASPT: 4.80 Jun 2010: SASS5 Score: 117 No of Taxa: 20 ASPT: 5.85 Flow modification was the major driver at this site with daily hydro power releases from the upstream dam cause fluctuation of approximately 1.5m per day. The taxa present at the site included the moderately sensitive Leptophlebiidae and more than 2 species of Baetidae. The remaining taxa were tolerant of low water quality conditions. The fluctuations in flows result in a regular disturbance to all of the habitats making colonization difficult. The MIRAI EC was calculated as a D (55.42%).
Fish	During the present study, a reduced frequency of occurrence was noted for all species expected to occur at the site. This was attributed to flow modification as a result of significant unseasonal releases from Vanderkloof Dam during the winter months for the purposes of hydroelectric power generation (releases noted to occur twice a day during the study period), as well as the reduction in the cover features expected to occur under reference conditions. In addition, a reduction in the slow-deep velocity class was noted which would have impacted on those species with a preference for this velocity class. During the study, the site was dominated by embedded boulders and mobile substrate (gravel) that was noted to act as an abrasive on habitat features present. Further, a reduction in the deposition of fine sediment and detritus was noted that would have support the occurrence of *Labeo umbratus* (Moggel) within the reach. While a cobble bar was noted to be present that may provide suitable habitat for species such as *Austroglanis sclateri* (Rock Catfish), regular fluctuations in water levels and the abrasive nature of the substrate as a result of the releases from Vanderkloof Dam severely limited their frequency of occurrence at the site. In addition, fluctuations in the abundance of velocity-depth classes and contact with cover features such as boulders was further likely to impact on the other species expected to occur under natural conditions. Decreased or loss of seasonality in the hydrology of the system at the site due to the presence of Vanderkloof Dam upstream of the study site was likely to have a detrimental impact on the fish community present within the reach, particularly with regards to seasonal migratory cues where increased flows would initiate upstream migration for the purposes of breeding, and reduced recruitment due to the loss of connectivity with suitable spawning habitat in the upper reaches. The habitat modifying species *Cyprinus carpio* (Common Carp), while likely to be present, was likely to have very little impact on the indigenous fish species. As such, a FRAI score of 56.7% (Ecological Category D) was obtained for the site.

3.1.2.14.3 EcoStatus

Driver Components	PES
IHI: Instream	C
IHI: Riparian	C
Water Quality (Diatom SPI)	B
Response Components	**PES**
Riparian Vegetation	D
Macroinvertebrates	D
Fish	D
EcoStatus	D

3.1.2.14.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	C	Flow modification	Daily releases from upstream dams resulting in greater than one meter fluctuations in water levels	F
RIHI	C	Unseasonal inundation	Daily releases from upstream dams temporarily inundations marginal vegetation	F
		Vegetation removal	Over grazing and trampling	NF
Rip veg	D	Vegetation removal	Vegetation removal at the site was moderate. This was largely the result of overgrazing on both banks.	NF
		Exotic vegetation	Low levels of exotic vegetation infestation were present at the site.	
		Water quantity	Water quantity fluctuations were severe, with Department of Water and Sanitation records indicating frequent releases from the Vanderkloof Dam upstream of the site. This altered the marginal zone substrate; and riparian vegetation species composition, abundances and cover in both the marginal and non-marginal zones. Certain sections of instream habitat were not available for colonisation (due to increased baseflows), which would have been present in the reference.	F
		Habitat modification	Bank collapse and incision (prevalent on the right-hand bank) resulted in reduced habitat availability and stability for the riparian vegetation.	NF
WQ	B	Altered temperature and dissolved oxygen regimes downstream of impoundments	Significantly altered flow regimes/fluctuations associated with releases from upstream impoundments	F
		Elevated nutrients due to fertilizer application and potential toxicant loads associated with pesticide usage	Impacts of agricultural activities	NF
I	D	Water quantity		F

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Habitat modification	Daily and unseasonal fluctuations in flow due to releases from upstream dams, regularly inundating habitats.	
Fish	D	Reduced recruitment as a result of loss of seasonal migration cues	Unseasonal releases from Vanderkloof Dam	F
		Substrate scouring as result of the abrasive substrate and magnitude of volumes released during winter	High magnitude hydroelectric releases from upstream Vanderkloof Dam	
		Reduced recruitment due to decease in suitable spawning habitat and loss of connectivity with suitable spawning habitat upstream	Presence of Vanderkloof Dam upstream of the site acting as a movement barrier	NF
		Constantly changing habitat availability and diversity	Daily releases hydroelectric releases from upstream Vanderkloof Dam	F

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.14.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	This site was not sampled in JBS1, and no riparian vegetation baseline is available. The sites for EFR O1 and JBS1's OSAEH_26_2 were further downstream of the present site. Riparian vegetation was less impacted (EC=B/C) at the site downstream. This not likely to be a temporal difference, but rather a spatial and land use difference between JBS1 and JBS2 sites. Therefore, trends cannot be extrapolated between sites. However, given the current impacts and their effects on the riparian zone, it is inferred that the ecological condition at the present site is in a relatively stable condition.
Water Quality	Unclear	Very limited data to determine trend at D3H012.
Macroinvertebrates	Stable	The site was not sampled in JBS1 and the site labelled as OSAEH_26_2 in JBS1 was located downstream. The downstream site sampled in JBS1 was less impacted in terms of the macroinvertebrate wellbeing and the lower score recorded in JBS2 was possibly a result of the land-use difference between the JBS1 and JBS2 sites.
Fish	Decline	Trend analysis is based on two points, namely results from JBS 1 and results obtained during JBS 2. However, the information provided as part of JBS 1 was summarised from WFA (2010a;b), and as such the FRAI models applied at the site assessed during JBS 1 were not available to draw comparisons from. In addition, sites assessed as part of JBS1 and JBS2 were approximately 25km apart. Accordingly, the assessment of trends for the site needs to be interpreted with caution.

3.1.2.15 OSAEH_26_03 – Orange River at Douglas

3.1.2.15.1 Site Description

The site is situated on the Orange River upstream of the confluence with the Vaal River, approximately 20km south-west of Douglas, South Africa. The primary land-use is irrigated agriculture/cultivation. Active channel features include densely vegetated islands of reeds and sedges, creating a braided system of open-water predominated by pools and runs. Instream habitat, particularly the runs and riffles, were comprised largely of boulder and cobble substrate, while fine sediments, gravel and sand were confined to marginal zones and vegetated islands. The riparian zone has a defined flood terrace dominated by grass cover leading to a steep, densely wooded embankment.

Longitude	23.692039	**Latitude**	-29.141709
Altitude (m.a.s.l.)	988	**Water Management Area**	Lower Orange
Level 2 EcoRegion	26.01	**Quaternary catchment**	D33K
Geomorphological zone	Lowland River	**Vegetation**	Upper Gariep Alluvial Vegetation

Upstream **Downstream**

3.1.2.15.2 Present Ecological State (PES)

IIHI	Integrity Score: 59 Integrity Category: C/D The principle impacts at the site were flow modification due to releases from the Vanderkloof and Gariep Dams, and bed modification arising from highly embedded stones and excessive algae growth. An additional minor impact was water quality modifications arising from upstream influences and surrounding agriculture.

RIHI	Integrity Score: 78 Integrity Category: B/C The primary impact at the site was the influence of the regulated flows from the Vanderkloof and Gariep Dams on the structure of the vegetation. Additional impacts included the presence of exotic vegetation, vegetation removal and consequent bank erosion from livestock access paths and solid waste.
Rip veg	EcoStatus: B/C (61.5%) **Marginal zone:** Dominated by *Cynodon dactylon* and *Phragmites australis* on sandy soils covering the right bank, dense *P. australis* with patches of sedges on islands with rocky-cobble base, and a combination of sedges and herbs with overhanging trees on the left bank. Invasive alien plants include *Conyza sp.*, *Xanthium strumarium* and *Verbena officinalis*. **Non-marginal zone:** The right bank is dominated by *C. dactylon* interspersed by a light cover of *Salix mucronata* on the lower banks, and densely wooded vegetation on the upper banks including *Acacia karoo*, *Lycium hirsutum*, *Searsia pendulina*, *Ziziphus mucronata*. The left bank is steep and narrow with a well-defined thicket of trees from the right bank. *Xanthium strumarium* is the dominant invasive alien plant in the non-marginal zone. A single *Eucalyptus sp.* was recorded at the site.
WQ	Overall, water quality was satisfactory at this site. However, some temperature impacts are expected due to altered flow regimes and releases from upstream impoundments. The dissolved oxygen was acceptable at 97.8% (9.74 mg/l) of saturation. Nutrient concentrations were low - moderate, but the historical data collected at site D3H008 indicated some elevated nutrient concentrations. The chlorophyll *a* concentration reported in JBS 2 was notably elevated at 27 µg/l. Conductivity and TDS results were low at 14.9 mS/m and 94 mg/l respectively, lower than the historical statistics calculated at DWS site D3H008 for the 2010 to 2015 period.
Diatoms	The diatoms assessment at this site resulted in a B/C or largely natural/moderately modified ecological category. The SPI score was 14.8 (out of maximum of 18). At this site the 400 diatoms evaluated included 37 species with a few deformities (1.5%). Overall the water quality was regarded as average.
Inverts	Jul 2015: SASS5 Score: 89 No of Taxa: 15 ASPT: 5.9 Several key taxa were expected but not observed at the site, such as Caenidae, Tricorythidae, Hydropsychidae, Aeshnidae, Gomphidae, Libellulidae, Simuliidae and a number of the more common families of Hemiptera (e.g. Belostomatidae, Gerridae, Notonectidae, and Veliidae). Generally taxa not observed were those that exhibit a preference for moderate to high water quality conditions and moderate to high flows as well as cobble and vegetation habitats. Although sampled, the biotopes that were somewhat limiting at the site included, stones and vegetation out of current as well as GSM. Small cobbles were absent from the site and the larger boulder/cobble substrate matrix revealed a moderate degree of embeddedness. The MIRAI EC was calculated as a D (55.6%).
Fish	The fish community wellbeing evaluation resulted in a moderately modified ecological state (Class C). Seven of the expected eleven indigenous fishes were collected at the site which was sampled extensively using a range of active electrofishing and netting methods. Common fishes included the *L. capensis* (Orange River mudfish) and the cichlids including *T. sparmanii* (Banded tilapia) and *P. philander* (Southern mouthbrooder). Although some of the cryptic fishes expected to occur at the site were collected, including *L. kimberleyensis* (Vaal-Orange largemouth yellowfish) and *A. sclateri* (Rock catfish), the *Barbus spp.* (barbs) and the *L. aeneus* (Vaal-Orange smallmouth yellowfish) that were expected to be common were only infrequently collected. The health of the fishes collected were generally good with no serious external abnormalities (deformities, ulcers, lesions and wounds) and low parasitic infections.

3.1.2.15.3 EcoStatus

Driver Components	PES
IHI: Instream	C/D
IHI: Riparian	B/C
Water Quality (Diatom SPI)	B/C
Response Components	**PES**
Riparian Vegetation	B/C
Macroinvertebrates	D
Fish	C
EcoStatus	C

3.1.2.15.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	C/D	Unseasonably high and sustained flows	Releases from Gariep and Vanderkloof Dam	F
		Bed modification	Sediment run-off from higher up in catchment and excessive nutrient input	NF
RIHI	B/C	Regulated flows influencing structure of vegetation	Releases from Gariep and Vanderkloof Dam	F
Rip veg	B/C	Increase in vegetation cover	Less frequent flooding by medium to large return period events and more continuous baseflows due to flow regulation of large impoundments upstream (e.g. Gariep and Vanderkloof Dam)	F
		Change in plant species composition	Minor infestation of invasive alien plants	NF
		Removal of vegetation, increase erosion and bank collapse	Stock farming	
WQ	B/C	Periodic elevated nutrients and potentially pesticides	Fertilised agricultural land	NF
Inverts	D	Increased flows during the dry season	Inter-basin transfers Dam/Hydropower plant releases	F
		Water temperature shocks		
		Water quality deterioration	Agriculture, mining and industries polluting the Vaal river which confluences upstream	NF
		Increased turbidity	Upstream agriculture and modification of riparian zones	NF

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
Fish	C	Flow alterations associated with upstream dams affects habitat suitability, cover features for fish and ecological cues associated with life cycle processes (such as recruitment). Indirect impacts include dilution fluctuations, water clarity issues and temperature threats.	Upstream Vanderkloof Dam.	F
		The Marksdrift weir (D3H025) acts as a barrier and affects the upstream movement of fishes in the study area. The barrier affects the movement of species between reaches in the study areas and affects habitat availability.	Marksdrift Weir	F/NF
		Water quality impacts associated with local and regional (upstream) land use activities are affecting fish community wellbeing slightly at the site.	Local and regional agriculture activities.	NF
		Habitat alterations and access associated with local and regional developments (road/bridge infrastructure and a gauging weir affect connectivity and diversity of local habitats.	Local gauging weir and infrastructure developments.	
		Competition with alien fishes *G. affinis* (Mosquito fish, observed), and *C. carpio* (Common carp, inferred to occur) is limited but may have a slight impact on the wellbeing of the indigenous fishes.	Alien invasive fishes	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.2.15.5 Trends Analysis

Response Components	Trend	Description
Water Quality	Stable	No significant changes from to water quality within the past 5 years
Fish	Stable	The wellbeing of the fish communities in the study area over the past five years (in comparison with JBS 1) appears to be stable. In this assessment a greater diversity of fishes were collected but these fishes were generally considered to have occurred in the study area previously. Some concerns associated with the commonness of the barbs, Orange-Vaal smallmouth yellowfish (LAEN) and the Rock catfish (ASCL) are concerning. There is no evidence that any fishes expected to occur in the study area are no longer present in the reach of the Orange River assessed in the study.
Macroinvertebrates	Stable	Upstream catchment processes are largely already accounted for in the current assessment and unlikely to dramatically change much further in the medium term.
Riparian Vegetation	Stable	No significant changes from to riparian vegetation dynamics within the past 5 years

3.1.3 Lower Orange River Catchment

Results from sites on the Lower Orange revealed that overall EcoStatus condition improved with downstream distance. Sites in the upper reaches of the system were generally in a C category (moderately modified), likely owing to the effects of intensive agriculture and upstream dam releases (modification of natural thermal and hydrological regimes). Sites on the lower reaches of the system were in B-B/C-C categories (largely natural condition to moderately modified condition). Sites exhibiting largely natural conditions (B-B/C) likely reflect that the fact that: a) less intensive agriculture occurs in the arid lower reaches of the Orange River, b) population densities are low with fewer major towns and c) more intact ecological infrastructure exists in the form of protected areas (such as the Richtersveld National Park) and low density livestock farming areas.

AEH sites located in the Lower Orange Catchment are shown in Figure 3.6, while overall EcoStatus condition of the sites is represented in Figure 3.7.

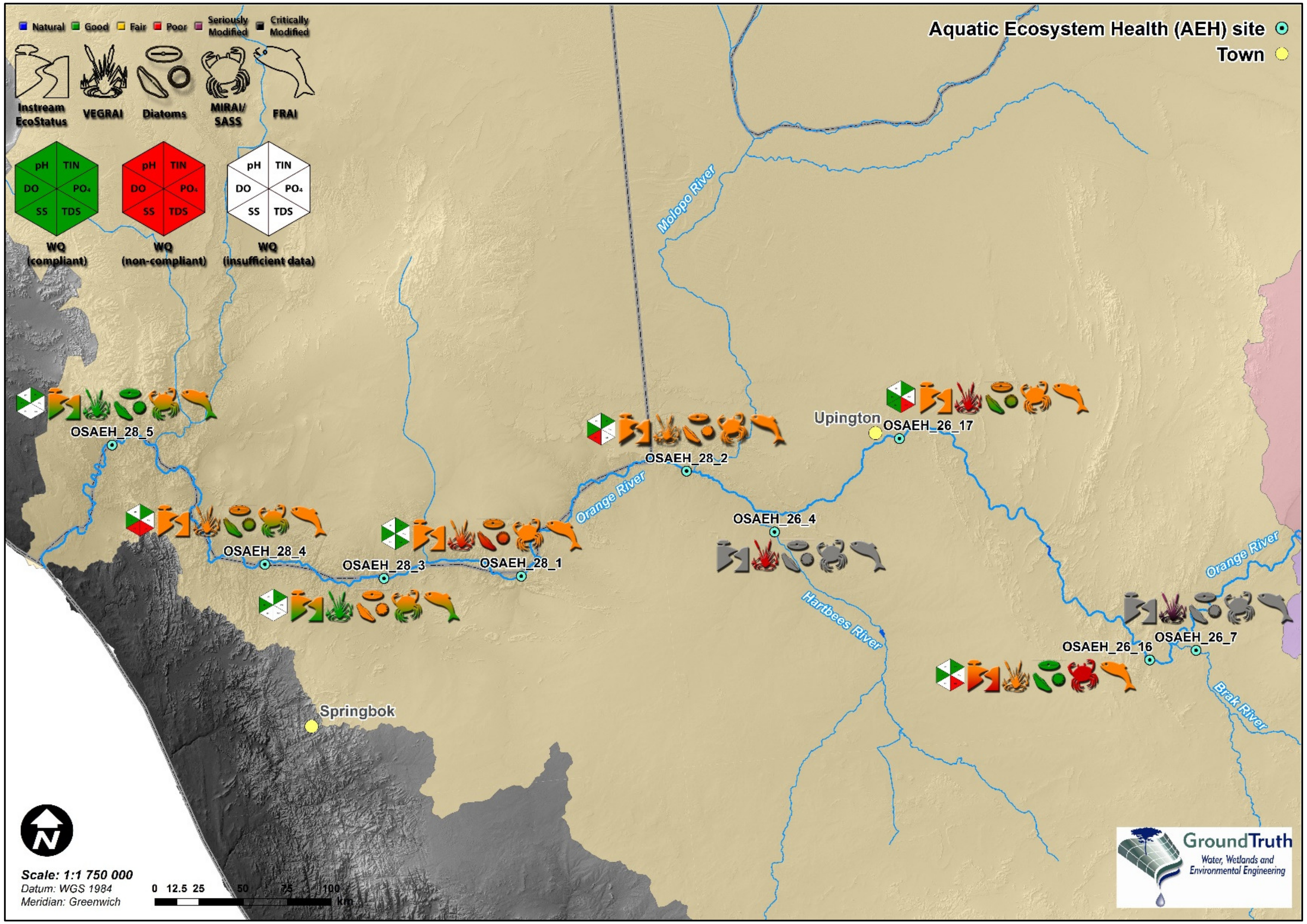

Figure 3.6 **Study sites within the Lower Orange catchment. AEH components are colour coded according to EcoStatus categories (grey symbols indicate the component was not sampled). Water quality (WQ) determinands are colour coded according to compliance with the DWAF (1996) chronic effect values for aquatic ecosystems.**

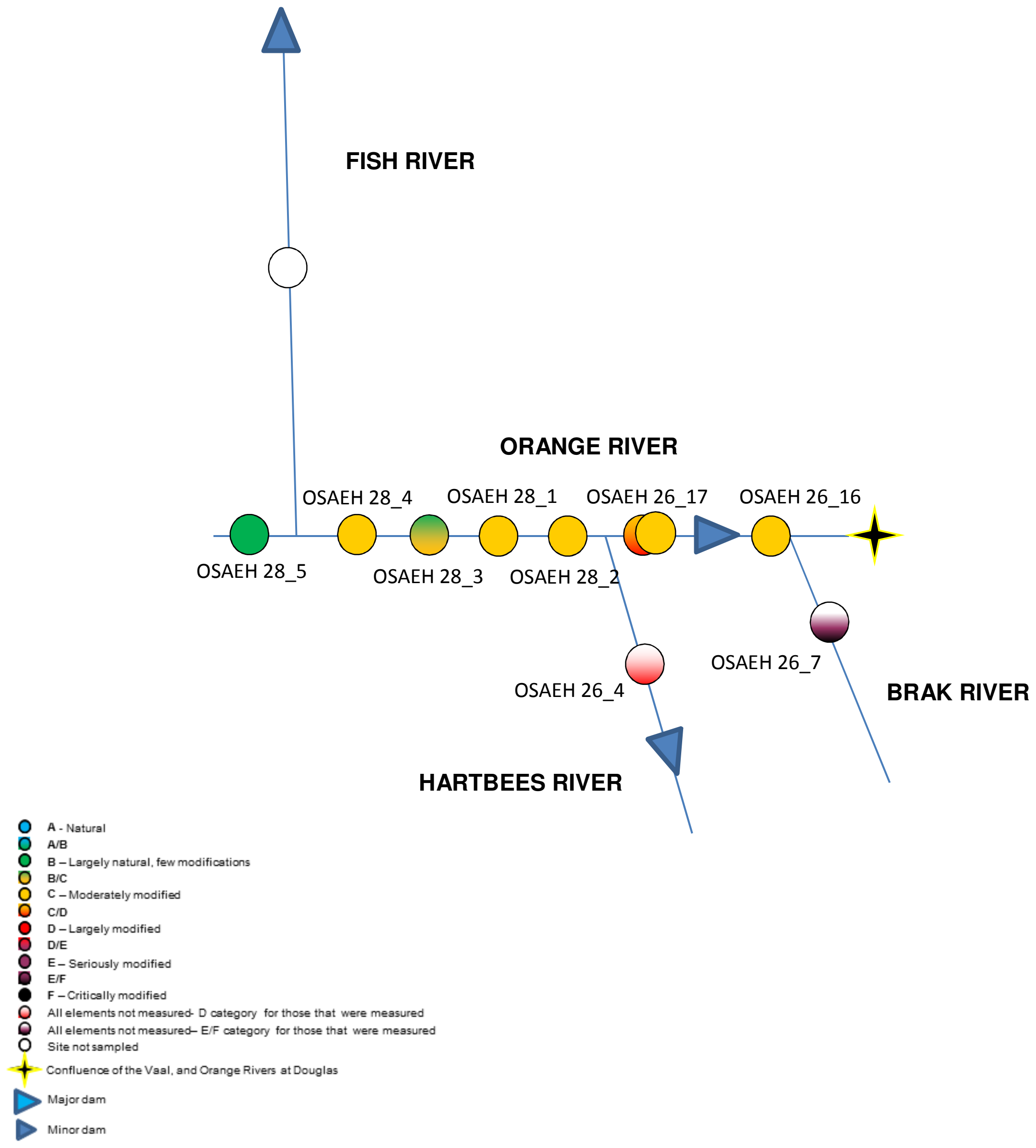

Figure 3.7 Map representing the AEH sites sampled in JBS2 in the Lower Orange catchment. Sites are colour coded according to overall EcoStatus Category.

3.1.3.1 OSAEH_26_07 – Brak River

3.1.3.1.1 Site Description

Site is on the Brak River approximately 27km west of Prieska, South Africa. In contrast to the Orange River main-stem, it is an ephemeral system that drains in a north-westerly direction into the Orange River. The site contains two main channels that flow intermittently, and for short periods of time, provided that rainfall is sufficient to generate surface run-off. For most of the time water is carried as sub-surface (or hyporheic) flow. During times of surface flow (albeit brief) the sandy river bed becomes inundated, collecting and transporting sediments and debris downstream. Only macroinvertebrates with rapid life-cycles (e.g. Baetidae, Chironomidae and certain Hemiptera) will persist. The site is noted for the very dense infestation of invasive *Prosopis* trees, forming dense thickets that out-compete natural vegetation. The extent of the broader floodplain is clearly defined by the contrast of a woody riparian component and the terrestrial shrub communities.

Longitude	23.016668°	**Latitude**	-29.622990°
Altitude (m.a.s.l.)	1002 m	**Water Management Area**	Lower Orange
Level 2 EcoRegion	26.02	**Quaternary catchment**	D62J
Geomorphological zone	Lowland River	**Vegetation**	Upper Gariep Alluvial Vegetation

Upstream	**Downstream**

3.1.3.1.2 Present Ecological State (PES)

RIHI	Integrity Score: 27 Integrity Category: E The primary impacts at the site were the intensive and extensive infestation by alien invasive plants and gulley and sheet erosion, particularly in close proximity to the bridge.
Rip veg	EcoStatus: E/F (21.5%) **Marginal zone:** Not well defined as the system is ephemeral in nature and has not experienced flow leading up to the time of the assessment. **Non-marginal zone:** Approximately 30 metres-wide and relatively steep with excessive soil erosion forming deep gullies extending through the non-marginal zone. The entire non-marginal zone is dominated by the exotic tree *Prosopis glandulosa* which has formed a dense, impenetrable thicket. A number of *Tamarix usneoides* occur throughout the site, along with the occasional indigenous herb and shrub (e.g. *Lyscium horridum* and *Atriplex sp.*). The site had very little grass cover with only a few tufts of *Phragmites australis* and *Eragrostis sp.* noted.

3.1.3.1.3 EcoStatus

Driver Components	PES
IHI: Riparian	E
Response Components	**PES**
Riparian Vegetation	E/F

3.1.3.1.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
RIHI	E	High infestation of alien invasive plants	Disturbance and lack of alien management	NF
		Extensive sheet and gulley erosion	Disturbance and lack of grazing /browsing management	
Rip veg	E/F	Change in plant species composition	Heavy infestation of *Prosopis glandulosa* trees	NF
		Removal of vegetation and plant cover	Road infrastructure and bridge, grazing by livestock and excessive erosion	

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2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.3.1.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	N/A	No available data to establish trends
Water Quality	N/A	No available data to establish trends
Macroinvertebrates	N/A	No available data to establish trends
Fish	N/A	No available data to establish trends

3.1.3.2 OSAEH_26_16 – Orange River at Prieska (D7ORAN-PRIES)

3.1.3.2.1 Site Description

The site is located on the Orange River in proximal distance to the town of Prieska, South Africa. The macro-channel is characterised by a floodplain on the right bank dominated by grasses with woody vegetation dominating the boundary and a left bank with a steep gradient dominated by woody vegetation. Active channel features are predominantly runs with a cobble bed. Additional features include boulder rapids and areas of slack water possessing a gravel and sand substrate.

Longitude	22.744638°	**Latitude**	-29.655185°
Altitude (m.a.s.l.)	943	**Water Management Area**	Lower Orange
Level 2 EcoRegion	26.02	**Quaternary catchment**	D72B
Geomorphological zone	Lowland river	**Vegetation**	Upper Gariep Alluvial Vegetation

Upstream

Downstream

3.1.3.2.2 Present Ecological State (PES)

IIHI	Integrity Score: 67 Integrity Category: C The principle impact was the unnaturally high flows caused by the Gariep and Vanderkloof Dam releases. A further major impact includes water abstraction upstream for irrigation Additional minor impacts include channel modification due to the bridge crossing, water quality modification and solid waste dumping.

RIHI	Integrity Score: 79 Integrity Category: B/C The principle impacts included flow modification that drives changes to riparian vegetation structure, vegetation removal for firewood collection, bank erosion and the presence of exotic vegetation and solid waste.
Rip Veg	EcoStatus: B/C (77.6%) **Marginal zone:** Largely comprises of herbaceous vegetation dominated by grasses (*Cynodon dactylon* and *Hemarthria altissima*) and a good mix of sedges (*Cyperus marginatus, Juncus sp., Schoenoplectus sp.* and *Typha capensis*). The marginal zone is interspersed by the occasional *Salix mucronata* and *Gomphostigma virgatum,* with *Phragmites australis* forming dense cover on islands. **Non-marginal zone:** The left bank has a broad flood terrace with undulating sand banks and a large area of exposed rocks/cobbles. Here *C. dactylon* is the dominant cover interspersed by *S. mucronata* leading to a dense thicket of mature *Acacia karoo*, *Prosopis glandulosa* (exotic tree), *Searsia pendulina*, *Ziziphus mucronata*. The left bank is steeper and narrow with a well-defined tree layer including a number of exotic *Eucalyptus* trees. Other invasive alien plants recorded at the site include *Chenopodium album*, *Argemone ochroleuca* and *Trifolium repens*. The site has a notable infestation of the aquatic macrophyte *Myriophyllum aquaticum*.
WQ	Water quality was generally satisfactory, but elevated nitrate concentrations were recorded in the JBS 2 data. The limited data available at site D7H002 confirmed sporadic nutrient enrichment. Moderate levels of dissolved salts.
Diatoms	The diatoms assessment at this site resulted in a B or largely natural ecological category. The SPI score was a high 15.5 (out of maximum of 18). At this site the 400 diatoms evaluated included just 30 species with no deformities. High dominance of diatom species intolerant to water quality alterations suggests that the water quality at this site is in a good state.
Inverts	Jul 2015: SASS5 Score: 57 No of Taxa: 13 ASPT: 4.4 Jun 2008: SASS5 Score: 75 No of Taxa: 16 ASPT: 4.7 Key taxa expected but not observed at the site were generally those that exhibit a preference for moderate to fast flowing waters, cobble and vegetation habitats as well as those that are sensitive to water quality deterioration, such as Hydropsychidae (> two species), Perlidae, Oligoneuridae, Ecnomidae, Simuliidae, Tricorythidae, Aeshnidae, Libellulidae. Other taxa expected but not observed included the Caenidae and Gomphidae (both exhibiting a preference for GSM habitat), Dytiscidae, Hydrophilidae as well as several families of Hemiptera (e.g. Belostomatidae, Gerridae, Notonectidae, Veliidae) which collectively indicate potential changes in the vegetation and water column habitats. All biotopes were present at the sites and a diverse range of habitats and vegetation was sampled. Flows were atypically high for the time of year (likely from upstream hydropower/dam bottom-water releases) and prevented sampling in the Thalweg itself, thereby limiting sampling efforts to the right hand bank. Notably cold water temperatures from bottom releases could possibly be affecting the presence of Simuliidae at the site, particularly in the warmer months. Turbidity was also high at the time of sampling and cobbles/boulders in the riffles and runs were covered in fine sediments with a high degree of embeddedness. Of the biotopes sampled, gravel, sand and mud was the most limiting at the site along with out of current areas. The MIRAI EC was calculated as a D (56.3%).
Fish	The fish community wellbeing evaluation resulted in a moderately modified ecological state (Category C (67.0%)). Seven of the expected eleven indigenous fishes were collected at the site which was sampled using active electrofishing methods only. Common fishes included *L. capensis* (Orange River mudfish). L. aeneus (Vaal-Orange yellowfish) and the local cichlids including *T. sparmanii* (Banded tilapia) and P. philander (Southern mouthbrooder). Many of the *Barbus spp.* (barbs) were collected at this site, as was an individual *C. gariepinus* (Sharptooth catfish). Although none of the cryptic fishes expected to occur at the site were collected, including *L. kimberleyensis* (Vaal-Orange largemouth yellowfish) and *A. sclateri* (Rock catfish) in particular, the absence of *L. umbratus* (Moggel) is concerning at this site. The health of the fishes collected was generally good with only one specimen that was obtained with an ulcer/lesion. Some parasitic infections were observed but prevalence was low.

3.1.3.2.3 EcoStatus

Driver Components	PES
IHI: Instream	C
IHI: Riparian	C
Water Quality (Diatom SPI)	B
Response Components	**PES**
Riparian Vegetation	B/C
Macroinvertebrates	D
Fish	C
EcoStatus	C

3.1.3.2.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	C	Modification of natural flows	Releases from Gariep and Vanderkloof Dams	F
			Abstraction for upstream irrigation	
RIHI	C	Increase in woody vegetation abundance and cover	Alteration of natural flow cycles	F
		Reduction in vegetation cover	Removal of vegetation for firewood	NF
Rip veg	B/C	Increase in woody vegetation cover	Less frequent flooding due to flow regulation by large impoundments upstream (e.g. Gariep and Vanderkloof Dam)	F
		Change in plant species composition	Infestation of invasive alien trees	NF
		Removal of vegetation	Firewood collecting, road/bridge infrastructure, vehicle tracks/footpaths and limited browsing/grazing by livestock	
WQ	B	Nutrient enrichment	Agricultural activities (particularly fertilizer usage and return flows) , WWTW effluent discharges, pollution and run-off from Prieska	NF
		Altered temperature and dissolved oxygen regimes downstream of impoundments	Releases from Gariep and Vanderkloof Dams	F
Inverts	D	Changed flow regimes (elevated low flows)	Bottom-water releases from Dams to meet irrigation demands and releases from Hydropower plants for winter power generation (e.g. Vanderkloof Dam)	F
		Temperature changes		
		Unseasonal releases		
		Increased turbidity and sediment	Intensive agriculture upstream	NF
		Water quality deterioration	Agricultural return flows, WWTW releases, pollution and run-off from Prieska	
Fish	C	Flow alterations associated the dams higher up in the catchment have resulted in changes in habitat availability at the site, cover features and water clarity.	Vanderkloof Dam and Gifkloof weir.	F
		Competition with alien fishes *G. affinis* (Mosquito fish, inferred), and *C. carpio* (Common carp, inferred	Alien invasive fishes	NF

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.

		to occur) is limited but may have a slight impact on the wellbeing of the indigenous fishes.		

2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.3.2.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	N/A	No available data to establish trends
Water Quality	N/A	Inadequate data at D7H002 to determine trend
Macroinvertebrates	Stable	No JBS1 data to establish MIRAI trends. Historical SASS data, although limited to one other point in 2008, indicates a generally stable trend, though a slight decrease in ASPT, SASS and the number of taxa was observed in 2015.
Fish	Stable	The wellbeing of the fish communities in the study area over the past five years (in comparison with JBS I) appears to be stable. In this assessment a greater diversity of fishes were collected but these fishes were generally considered to have occurred in the study area previously. Some concerns associated with the commonness of the barbs, Orange-Vaal smallmouth yellowfish (LAEN) and the Rock catfish (ASCL) are concerning. There is no evidence that any fishes expected to occur in the study area are no longer present in the reach of the Orange River assessed in the study.

3.1.3.3 OSAEH_26_17 – Orange River at Gifkloof (D7ORAN-GIFKL)

3.1.3.3.1 Site Description

The site is located approximately 400 meters downstream of the weir on the Orange River near Gifkloof. Surrounding land-use is predominantly irrigated agriculture, with several small holdings in close proximity to the river. The macro-channel, while over 1km wide, encompasses numerous smaller vegetated islands as well as several larger cultivated islands. The islands are separated by a network of open water braids comprising riffle-run habitat with loose cobble/boulder and bedrock substrate. Gravel sand and mud habitats at the site are confined mainly to the edges of the vegetated islands, while loose cobble riffle habitat is limited to a short reach of about 15 meters on the left hand bank. Riparian zones are dominated by dense woody vegetation that includes alien invasive species.

Longitude	21.401059°	**Latitude**	-28.437353°
Altitude (m.a.s.l.)	851	**Water Management Area**	Lower Orange
Level 2 EcoRegion	26.05	**Quaternary Catchment**	D73E
Geomorphological Zone	Lowland river	**Vegetation**	Lower Gariep Alluvial Vegetation

Upstream	Downstream

3.1.3.3.2 Present Ecological State (PES)

IIHI	Integrity Score: 72 Integrity Category: C The primary impact at the site was the unnaturally high flows from the Gariep and Vanderkloof Dam releases. Additional impacts included limited water abstraction, water quality modification from upstream and surrounding agricultural influences and solid waste.
RIHI	Integrity Score: 68 Integrity Category: C The principle impacts were the removal of vegetation from the riparian zone for agriculture and canal and road construction, the flow modification leading to changes in vegetation structure and channel modification from construction of the canal. Further minor impacts included the presence of exotic vegetation and bank erosion.
Rip veg	EcoStatus: D (56.9%) **Marginal zone:** A narrow band dominated by grasses: *Cynodon dactylon*, *Hemarthria altissima* and *Phragmites australis*. *Gomphostigma virgatum* forms a less dominant woody instream component with overhanging trees from the non-marginal zone. **Non-marginal zone:** Left bank comprises of a very steep bank with dense cover provided by mature trees such as *Salix mucronata*, *Searsia pendulina*, *Tamarix usneoides*, *Ziziphus mucronata*, and the occasional shrub (*Diospyros lyciodes* and *Lycium bosciifolium*). Open, less wooded areas contain herbs such as *Mesembryanthemum guerichianum* and *Senecio* cf. *erysimoides*. Islands are predominantly made up of dense stands of *P. australis* with patches of thickets established on larger islands. Invasive alien plants recorded at the site include *Eucalyptus* cf. *camaldulensis*, *Prosopis glandulosa* (dominant), *Verbena officinalis* and *Verbesina encelioides*.

WQ	Moderate salt concentrations recorded at this site. JBS 2 data indicated moderately elevated nitrate concentrations, aligned to sporadic excessive nitrogen levels recorded in the historical data for site D7H005. The chlorophyll *a* concentration recorded during JBS 2 was also notably elevated at 17 µg/l. Phosphorus concentrations in the historical data were generally low to moderate.
Diatoms	The diatoms assessment at this site resulted in a B/C or moderately modified ecological category. The SPI score was a high 14.8 (out of maximum of 18). At this site the 400 diatoms evaluated included just 28 species with a few deformities (0.3%). Very high dominance of diatom species intolerant to water quality alterations suggests that the water quality at this site is in a very good state.
Inverts	Jul 2015 (JBS2): SASS5 Score: 151 No of Taxa: 26 ASPT: 5.8 Jul 2015: SASS5 Score: 122 No of Taxa: 20 ASPT: 6.1 Aug 2014: SASS5 Score: 144 No of Taxa: 23 ASPT: 6.3 Nov 2013: SASS5 Score: 128 No of Taxa: 20 ASPT: 6.4 Nov 2010: SASS5 Score: 134 No of Taxa: 22 ASPT: 6.1 Key taxa expected but not observed at the site were generally those with preferences for moderate water quality, cobble and vegetation habitats such as Perlidae, Hydropsychidae (> 2 species), Ecnomidae, Libellulidae and Aeshnidae, but also those taxa that prefer standing water to low flow as well as vegetation (Gerridae, Corixidae, Nepidae, Notonectidae, Belostomatidae, Hydrophilidae). Abundances of most invertebrate taxa at the site were as expected. Elevated flows in conjunction with deep run and riffle sections at the site resulted in sampling efforts being restricted largely to left hand bank, where suitable cobble/boulder riffle habitat along with marginal and submerged aquatic vegetation occurred - all of which was present both in and out of current. GSM and some vegetation were also sampled from the edges of a vegetated island in the main channel. Both the Thalweg and the right hand bank were dominated by large bedrock areas with deep and fast-flowing rapids. The MIRAI EC was calculated as a C (69.6%).
Fish	The fish community wellbeing evaluation resulted in a moderately modified ecological state (Category C (69.6%)). At this site six of the expected eleven indigenous fishes were collected using active electrofishing methods and passive netting techniques. Common fishes included *L. capensis* (Orange River mudfish). *L. aeneus* (Vaal-Orange yellowfish) and the local cichlids including *T. sparmanii* (Banded tilapia) and *P. philander* (Southern mouthbrooder). At this site a few *C. gariepinus* (Sharptooth catfish) individuals and *L. kimberleyensis* (Vaal-Orange largemouth yellowfish) were collected in the deeper habitats using netting techniques. At this site no *Barbus* sp. (barbs) *A. sclateri* (Rock catfish) and *L. umbratus* (Moggel) individuals were collected. The health condition of the fishes collected was generally good with limited parasitic infections observed.

3.1.3.3.3 EcoStatus

Driver Components	PES
IHI: Instream	C
IHI: Riparian	C
Water Quality (Diatom SPI)	B/C
Response Components	**PES**
Riparian Vegetation	D
Macroinvertebrates	C
Fish	C
EcoStatus	C

3.1.3.3.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	C	Modification of natural flows	Releases from Gariep and Vanderkloof Dams	F
RIHI	C	Reduction in vegetation cover and abundance	Vegetation removal for agriculture and construction	NF
		Modification of channel shape and habitat continuity	Construction of the canal	
Rip veg	B/C	Increase in woody vegetation cover	Less frequent flooding due to flow regulation by large impoundments upstream	F
		Removal of vegetation	Extensive cultivation on the main island, water canal, access roads and picnic sites	NF
		Change in plant species composition	Heavy infestation of *Prosopis glandulosa*	
WQ	B	Sporadic nitrogen enrichment.	Irrigated agriculture.	NF
		Altered temperature and dissolved oxygen regimes downstream of impoundments	Releases from Gariep and Vanderkloof Dams	F
Inverts	C	Decreased flows during wet season and increased base flows in dry season.	Dams and weirs upstream	F
		More uniform flows throughout the year		
		Limited available cobble habitat	Flow regime changes from dams	
		Water quality deterioration and algal growth	Surrounding agriculture. Increases in nutrients as a result of agricultural return flows and irrigation/fertilisers	NF
Fish	C	Flow alterations associated with the weir at Gifkloof and altered flows in the river due to the dams higher up in the catchment have resulted in changes in habitat availability at the site, cover features and water clarity.	Vanderkloof Dam and Gifkloof weir.	F
		The Gifkloof weir acts (D7H006) as a barrier and affects the upstream movement of fishes in the study area. The barrier affects the movement of species between reaches in the study areas and affects habitat availability.	Gifkloof weir	
		Water quality alterations affecting fish community wellbeing at the site included nutrient enrichment threats attributed to the local agricultural activities. Associated threats may include pesticide for example.	Local/regional agricultural activities upstream of the site.	NF
		Competition with alien fishes *G. affinis* (Mosquito fish, inferred), and *C. carpio* (Common carp, inferred to occur) is limited but may have a slight impact on the wellbeing of the indigenous fishes.	Alien invasive fishes	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.3.3.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	The VEGRAI category fromJBS2 remains unchanged from JBS1 (i.e. D category)
Water Quality	Unclear	Inadequate data at D7H005 to determine trend
Macroinvertebrates	Decline	When compared to JBS1 data, the MIRAI calculated for JBS2 revealed a decline from a mid B to a mid C category. SASS 5 data from JBS2 compared to historical SASS data for the site (from the

		River Health Programme) also indicates a slight decline from an ASPT of 6.4 to 5.8 from 2013-2015. Confidence in the trend is, however, low owing to minimal data.
Fish	Stable	The wellbeing of the fish communities in the study area over the past five years (in comparison with JBS I) appears to be stable. In this assessment a greater diversity of fishes were collected but these fishes were generally considered to have occurred in the study area previously. Some concerns associated with the commonness of the barbs, Orange-Vaal smallmouth yellowfish (LAEN) and the Rock catfish (ASCL) are concerning. There is no evidence that any fishes expected to occur in the study area are no longer present in the reach of the Orange River assessed in the study.

3.1.3.4 OSAEH_26_04 – Hartbees River

3.1.3.4.1 Site Description

Site is on the Hartbees River 15 km south of Kakamas town. It is an ephemeral system bounded by a relatively extensive floodplain (approximately 600 metres-wide) that drains in a northerly direction into the Orange River. The river system forms part of the Nama-Karoo Ecoregion. The site contains two main channels that flow intermittently, and for short periods of time, provided that rainfall is sufficient to generate surface run-off. For most of the time water is carried as sub-surface (hyporheic) flow. During times of surface flow (*albeit* brief) the sandy river bed becomes inundated, collecting and transporting sediments and debris downstream. Marginal and non-marginal zones are dominated by woody vegetation cover, notably the invasive trees *Prosopis* and *Tamarix*. Both species tolerate harsh, dry environments, and form dense thickets thereby outcompeting natural vegetation. The extent of the broader floodplain is clearly defined by the contrast of a woody riparian component and the terrestrial shrub communities.

Longitude	20.642833°	**Latitude**	-28.857377°
Altitude (m.a.s.l.)	683	**Water Management Area**	Lower Orange
Level 2 EcoRegion	26.02	**Quaternary catchment**	D53J
Geomorphological zone	Lower Foothills	**Vegetation**	Bushmanland Arid Grassland

Upstream

Downstream

3.1.3.4.2 Present Ecological State (PES)

RIHI	Integrity Score: 63 Integrity Category: C The key impacts at the site were vegetation removal and channel modification from the construction of the road crossing across the channel width and intensive bank erosion.
Rip veg	EcoStatus: D (57%) **Marginal zone:** Not well defined as the system is ephemeral in nature and has not experienced flow in months preceding the assessment. **Non-marginal zone:** The broad, relatively flat non-marginal zone is dominated by *Tamarix usneoides* and exotic *Prosopis* trees. Other less dominant plants include *Acacia karoo* (tree), *Caroxylon sp.* (shrub), *Lycium horridum* (shrub) and various herbs (e.g. *Atriplex sp.*, *Galenia sp.*, *Mesembryanthemum guerichianum* and *Tribulus sp.*). The site had very little grass cover with only a few species recorded, namely *Cladoraphis spinosa*, *Schmidtia kalahariensis* and *Stipagrostis sp.* Invasive alien plants recorded include *Prosopis sp.* (dominant) and *Argemone ochroleuca*.

3.1.3.4.3 EcoStatus

Driver Components	**PES**
IHI: Riparian	C
Response Components	**PES**
Riparian Vegetation	D

3.1.3.4.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
RIHI	C	Channel modification	Construction of road-crossing	NF
		Vegetation removal	Construction of road-crossing	
Rip veg	D	Change in plant species composition	Infestation of invasive alien plants	NF
		Removal of vegetation and plant cover	Road crossing and culverts and grazing by livestock	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.3.4.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	N/A	No available data to establish trends
Water Quality	N/A	No available data to establish trends
Macroinvertebrates	N/A	No available data to establish trends
Fish	N/A	No available data to establish trends

3.1.3.5 OSAEH_28_02 – Orange River at Blouputs (D7ORAN-BLOUP)

3.1.3.5.1 Site Description

The site is located on the Orange River at Blouputs approximately 21 km downstream of Augrabies Falls National Park. Surrounding land-use comprises of intensive cultivation along the banks of the river with certain areas of natural or degraded vegetation. The site is characterised by a braided macro-channel with interspersed islands possessing dense reed vegetation. The active channel had a wide range of flow and habitats with a dominant rapid section and large pools upstream and downstream. Instream features include medium to fast flowing cobble biotopes, limited slow-flowing out-of-current marginal sections with gravel, sandy and rock substrate and an array of marginal and submerged vegetation. The riparian zone has a reasonable diversity of vegetation with large areas of dense reed vegetation and a narrow band of *Tamarix* trees.

Longitude	20.171900°	**Latitude**	-28.510598°
Altitude (m.a.s.l.)	310	**Water Management Area**	Lower Orange
Level 2 EcoRegion	28.01	**Quaternary catchment**	D81B
Geomorphological zone	Lowland river	**Vegetation**	Lower Gariep Alluvial Vegetation

Upstream	**Downstream**

3.1.3.5.2 Present Ecological State (PES)

IIHI	Integrity Score: 70 Integrity Category: C The key impact was the excessive flows resulting from upstream Gariep and Vanderkloof Dam releases and possible releases from Boegoeberg Dam. Additional impacts include bed modification from filamentous algal growth, water abstraction for agriculture and water quality modification.
RIHI	Integrity Score: 77 Integrity Category: C The primary impacts include flow modifications from dam releases leading to a change in vegetation structure and vegetation removal for agriculture, road construction and trampling by livestock. Further impacts include the presence of exotic vegetation and channel modification from the road construction.
Rip veg	EcoStatus: C (63.1%) **Marginal zone:** Dominated by dense stands of *Phragmites australis* (reed) with localised patches of *Hemarthria altissima* (grass) and *Gomphostigma virgatus* (shrub). **Non-marginal zone:** Lower flood terraces and islands have dense stands of *P. australis* (dominant), with woody vegetation occupying the upper banks. Dominant trees recorded at the site include *Tamarix usneoides* and the exotic tree *Prosopis glandulosa*. Open, sandy areas support patches of *Cynodon dactylon* and a good diversity of herbs (e.g. *Hypertelis salsoloides*, *Helichrysum sp.*, *Heliotropium sp.*, *Osteospermum microcarpum*, *Tricodesma africanum*). Other invasive alien plants recorded at the site include: *Nicotiana gluaca*, *Ricinus communis*, *Solsala kali*.
WQ	There is no representative DWS historical water quality site in the proximity of OSAEH 28_2. This assessment if is low confidence as is currently only based on JBS 1 data. The data indicates moderate levels of dissolved salts and nutrients. However, based on the surrounding land-use comprising intensive cultivation along the banks of the river, nutrient enrichment is likely.
Diatoms	The diatoms assessment at this site resulted in a C or moderately modified category. The SPI score was a 13.9 (out of maximum of 18). At this site the 400 diatoms evaluated included 23 species with a low deformity percentage of 0.8%. Overall the water quality was rated as fair.
Inverts	Jul 2015 (JBS 2): SASS5 Score: 145 No of Taxa: 23 ASPT: 6.3 Jul 2015: SASS5 Score: 139 No of Taxa: 24 ASPT: 5.8 Nov 2013: SASS5 Score: 120 No of Taxa: 21 ASPT: 5.7 May 2010: SASS5 Score: 135 No of Taxa: 20 ASPT: 6.8

	In general, most taxa present at the site were recorded in a B abundance (specifically the mayfly taxa including Tricorythidae, Caenidae, Heptageniidae, Leptophlebiidae, Baetidae) while Chironomidae were present in a C abundance. Only two species of Hydropsychidae (namely *C. thomasetti* and *C. scottae*) were present. Taxa expected but not observed at the site included those with a preference for standing to very slow water with low to moderate water quality requirements, and also vegetation and cobble habitats namely, Libellulidae, Corixidae, Gerridae, Belostomatidae, Dytiscidae, Tabanidae, and Ceratopogonidae. A few taxa with a preference for very fast flow and high water quality requirements (e.g. Perlidae, Hydropsychidae (>2 species)) were also absent. High flows, atypical for the time of year, again resulted in the main channel (comprising fast and deep rapid sections dominated by boulder/cobble substrates) being inaccessible for sampling. The section of active channel, immediately adjacent to the left hand bank, that was sampled included cobble/boulder riffles of varying depths and velocities. Marginal out of current areas in conjunction with the edges of vegetated islands provided a wide range of habitats which were comprised of GSM, marginal and submerged vegetation as well as stones. Filamentous algae was present on the stones in both the run and riffle biotopes in great abundance. The MIRAI EC was calculated as a C (67.7%).
Fish	The application of the fish community metric index resulted in a moderately modified state (Category C (63.1%)). Five species of indigenous fishes from an expected species list of 13 species were collected using electrofishing techniques. Common fishes observed included *L. capensis* (Orange River mudfish), *L. aeneus* (Vaal-Orange yellowfish) and the local cichlids including *T. sparmanii* (Banded tilapia) and *P. philander* (Southern mouthbrooder). At this site a few *B. hospes* (Namaqua barb) individuals were collected. Although the sampling effort was limited, no other expected barbs (B. trimaculatus, Threespot barbs and Barbus paludinisus, Straightfin barb), *A. sclateri* (Rock catfish), A. mossambicus (longfin eel) and *L. umbratus* (Moggel) individuals were collected. The health condition of the fishes collected was excellent with limited parasitic infections observed.

3.1.3.5.3 EcoStatus

Driver Components	**PES**
IHI: Instream	C
IHI: Riparian	C
Water Quality (Diatom SPI)	C
Response Components	**PES**
Riparian Vegetation	C
Macroinvertebrates	C
Fish	C
EcoStatus	C

3.1.3.5.4 Main Impacts at the Site

	PES	**Causes[1]**	**Sources[2]**	**F[3]/NF[4]**
IHI	C	Alteration to natural flows	Releases from Gariep and Vanderkloof Dams	F
		Bed modification from excessive filamentous algae growth	Increase in excessive nutrients from surrounding agriculture	NF
		Water quality modification	Increase in excessive nutrients from surrounding agriculture	

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2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

RIHI	C	Reduction in vegetation cover and abundance	Vegetation removal for agriculture, road construction and livestock trampling	NF
Rip Veg	C	Increased cover and abundance of herbaceous vegetation	Due to flow regulation by large impoundments upstream	F
		Increased woody vegetation	Less frequent flooding by large return period events	
		Removal of vegetation	Cultivation on upper banks, footpaths, livestock and associated bank collapse	NF
		Change in plant species composition	Small infestation of invasive alien plants	
WQ	C	The dominance of the diatom species that are highly tolerant to altered water quality indicate that there are high nutrient and or salt loads at this site	Agricultural activities upstream and locally	NF
		Potential nutrient enrichment		
		Altered temperature and dissolved oxygen regimes downstream of impoundments	Releases from Gariep and Vanderkloof Dams	F
Inverts	C	Elevated base flows	Discharges to meet demands for winter power generation and irrigation (e.g. Vanderkloof Dam)	F
		Aseasonal releases		
		Water quality deterioration	Agriculture upstream	NF
		Pesticides	Blackfly control programme	F/NF
		Filamentous/benthic algal growth	Agriculture, increased nutrients	NF
Fish	C	Flow alterations associated with releases from upstream dams have affected the habitat availability at this site, the water quality and cover features. The fish communities may be responding negatively to flow variability in the study area due to releases for power generation.	Upstream dams (Vanderkloof)	F
		Water quality alterations associated with the local and regional agricultural activities may also be altering the wellbeing of the fish communities at the site. These water quality impacts may include nutrient enrichment and associated pesticide threats.	Local and regional agricultural activities	NF
		Competition with alien fishes *G. affinis* (Mosquito fish, inferred), and *C. carpio* (Common carp, inferred to occur) is limited but may have a slight impact on the wellbeing of the indigenous fishes.	Alien invasive fishes	

3.1.3.5.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	The VEGRAI category fromJBS2 remains unchanged from JBS1 (i.e. C category)
Water Quality	N/A	No available data to establish trends
Macroinvertebrates	Increase	No JBS1 data to establish MIRAI trends. The JBS2 SASS 5 and ASPT scores when analysed in conjunction with historical SASS data, dating back to 2004 (n=6), indicates a gentle but increasing trend, with ASPT scores ranging between 4.9-6.8, SASS between 59-135 and the number of taxa between 12-22. Confidence in the trend is low owing to too few data and limited knowledge of seasonal patterns of invertebrates at the site.
Fish	N/A	No available data to establish trends

3.1.3.6 OSAEH_28_01 – Orange River at Pella (D8ORAN-PELLA)

3.1.3.6.1 Site Description

The site is located approximately 0.78 km from the Pella Pump Station. The site has a relatively constrained active channel of 0.12 km with a shallow, fast-flowing section upstream becoming deeper and slower flowing downstream. Flow across the channel width is fairly uniform. The left bank possesses limited habitat diversity of instream habitats. Substrate is mostly of cobbles and boulders with a high degree of embeddedness. Marginal vegetation was limited but there was extensive aquatic plant growth. The riparian zone was relatively narrow along the left bank.

Longitude	19.172805°	**Latitude**	-28.958260°
Altitude (m.a.s.l.)	441	**Water Management Area**	Lower Orange
Level 2 EcoRegion	28.01	**Quaternary catchment**	D81F
Geomorphological zone	Lowland river	**Vegetation**	Eastern Gariep Rocky Vegetation

Upstream	Downstream

3.1.3.6.2 Present Ecological State (PES)

IIHI	Integrity Score: 63 Integrity Category: C The key impacts included the regulation of flows from impoundment releases, excessive sedimentation leading to a high degree of cobble embeddedness and water quality impairment from surrounding land-use and upstream influences. Additional impacts include water abstraction for agriculture, the presence of invasive alien macrophytes and solid waste dumping.
RIHI	Integrity Score: 78 Integrity Category: B/C The primary impacts were removal of vegetation for agriculture and livestock trampling, bank erosion and physico-chemical inputs from the active channel. An additional minor impact was the presence of invasive alien plants.
Rip veg	EcoStatus: C/D (61.9%) **Marginal zone:** The left bank has dense herbaceous cover dominated by *Cynodon dactylon*, *Cyperus marginatus* and *Phragmites australis*, while the right bank is more open with exposed sands, rocks and cobbles and patches of *C. dactylon*. **Non-marginal zone:** The exotic tree *Prosopis glandulosa* has formed dense thickets on the narrow, relatively steep left bank with the occasional *Acacia karoo* and *Tamarix usneoides*. The right bank is largely covered by a mosaic of sands and rocks/cobbles with open scrub vegetation positioned higher up the non-marginal zone. The small shrubs *Kissenia capensis* and *Litogyne gariepina* occur as patches across the site, and few herbs were noted (e.g. *Cleome foliosa* var. *lutea*). Islands have dense mats of *C. dactylon* on alluvial deposits. Invasive alien plants recorded at the site include: *Conyza sp.*, *Nicotiana gluaca* and *Prosopis glandulosa* (dominant).
WQ	Historical data from D8H008 indicates moderate concentrations of dissolved salts, with elevated suspended solids at times (95-percentile statistic 145 mg/l). Intermittent nutrient enrichment was also recorded.
Diatoms	The diatoms assessment at this site resulted in a C/D or moderately/largely modified category. The SPI score was a 10.7 (out of maximum of 18). At this site the 400 diatoms evaluated included 37 species with a low deformity percentage of 0.5%. Overall the index indicates very poor integrated water quality.
Inverts	Jul 2015 (JBS 2): SASS5 Score: 138 No of Taxa: 23 ASPT: 6.0 Jul 2015: SASS5 Score: 78 No of Taxa: 16 ASPT: 4.9 Nov 2013: SASS5 Score: 104 No of Taxa: 19 ASPT: 5.5

	The greatest factor affecting invertebrates at the site were atypically high flows for this time of year as a result of upstream Dam and Hydropower releases and also water quality impacts including increased sedimentation and benthic algal growth. The increased base flows appear to have had an impact on those taxa with a preference for moderate flows as well as standing water such as Ancylidae, Lymnaeidae and Thiaridae - all of which were expected but not observed. Furthermore invertebrates with a preference for vegetation and loose cobble habitat were also affected, with taxa such as Tricorythidae and Hydropsychidae (>2 species) and various Hemiptera (e.g. Gerridae, Belostomatidae and Notonectidae) not being observed. Gomphidae and Corixidae though sampled at the site were expected in higher abundances. Elevated flows resulted in limited habitat being accessible for sampling. Sampled habitat included areas of deep and fast flowing runs, dominated by boulder/cobble substrate with a high degree of embeddedness. In addition recently inundated riffles comprising cobble and gravel substrate, close to the left hand bank, were sampled along with slow flowing areas of out of current submerged aquatic and riparian vegetation and stones. Marginal vegetation consisted primarily of Phragmites and grass. The MIRAI EC was calculated as a C (69.6%).
Fish	The wellbeing evaluation of the fish community at this site resulted in a moderately modified ecological state (Category C (64.1%)). At this site five of the expected eleven indigenous fishes were collected using active electrofishing methods only. Common fish species observed included *L. capensis* (Orange River mudfish) *L. aeneus* (Vaal-Orange yellowfish) and the local cichlids including *T. sparmanii* (Banded tilapia) and *P. philander* (Southern mouthbrooder). At this site *C. gariepinus* (Sharptooth catfish) and the alien *C. carpio* (Common carp) was observed. At this site no *Barbus* sp. (barbs) *A. sclateri* (Rock catfish), *A. mossambicus* (longfin eel) and *L. umbratus* (Moggel) individuals were collected. The health condition of the fishes collected was excellent with limited parasitic infections observed.

3.1.3.6.3 EcoStatus

Driver Components	PES
IHI: Instream	C
IHI: Riparian	B/C
Water Quality (Diatom SPI)	C/D
Response Components	**PES**
Riparian Vegetation	C/D
Macroinvertebrates	C
Fish	C
EcoStatus	C

3.1.3.6.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	C	Deterioration of water quality	Excessive nutrient input from surrounding agriculture	NF
		Excessive sedimentation of benthic habitats	Overgrazing by livestock from surrounding landscape has caused an increase in erosion	
		Modification of natural flows	Releases from Gariep and Vanderkloof Dams	F
RIHI	B/C	Reduction in vegetation cover and abundance	Overgrazing and trampling by livestock	NF
		Bank erosion	Reduction in vegetation cover and livestock paths	

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
Rip Veg	C/D	Removal of riparian vegetation	Predominantly for cultivation/firewood, but also footpaths/vehicle tracks and livestock grazing/browsing	NF
		Change in plant species composition and decrease in diversity of indigenous plants	High infestation of *Prosopis glandulosa* on the left bank	
WQ	C/D	The dominance of the diatom species that are highly tolerant to altered water quality indicate that there are high nutrient and or salt loads at this site	Agricultural activities upstream and locally	NF
		Intermittent nutrient enrichment		
		Altered temperature and dissolved oxygen regimes downstream of impoundments	Releases from Gariep and Vanderkloof Dams	F
Inverts	C	Decreased flows during wet season and increased base flows in dry season.	Dams and weirs upstream leading to flow regime changes	F
		Water quality deterioration and algal growth	Increases in nutrients as a result of upstream agricultural return flows and irrigation/ fertilisers	NF
		Sedimentation	Dam maintenance upstream, upstream agriculture, catchment run-off	
		Pesticides	Blackfly control programme	NF/F
Fish	C	Flow alterations associated with releases from upstream dams has affected the habitat availability at this site, the water quality and cover features. The fish communities may be responding negatively to flow variability in the study area due to releases for power generation.	Upstream dams (Vanderkloof)	F
		Competition with alien fishes *G. affinis* (Mosquito fish, observed), and *C. carpio* (Common carp, inferred to occur) is limited but may have a slight impact on the wellbeing of the indigenous fishes.	Alien invasive fishes	NF

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.3.6.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	N/A	No available data to establish trends
Water Quality	N/A	Inadequate data at D8H008 to determine trend
Macroinvertebrates	Stable	No JBS1 data to establish MIRAI trends. The JBS2 SASS 5 and ASPT scores are the highest recorded for the site. Analysis of historical SASS data, dating back to 2004 (n=5), indicates a generally stable trend, with ASPT scores ranging between 5.7-4.8, SASS between 34-104 and the number of taxa between 6-19.
Fish	Stable	The wellbeing of the fish community at the study area has been maintained over the past five years (between JBS 1 and JBS 2). Impacts identified at the site that are altering the wellbeing of the fish community moderately are flow related due to abnormal flow released from upstream dams

		for power generation and to maintain the irrigation requirements along the Orange River.

3.1.3.7 OSAEH_28_03 – Orange River at Grootmelkboom

3.1.3.7.1 Site Description

The site is located on the Orange River approximately 80 km upstream of Vioolsdrif and 20 km upstream of the RHP site D8ORAN-GOODH. The surrounding land-use was largely natural vegetation barring a small area of low-density subsistence livestock farming. The macro-channel was approximately 0.32 km wide with an extensive floodplain on the left bank. The active channel at the site was an un-braided system possessing a relatively large boulder/cobble-dominated riffle section with a deep pool downstream. However, a network of braids was present immediately upstream of the site. The right-hand bank was deeply incised creating deep fast-flowing rapids with large areas of bedrock. A narrow riparian area was present on the right bank, bordered by a steep rocky hillside. The left bank possessed small alcoves of slack water vegetated with reeds and other aquatic plants.

Longitude	18.391482°	**Latitude**	-28.897728°
Altitude (m.a.s.l.))	209	**Water Management Area**	Lower Orange
Level 2 EcoRegion	28.01	**Quaternary catchment**	D82A
Geomorphological zone	Lowland river	**Vegetation**	Lower Gariep Alluvial Vegetation

Upstream **Downstream**

3.1.3.7.2 Present Ecological State (PES)

IIHI	Integrity Score: 85 Integrity Category: B The key impact is the unnaturally high flows as a result of releases from Vanderkloof and Gariep Dams and possibly Boegoeberg Dam. Additional impacts include bed modification from hair algae growth and sedimentation and impacts to water quality from upstream influences.
RIHI	Integrity Score: 82 Integrity Category: B The principle impacts to the site comprise of vegetation removal from livestock grazing and trampling and sustained flows during the dry season influencing vegetation structure.
Rip veg	EcoStatus: B (82.0%) **Marginal zone:** The left bank has fairly wide marginal zone of cobbles and boulders, with patches of *Cynodon dactylon*, *Gomphostigma virgatus* and *Phragmites australis* interspersed. A smaller proportion of cover comprised of *Cyperus marginatus* (sedge), *Litogyne gariepina* (small shrub), *Heliotropium sp.* (herb), *Melica decumbens* (grass). The right bank has a narrow marginal zone dominated by *P. australis* with overhanging trees broken by sections of exposed boulders and bedrock. **Non-marginal zone:** The left bank has a wide, relatively flat non-marginal zone with an extensive band of rocks/cobbles bounded by exposed sands on the upper banks. The dominant vegetation cover is made up of *Prosopis glandulosa* (exotic tree), followed by indigenous shrubs and trees (e.g. *Euclea pseudebenus*, *Ficus cordata*, *Sisyndite spartea* and *Tamarix usneoides*). A variety of herbs were also noted (e.g. *Hermannia stricta*). The right bank has a steep and narrow non-marginal zone with dense thickets of *Acacia karoo*, *Salix mucronata*, *Searsia pendulina* and *Ziziphus mucronata*, and exposed rocks and boulders.
WQ	There is no representative DWS historical water quality site in the proximity of OSAEH 28_3, and this site was not sampled during JBS 1. Onsite water quality tests indicated moderately elevated dissolved salt concentrations.
Diatoms	The diatoms assessment resulted in a C or moderately modified category. The SPI score was a 13.9 (out of maximum of 18). At this site the 400 diatoms evaluated included 25 species with a low deformity percentage of 0.5%. Overall the water quality was rated as average.
Inverts	Jul 2015 (JBS 2): SASS5 Score: 151 No of Taxa: 26 ASPT: 5.8 Jul 2015: SASS5 Score: 138 No of Taxa: 24 ASPT: 5.8 Aug 2014: SASS5 Score: 104 No of Taxa: 19 ASPT: 5.5 Nov 2013: SASS5 Score: 109 No of Taxa: 19 ASPT: 5.7 Compared to the sites further upstream, some improvement was observed in the overall EcoStatus of invertebrates at this site with the MIRAI EC calculated as a B/C (78.0%). Surrounding land use was largely natural, barring some low intensity grazing, and the site had an extensive natural cobble floodplain area that was dry at the time of sampling. Very little agriculture is present upstream (from around Blouputs to the site) and water quality conditions were noticeably improved. Key taxa expected but not observed were those with a preference for standing water, vegetation habitats and moderate water quality, including: Gomphidae, Gerridae, Veliidae, Tabanidae, Gyrinidae (which were observed but in lower abundance than expected) and Simuliidae (also in lower abundances than expected – likely owing to the spraying for blackfly). Perlidae have been recorded in the reference data for the site but were not collected. The sampled habitat diversity was good, barring the fact that cobbles and boulders in the riffles were somewhat embedded. The thalweg was inaccessible and thus not sampled owing to elevated flows. The MIRAI EC calculated for the site was a B/C (78.0%).
Fish	The wellbeing of the fish communities at this site were observed to be in a largely natural to moderately modified ecological state (Category B/C (64.1%)). During the survey, seven of the 13 indigenous fishes expected to occur in the study area were expected. Observed fishes included the common cyprinids; *L. aeneus* (Vaal-Orange smallmouth yellowfish), *L. capensis* (Orange River mudfish) and *B. trimaculatus* (Threespot barb), and the cichlids; *T. sparmanii* (Banded tilapia) and *P. philander* (southern mouthbrooder). Other fishes collected included a few *L. kimberleyensis* (Vaal-Orange largemouth yellowfish) and *B. hospes* (Namaqua barb). The absence of A. sclateri (Rock catfish), A. mossambicus (longfin eel), *L. umbratus* (Moggel) and *B. paludinosus* (Straightfin barb) is concerning while *C. gariepinus* (Sharptooth catfish) is considered to occur in the study area. The condition of the fishes collected was excellent with the yellowfishes in particular appearing to be in the best condition of any population observed in the study.

3.1.3.7.3 EcoStatus

Driver Components	PES
IHI: Instream	B
IHI: Riparian	B
Water Quality (Diatom SPI)	C
Response Components	**PES**
Riparian Vegetation	B
Macroinvertebrates	B/C
Fish	B/C
EcoStatus	B/C

3.1.3.7.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	B	Flow modification	Releases from upstream dams and site is situated downstream of the Orange-Pofadder and Orange-Aggenys transfers	F
		Water quality deterioration	Nutrient input from upstream land-use	NF
RIHI	B	Reduction in vegetation cover	Livestock browsing and trampling	
Rip Veg	B	Removal of vegetation cover	Footpaths, vehicle tracks, recreational area and livestock	NF
		Change in plant species composition	Infestation of *Prosopis glandulosa*	
WQ	C	The dominance of the diatom species that are tolerant to altered water quality indicate that there are water quality issues at the site	Agricultural activities upstream	NF
		Altered temperature and dissolved oxygen regimes downstream of impoundments	Releases from Gariep, Vanderkloof and Boegoeberg Dams	F
Inverts	B/C	Elevated base flows	Discharges to meet demands for winter power generation and irrigation (e.g. Vanderkloof Dam)	F
		Unseasonal releases		
		Pesticides	Blackfly control programme	NF
Fish	B/C	Flow alterations associated with releases from upstream dams have affected the habitat availability at this site, the water quality and cover features. The fish communities may be responding negatively to flow variability in the study area due to releases for power generation.	Upstream dams (Vanderkloof)	F
		Competition with alien fishes *G. affinis* (Mosquito fish, observed), C. idella (Grass carp, inferred to occur with comments from stakeholders/historical data) and *C. carpio* (Common carp, inferred to	Alien invasive fishes	NF

		occur) is limited but may have a slight impact on the wellbeing of the indigenous fishes.		

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.3.7.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	N/A	No available data to establish trends
Water Quality	N/A	Inadequate data available to determine trends
Macroinvertebrates	Stable	No JBS1 data to establish MIRAI trends. The JBS2 SASS 5 and ASPT scores when analysed in conjunction with historical SASS data, dating back to 2005 (n=6), indicates a stable trend. The ASPT score for JBS2 is very close to the historical average of 5.7. SASS5 and the no of taxa recorded in JBS2 were both higher than the historical ranges of 28-104 and 7-19 respectively.
Fish	Stable	The wellbeing of the fish communities at this site are in a stable condition which may be a slight improvement from recent (<5yrs) assessments. In particular the condition of the individuals at this site was excellent. Some important fishes were not however observed at the study area. This is indicative of the flow alterations observed at this site.

3.1.3.8 OSAEH_28_04 – Orange River at Vioolsdrift (D8ORAN-VIOOL)

3.1.3.8.1 Site Description

The site is located on the Orange River approximately 12 km from Vioolsdrift Border Post and 0.33 km downstream of the diversion weir (D8H003). Surrounding land-use includes intensive cultivation on the left bank and natural vegetation on the right bank. The channel is approximately 0.09 km wide and un-braided with fairly uniform velocity across the width of the channel. The active channel features were dominated by riffle habitat with a cobble substrate interspersed with slower flowing areas of sandy substrate, mud and submerged aquatic vegetation, particularly along the banks. The riparian zone on both banks was a floodplain system, with the right bank wider than the left bank. However, the left bank possessed a greater abundance and cover of marginal vegetation than the right bank.

Longitude	17.725099°	**Latitude**	-28.762038°
Altitude	181 m	**Water Management Area**	Lower Orange
Level 2 EcoRegion	28.01	**Quaternary catchment**	D82J
Geomorphological zone	Lowland river	**Vegetation**	Lower Gariep Alluvial Vegetation

Upstream	Downstream

3.1.3.8.2 Present Ecological State (PES)

IIHI	Integrity Score: 75 Integrity Category: C The principle impacts include flow modification from Vanderkloof and Gariep Dams and possibly Boegoeberg Dam. Further flow modifications include the upstream diversion weir and abstraction for irrigation. Minor impacts include bed modification from sedimentation and water quality impacts from surrounding land-use.
RIHI	Integrity Score: 71 Integrity Category: C The key impacts include the sustained flows during the dry season from upstream dam releases that will influence vegetation structure and the vegetation removal for the construction of the canal, agriculture and road. Further impacts include the presence of alien invasive plants and minimal bank erosion.
Rip Veg	EcoStatus: C (63%) **Marginal Zone:** The left bank has a narrow marginal zone covered predominantly by *Phragmites australis* (reed) and *Cynodon dactylon* (grass) which extend into the non-marginal zone, and large areas of exposed bedrock. The right bank consists mostly of *C. dactylon* and alluvial soils. **Non-marginal Zone:** The left bank has been altered by historic construction of the canal and access road with a low diversity of woody vegetation on the upper banks and herbaceous vegetation on the lower banks. The woody component consists largely of the trees *Searsia pendulina*, *Tamarix usneoides* and *Ziziphus mucronata*. The right bank is defined by *C. dactylon* growing on alluvial deposits with a recruitment by young *A. karoo* and *Prosopis glandulosa* that appear to be dying, possibly as a result of recent/more frequent inundation. A large proportion of the site contains exposed sands, rocks and boulders.

	Extensive areas on the right bank have recently been cleared of *P. glandulosa* resulting in sandy alluvia becoming exposed.
WQ	Data collected at the DWS site D8H003 and JBS 1 indicate moderate dissolved salt concentrations, with elevated sulphate concentration at times. Intermittent nutrient (nitrogen and phosphorus) concentrations were noted.
Diatoms	The diatoms assessment resulted in a B/C or largely natural/moderately modified category. The SPI score was a 14.4 (out of maximum of 18). At this site the 400 diatoms evaluated included 25 species with a low deformity percentage of 0.5%. Overall the water quality was rated as average.
Inverts	Jul 2015 (JBS 2): SASS5 Score: 137 No of Taxa: 24 ASPT: 5.7 Jul 2015: SASS5 Score: 87 No of Taxa: 18 ASPT: 4.8 Nov 2013: SASS5 Score: 100 No of Taxa: 18 ASPT: 5.6 May 2010: SASS5 Score: 96 No of Taxa: 16 ASPT: 6.0 Similar to site 28_3 upstream the conditions at this site were much the same and also indicative of improved water quality and habitat. Flows at this point along the lower Orange River had abated somewhat, compared to sites near Prieska, but were still elevated owing to flow regulation by dams and weirs. The diversity of sampled habitats was good at the site, with a range of substrates occurring both in and out of current. Large sections of shallow riffle, dominated by loose cobble habitat interspersed with boulder and bedrock allowed for a large area of the active channel to be sampled, barring the Thalweg which was too deep. Key taxa expected at the site but not observed were those with a preference for standing water, cobble substrate and also moderate water conditions. Most noticeably, the following reference taxa were not observed: Perlidae, Hydropsychidae (> 2 species), Aeshnidae, Dytiscidae and Culicidae. In addition although Caenidae were collected they were observed in a lower abundance than expected. As highlighted in JBS1, warmer water temperatures experienced at this site, and other areas on the lower reaches of the Orange River, promote faster growth and life-histories of invertebrates. This in turn favours taxa such as the pest blackfly Simuliidae (mainly S. *chutteri*) which can produce multiple generations in a year – leading to outbreaks of the species. Simuliidae at several riffle sites on the Orange are sprayed each year with bacteria to curb the population and prevent outbreaks. The MIRAI EC calculated for the site was a B/C (78.9%).
Fish	The state of the fish communities at this site were assessed to be in a moderately modified (Category C (73.4%)) state. At this site, six of the 13 species expected to be collected in the study area were observed using electrofishing techniques alone. Common fishes included *L. aeneus* (Vaal-Orange smallmouth yellowfish), *L. capensis* (Orange River mudfish); *B. trimaculatus* (Threespot barb), and the cichlids; *T. sparmanii* (Banded tilapia) and *P. philander* (southern mouthbrooder). A low abundance of *B. hospes* (Namaqua barb) was also collected at this site. The absence of A. sclateri (Rock catfish), A. mossambicus (longfin eel), *L. umbratus* (Moggel) and *B. paludinosus* (Straightfin barb) is concerning while *C. gariepinus* (Sharptooth catfish) is considered to occur at this site.

3.1.3.8.3 EcoStatus

Driver Components	**PES**
IHI: Instream	C
IHI: Riparian	C
Water Quality (Diatom SPI)	B/C
Response Components	**PES**
Riparian Vegetation	C
Macroinvertebrates	B/C
Fish	C
EcoStatus	C

3.1.3.8.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IIHI	C	Alteration of flows	Presence of diversion weir and releases from upstream dams and upstream abstraction of water for irrigation. Site is situated downstream of the Orange-Springbok Transfer	F
RIHI	C	Alteration of vegetation structure	Modification of natural flow cycles from upstream weirs and dam releases	
		Reduction in vegetation cover and abundance	Construction of the road and canal and clearing for agriculture	NF
Rip veg	C	Altered riparian structure	Historic construction of the canal and access road	NF
		Change in composition of indigenous riparian vegetation	High infestation of *Prosopis glandulosa* (recently cleared).	
		Removal of vegetation cover	Recreational areas, footpaths and grazing/browsing by livestock	
		Increase in cover and abundance of reed vegetation in the marginal	Reduced seasonality of base flows due to flow regulation by impoundments	F
WQ	B/C	The limited occurrence of taxa tolerant/indicative of water quality deterioration	Local and upstream input of pollutants	NF
		Intermittent nutrient enrichment	Upstream agricultural activities	
		Altered temperature and dissolved oxygen regimes downstream of impoundments	Releases from Gariep, Vanderkloof and Boegoeberg Dams	F
Inverts	B/C	Elevated base flows	Discharges to meet demands for winter power generation and irrigation (e.g. Vanderkloof Dam)	F
		Unseasonal releases		
		Water quality deterioration and algal growth	Agriculture upstream	NF
		Deteriorate marginal habitat for waders	Loss of floods (dams) and lack of zero flows	F
Fish	C	Flow alterations associated with upstream elevated releases into the lower Orange River particularly during winter are abnormal and have affected the habitat availability, cover features and	Upstream dams (Vanderkloof) and irrigation activities.	F
		Department of Water and Sanitation irrigation/gauging weir (D8H003) located upstream of this site causes barrier impacts which partially affects the upstream migration of fishes. While this weir has a fish ladder constructed on it, extremely high velocities on selected segments of the fishway will restrict access by most of the fishes (excludes the Anguillid eel).	Department of Water and Sanitation irrigation/gauging weir (D8H003)	NF
		Competition with alien fishes *G. affinis* (Mosquito fish, observed), and *C. carpio* (Common carp, inferred to occur) is limited but may have a slight impact on the wellbeing of the indigenous fishes.	Alien invasive fishes	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.3.8.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	The VEGRAI category fromJBS2 remains unchanged from JBS1 (i.e. C category)
Water Quality	Stable	Trend noted at D8H003
Macroinvertebrates	Incline	No JBS1 data to establish MIRAI trends. The JBS2 SASS 5 and ASPT scores when analysed in conjunction with historical SASS data, dating back to 2005 (n=5), indicates a gentle but increasing trend, with ASPT score for JBS2 lying just above the historical average of 5.4, while the SASS5 score and the no. of taxa in JBS2 were also higher than the historical ranges of 44-100 and 9-18 respectively. Confidence in the trend is low owing to too few data and limited knowledge of seasonal patterns of invertebrates at the site.
Fish	Stable	The wellbeing of the fish communities at the site has been maintained in a moderately modified state. Flow alterations and barrier impacts are still affecting the wellbeing of the fish communities at this site.

3.1.3.9 OSAEH_28_05 – Orange River at Potjiespram (D8ORAN-RICHT)

3.1.3.9.1 Site Description

The site was located on the Orange River at Potjiespram within the Richtersveld National Park, a formally protected area with a largely natural vegetation land-cover and close to the EWR site D8ORAN-SENDU. The macro-channel width was approximately 0.5 km wide with relatively wide floodplains. Overall, the site was characterised by a relatively high diversity of biotopes encompassing a wide range of flow velocities and available micro-habitats. Included amongst these were riffles and runs with a predominantly cobble substrate, as well as boulder-dominated rapids and vegetated islands. Flow velocity varied across the width of the channel with slower flowing areas along the margins having a high degree of cobble embeddedness. Small and shallow (less than 50 cm in depth) pools were present on the left bank flood plain. In addition, the floodplains at the site were bordered by stands of *Tamarix usneoides* within the non-marginal zone.

Longitude	16.944311°	**Latitude**	-28.077724°
Altitude	54 m	**Water Management Area**	Lower Orange
Level 2 EcoRegion	28.01	**Quaternary catchment**	D82J
Geomorphological zone	Lowland river	**Vegetation**	Lower Gariep Alluvial Vegetation

Upstream | **Downstream**

3.1.3.9.2 Present Ecological State (PES)

IIHI	Integrity Score: 86 Integrity Category: B The primary impact to the site was the excessive flows during the dry season a result of upstream dam releases. Additional impacts include slight nutrient enrichment from upstream agriculture and bed modification due to the excessive growth of filamentous algae.
RIHI	Integrity Score: 92 Integrity Category: A The primary impacts include the presence of alien invasive plants and sustained flows during the dry season that will alter vegetation structure.
Rip Veg	EcoStatus: B (86.3%) **Marginal zone:** For most part it is wide and flat, and dominated by grasses, reeds and sedges on a largely rock/cobble base. *Cynodon dactylon* and *Phragmites australis* are dominant with additional cover provided by sedges such as *Cyperus longus* and *Cyperus marginatus*. There is a small woody component made up of *Gomphostigma virgatum* and overhanging trees (*Acacia karoo* and *Salix mucronata*). **Non-marginal zone:** Both left and right banks have broad (~100 metres), flat non-marginal zones with extensive areas of exposed rocks, cobbles and boulders with patches of alluvium. Alluvial deposits on the flat areas have good grass cover, which is dominated by *C. dactylon* and a mosaic of herbs (e.g. *Sesuvium sesuvioides* and *Spergularia bocconi*) and shrubs (e.g. *Gomphocarpus fruticosus*). The upper banks have a well-defined woody component dominated by *Tamarix usneoides* on the left bank, and dense thicket of *A. karoo*, *S. pendulina*, and *Ziziphus mucronata* on the right bank. A small invasive alien component was noted, which included *Medicago polymorpha*, *Nicotiana gluaca* and *Prosopis glandulosa*.

WQ	Data collected at the DWS site D8H003 and JBS 1 indicate moderate dissolved salt concentrations, with elevated sulphate concentration at times. Intermittent nutrient (nitrogen and phosphorus) concentrations were noted.
Diatoms	The diatoms assessment resulted in a B or largely natural category. The SPI score was a 15.4 (out of maximum of 18). At this site the 400 diatoms evaluated included 22 species with no deformed cells. Overall the water quality was rated as excellent.
Inverts	Jul 2015 (JBS 2): SASS5 Score: 155 No of Taxa: 28 ASPT: 5.5 Jul 2015: SASS5 Score: 116 No of Taxa: 19 ASPT: 6.1 Nov 2013: SASS5 Score: 120 No of Taxa: 19 ASPT: 6.3 Nov 2010: SASS5 Score: 150 No of Taxa: 26 ASPT: 6.3 There was wide diversity of habitat sampled at the site and the majority of the active channel was easily accessible. As such, this site is recommended over the site at De Hoop which was sampled in JBS1. As with the sites upstream, the overall water quality and EcoStatus score of the invertebrates showed improvement compared to sites closer to Prieska and Douglas – this most likely owing to the natural surrounding land use and the result of being situated within a protected area. Similar to JBS1 the key taxa expected but not observed at the site were those with a preference for standing water or low flows (also moderate flows to some extent) as well as vegetation and water column habitat as well as low to moderate water quality. As was the case with JBS1, Belostomatidae and Planorbinae were not present. Other taxa expected but not sampled included: Leptophlebiidae, Naucoridae, Pleidae, Ecnomidae, Leptoceridae and Hydraenidae. The MIRAI EC was calculated as B/C (81.8%).
Fish	The wellbeing of the fish community at this site was evaluated to be in a largely natural to moderately modified state (Category B/C (78%)). At this site seven of the 13 species expected to occur at this site were collected. The common fishes included *L. aeneus* (Vaal-Orange smallmouth yellowfish), *L. capensis* (Orange River mudfish); *B. trimaculatus* (Threespot barb), and the cichlids; *T. sparmanii* (Banded tilapia) and *P. philander* (southern mouthbrooder). A low abundance of *C. gariepinus* (Sharptooth catfish), *B. hospes* (Namaqua barb) were also collected at this site. The absence of *A. sclateri* (Rock catfish), *A. mossambicus* (longfin eel), *L. umbratus* (Moggel) and *B. paludinosus* (Straightfin barb) is concerning.

3.1.3.9.3 EcoStatus

Driver Components	**PES**
IHI: Instream	B
IHI: Riparian	A
Water Quality (Diatom SPI)	B
Response Components	**PES**
Riparian Vegetation	B
Macroinvertebrates	B/C
Fish	B/C
EcoStatus	B

3.1.3.9.4 Main Impacts at the Site

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
IHI	B	Modification of natural flow cycles	Releases from upstream Gariep, Vanderkloof and Boegoeberg Dams	F
		Bed modification from excessive benthic algae growth	Increase in nutrient inputs from upstream agriculture	NF
RIHI	A	Alteration of vegetation structure	Sustained flows during the dry season from upstream dam releases	F

Rip veg	B	Increase in woody cover on the upper banks	Less frequent flooding by large return period events	F
		Small change in plant species composition	Minor infestation of invasive alien plants	NF
		Removal of vegetation	Limited stock farming	
Inverts	B/C	Decreased flows during wet season and increased dry season flow as well as a change in the seasonality (winter and summer flows are not as distinct as before dams were built upstream).	Dams and weirs upstream	F
		Water quality and associated algal growth	Agriculture. Increase in nutrients as a result of irrigation	NF
Fish	B/C	Flow alterations associated with upstream elevated releases into the lower Orange River particularly during winter are abnormal and have affected the habitat availability, cover features and	Upstream dams (Vanderkloof) and irrigation activities.	F
		Limited water quality impacts associated with nutrient enrichment from upstream agricultural activities and or from the Fish River were observed at this study.	Agricultural activities upstream of the Richtersveld nature reserve and/or the Fish River.	NF
		Competition with alien fishes *G. affinis* (Mosquito fish, observed), and *C. carpio* (Common carp, inferred to occur) is limited but may have a slight impact on the wellbeing of the indigenous fishes.	Alien invasive fishes	

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).
3 Flow related 4 Non Flow related

3.1.3.9.5 Trends Analysis

Response Components	Trend	Description
Riparian Vegetation	Stable	The VEGRAI category fromJBS2 remains unchanged from JBS1 (i.e. B category)
Water Quality	N/A	Inadequate data to determine trends
Macroinvertebrates	Stable	When compared to JBS1 data, the MIRAI calculated for JBS2 revealed the same EC category of B/C indicative of a stable trend (although only based on two points). SASS 5 data from JBS2 when compared to historical SASS data for the region (n=8) also indicated a stable trend in ASPT. The score for JBS2 (5.5) was very close to the historical average of 5.7, while the SASS score and no. of taxa recorded were both slightly higher than the average of 104 and 17 respectively. Confidence in the trend is, however, low owing to minimal data.
Fish	Stable	The wellbeing of the fish communities at the site has been maintained in a moderately modified state. Flow alterations and barrier impacts are still affecting the wellbeing of the fish communities at this site.

3.2 Groundwater Sites

In contrast to the upper Orange and Vaal River catchments, where annual rainfall is typically within the 800 to >1 000mm range, rainfall within the catchments of the lower Orange falls within the range of 100 to 500mm per annum. As such these catchments are dominated by non-perennial, intermittent and ephemeral rivers and tributaries. As a result the region relies heavily on groundwater resources for drinking water, domestic use (including municipal supply), agricultural activities (irrigation and livestock) and mining.

In addition to the low precipitation volumes, rainfall of the region is highly variable. Analysis of historical rainfall records in relation to groundwater levels shows that key recharge periods of the aquifers occur during significant rainfall events. This places impetus on the correct monitoring and management of both the quality and quantity of groundwater in these catchments for sustainable use management. A particular challenge is collaboration between counties in the monitoring and sustainable management of the key aquifers of the region which are transboundary. ORASECOM can play a strong role in facilitating cooperative governance of these groundwater resources shared by neighbouring countries.

The Joint Basin Survey 2 thus includes the sampling of select boreholes within the catchments in order to feed current data into dialogue around groundwater resource quality and management (as per recommendations in Section 2.3.3.2 of the tender dossier). For JBS2 the groundwater sampling sites were chosen based on those identified in the groundwater review of the Molopo-Nossob Basin (ORASECOM, 2009b), being further discussed during the JBS2 inception workshop. Six sites were selected (Table 1) based on their importance in sampling aquifers of key systems, all of which are located within or feed into transboundary water systems. Two sites fell in Namibia, three in Botswana (two rivers being on the border of Botswana/South Africa), and a last site in South Africa (Figure 3.8). The survey team met with member state personnel from each country in order to facilitate the sampling at their sites

Table 3.2 Groundwater sampling sites of Joint Basin Survey 2

Site code	Site name/location	Country	Latitude	Longitude	Altitude (m)
WW39840	Blumfelde/ Olifants wes	Namibia	-23.647475°	18.388726°	1 277
WW40960	Stampriet	Namibia	-24.550110°	18.562200°	1 163
BH5229	Two Rivers	Botswana	-26.469361°	20.617194°	876
BH9087	Tsabong	Botswana	-26.072368°	22.374588°	969
BH1255	Mokatako	Botswana	-25.763613°	25.226076°	1 168
42477	Tswalu	South Africa	-27.285922°	22.488683°	1 210

Water samples were collected for the laboratory analysis of 17 water quality determinands appropriate for the assessment of drinking and agricultural use purposes (Table 3.3). In addition to the laboratory analysis, an *in-situ* sample for *E. coli* contamination was collected, as well as any *in-situ* data collected by the member state personnel. For the purposes of reporting for JBS2, the sample results are compared to four sets of water quality standards or guidelines (Table 3.3);

- The World Health Organisation Guidelines for Drinking Water Quality. Fourth Edition (WHO, 2011)
- The South African National Standard for drinking water SANS: 241 (SANS, 2011).
- South African Water Quality Guidelines (Volume 5) Agricultural Use: Livestock Watering (DWAF, 1996a).
- South African Water Quality Guidelines (Volume 4) Agricultural Use: Irrigation (DWAF, 1996b).

Table 3.3 Water quality determinands against which the groundwater sampling results of Joint Basin Survey 2 were compared

Determinand	Units	Drinking WHO	Drinking SANS	Livestock DWS	Irrigation DWS
		World Health Organisation Guidelines for Drinking Water Quality. Fourth Edition (2011)	South African National Standard for drinking water SANS: 241 (2015)	South African Water Quality Guidelines (Volume 5) Agricultural Use: Livestock Watering (DWAF,1996a)	South African Water Quality Guidelines (Volume 4) Agricultural Use: Irrigation (DWAF,1996b)
Alkalinity	mg CaCO3/L	N/A	N/A	N/A	N/A
Arsenic	µg As/L	≤ 10	≤ 10	≤ 1 000	≤ 100
Calcium	mg Ca/L	N/A	N/A	≤ 1 000	N/A
Chloride (Soluble)	mg Cl/L	250	≤ 300	≤ 2 000	≤ 100
Conductivity	mS/m	25	≤ 170	N/A	N/A
Fluoride	µg F/L	1 500	N/A	≤ 2 000	≤ 2 000
Iron	mg Fe/L	N/A	≤ 0.3 (aesthetic)	≤ 10	≤ 5
Total hardness	mg CaCO3/L	N/A	N/A	N/A	N/A
Magnesium	mg Mg/L	N/A	N/A	≤ 500	N/A
Manganese	mg Mn/L	0.5	≤ 0.1 (aesthetic)	≤ 10	≤ 0.02
Sodium	mg Na/L	200	≤ 200	≤ 2 000	≤ 70
Ammonia (Soluble)*	mg N/L	N/A	≤ 1,5	N/A	N/A
Nitrate (Soluble)	mg N/L	50	≤ 11	≤ 100	N/A
pH	pH units	N/A	≥ 5 to ≤ 9,7	N/A	≥ 6.5 - ≤ 8.4
Selenium	µg Se/L	40	≤ 40	≤ 50	≤ 20
Sulphate (Soluble)	mg SO4/L	500	250 (aesthetic)	≤ 1 000	N/A
Turbidity	NTU	N/A	≤ 1(operational)	N/A	

Table 3 illustrates the legend used to indicate which samples exceed which guideline limit/s in the results tables of the groundwater sample sites which follow.

Table 3.4 Legend of colour-coding to indicate water quality guideline limit exceedance

Legend			
	Exceeds drinking water limit (WHO, 2011)	Exceeds drinking water limit (SANS, 2015)	No limit/ no exceedance
	Exceeds livestock watering limit (DWAF, 1996a)	Exceeds irrigation limit (DWAF, 1996b)	

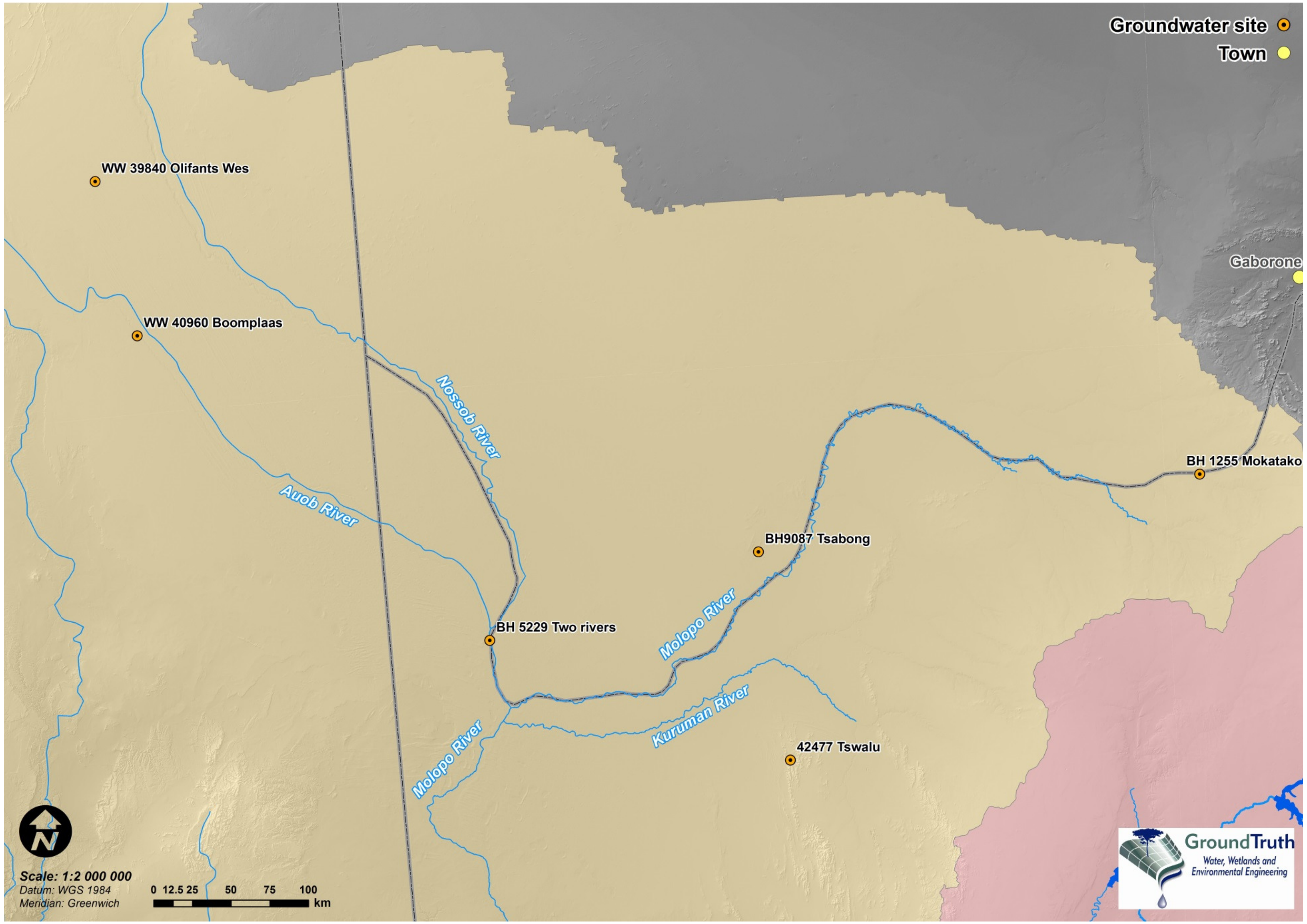

Figure 3-8 Location of Groundwater sites sampled in JBS2.

Figure 3-9 below represents a summary of four key water quality determinants per site, namely; Arsenic, Nitrate, Sodium and electrical conductivity. The subsequent sections tabulate and discuss the water quality sampling results in greater detail per site.

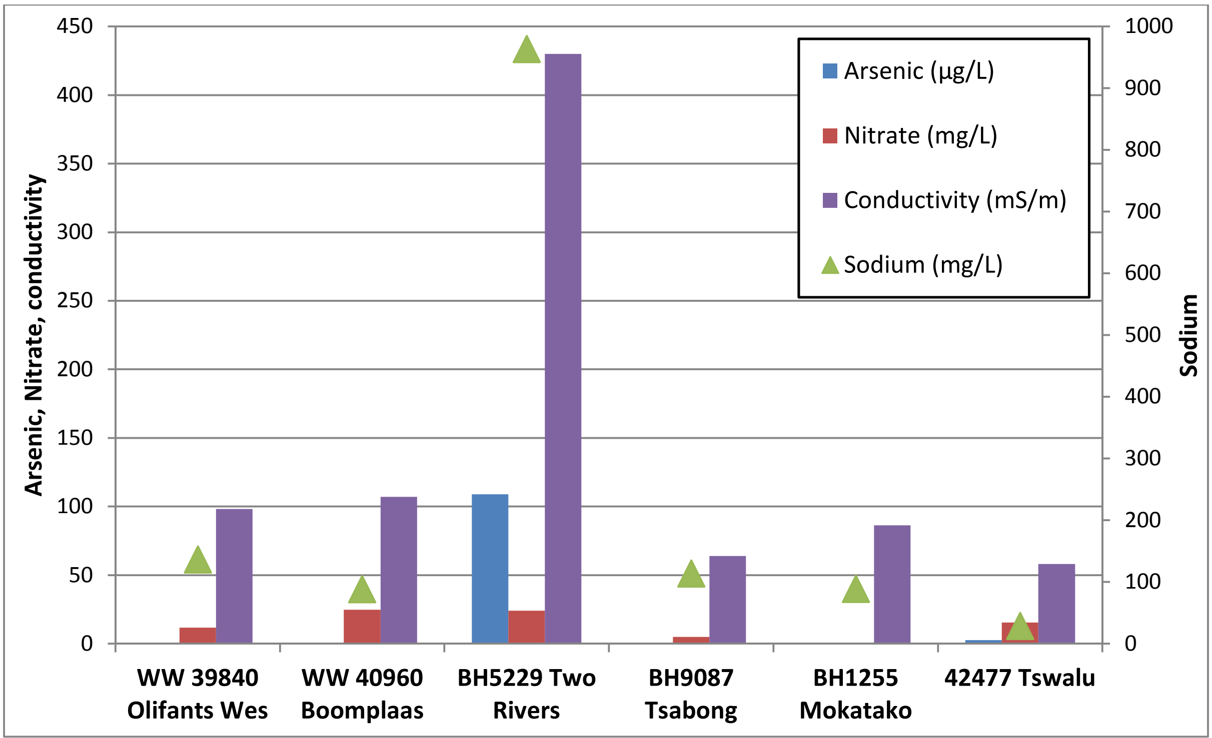

Figure 3-9 Water quality results for four key determinants at the six groundwater sites

With the exception of the Two Rivers site, the electrical conductivity across the sites falls within similar ranges, and which are typical of these groundwater sources. The Two Rivers site is located adjacent to the Nossob River immediately downstream of the Auob River confluence. Groundwater quality records associated with the Auob River system downstream of Gochas (the Salt-Block area) to the confluence shows records of poor water quality which exceeds guidelines for livestock and drinking water as a result of the regional geology (ORASECOM, 2009b). The high Arsenic level sampled shows a presence of arsenic minerals within the regional geology. While Arsenic toxicity is a risk, this sample was not at levels expected to result in a risk of chronic health effects, but may affect sensitive user groups.

Several of the determinants which are highlighted as exceeding guidelines are typically elevated in the groundwater of hot, arid areas with saline soils (i.e. Chloride, Sodium, Nitrate, electrical conductivity, Iron, Manganese) (DWAF, 1998). Nitrate and other select determinants are at a risk of being elevated by land use activities, however at the six sites sampled the underlying geology of these regions is seen as the chief driver of the water quality determinants which exceed limits and guidelines.

Various studies and reports (i.e. ORASECOM, 2009b, IGRAC, 2013) provide detailed assessments of ground water within the region, including measures to inform monitoring and management. Key challenges include the improvement of groundwater monitoring programmes, laboratory analysis and the effective cataloguing of data in databases which can inform sustainable and cooperative transboundary management. ORASECOM is working in conjunction with member states in introducing various interventions and projects which address groundwater quality and promote the cooperative governance of groundwater resources.

3.2.1 Site WW39840, Olifants Wes, Namibia

3.2.1.1 Site Description

The site is situated directly adjacent to the Olifants River near Blumfelde, approximately 115 km north-east of Mariental, Namibia. The Olifants River is a tributary of the Auob River, with the confluence located approximately 230 km downstream. The Auob River flows into South Africa, whereafter it joins the Molopo River system thus forming a transboundary water resource. The primary land-use within vicinity of Site WW39840 is livestock agriculture, with irrigated crops also present. The borehole is a Namibia Ministry of Agriculture, Water & Forestry (MWAF) monitoring borehole, which is used for monitoring purposes only. No water is drawn at this site, but with neighbouring farms drawing water for livestock watering, crop irrigation and domestic use. This borehole is 130m deep, and draws on the Auob aquifer for the purposes of monitoring the aquifer. A second monitoring borehole is located within 50m, but which draws on the deeper Nossob aquifer for monitoring purposes. The sites are sampled by the Namibian Ministry of Agriculture, Water & Forestry.

Longitude	18.388726°	**Latitude**	-23.647475°
Altitude (m.a.s.l.)	1 277	**Country**	Namibia
Date sampled	21 July 2015	**Site name**	Olifants wes
River catchment	Olifants/Auob	**Aquifer**	Auob

3.2.1.2 Water quality

At site WW 39840, while electrical conductivity exceeds the WHO guideline, the result indicates that the Total Dissolved Salt (TDS) levels of the water should produce no taste problems, with no significant health effect even on sensitive consumer groups (DWAF, 1998). The pH of the sample fell within ideal ranges for drinking water (DWAF, 1998). The *in-situ E. coli* hygiene and monitoring swab detected no signs of *E. coli*. Manganese and Sodium exceed the irrigation guideline limit (DWAF, 1996b), while Nitrate exceeds the SANS 241 drinking water limit (SANS, 2015). Sodium is typically elevated in the groundwater of hot, arid areas (DWAF, 1998). Nitrate levels can also be elevated in groundwater, and at this site exceeded the drinking water limit only by a marginal value (0,6mg/l).

In-situ water quality sampling

Determinand	Units	WW 39840
pH	pH units	8.11
Temperature	(°c)	27.5
Conductivity	(mS/m)	91.4
E.coli[1]	(CFU/ml)	0

[1]sampled *in-situ* using an *E. coli* hygiene and monitoring swab

Laboratory water quality sampling

Determinand	Units	WW 39840
Alkalinity	mg CaCO3/L	298
Arsenic	µg As/L	<2.00
Calcium	mg Ca/L	22.8
Chloride (Soluble)	mg Cl/L	59.9
Conductivity	mS/m	98.1
Fluoride	µg F/L	725
Iron	mg Fe/L	<0.02
Total hardness	mg CaCO3/L	154
Magnesium	mg Mg/L	23.4
Manganese	mg Mn/L	0.03
Sodium	mg Na/L	137
Ammonia (Soluble)*	mg N/L	<0.10
Nitrate (Soluble)	mg N/L	11.6
pH	pH units	8.10
Selenium	µg Se/L	6.15
Sulphate (Soluble)	mg SO4/L	30.9
Turbidity	NTU	0.4

Legend			
	Exceeds drinking water limit (WHO, 2011)	Exceeds drinking water limit (SANS, 2015)	No limit/ no exceedance
	Exceeds livestock watering limit (DWAF, 1996a)	Exceeds irrigation limit (DWAF, 1996b)	

3.2.1.3 Main Impacts at the Site

Causes[1]	Sources[2]
Agricultural activities may explain marginal exceedance of nitrate guideline, but may indicate natural background levels.	High volumes of water extracted for irrigated crops Agriculture: livestock and crops Natural geology of the region (nitrate belt). Salt blocks within close proximity to the site

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions. 2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).

3.2.1.4 Trend Analysis

Limited historical data was provided for this site. Samples of the last five years show similar levels of key determinants. Conductivity has increased slightly but steadily, while Fluoride showed an increase for the 2015 sample.

Historical water quality results

Site WW39840, Olifants Wes, Namibia				
Determinand	**Unit**	**Jul-10**	**Oct-14**	**Jul-15**
Alkalinity	mg CaCO3/L	295	295	298
Arsenic	µg As/L			<2.00
Calcium	mg Ca/L	18	26	22.8
Chloride (Soluble)	mg Cl/L	68	60	59.9
Conductivity	mS/m	82.6	90	98.1
Fluoride	µg F/L	500	500	725
Iron	mg Fe/L	0.01	0.23	<0.02
Total hardness	mg CaCO3/L	131	184	154
Magnesium	mg Mg/L	21	29	23.4
Manganese	mg Mn/L	0.01	0.02	0.03
Sodium	mg Na/L	137	151	137
Ammonia (Soluble)*	mg N/L			<0.10
Nitrate (Soluble)	mg N/L	7.2	14	11.6
pH	pH units	8.7	8.7	8.1
Selenium	µg Se/L			6.15
Sulphate (Soluble)	mg SO4/L	28	45	30.9
Turbidity	NTU	7.2	0.35	0.4

3.2.2 Site WW40960, Boomplaas, Namibia

3.2.2.1 Site Description

The site is situated in the Auob River catchment (900m from the Auob River) on the farm Boomplaas near Stampriet, approximately 65 km east of Mariental, Namibia. The primary land use is livestock agriculture, with irrigated crops also present. The borehole is a Namibia Ministry of Agriculture, Water & Forestry (MWAF) monitoring borehole. The site is sampled by the Namibian Ministry of Agriculture, Water & Forestry.

Longitude	18.562200°	**Latitude**	-24.550110°
Altitude (m.a.s.l.)	1 163	**Country**	Namibia
Date sampled	23 July 2015	**Site name**	Boomplaas
River catchment	Auob		

3.2.2.2 Water quality

The sample from borehole site WW40960 exceeded the WHO guideline for electrical conductivity, but was still at a level where the water should have no significant taste problems and no significant health effect even on sensitive consumer groups (DWAF, 1998). The sample showed Sodium, and to a lesser extent Manganese, to exceed the irrigation guideline limit (DWAF, 1996b). Sodium is typically elevated in the groundwater of hot, arid areas (DWAF, 1998). Nitrate and Iron both exceed the SANS 241 drinking water limit (SANS, 2015). Nitrate elevated to these levels (20mg/l) can be typical of groundwater samples (DWAF, 1998). Turbidity at this site was unusually high at the time of laboratory analysis, however it is expected that the turbidity increased artificially between the time of sampling and analysis. With non-admittance to the property during the visit, MWAF staff collected the sample two days later, with the result that the sample was couriered separately and incurred significant delays. It is expected that the raised iron in the sample precipitated with exposure to oxygen, producing elevated turbidity once it reached the laboratory. The Iron is at a level producing increasing effects in sensitive groups (DWAF, 1998). The *in-situ E. coli* hygiene and monitoring swab detected no signs of *E. coli*.

In-situ water quality sampling

Determinand	Units	WW 40960
pH	pH units	7.3
Temperature	(°c)	26.2
Conductivity	(mS/m)	105.0
E. coli [1]	(CFU/ml)	0

[1]sampled *in-situ* using an *E. coli* hygiene and monitoring swab.

Laboratory water quality sampling

Determinand	Units	WW 40960
Alkalinity	mg CaCO3/L	335
Arsenic	µg As/L	<2.00
Calcium	mg Ca/L	81.7
Chloride (Soluble)	mg Cl/L	44.8
Conductivity	mS/m	107
Fluoride	µg F/L	377
Iron	mg Fe/L	2.75
Total hardness	mg CaCO3/L	405
Magnesium	mg Mg/L	48.1
Manganese	mg Mn/L	0.06
Sodium	mg Na/L	88.5
Ammonia (Soluble)*	mg N/L	0.28
Nitrate (Soluble)	mg N/L	24.8
pH	pH units	7.22
Selenium	µg Se/L	4.49
Sulphate (Soluble)	mg SO4/L	11.8
Turbidity	NTU	138

Legend			
	Exceeds drinking water limit (WHO, 2011)	Exceeds drinking water limit (SANS, 2015)	No limit/ no exceedance
	Exceeds livestock watering limit (DWAF, 1996a)	Exceeds irrigation limit (DWAF, 1996b)	

3.2.2.3 Main Impacts at the Site

Causes[1]	Sources[2]
N/A	High volumes of water extracted for irrigated crops Livestock and agricultural cultivation Natural geology of the region

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions. 2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).

3.2.2.4 Trend Analysis

Limited historical data was provided for this site. While samples of the last five years show comparable levels of certain determinants over the period, a number have increased since 2010. Conductivity shows a slight increase in 2015. Fluoride, hardness, Magnesium and Calcium have increased significantly since 2010, but still fall well within guideline levels. Nitrate has also shown a significant increase, now exceeding the SANS drinking water limit for the 2015 sample.

Historical water quality results

Site WW40960, Boomplaas, Namibia				
Determinand	**Unit**	**Jul-10**	**Oct-14**	**Jul-15**
Alkalinity	mg CaCO3/L	316	318	335
Arsenic	µg As/L			<2.00
Calcium	mg Ca/L	2.2	6.2	81.7
Chloride (Soluble)	mg Cl/L	46	1.1	44.8
Conductivity	mS/m	76.1	75.5	107
Fluoride	µg F/L	0.6	400	377
Iron	mg Fe/L	4	7.6	2.75
Total hardness	mg CaCO3/L	35	90	405
Magnesium	mg Mg/L	7.2	18	48.1
Manganese	mg Mn/L	0.02	0.03	0.06
Sodium	mg Na/L	150	152	88.5
Ammonia (Soluble)*	mg N/L			0.28
Nitrate (Soluble)	mg N/L	1.1	0.7	24.8
pH	pH units	9.3	8.5	7.22
Selenium	µg Se/L			4.49
Sulphate (Soluble)	mg SO4/L	37	57	11.8
Turbidity	NTU	62	24	138

3.2.3 Site BH5229, Two Rivers, Botswana

3.2.3.1 Site Description

The site is situated in the Nossob River catchment at Two Rivers within the Botswana side of the Kgalagadi Transfrontier Park. The borehole is situated 150m from the Nossob River, 4km downstream of the confluence with the Auob River. The primary land use is the Kgalagadi Transfrontier Park, with Two Rivers forming a small settlement in the park containing a border post, staff housing, tourist accommodation, a petrol station, shop and workshops. The borehole supplies water for domestic purposes, subsequent to desalinitation, to the Botswana staff housing in the park at Two Rivers. This borehole draws on the Nossob aquifer.

Longitude	20.617194°	**Latitude**	-26.469361°
Altitude (m.a.s.l.)	876	**Country**	Botswana
Date sampled	23 July 2015	**River catchment**	Nossob

3.2.3.2 Water quality

At site BH5229 the *in-situ E. coli* hygiene and monitoring swab detected no signs of *E. coli*. Nine of the 17 water quality determinants sampled exceeded guideline limits for drinking, irrigation or livestock watering at this site. Excessive amounts of Arsenic can make the water poisonous. Levels at this site do exceed both the WHO (2011) and SANS (2015) guidelines for drinking water quality. While not at levels expected to result in a risk of chronic health effects, the Arsenic is at a level that may affect sensitive user groups. These sensitive groups include “some infants under 2 years of age, individuals with kidney disease and users with high water intakes (e.g. under hot conditions)” (DWAF, 1998). Chloride and Sodium exceed both the WHO (2011) and SANS (2015) guidelines for drinking water quality, but are typically elevated in the groundwater of hot, arid areas with saline soils. Chloride levels in the sample may only affect sensitive user groups, while the Sodium levels fall into a higher health risk category, particularly for sensitive groups (DWAF, 1998). The *in-situ E. coli* hygiene and monitoring swab detected no signs of *E. coli*. Electrical conductivity exceeds both the WHO (2011) and SANS (2015) guidelines for drinking water quality, reaching conductivities indicating that salt levels introduce “possible health risks to all individuals” (DWAF, 1998). Fluoride levels exceed the WHO (2011) guidelines for drinking water quality, as well as irrigation and livestock watering limits. Nitrate levels exceed the drinking water limit (SANS, 2015), and may introduce a “possible chronic health risk to some babies” (DWAF, 1998). Sulphate levels fall outside of ideal range, exceeding the SANS limit, but at levels resulting in no significant health affects (DWAF, 1998).

***In-situ* water quality sampling**

Determinand	Units	BH5229
pH	pH units	N/A[2]
Temperature	(℃)	N/A[2]
Conductivity	(mS/m)	N/A[2]
E.coli[1]	(CFU/ml)	0

[1]sampled *in-situ* using an *E. coli* hygiene and monitoring swab [2]Member state personnel did not sample *in-situ* determinands

Laboratory water quality sampling

Determinand	Units	BH5229
Alkalinity	mg CaCO3/L	859
Arsenic	µg As/L	109
Calcium	mg Ca/L	<1.00
Chloride (Soluble)	mg Cl/L	568
Conductivity	mS/m	430
Fluoride	µg F/L	6 980
Iron	mg Fe/L	<0.02
Total hardness	mg CaCO3/L	<6.67
Magnesium	mg Mg/L	<1.00
Manganese	mg Mn/L	<0.01
Sodium	mg Na/L	964
Ammonia (Soluble)*	mg N/L	<0.10
Nitrate (Soluble)	mg N/L	24.0
pH	pH units	9.38
Selenium	µg Se/L	12.2
Sulphate (Soluble)	mg SO4/L	350
Turbidity	NTU	1.2

Legend	Exceeds drinking water limit (WHO, 2011)	Exceeds drinking water limit (SANS, 2015)	No limit/ no exceedance
	Exceeds livestock watering limit (DWAF, 1996a)	Exceeds irrigation limit (DWAF, 1996b)	

3.2.3.3 Main Impacts at the Site

Causes[1]	Sources[2]
	No significant impacts or sources in the immediate upstream catchment, being a transfrontier park. The following facilities are present on a limited scale downstream of the site; border post, staff housing, tourist accommodation, a petrol station, shop and workshops. Natural geology of the region.

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions. 2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).

3.2.3.4 Trend Analysis

With limited historical data, it is evident that the exceedance of various limits is characteristic of the site. Nitrate, Magnesium and Fluoride concentrations sampled have decreased since since 2012. The pH is consistently alkaline at the site confirming the influence of the natural geology in driving the water quality and exceeding various limits.

Historical water quality results

Site BH5229, Two Rivers, Botswana				
Determinand	**Unit**	**Oct-12**	**May-14**	**Jul-15**
Alkalinity	mg CaCO3/L			859
Arsenic	µg As/L			109
Calcium	mg Ca/L	2.44	1.21	<1.00
Chloride (Soluble)	mg Cl/L	495.25	615.95	568
Conductivity	mS/m	369.8	428	430
Fluoride	µg F/L	7 440	8 090	6 980
Iron	mg Fe/L	0	0	<0.02
Total hardness	mg CaCO3/L			<6.67
Magnesium	mg Mg/L	37.31	0.39	<1.00
Manganese	mg Mn/L	0.02	0.26	<0.01
Sodium	mg Na/L	861	484.08	964
Ammonia (Soluble)*	mg N/L			<0.10
Nitrate (Soluble)	mg N/L	121.78	113.39	24
pH	pH units	9.48	9.51	9.38
Selenium	µg Se/L			12.2
Sulphate (Soluble)	mg SO4/L	303.1	360.49	350
Turbidity	NTU			1.2

3.2.4 Site BH9087, Tsabong, Botswana

3.2.4.1 Site Description

The site is situated 6km south-west of the town of Tsabong in Botswana within a sparsely populated housing area on the outskirts of the town. The primary land use of the surrounding area is the town of Tsabong, with associated housing, retail and light industrial activities. The immediate area of the borehole is comprised of sparsely distributed housing, with many residents having a small number of livestock. No irrigated crops were evident. The borehole supplies water for domestic purposes to neighbouring communities. The borehole is located within the Molopo River catchment, 17 km from the river itself.

Longitude	22.374588°	**Latitude**	-26.072368°
Altitude (m.a.s.l.)	969	**Country**	Botswana
Date sampled	23 July 2015	**River catchment**	Molopo

3.2.4.2 Water quality

The sample from borehole BH9087 south-west of the town of Tsabong in Botswana exceeded irrigation guideline limits (DWAF, 1996b) for Chloride, Sodium and pH. The sample exceeded the WHO guideline for electrical conductivity, but was still at a level where the water should have no significant taste problems and no significant health effect even on sensitive consumer groups (DWAF, 1998). In terms of drinking, the Chloride and Sodium levels in the sample fall outside of ideal ranges but form no significant health risk. The pH still falls within ideal ranges for drinking water (DWAF, 1998). The *in-situ E. coli* hygiene and monitoring swab detected no signs of *E. coli*.

In-situ water quality sampling

Determinand	Units	BH9087
pH	pH units	N/A[2]
Temperature	(°C)	N/A[2]
Conductivity	(mS/m)	N/A[2]
E.coli[1]	(CFU/ml)	0

[1]sampled *in-situ* using an *E. coli* hygiene and monitoring swab [2]Member state personnel did not sample *in-situ* determinands

Laboratory water quality sampling

Determinand	Units	BH9087
Alkalinity	mg CaCO3/L	29.1
Arsenic	µg As/L	<2.00
Calcium	mg Ca/L	<1.00
Chloride (Soluble)	mg Cl/L	123
Conductivity	mS/m	64.0
Fluoride	µg F/L	174
Iron	mg Fe/L	0.03
Total hardness	mg CaCO3/L	<6.67
Magnesium	mg Mg/L	<1.00
Manganese	mg Mn/L	<0.01
Sodium	mg Na/L	114
Ammonia (Soluble)*	mg N/L	<0.10
Nitrate (Soluble)	mg N/L	5.00
pH	pH units	6.49
Selenium	µg Se/L	<2.00
Sulphate (Soluble)	mg SO4/L	49.9
Turbidity	NTU	0.4

Legend			
	Exceeds drinking water limit (WHO, 2011)	Exceeds drinking water limit (SANS, 2015)	No limit/ no exceedance
	Exceeds livestock watering limit (DWAF, 1996a)	Exceeds irrigation limit (DWAF, 1996b)	

3.2.4.3 Main Impacts at the Site

Causes[1]	Sources[2]
Increased salinity	Rural housing/small holdings. Retail and light industrial activities in the broader catchment. Natural geology of the region

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions. 2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).

3.2.4.4 Trend Analysis

A longer record of data was available for the Tsabong site, illustrating a fairly consistent exceedance of certain determinants over the past 10 years. This again confirms the natural geology as the driver of water quality. Certain determinants such as Chloride, Sodium and conductivity show some increase over the 10 year period. Other determinants, such as Fluoride, Iron and Magnesium show some fluctuation, but still fall well within drinking water guidelines.

Historical water quality results

Site BH9087, Tsabong, Botswana									
Determinand	**Unit**	**Feb-05**	**Mar-05**	**Jun-05**	**Mar-07**	**Aug-07**	**May-10**	**Nov-10**	**Jul-15**
Alkalinity	mg CaCO3/L								29.1
Arsenic	µg As/L								<2.00
Calcium	mg Ca/L	32.32	21.14	1.86	16.08	2.34	30.91	0.23	<1.00
Chloride (Soluble)	mg Cl/L	83.71	85.71	94.24	133.75	81.27	144.56	105.33	123
Conductivity	mS/m	55	48	49	49	52	53	57	64
Fluoride	µg F/L	90	120	100			50		174
Iron	mg Fe/L	0.063	0.24	0.061	0.14	0	0.27	0.15	0.03
Total hardness	mg CaCO3/L								<6.67
Magnesium	mg Mg/L	0.165	1.23	3.74	0.24	2.34	1.79	0.52	<1.00
Manganese	mg Mn/L	0	0	0	0	0	0	0	<0.01
Sodium	mg Na/L	84.95	82.9	86.9	93.22	86.04	103.9	91.68	114
Ammonia (Soluble)*	mg N/L								<0.10
Nitrate (Soluble)	mg N/L	17.43	16.99	20.39	21.2	18.01	23.31	18.41	5
pH	pH units	6.27	6.01	6.15	5.44	6.88	5.66	5.44	6.49
Selenium	µg Se/L								<2.00
Sulphate (Soluble)	mg SO4/L	28.62	29.08	32.77	38.16	28.67	41.7	34.07	49.9
Turbidity	NTU								0.4

3.2.5 Site BH1255, Mokatako, Botswana

3.2.5.1 Site Description

The site is located on the outskirts of the village of Mokatako in Botswana. The borehole is situated directly adjacent (700m) to the Ramatlabama River, less than 1km upstream of the confluence with the Molopo River. The primary land use is a sparsely populated, small, rural village with a school and limited other amenities. Livestock were present in the village, with subsistence agriculture present on a limited scale. Large scale agriculture was present within the surrounding region, but all croplands observed were dryland agriculture. Commercial livestock farming was also observed in the region. The water is used for domestic purposes but undergoes desalinination prior to use.

Longitude	25.226076°	**Latitude**	-25.763613°
Altitude (m.a.s.l.)	1168	**Country**	Botswana
Date sampled	24 July 2015	**River catchment**	Ramatlabama/Molopo

3.2.5.2 Water quality

Site BH1255 near the Ramatlabama River at Mokatako in Botswana exceeded irrigation guideline limits (DWAF, 1996b) for Sodium. At this concentration in drinking water Sodium has no effect on human health (DWAF, 1998). The sample did exceed the WHO guideline for electrical conductivity, but was still at a level where the water should have no significant taste problems and no significant health effect even on sensitive consumer groups (DWAF, 1998). The *in-situ E. coli* hygiene and monitoring swab detected no signs of *E. coli*.

In-situ water quality sampling

Determinand	Units	BH1255
pH	pH units	N/A[2]
Temperature	(℃)	N/A[2]
Conductivity	(mS/m)	N/A[2]
E.coli[1]	(CFU/ml)	0

[1]sampled *in-situ* using an *E. coli* hygiene and monitoring swab. [2]Member state personnel did not sample *in-situ* determinands.

Laboratory water quality sampling

Determinand	Units	BH1255
Alkalinity	mg CaCO3/L	377
Arsenic	µg As/L	<2.00
Calcium	mg Ca/L	59.2
Chloride (Soluble)	mg Cl/L	34.6
Conductivity	mS/m	86.3
Fluoride	µg F/L	816
Iron	mg Fe/L	0.02
Total hardness	mg CaCO3/L	258
Magnesium	mg Mg/L	26.3
Manganese	mg Mn/L	0.02
Sodium	mg Na/L	89.2
Ammonia (Soluble)*	mg N/L	<0.10
Nitrate (Soluble)	mg N/L	<0.10
pH	pH units	7.35
Selenium	µg Se/L	3.69
Sulphate (Soluble)	mg SO4/L	29.1
Turbidity	NTU	0.3

Legend			
	Exceeds drinking water limit (WHO, 2011)	Exceeds drinking water limit (SANS, 2015)	No limit/ no exceedance
	Exceeds livestock watering limit (DWAF, 1996a)	Exceeds irrigation limit (DWAF, 1996b)	

3.2.5.3 Main Impacts at the Site

Causes[1]	Sources[2]
	Rural housing/small holdings, subsistence and commercial livestock and agricultural activities Mining within the broader catchment area Natural geology of the region

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions. 2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).

3.2.5.4 Trend Analysis

Data records from the last 5 years at Mokatako show a strong consistency in the concentrations of key determinants, including Sodium and conductivity (which routinely exceed irrigation and drinking water guidelines respectively). Other salts also show consistency in concentration, in line with the stable conductivity readings.

Historical water quality results

Site BH1255, Mokatako, Botswana							
Determinand	**Unit**	**Aug-10**	**Sep-11**	**Dec-11**	**Dec-13**	**May-14**	**Jul-15**
Alkalinity	mg CaCO3/L						377
Arsenic	µg As/L						<2.00
Calcium	mg Ca/L	60.2	67.8	59.9	101.1	58.75	59.2
Chloride (Soluble)	mg Cl/L	36.76	72.32	32.83	32.66	34.81	34.6
Conductivity	mS/m	86	81.1	85.4	89.4	85	86.3
Fluoride	µg F/L	0.49	0.7	0.72	0.46	0.47	816
Iron	mg Fe/L	0.14	0.05	0.2	0.35	2.11	0.02
Total hardness	mg CaCO3/L						258
Magnesium	mg Mg/L	41.05	30.1	23.05	31.2	39.62	26.3
Manganese	mg Mn/L	0.13	0	0	0	0	0.02
Sodium	mg Na/L	82.5	81.7	96.8	86.83	62.48	89.2
Ammonia (Soluble)*	mg N/L						<0.10
Nitrate (Soluble)	mg N/L	3.31	46.19	1.73	2.43	1.7	<0.10
pH	pH units	7.76	8.31	7.06	7.29	7.63	7.35
Selenium	µg Se/L						3.69
Sulphate (Soluble)	mg SO4/L	23.23	31	21.68	24.38	27.43	29.1
Turbidity	NTU						0.3

3.2.6 Site 42477, Tswalu, South Africa

3.2.6.1 Site Description

The site is situated within the Kuruman River catchment in the Tswalu Private Game Reserve, 100km north-west of the town of Kuruman. The Kuruman River is a tributary of the Molopo River. The primary land use is the game reserve, with the borehole supplying water to the staff accommodation of the reserve for domestic use.

Longitude	22.488683°	**Latitude**	-27.285922°
Altitude (m.a.s.l.)	1210	**Country**	South Africa
Date sampled	25 July 2015	**River catchment**	Kuruman

3.2.6.2 Water quality

At the monitoring borehole number 42477 within the Tswalu Private Game Reserve, only Nitrate levels exceeded the SANS 241 drinking water limit. At the concentration present in this sample, the Nitrate level may pose a "slight chronic risk to some babies" (DWAF, 1998). The only other determinant which slightly exceeded guidelines (WHO, 2011), was electrical conductivity. However the conductivity was at a level where the water should have no significant taste problems and no significant health effect even on sensitive consumer groups (DWAF, 1998).

The *in-situ E. coli* hygiene and monitoring swab detected no signs of *E. coli*.

In-situ water quality sampling

Determinand	Units	42477
pH	pH units	N/A[2]
Temperature	(°C)	N/A[2]
Conductivity	(mS/m)	N/A[2]
E.coli[1]	(CFU/ml)	0

[1]sampled *in-situ* using an *E. coli* hygiene and monitoring swab. [2]Member state personnel did not sample *in-situ* determinands.

Laboratory water quality sampling

Determinand	Units	42477
Alkalinity	mg CaCO3/L	135
Arsenic	µg As/L	2.48
Calcium	mg Ca/L	39.2
Chloride (Soluble)	mg Cl/L	41.9
Conductivity	mS/m	58.0
Fluoride	µg F/L	335
Iron	mg Fe/L	0.02
Total hardness	mg CaCO3/L	206
Magnesium	mg Mg/L	25.9
Manganese	mg Mn/L	<0.01
Sodium	mg Na/L	29.2
Ammonia (Soluble)*	mg N/L	<0.10
Nitrate (Soluble)	mg N/L	15.4
pH	pH units	6.67
Selenium	µg Se/L	<2.00
Sulphate (Soluble)	mg SO4/L	15.4
Turbidity	NTU	0.6

Legend			
	Exceeds drinking water limit (WHO, 2011)	Exceeds drinking water limit (SANS, 2015)	No limit/ no exceedance
	Exceeds livestock watering limit (DWAF, 1996a)	Exceeds irrigation limit (DWAF, 1996b)	

3.2.6.3 Main Impacts at the Site

Causes[1]	Sources[2]
	No significant known impacts or sources in the immediate upstream catchment, being a private game reserve. The following facilities are present on a limited scale in proximity the site; staff housing, tourist accommodation, workshop. Natural geology of the region

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions. 2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the water body (EPA, 2000).

3.2.6.4 Trend Analysis

Water quality records covering 35 sampling events over the period November 1996 to March 2015 were available for the Tswalu site in South Africa. The table below forms a representative sample of these records. Conductivity appears to show a slight but steady decrease at the site over the last 20 odd years. The pH of 6.67, uncharacteristic of the site, may be influenced by deterioration of the sample, given the length of time between sampling and laboratory analysis. None of the determinants analysed shows an increasing trend over the 20 year period.

Historical water quality results

	Site 42477, Tswalu, South Africa									
Determinand	**Unit**	**Nov-96**	**Sep-98**	**Sep-00**	**Sep-02**	**Sep-05**	**Sep-07**	**Sep-10**	**Sep-12**	**Jul-15**
Alkalinity	mg CaCO3/L									135
Arsenic	µg As/L									2.48
Calcium	mg Ca/L	48.9	57.1	50.0	47.4	46.1	47.5	45.0	45.5	39.2
Chloride (Soluble)	mg Cl/L	45.6	46.6	45.2	44.2	51.2	41.5	42.3	39.7	41.9
Conductivity	mS/m	78.5	90.0	77.8	73.7	74.3	69.2	66.8	65.1	58.0
Fluoride	µg F/L	340	400	321	331	361	324	301	201	335
Iron	mg Fe/L									0.02
Total hardness	mg CaCO3/L									206
Magnesium	mg Mg/L	32.9	35.0	33.3	31.0	31.7	27.8	38.7	27.3	25.9
Manganese	mg Mn/L									<0.01
Sodium	mg Na/L	59.7	67.8	52.4	56.2	55.8	44.8	44.1	42.5	29.2
Ammonia (Soluble)*	mg N/L	0.078	0.02	0.045	0.043	0.052	0.085	0.025	0.062	<0.10
Nitrate (Soluble)	mg N/L									15.4
pH	pH units	7.38	7.69	7.77	8.22	8.04	7.44	8.49	8.04	6.67
Selenium	µg Se/L									<2.00
Sulphate (Soluble)	mg SO4/L	19.8	25.1	25.1	25.6	22.9	20.7	20.6	19.2	15.4
Turbidity	NTU									0.6

Please note this table forms a sample of the full length of record available between 1996 and 2015.

4. SUMMARY OBSERVATIONS, CONCLUSIONS AND RECOMMENDATIONS

4.1 General Threats to the Wellbeing of the Orange-Senqu River Basin

The Orange-Senqu River is South Africa's most economically important river system. This river ecosystem is heavily used, primarily to provide water to Johannesburg, Africa's largest economic hub, and its people, and an extensive agriculture industry in the catchment. The system also facilitates the removal of water borne wastes from urban centres, mines and industries in the catchment. The water resource use scenarios and associated threats to the wellbeing of the aquatic ecosystems in the Orange-Senqu River Basin differ considerably between the Vaal, Upper Senqu/Orange and Lower Orange Catchments of the Basin.

4.1.1 Vaal River Catchment

The Vaal River originates in the Mpumalanga Highveld close to Ermelo. This coal-risk region (an area possessing extensive coal mining operations) of South Africa has been moderately used for agricultural activities primarily until the recent increase in prospecting and associated mining activities from the early 2000s. The upper reaches of the Vaal River are threatened by water quality alterations associated with extensive agriculture and intensive mining activities, and partially treated waste from the water treatment works of urban centres.

Important tributaries of the upper Vaal River include the Klip, Waterval the Liebenbergsvlei and Wilge Rivers. These are variously affected by agricultural activities, salts and toxicants associated with the industrial and mining activities in the catchment and augmentation due to the Lesotho Highlands Transfer Scheme. These tributaries all flow into the Vaal Dam from wherein a large quantity of the water is abstracted by Rand Water for domestic use in Johannesburg and surrounds. Below the Vaal Dam extremely polluted water enters the river via the Suikerbosrand, Klip and Rietspruit Rivers. In addition, the Vaal River receives waste water treatment works return effluent from Vereeniging, Sasolburg and Vanderbijlpark – often not fully treated or to adequate levels of treatment. These stressors significantly alter the wellbeing of the Vaal River in the vicinity of the Vaal Barrage, south of Johannesburg.

Although water quality and flow alterations originating from upstream still have their impacts, the assimilative capacity of the Vaal River below the Barrage appears to be considerable and as a result the wellbeing of the Vaal River improves in the vicinity of Parys. However below Parys the Vaal River is again threatened by poor water quality originating in the Wonderfonteinspruit and the Mooi River and the Skoonspruit close to Stilfontein. This decline in water quality can be attributed to the gold mining industry and urbanisation. This impaired state continues to the Bloemhof Dam where local agricultural activities and urban pollution exacerbates the condition of the Vaal River. Fortunately Bloemhof Dam acts as a sink for many toxicants and allows a large portion of the nutrients in the system to be assimilated.

Below Bloemhof Dam, the Vaal River is threatened by water quality and habitat alterations associated with alluvial diamond mining activities, agriculture activities and urban centres, whilst in the lower reaches of the Vaal River the Vaal-Harts Irrigation Scheme impacts the wellbeing of the catchment through water quality alterations including pesticides, nutrient enrichment and toxicants and quantity alterations.

The water quality in the lower Vaal River is generally considered to be so poor that the river is managed to restrict the volume of Vaal River water entering the Orange River at the confluence.

Additional threats in the Vaal River include habitat fragmentation through the construction of numerous weirs and dams. In addition, as many as six alien invasive fishes, numerous alien plants, invertebrates and pathogens (including diseases) threaten the wellbeing of the ecosystem.

4.1.2 Upper Senqu/Orange River Catchment

The Senqu River originates and drains much of the Lesotho Highlands before flowing into South Africa. The major threats to the upper Senqu River in Lesotho are associated with the transfer of water through the extensive Lesotho Highlands Water Transfer Scheme which has significantly altered the volume, timing and duration of flows in the catchment. The water resources in Lesotho are also threatened by agricultural practices that result in excessive loss of terrestrial sediments into the riverine ecosystems in Lesotho (Figure 4.1). As a result the rivers in Lesotho have modified flows and habitats which have considerably affected the wellbeing of the rivers in the catchment. In addition many alien fishes and plants threaten the wellbeing of the endemic biodiversity of the river in the upper reaches of this system.

Figure 4.1 An example of extensive erosion in the Upper Orange catchment

Once in South Africa, the upper Orange River flows past a series of major barriers in the vicinity of Aliwal North to the Gariep Dam, Vanderkloof Dam and towards the confluence with the Vaal River at Douglas in the Northern Cape. The effects of the numerous dams on the Upper Orange River between Lesotho and the confluence with the Vaal River has noticeably altered the wellbeing of the Orange River. These impacts have been exacerbated through the generation of power particularly at Vanderkloof Dam where the flows have become highly variable on a daily basis (see later summary under Hydrology). These dams and variable releases have also resulted in a reduction in sediments in the Orange River and changes in water temperatures and other water quality variables. Other stressors affecting the wellbeing of the upper Orange River in South Africa include competition by alien fishes, plants and invertebrates and productivity threats to the system associated with a change in sediment transport potential in the system and abnormal water clarity changes.

4.1.3 Lower Orange River Catchment

Whilst the Orange River below the confluence with the Vaal is for the most part only marginally affected by pollution from the latter river, as the releases into the Orange River are specifically regulated, flow modifications from the upper Orange River are distinct, and in combination these stressors affect a large portion of the lower Orange River. Numerous irrigation schemes and associated weirs and canals exacerbate these impacts through nutrient enrichment, pesticides and sedimentation threats, altered riparian vegetation communities (often dominated by alien invasive species), negatively affecting the riparian and instream aquatic ecosystems. In addition alluvial mining and associated infrastructure has also affected the wellbeing of the lower Orange River and its estuary.

4.2 Overview of the Hydrology of the Orange-Senqu River Basin

One of the most dominant drivers of the aquatic ecosystem health condition of the Orange River was flow modification. This modification has been at several levels, namely, timing, duration and extent. For example, the lower Orange in a typical winter would have almost dried up on occasions, with an anecdotal account from this JBS 2 survey of a local farmer in the Hopetown area able to wade across the river as a youngster, with a pair of gumboots on and fishing using a garden fork for stabbing at yellow fish! This condition is typically very different now with much higher average winter flows to meet irrigation demands of agriculture (largely centre pivots) down the river. At the other end of the spectrum, much of the natural summer flow variability in the river has been removed by a cascade of dams down the river which have captured much of the high flow events in summer, for later release to meet drinking and irrigation demands downstream. Hydroelectricity generation below some of the dams (e.g. below Vanderkloof Dam) further modifies the natural flow regime (rapid and irregular flow changes which are often out of season to the natural regime).

The net result is that much of the natural biota measured during this survey are highly stressed or have disappeared, having to cope with some of the following:

- Out of season high flows
- Constant or highly regulated base flows
- Rapidly varying out of season winter flows
- Lack of high season flows during summer
- Inter-basin transfers
- etc.

This is in addition to water quality changes and habitat loss/modification drivers.
For illustrative purposes just one of these aspects of flow variation is summarised below for three sites down the Orange, below the two largest dams, Gariep, Vanderkloof and at Marksdrift weir (upstream of the confluence with the Vaal).

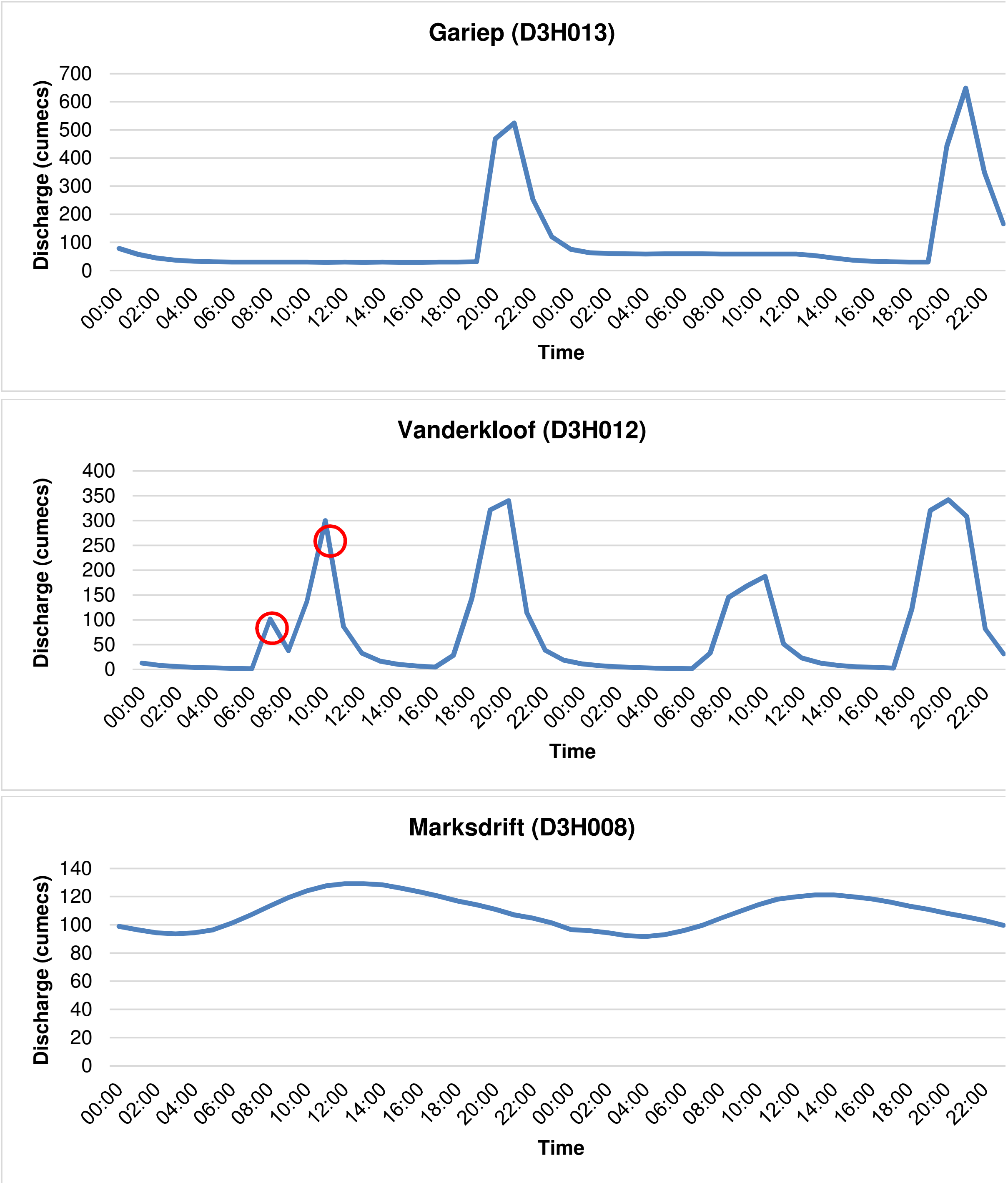

Figure 4.2 **Illustrative flow records covering the same 48-hour period at the end of July 2015 for two sites on the Orange River; namely below Gariep and Vanderkloof Dams, and at Marksdrift, upstream of the confluence with the Vaal.**

The first two graphs are most dramatic, with the Vanderkloof gauging weir showing a change from virtually no flow below the dam (1.5cumecs at 6am) to over 300cumecs, only four hours later at 10am (see red circles on figure). These flows would be completely unseasonal, have dramatically unnatural temperatures and chemistry to that naturally occurring in the river and are a key determinant in describing the current aquatic ecosystem health status of river reaches downstream of the dam.

4.3 Long-term Water Quality Trends in the Orange-Senqu River Basin

Long-term water quality trends were assessed at key sites using all DWS historical water quality data available, as well as indicating the JBS 1 and 2 data where relevant. The sites were chosen to broadly represent the conditions in the upper, middle and lower Orange, and the Vaal River systems respectively. Three determinands were selected for long-term trend analysis, including electrical conductivity (a measure of dissolved salts and a general water quality indicator) and the nutrients, namely nitrogen and phosphorus (indicators of eutrophication which stimulate the growth of algae, which may decrease the treatability of water as well as pose recreational and public health risks).

Time series plots were prepared indicating the actual measured concentrations as well as the 11-point moving average (an average of 5 data points on either side of the measured concentration). For comparative purposes, key statistics, per decade, were calculated to provide supplementary information about trends in water quality through the system. A broad summary of these results is presented here.

4.3.1 Upper Orange River – Aliwal North

Table 4.1 Statistical summary of Electrical Conductivity (mS/m) recorded for the Orange River at Aliwal North

D1H003Q01	N	Average	Median	95-percentile
1970 - 1979	193	19.2	18.5	29.0
1980 - 1989	405	17.1	16.2	25.1
1990 - 1999	545	19.2	18.0	29.2
2000 - 2009	130	19.6	19.1	27.3
2010 - 2015	86	20.6	20.5	27.1

While remaining low, a slight increasing trend in conductivity was noted at the Orange River at Aliwal. The JBS 2 sample result was 16.4 mS/m.

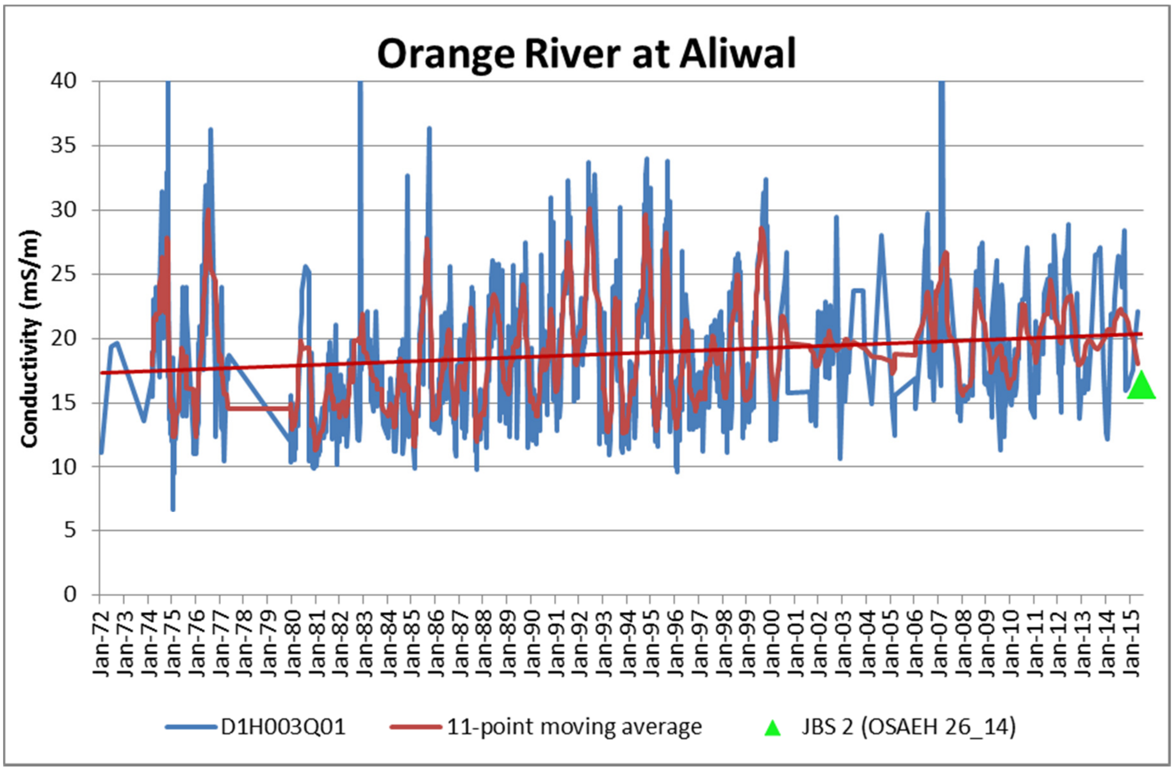

Figure 4.3 The average annual Electrical Conductivity (mS/m) recorded for the Orange River at Aliwal North

Table 4.2 Statistical summary of Total Inorganic Nitrogen (mg/l) recorded for the Orange River at Aliwal North

D1H003Q01	N	Average (Trophic Status)	Median	95-percentile
1970 - 1979	40	0.238 (oligotrophic)	0.100	0.652
1980 - 1989	357	0.431 (oligotrophic)	0.370	0.932
1990 - 1999	505	0.255 (oligotrophic)	0.225	0.656
2000 - 2009	117	0.400 (oligotrophic)	0.174	0.468
2010 - 2015	87	0.142 (oligotrophic)	0.100	0.353

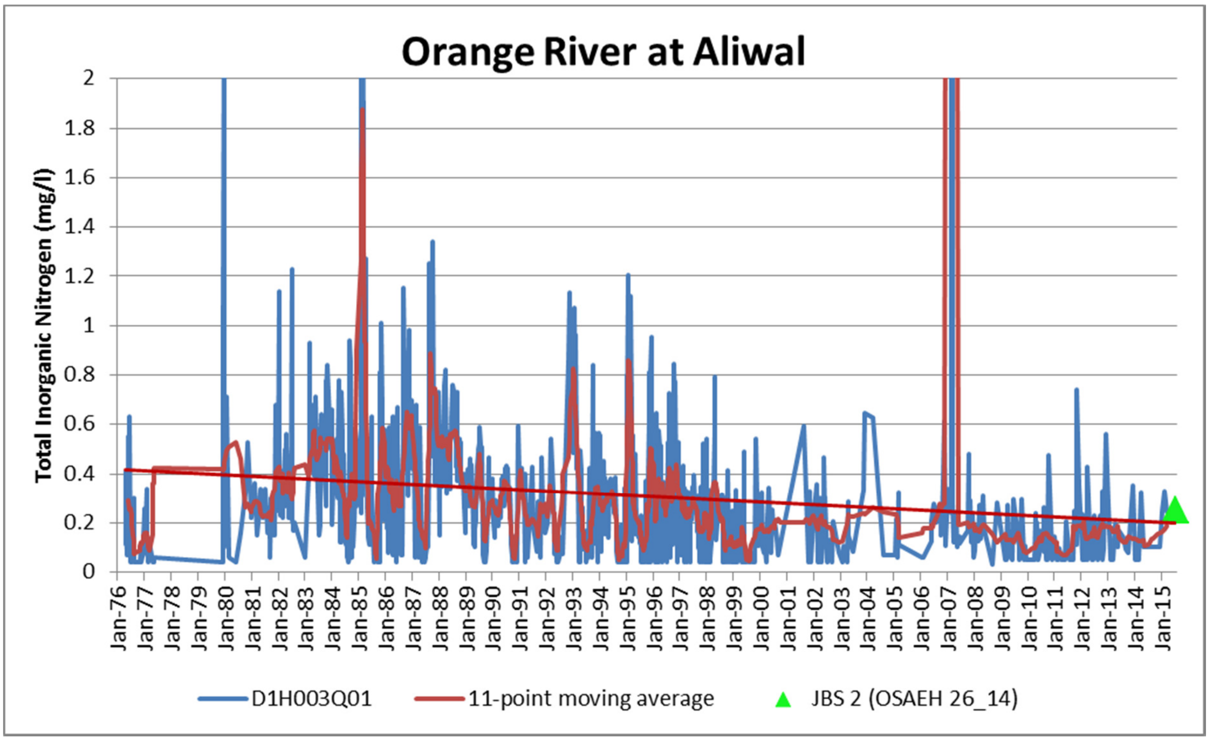

Figure 4.4 The average annual Total Inorganic Nitrogen (mg/l) recorded for the Orange River at Aliwal North

Total Inorganic Nitrogen has generally decreased since the 1980s at the Orange River at Aliwal North. The trophic status according to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) for Total Inorganic Nitrogen was reported as oligotrophic.

The sample results for JSB 2 for nitrate, nitrite and ammonia were all below the analytical detection limit at this site.

Table 4.3 Statistical summary of Orthophosphate (mg/l) recorded for the Orange River at Aliwal North

D1H003Q01	N	Average (Trophic Status)	Median	95-percentile
1970 - 1979	191	0.242 (eutrophic)	0.032	0.268
1980 - 1989	357	0.038 (meso-eutrophic)	0.023	0.127
1990 - 1999	505	0.029 (meso-eutrophic)	0.025	0.054
2000 - 2009	128	0.101 (eutrophic)	0.030	0.076
2010 - 2015	87	0.016 (mesotrophic)	0.005	0.042

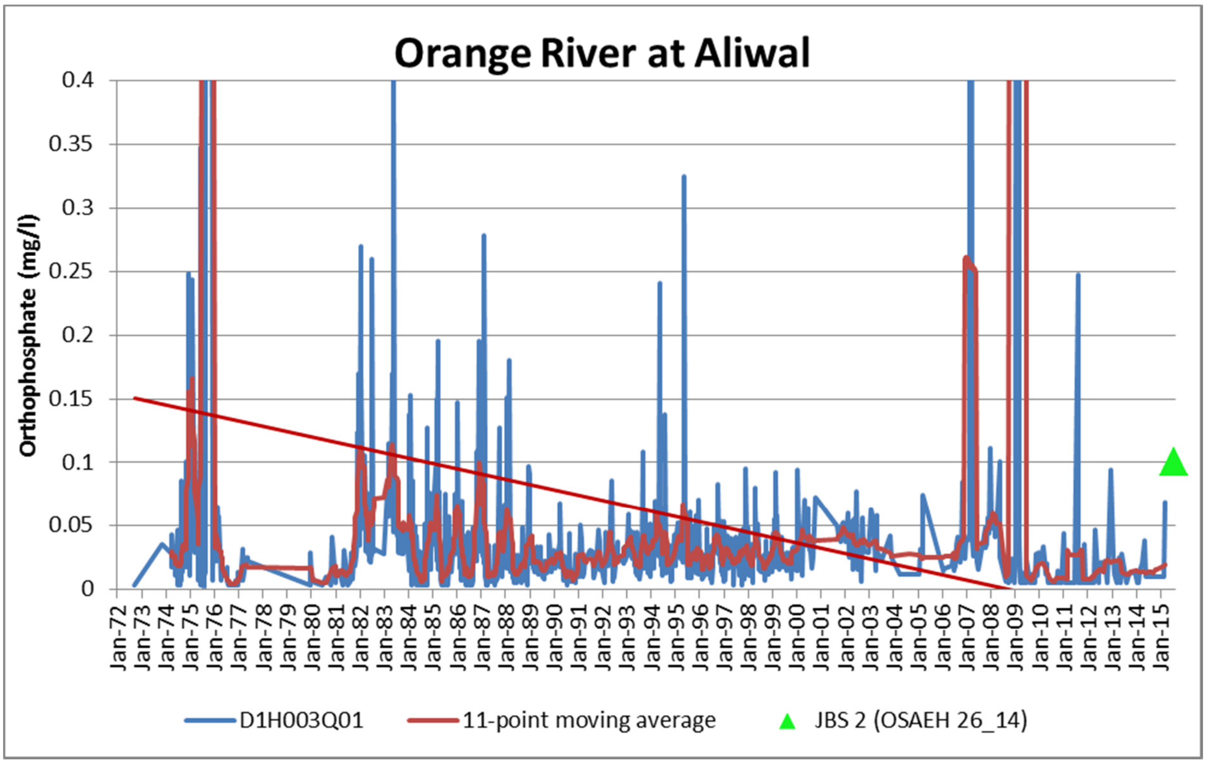

Figure 4.5 The average annual Orthophosphate (mg/l) recorded for the Orange River at Aliwal North

While an overall decreasing trend was apparent, orthophosphate results were highly variable at the Orange River at Aliwal North, with a number of highly elevated results recorded between 2007 and 2009. Notwithstanding the decreasing trend, the trophic status according to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) for Inorganic Phosphorus varied between mesostrophic and eutrophic.

The JSB 2 survey the orthophosphate result was less than the analytical detection limit of 0.2 mg/l and was included into the graph as half the value of the detection limit (0.1 mg/l).

4.3.2 Upper Orange River - Colesberg (Downstream of Gariep Dam)

Table 4.4 Statistical summary of Electrical Conductivity (mS/m) recorded for the Orange River at Colesberg

D3H013Q01	N	Average	Median	95-percentile
1970 - 1979	31	21.5	19.2	31.6
1980 - 1989	445	16.5	16.0	19.8
1990 - 1999	351	17.9	16.8	21.2
2000 - 2009	278	18.3	18.0	21.9
2010 - 2015	99	18.2	17.7	22.5

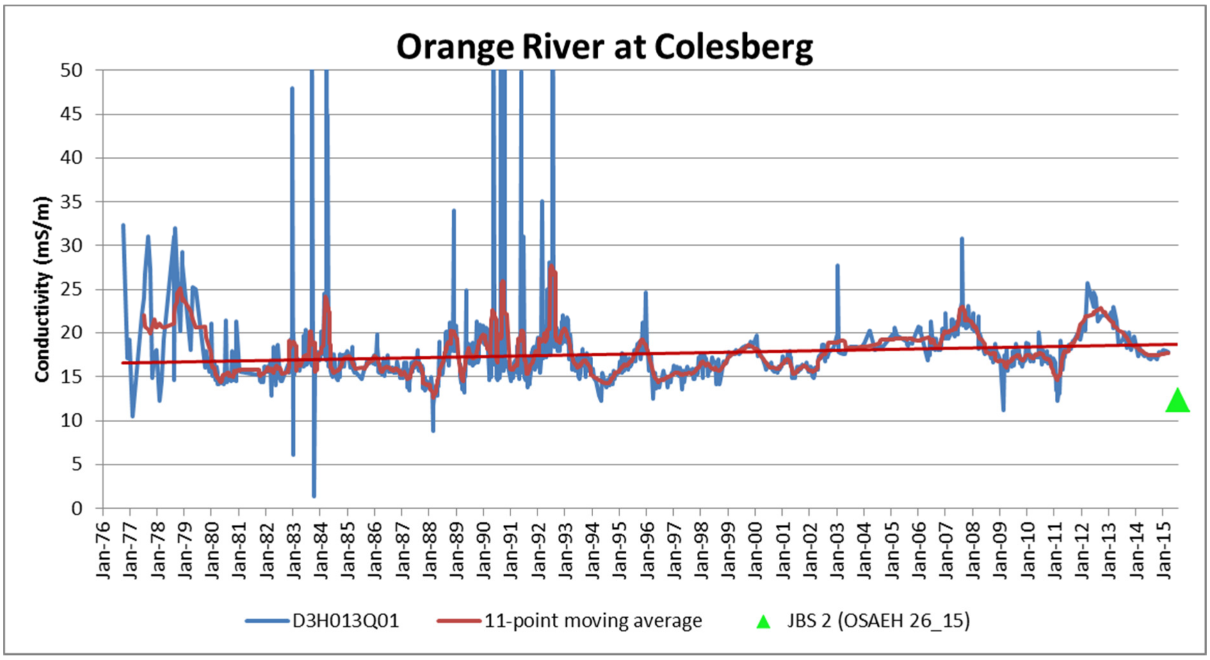

Figure 4.6 **The average annual Electrical Conductivity (mS/m) recorded for the Orange River at Colesberg**

While remaining low and significantly less variable due to the impact of the large upstream impoundments, a slight increasing trend in conductivity was recorded at the Orange River at Colesberg. The sample collected during JBS 2 recorded a lower conductivity (12.3 mS/m) compared to the recent data collected by DWS.

Table 4.5 **Statistical summary of Total Inorganic Nitrogen (mg/l) recorded for the Orange River at Colesberg**

D3H013Q01	N	Average (Trophic Status)	Median	95-percentile
1970 - 1979	31	0.495 (oligotrophic)	0.400	1.525
1980 - 1989	436	0.852 (mesotrophic)	0.770	1.100
1990 - 1999	306	0.915 (mesotrophic)	0.612	1.099
2000 - 2009	259	0.397 (oligotrophic)	0.405	0.607
2010 - 2015	103	0.437 (oligotrophic)	0.342	0.877

A significant decrease in Total Inorganic Nitrogen was recorded at the Orange River at Colesberg between 1976 and 2015. The trophic status according to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) for Total Inorganic Nitrogen varied between oligotrophic and mesotrophic. However, the Total Inorganic Nitrogen result measured during JBS 2 was elevated due a nitrate concentration of 0.5 mg/l measured in July 2015.

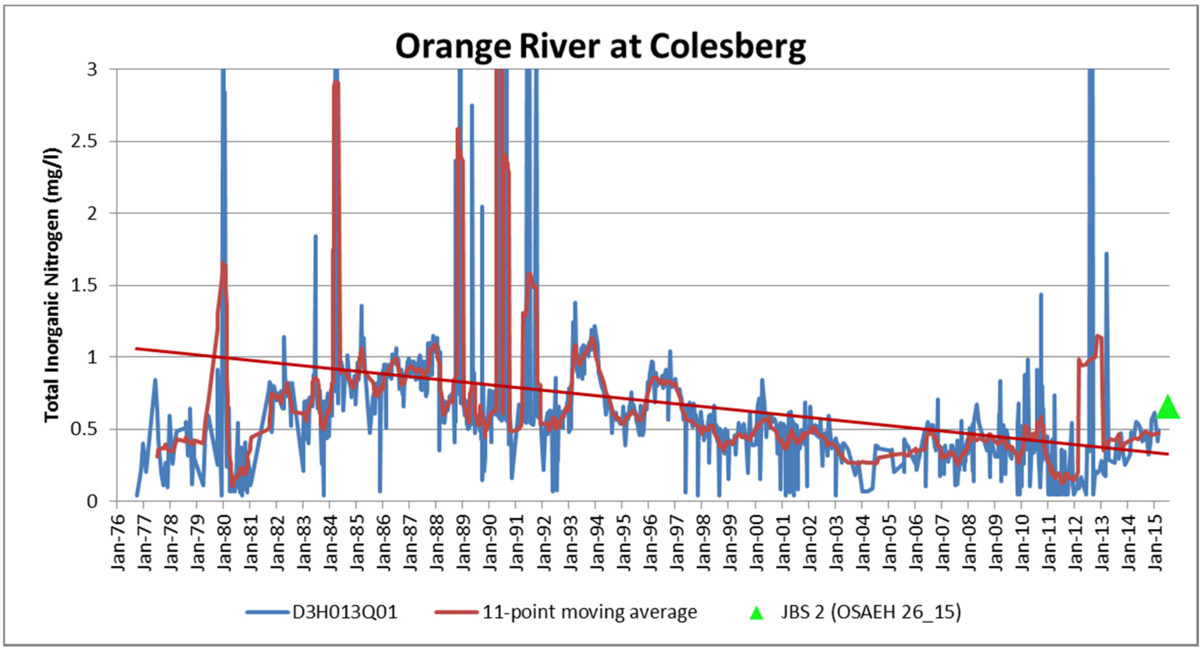

Figure 4.7 The average annual Total Inorganic Nitrogen (mg/l) recorded for the Orange River at Colesberg

It is speculated that the large impoundments upstream of this site (and associated denitrification processes) are largely responsible for this largely low nitrogen "signal" in this part of the system.

Table 4.6 Statistical summary of Orthophosphate (mg/l) recorded for the Orange River at Colesberg

D3H013Q01	N	Average (Trophic Status)	Median	95-percentile
1970 - 1979	31	0.054 (eutrophic)	0.039	0.237
1980 - 1989	436	0.063 (eutrophic)	0.034	0.131
1990 - 1999	612	0.056 (eutrophic)	0.027	0.087
2000 - 2009	275	0.041 (eutrophic)	0.030	0.084
2010 - 2015	103	0.025 (mesotrophic)	0.005	0.051

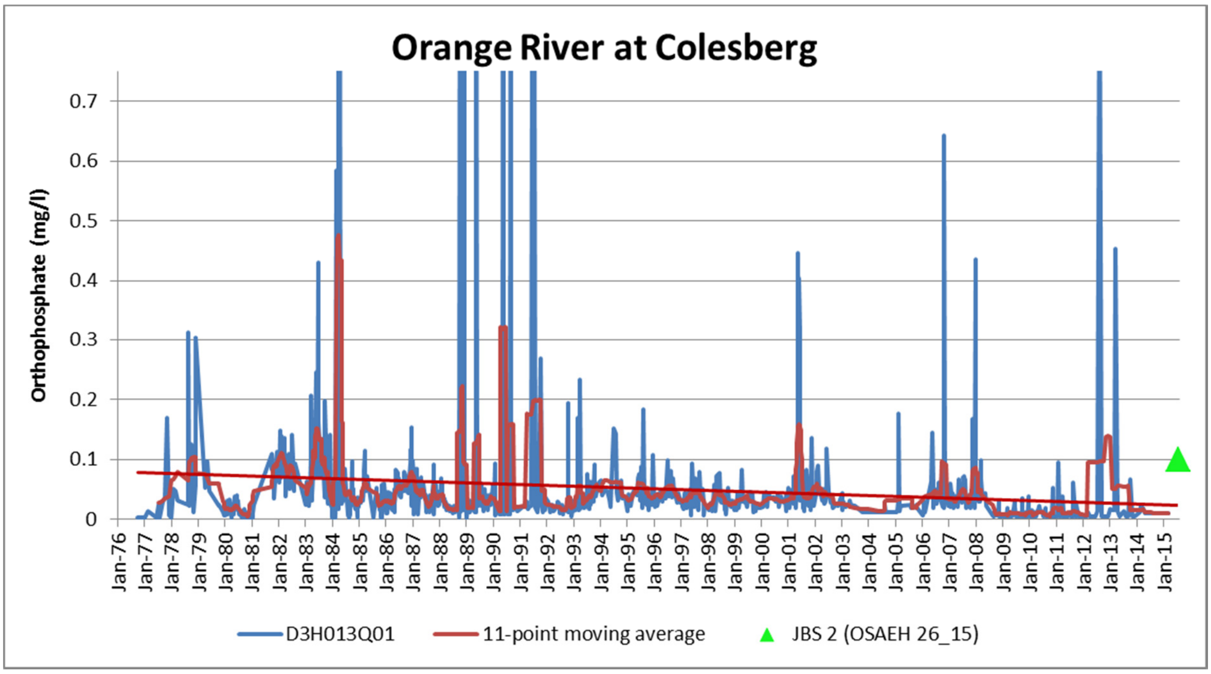

Figure 4.8 The average annual Orthophosphate (mg/l) recorded for the Orange River at Colesberg

Overall, as with nitrogen, a decreasing trend in orthophosphate was recorded at the Orange River at Colesberg. However, episodic nutrient enrichment was noted. The trophic status according to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) for Inorganic Phosphorus indicated an improvement to mesostrophic in the current decade.

The JSB 2 survey produced an orthophosphate result less than the analytical detection limit of 0.2 mg/l and was included into the graph as half the value of the detection limit (0.1 mg/l).

4.3.3 Lower Orange River – Vioolsdrift

Table 4.7 Statistical summary of Electrical Conductivity (mS/m) recorded for the Orange River at Vioolsdrift

D8H003Q01	N	Average	Median	95-percentile
1970 - 1979	106	29.9	29.0	40.7
1980 - 1989	459	30.2	29.0	42.8
1990 - 1999	480	38.3	36.4	60.0
2000 - 2009	376	44.1	42.4	71.8
2010 - 2015	104	48.6	48.5	85.8

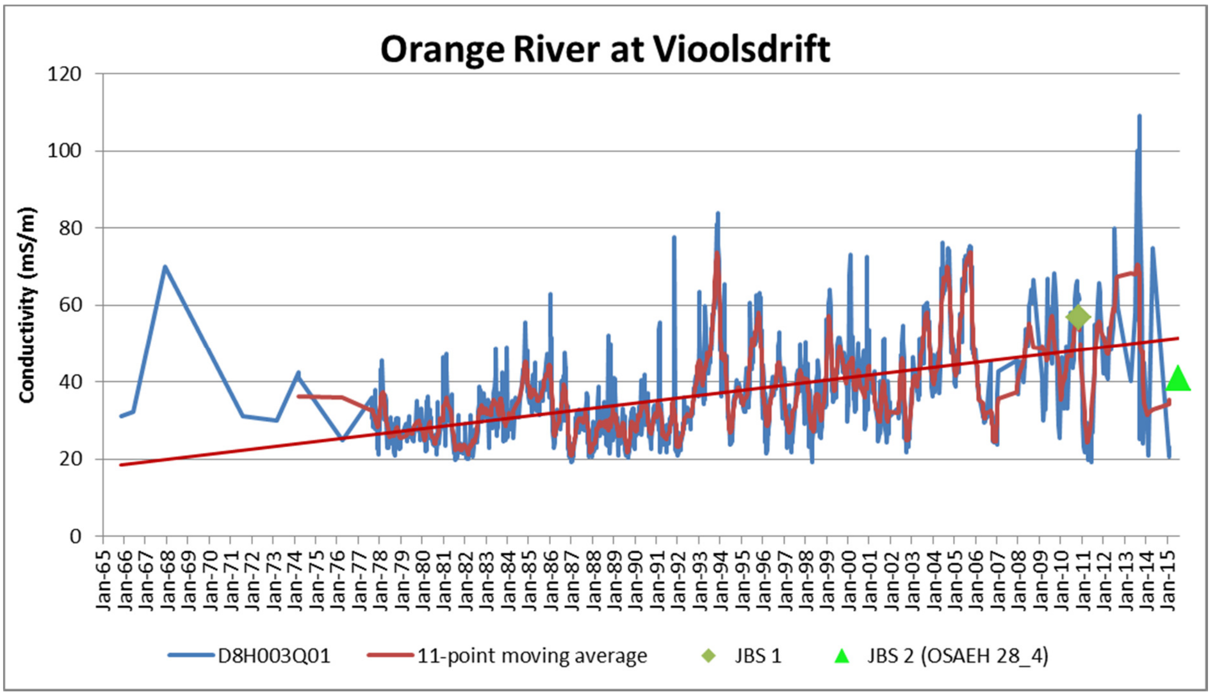

Figure 4.9 The average annual Electrical Conductivity (mS/m) recorded for the Orange River at Vioolsdrift

There has been a notable increase in conductivity since the commencement of monitoring as well as an increase in conductivity along the reaches of the lower Orange River due to the cumulative effect of significant abstraction of water, irrigation return flows and evaporative losses along the river. The sample collected during JBS 2 recorded a conductivity of 41.0 mS/m.

Table 4.8 Statistical summary of Total Inorganic Nitrogen (mg/l) recorded for the Orange River at Vioolsdrift

D8H003Q01	N	Average (Trophic Status)	Median	95-percentile
1970 - 1979	75	0.207 (oligotrophic)	0.110	0.485
1980 - 1989	139	0.248 (oligotrophic)	0.130	0.782
1990 - 1999	403	0.137 (oligotrophic)	0.060	0.535
2000 - 2009	353	0.141 (oligotrophic)	0.070	0.538
2010 - 2015	89	0.227 (oligotrophic)	0.098	0.679

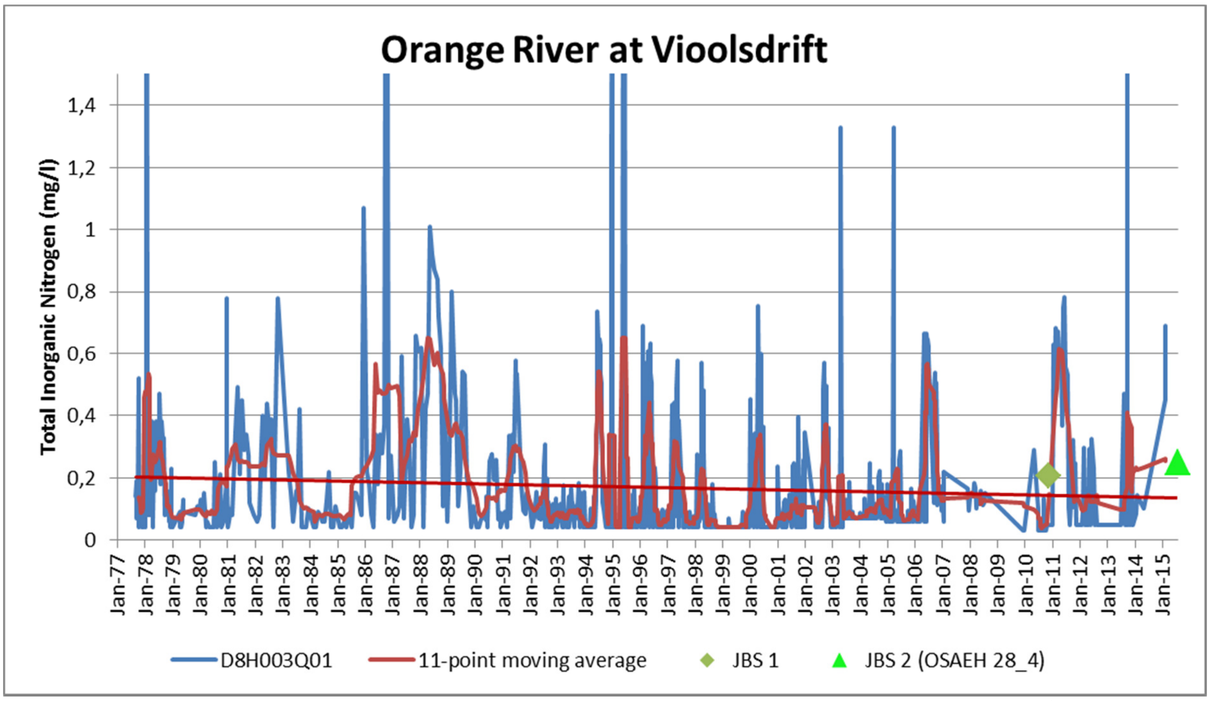

Figure 4.10 **The average annual Total Inorganic Nitrogen (mg/l) recorded for the Orange River at Vioolsdrift**

Highly variable Total Inorganic Nitrogen concentrations have been recorded at Vioolsdrift over the years, with a number of results indicating intermittent nutrient enrichment, likely to be associated with agricultural activities and return flows. However, the trophic status according to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) for Total Inorganic Nitrogen was reported as oligotrophic at Vioolspruit. In general, the trend remains stable.

The sample results for JSB 2 for nitrate, nitrite and ammonia were all below the analytical detection limit at Vioolsdrift.

Table 4.9 **Statistical summary of Orthophosphate (mg/l) recorded for the Orange River at Vioolsdrift**

D8H003Q01	N	Average (Trophic Status)	Median	95-percentile
1970 - 1979	79	0.035 (eutrophic)	0.022	0.112
1980 - 1989	124	0.016 (mesotrophic)	0.011	0.042
1990 - 1999	403	0.025 (mesotrophic)	0.022	0.060
2000 - 2009	377	0.026 (eutrophic)	0.021	0.063
2010 - 2015	102	0.020 (mesotrophic)	0.006	0.047

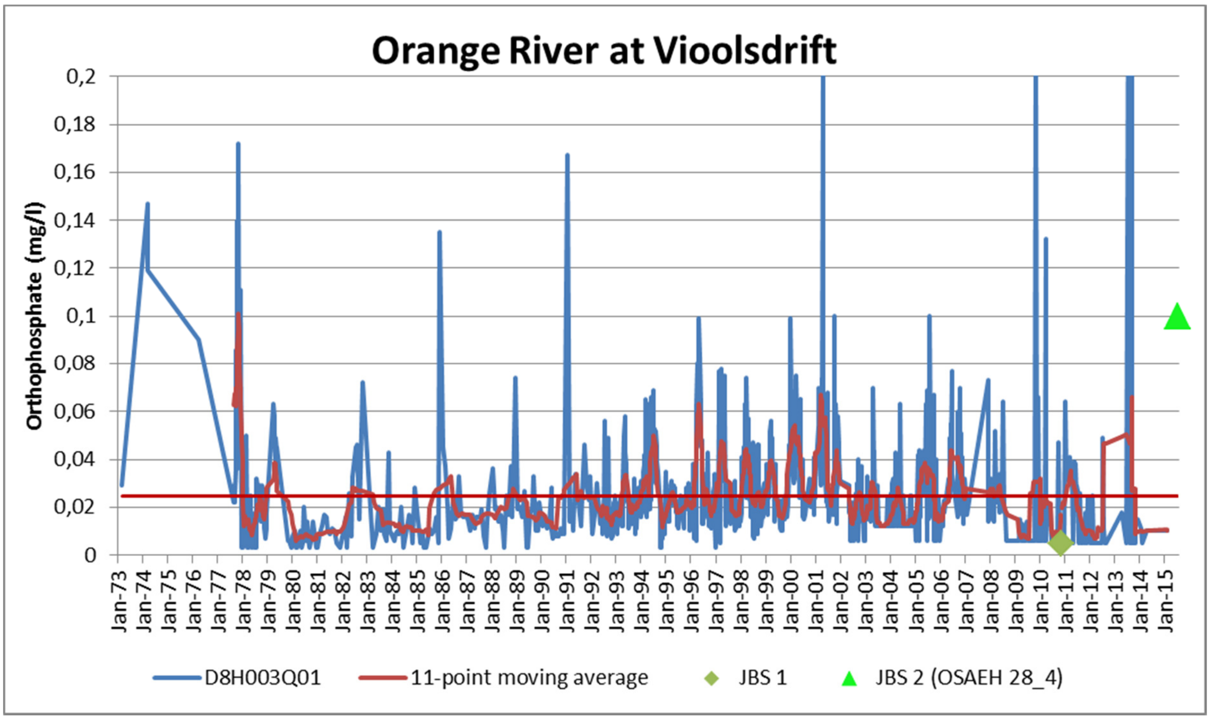

Figure 4.11 The average annual Orthophosphate (mg/l) recorded for the Orange River at Vioolsdrift

A generally stable trend was noted for the Orthophosphate concentrations at Vioolsdrift, but as with the nitrogen results, the orthophosphate results were variable and episodic nutrient enrichment was apparent. The trophic status according to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) for Inorganic Phosphorus varied between mesostrophic and eutrophic.

The JSB 2 survey the orthophosphate result was less than the analytical detection limit of 0.2 mg/l and was included into the graph as half the value of the detection limit (0.1 mg/l).

4.3.4 Vaal River - Orkney (Upstream of Bloemhof Dam)

Table 4.10 Statistical summary of Electrical Conductivity (mS/m) recorded for the Vaal River at Orkney

C2H007Q01	N	Average	Median	95-percentile
1970 - 1979	12	94.1	99.3	108.0
1980 - 1989	482	86.6	89.2	132.2
1990 - 1999	530	75.4	81.7	109.5
2000 - 2009	492	75.6	80.7	101.2
2010 - 2015	249	63.7	67.5	81.4

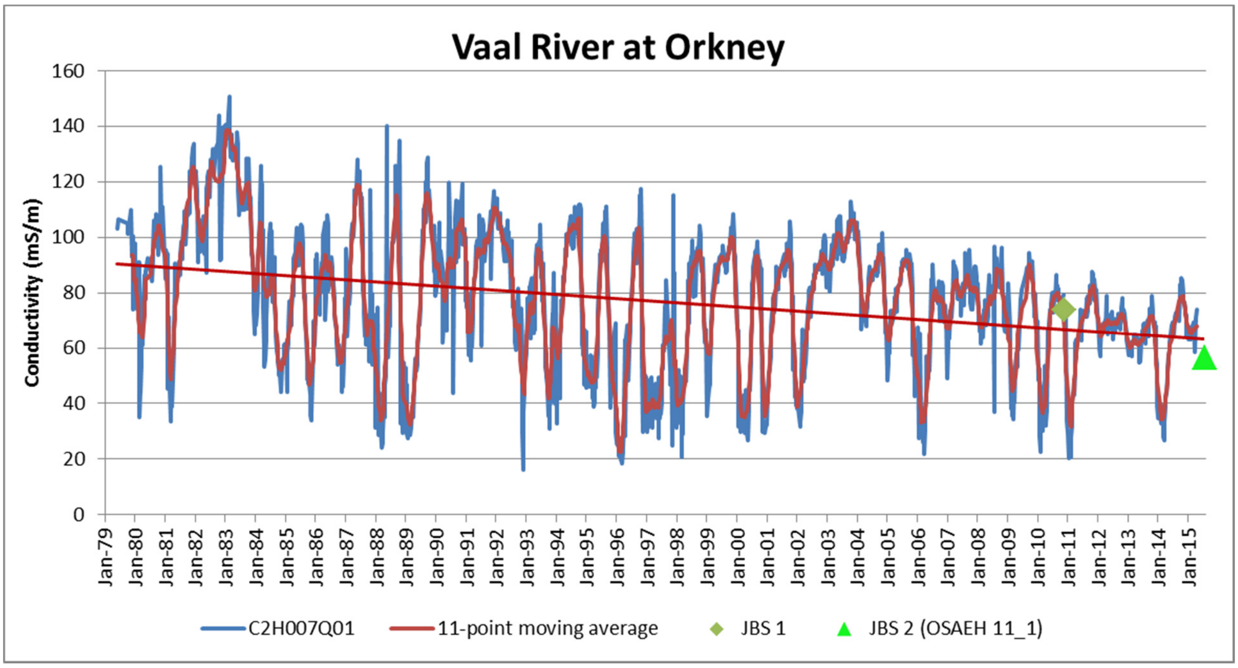

Figure 4.12 The average annual Electrical Conductivity (mS/m) recorded for the Vaal River at Orkney

Salt concentrations in the middle Vaal River at Orkney, while fluctuating significantly, are considered high due to mining impacts. However, conductivity results have steadily decreased since the commencement of water quality monitoring at this site in 1979. The decrease from an average of 94 mS/m in the 1970s to 64 mS/m after 2010 is likely to be associated with the introduction of a dilution option of releasing water from the Vaal Dam.

Table 4.11 Statistical summary of Total Inorganic Nitrogen (mg/l) recorded for the Vaal River at Orkney

C2H007Q01	N	Average (Trophic Status)	Median	95-percentile
1970 - 1979	12	2.178 (mesotrophic)	1.310	7.358
1980 - 1989	474	0.896 (mesotrophic)	0.815	1.870
1990 - 1999	526	0.666 (mesotrophic)	0.551	1.680
2000 - 2009	458	0.575 (mesotrophic)	0.430	1.597
2010 - 2015	248	0.830 (mesotrophic)	0.731	2.039

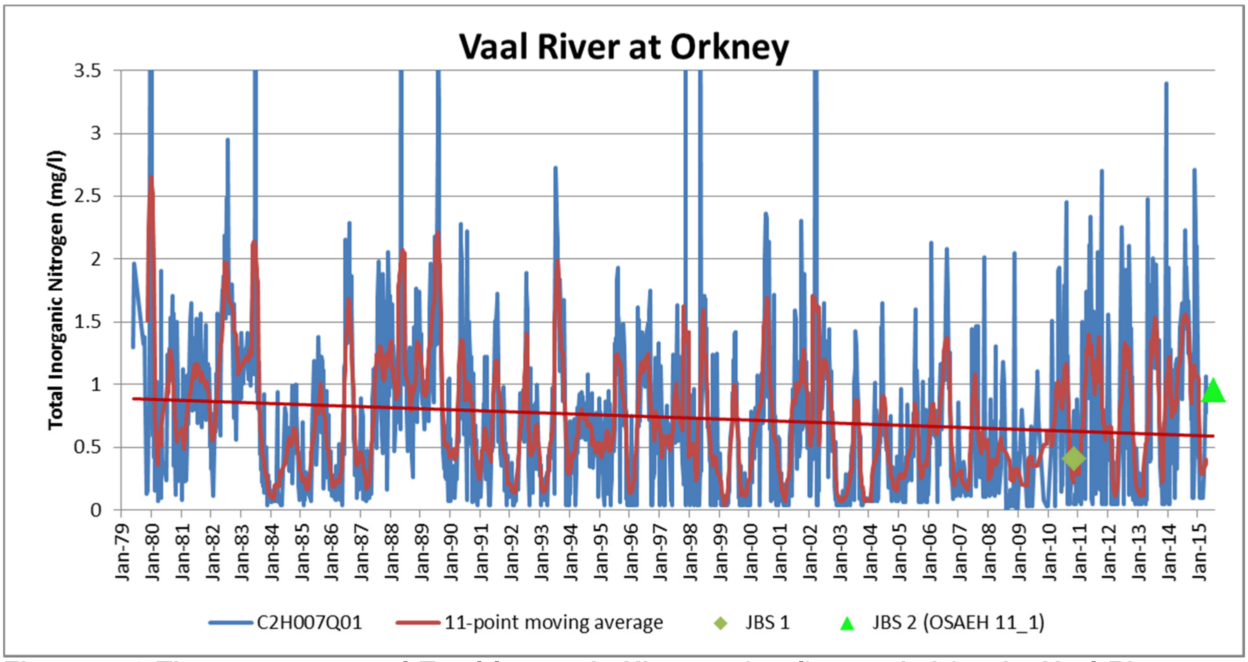

Figure 4.13 The average annual Total Inorganic Nitrogen (mg/l) recorded for the Vaal River at Orkney

Total inorganic nitrogen concentrations, while notably elevated, generally decreased between the 1970s and 2000s. An increase has been noted since 2010. The trophic status according to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) for Total Inorganic Nitrogen was reported as mesotrophic at Orkney.

Table 4.12 Statistical summary of Orthophosphate (mg/l) recorded for the Vaal River at Orkney

C2H007Q01	N	Average (Trophic Status)	Median	95-percentile
1970 - 1979	12	0.045 (eutrophic)	0.047	0.105
1980 - 1989	474	0.048 (eutrophic)	0.031	0.152
1990 - 1999	530	0.074 (eutrophic)	0.053	0.210
2000 - 2009	483	0.212 (eutrophic)	0.163	0.437
2010 - 2015	253	0.134 (eutrophic)	0.123	0.327

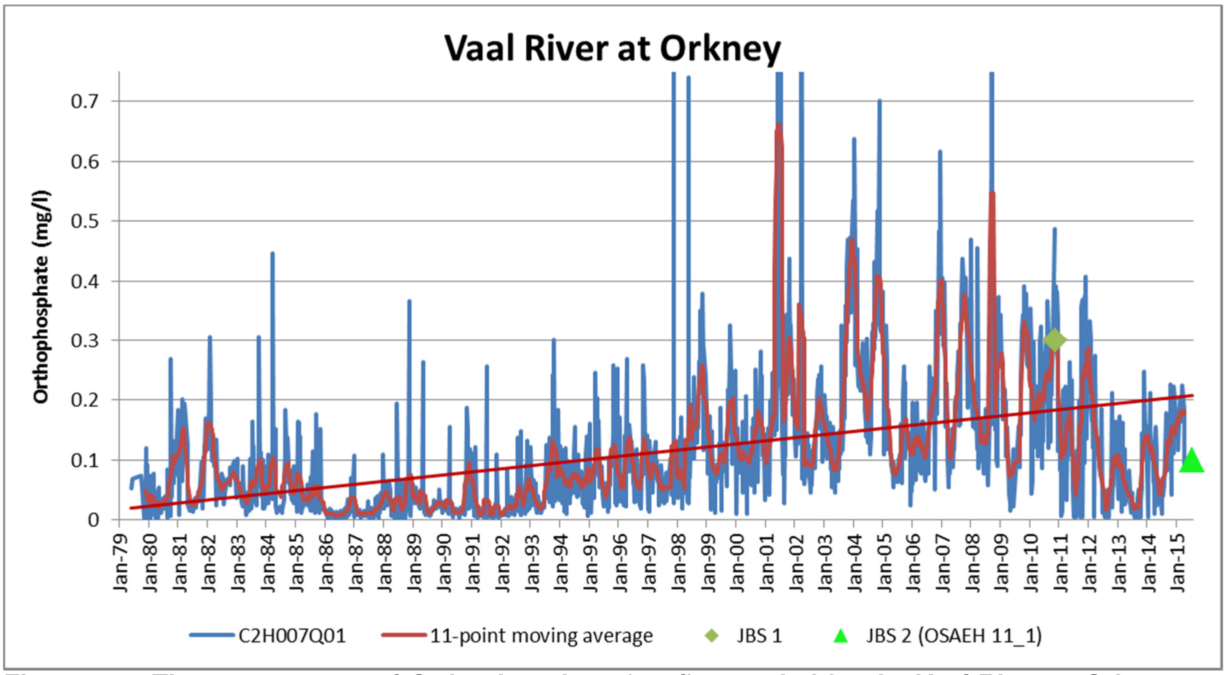

Figure 4.14 The average annual Orthophosphate (mg/l) recorded for the Vaal River at Orkney

An overall increasing trend in orthophosphate concentrations was noted, with lower concentrations recorded during the 1970s to early 1990s, and notable nutrient enrichment in the latter 1990 period. Limited improvement has been noted in recent years with lower concentrations recorded.

The trophic status according to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) for Inorganic Phosphorus was eutrophic at the Vaal River at Orkney.

4.4 Overview of Fish Wellbeing in the Orange-Senqu River Basin

The general wellbeing of the fishes in the Orange-Senqu River Basin has been shown to respond to the altered state of the major environmental variables considered in the study. This included alterations to the water quality and quantity (volume, timing and duration of flows) and habitat fragmentation and alterations. The fishes of the catchment are dominated by slow but large growing cyprinids (*Labeobarbus spp. and Labeo spp.*) that have social, economic and ecological values. These fishes used to carry out extensive migrations from the lower Vaal River and Orange River into the upper reaches primarily for spawning. These migrations have generally been disrupted through the construction of major dams throughout the catchment and changes in river connectivity associated with flow alterations and water quality pollution. These dams that have hampered the migration of many species have also provided new habitats which many species use which has altered the distribution of many species in the catchment. These new deep non-flowing (lentic) habitats have facilitated the establishment of many populations of alien fishes throughout the catchment. These fishes compete with indigenous fishes for habitat and food and predate directly on indigenous fishes and other aquatic animals. Other species include many small (<100mm in length) barbs, and one *Pseudobarbus sp.* (the maloti minnow) that are relatively intolerant to habitat, water quality and flow alterations, two catfishes including the Sharptooth catfish (*Clarius gariepinus*) and the cryptic Rock catfish (*Austroglanis sclateri*), two cichlids (*Tilapia sparmanii* and *Pseudocrenilabrus philander*) and in the lower reaches of the Orange River an Anguillid eel (*Anguilla mossambica*).

The augmentation of the Vaal River through the Lesotho Highlands Transfer Scheme has increased the habitat availability in the Vaal River and resulted in a reduction of habitats for fishes in the upper Orange/Senqu River (from where the water transferred originates). These effects have also affected the distribution of fishes in the catchment. In the Vaal River portion of the catchment, water quality threats associated with mining and industrial developments, agriculture and large urban centres and their associated discharge of partially treated wastes have been identified as major determinants of the altered wellbeing of the fishes in the system. These activities have altered the nutrient loads, salt content, toxicant loads and reduced oxygen and temperatures abnormally in the river. The fish communities in the middle and lower portion of the Vaal River have as a result, been largely modified with a considerable reduction in the abundances, distribution and viability of many species. In the Vaal River many individuals were observed with lesions, wounds and excessive parasitic infections which are all indicative of heightened stress levels and the occurrence of pathogens that further affect the wellbeing of the fishes. The populations of many ecologically important fishes in the Vaal River are also threatened by large abundant urban communities who disturb these populations through excessive, often commercial harvesting, and through litter, debris and recreational activities in the Vaal River. In the lower reaches of the Vaal River alluvial diamond mining activities affect the suitability of the spawning habitat and refuge habitats for many species.

The fishes of the upper Orange/Senqu River have also been affected by habitat fragmentation associated with water abstraction and dam developments. In particular the large summer migrations of cyprinids into Lesotho have been disrupted through the construction of dams and weirs on the Orange/Senqu Rivers. While large populations of these fishes still occur in the upper Orange River, particularly in the large dams, the effect of these migration disruptions is largely unknown. Surprisingly the dependence of local communities in Lesotho on these migrations appears to have reduced considerably and or shifted to the use of alien trout in the upper Senqu River. Other threats to the wellbeing of the fishes in the upper Orange/Senqu River include habitat changes associated with erosion of terrestrial sediments and the sedimentation of critical habitats and a reduction in the fine particulate organic matter due to the dams in the study area. The reduction in the fine particulate organic matter in the Orange River has affected the productivity of the river and the associated feeding biology and diel behaviour of many fishes in the system.

In the lower Orange River the wellbeing of the fishes has been affected by flow alterations associated with the dams in the upper Orange River. Many fishes that require stable habitats in the lower Orange have been forced to make use of sub-optimum habitats and or have been removed from the system. These threats can also be linked to increased water clarity in the lower Orange which has changed the productivity and associated food availability in the system and interestingly the daily behavioural patterns of many fishes that now occupy deep habitats during the day and feed in shallower habitats that were historically available all day, at night only. Some water quality impacts were also observed in the lower Orange River that affects the wellbeing of the fishes. These threats were all associated with agricultural centres, urban areas and mining activities in the lower reaches. Finally the wellbeing of the fish communities in the lower Orange River and Estuary have been considerably affected by flow reductions, water quality impacts, habitat changes and competition from alien invasive fishes and plants.

4.5 General Trends in EcoStatus

In JBS2, only one site (OSAEH 28_5 – the most downstream site on the Lower Orange) was in an Overall EcoStatus Category of B (largely natural, with few modifications). Two sites were in a B/C category (OSAEH 29_5 on the Riet River a tributary of the Lower Vaal, and OSAEH 28_3 a site on the Lower Orange). The majority of sites were in an overall EcoStatus category of a C (n=16) (moderately modified), while seven were in a C/D category. Eight sites were in a D category (largely modified). Of these sites two occurred in the Upper Vaal WMA - Vaal catchment and surprisingly six occurred within the Upper Orange/Senqu catchment. The site with the lowest overall EcoStatus Category (D/E) (seriously modified) was OSAEH 11_8 (on the Blesbokspruit)-the most upstream site in the Vaal catchment.

Compared to the sites reported on in JBS1, seven sites remained in a C category, while 11 showed deterioration in EcoStatus category. Of the sites that showed deterioration, one changed from a D to a D/E (OSAEH 11_8), six changed from a C to C/D, one site (OSAEH 11_14) from a B/C to D and three sites from a C to D category. Of concern is that these results indicate a general decline in the overall EcoStatus for the sites that were measured in both JBS1 and JBS2. Only three improvements in overall EcoStatus score from JBS1 were noted. OSAEH 11_3 improved from an E to a D category, OSAEH 29_1 improved from a D to a C category and OSAEH 28_5 improved from a B/C to B category. With only two surveys available to compare trends- confidence in the observed trends is low. Future surveys will be necessary to determine if these trends are consistent.

4.6 General Management Recommendations for the Orange-Senqu River Basin

From analysis and discussion within the catchment overview sections, the following key management recommendations are highlighted for the Orange-Senqu River Basin:

- The correct management of hydropower and irrigation releases (particularly in the Orange River) as per recommendations emanating from Instream Flow Requirement (IFR) studies and Reserve studies
- The controlling and monitoring of sediment loads emanating from overgrazing, crop and cattle farming (particularly high impact within the Upper Orange/Senqu)
- Managing the condition of riparian zones with particular impacts related to adjacent land uses, buffer zones and loss of ecological infrastructure
- Water quality monitoring and control (especially the Vaal River and Caledon Rivers)
- Assessment of Waste Water Treatments Works, along with effluent compliance and management. This should entail a survey to assess the number of WWTW's within the Basin and determine their individual Green Drop status scores. If Green Drop scores for certain WWTW's are found to be below national guideline limits then enquiries should be made with local authorities to a) assess problems with those WWTW's and b) rectify the issues,
- Investigation of acid mine drainage and industry releases, including addressing the following questions;
    - How many mines and industries are located in riparian zones?
    - What is the nature of their effluents?
    - Investigate whether stricter monitoring by local authorities is needed?
- Investigate the impacts of weirs, barrages and dams on migration and habitat connectivity.

To aid in achieving the above recommendations and to contribute to the effective management of the Orange-Senqu River Basin the following suggestions are proposed:

- The responsible parties from the member states should undertake quarterly to bi-annual monitoring of some of the components of aquatic ecosystem health (e.g. macroinvertebrates, diatoms and water chemistry) at key and/or strategic sites within their jurisdiction. The frequency of monitoring will be dependent on the biological component monitored. Water chemistry and Diatoms can be monitored quarterly to determine integrated water quality, while fish and macroinvertebrates can be monitored bi-annually to determine ecosystem health.
- In order to ensure that data is collected in a standardised manner across the Orange-Senqu River Basin it is recommended that ORASECOM promote the use of EcoStatus assessment methods in member states and provide capacity building/training opportunities to the designated parties to undertake these assessments. It is further strongly recommended that an external review by personnel of the funders to the Joint Basin Surveys be undertaken subsequent to the termination of the following survey. This external review is to ensure that the basin management recommendations are being attended and adhered to, and will provide motivation of the responsible parties

to improve and maintain on the effective management of the water resources within the Basin.

Of crucial importance to the future sustainable management of the catchment is the dissemination of the information generated during the Joint Basin Surveys, by ORASECOM. This is in order to create awareness amongst the land owners, farmers, industries etc. as to the impacts, drivers and management needs within the Orange-Senqu River Basin, and how water and land users can play a role.

4.7 General Recommendations for Future Joint Basin Surveys

Through undertaking the Joint Basin Survey 2, the following recommendations are made with respect to future surveys:

- It is important to plan the survey such that the fieldwork component can be undertaken within the optimal season for sampling. It is suggested that this may be spring or autumn, where flows are more favourable and vegetation sampling can be undertaken to greater effect. This is particularly crucial with regards to the ephemeral systems present in the Basin and therefore, it is recommended that the responsible parties in the member states sample when surface water flow is present in these systems. This will aid in creating a database of the biota that inhabit/utilise these ephemeral systems and will inform their management in the Basin.
- Continuity in sampling, data gathering and record keeping is important across subsequent surveys, to best assess changes and inform management actions. Consistent sampling of the same sites at the same periods and through the same suite of assessments is important to achieve this. Detailed record keeping and the development and maintenance of databases which cover all surveys is of importance. These data must be made available during the planning and proposal stages of subsequent surveys in order to facilitate continuity of sampling and efficiency of operations and costs.
- Project timeframes must be planned to allow adequate time for effective project implementation. Additional time is suggested for logistical planning, reporting and fieldwork. For example:
    - Lead time to organise work visas for the neighbouring countries is approximately 3 months; and
    - Lead time needed for organising access permits for Sperregebiet, Namdeb diamond mine area near Alexander Bay is one to two weeks (if all forms and supporting documentation is provided). However, police clearance, which is also required to access the site, can take 2-3 months to obtain in respective countries. Access to this area is strictly controlled by Namdeb Diamond Corporation and the Namibian Ministry of Mining and Energy. As such, if this site is to be considered in future surveys, the application process for work permits should be initiated with Namdeb Diamond Corporation timeously and police clearance to obtain access to Alexander Bay must occur at least five months prior to the date of sampling.

- It should be noted that the JBS project co-ordinator from ORASECOM should apply for necessary work visas on behalf of the sampling teams in conjunction with negotiating a diplomatic agreement with the relevant governmental departments of participating member states at least three to four months prior to the date of sampling. The diplomatic agreements should be arranged by ORASECOM (at higher levels than the project co-ordinator) well in advance of sampling.
- The ILB program sampling should be undertaken separately from the JBS AEH survey. As an alternative approach, member state personnel could collect samples from the sites in their respective countries, which are then couriered to participating states. A second option is to utilise the SABS Proficiency Testing Scheme (PTS), which is already operational, is accredited and operated independently. While several labs already participate in the SABS PTS, those laboratories could offer to disclose their results every five years to a water quality expert (as part of the Joint Basin Survey team) who could compile a laboratory comparison report, based on the SABS PTS results rather than collected field samples. Laboratories in the member states not currently participating in the SABS PTS could aim to join the scheme over the next five years before JBS3 is conducted.
- A final protocol for the site nomenclature should be developed for the Joint Basin Surveys. (could either continue to use OSAEH nomenclature or change it to JBS site names) They recommended this in JBS1 but the sites they used were EWR and IFR sites (they assigned JBS site names to these sites in their recommendations) but many of these sites were not used in JBS2.
- For JBS2, all of the final sites selected proved suitable and accessible. The sampling manual will highlight sites with specific access requirements.
- For further JBS's it is imperative that the designated consultants utilise the JBS1 and JBS2 documentation to determine sampling sites. This will entail filtering of recommended sites from JBS1 and JBS2 during the tender process. In addition, the Orange-Senqu Aquatic Ecosystem Health Monitoring Programme (ORASECOM, 2009a) should be reviewed to identify sample sites.

4.7.1 Water quality data recommendations for future surveys

Due to the importance of the assessment of nutrient enrichment and trophic status in the evaluation ecosystem health, it is important that the analytical detection limits of nutrients analysed by laboratories are low. Ideally, to facilitate assessment, the limits of detection are recommended to be within the oligotrophic category of South African Water Quality Guidelines for Aquatic Life (DWAF, 1996) and other international guidelines, for example Inorganic Phosphorus: 5 µg/l. It is therefore recommended that a rigorous assessment of the suitability of detection limits of the selected laboratory is undertaken in relation to the applicable guidelines/water quality objectives, prior to the appointment of the laboratory.
Data validation and an assessment of internal consistency are recommended to be undertaken for electrical conductivity and TDS data for the same sample. Since TDS (mg/l) is approximately equal to electrical conductivity (mS/m) x 6.5, any TDS/conductivity ratio that falls outside of 50% ± 6.5 (3.25 and 9.75), should be flagged for further investigation.

To ensure the credibility of pH measurement, it is recommended that meters are calibrated at a daily frequency prior to commencement of sampling. After calibration, an Analytical Quality

Control (AQC) sample of a known pH is recommended to be measured, and the result assessed whether it falls within the allowable range. If the result falls outside the allowable range, calibration and measurement of the AQC is recommended to be repeated. Alternately, the pH probe may require replacement.

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APPENDIX A

Table App A. 1. Summary of AEH site information in relation to JBS1 and governmental water quality monitoring points (DWS, Lesotho, Namibia). Actual Long and Actual Lat columns denote site GPS co-ordinates for JBS2 versus those provided by the ORASECOM secretariat (Proposed Lat, Proposed Long)

Site Number	Major River	Cross reference to Historical WQ data	Lesotho SASS and WQ Data	Namibian Monitoring Points	Cross reference to JBS 1 site	Member State	Proposed Long.	Proposed Lat.	Actual Long	Actual Lat
OSAEH_11_1	Vaal	C2H061 / WMS C25_90645 (1972-2014)			OSAEH 11.1 (C2VAALBLOEM)	South Africa	26.21604	-27.51729	26.20999	-27.51606
OSAEH_11_3	Vaal	C2H001 / WMS C23_90613 (1979-2014); C2R004 (1979-2015);C2H252 (1998-2013)			OSAEH 11.3 (C2MOOIMEULS)	South Africa	28.57393	-26.68283	27.09980	-26.68437
OSAEH_11_4	Vaal/ Mooi	C2H084 / WMS C24_90667 (1979-2015); C2H073 / WMS C24_90656 (1980-2015)			OSAEH 11.4 Skoonspruit (C2SKOOURANI)	South Africa	26.66527	-26.93333	26.66428	-26.93451
OSAEH_11_6	Vaal/ Skoonspruit	C7H006 / WMS C70_90853 (1974-2014)			OSAEH 11.6 Renoster (C7RENOR501B)	South Africa	27.00991	-27.05286	26.99638	-27.04099
OSAEH_11_8	Vaal/ Renoster	C2H185 / WMS C21_177840 (1992-2013); C2H133 / WMS C21_90681			EWR11; OSAEH 11.8 (C2BLESMARAI)	South Africa	28.43194	-26.47500	28.42692	-26.47759
OSAEH_11_13	Vaal/ Blesbokspruit	C2H140 / WMS C23_90688 (1996-2015)			OSAEH 11.13 Vaal at Parys C2KROMAVAAL)	South Africa	27.58428	-26.80030	27.57442	-26.81117
OSAEH_11_14	Vaal/ Kromellenboogspruit	C2H004 / WMS C21_90615 (1984-2013)			EWR1; OSAEH 11.14 (C2SUIKBADFO)	South Africa	28.05011	-26.68122	28.04964	-26.68119
OSAEH_11_18	Vaal/Modder/ (Suikerbosrand?)	C5H003 / WMS C52_90811 (1987-2015)			OSAEH 11.18 (C5MODDSANNA)	South Africa	26.57194	-29.16111	26.57225	-29.16067
OSAEH_11_21	Modder/ Karonnaspruit	C5H026 / WMS C52_90826 (Only six points 1987-1988)			OSAEH 11.21 (C5KORAMOCKE)	South Africa	26.62615	-29.08107	26.63384	-29.08584
OSAEH_26_1	Vaal	C9R003 / WMS C92_101787 (1977-2014)			Osaeh 26.1 – Riet/Vaal (C9VAALDOUGL)	South Africa	23.80646	-29.00083	23.82103	-29.05503
OSAEH_26_10	Riet	C5H012 / WMS C51_90816 (1975-2014; C5R001 / WMS C51_90838 (1972-2015); WMS C51_189023 (2011-2015)			OSAEH 26.10 - Riet (C5RIETIFR03)	South Africa	25.70805	-29.57528	25.70805	-29.57528
OSAEH_29_1	Vaal/ Harts	C3H016 / WMS C33_90788 (1992-2015)			OSAEH 29.1;EWR 17	South Africa	24.31354	-28.35124	24.30178	-28.37928
OSAEH_29_2	Vaal	C9H008 / WMS C91_90898 (1957-2015)			Not sampled	South Africa	24.80193	-28.11097	24.81138	-28.11180
OSAEH_29_4	Vaal	C9H024 / WMS C92_101770; C9H023 (1992-2013)			OSAEH 29.4 (C9VAALSCHMI) – Vaal; EWR 18	South Africa	24.07293	-28.72533	24.07428	-28.70310
OSAEH_29_5	Riet	C5H018 / WMS C52_90820 (1971-2013); C5H014 / WMS C51_90817 (1992-2014)			Osaeh 29.5 - Riet; EWR 19	South Africa	24.51250	-29.02805	24.51292	-29.02696
OSAEH_11_20	Riet/ Modder	None			Not sampled	South Africa	27.13561	-29.52197	27.12968	-29.51769
OSAEH_11_22	Orange	D1H009 / WMS D12_101793 (1963-2015); WMS D12_186214 (One point only in 2002)			Not sampled	South Africa	27.21889	-30.50472	27.21398	-30.48755
OSAEH_15_1	Caledon	D2H012 / WMS D21_101808			EFR C5	South Africa	28.15083	-28.72231	28.15575	-28.72313
OSAEH_15_2	Malibamatso/ Matsuko	None			LHDA IFR9	Lesotho	28.56417	-29.25583	28.56182	-29.23410

Site Number	Major River	Cross reference to Historical WQ data	Lesotho SASS and WQ Data	Namibian Monitoring Points	Cross reference to JBS 1 site	Member State	Proposed Long.	Proposed Lat.	Actual Long	Actual Lat
OSAEH_15_3	Senqu	D1H005 / WMS D17_101790 (1952-2007); D1H035 WMS D17_101802 (1987-2014)	Senqu @ Whitehill		LHDA IFR5	Lesotho	28.40770	-30.06556	28.40896	-30.06558
OSAEH_15_5	Malibamatso	WMS D17_186211 (One point 2002)			LHDA IFR8	Lesotho	28.22250	-30.03630	28.18295	-30.02106
OSAEH_15_6	Caledon	D2H020 / WMS D22_101809 (1982-1991); D2H011 / WMS D22_101807 (1981-1994); WMS D22_191354; WMS D22_191353	Mohokare at Ratjomose (CQ34)		Not sampled	Lesotho	27.44597	-29.35434	27.40529	-29.37106
OSAEH_26_2	Orange	D3H012 / WMS D33_101827 (1971-2014)			EFR OR 1	South Africa	24.09160	-29.60070	24.21554	-29.64356
OSAEH_26_3	Orange	D3H008 / WMS D33_101824 (1966-2015)			Not sampled	South Africa	23.69651	-29.16207	23.69191	-29.14207
OSAEH_26_8	Caledon	D2H036 / WMS D24_101816			EFR C6	South Africa	26.27088	-30.45233	26.30501	-30.42757
OSAEH_26_11	Orange/ Kraai	D1H007 / WMS D13_101792 (1974-1975); WMS D13_100164 (Eight points 1974-1974			EFR K7	South Africa	26.77132	-30.70364	26.74157	-30.69007
OSAEH_26_12	Orange/ Seekoei	D3H015 / WMS D32_101829 (1981-2015)			Not sampled	South Africa	25.00357	-30.38766	25.00095	-30.37358
OSAEH_26_13	Orange/ Stormbergspruit	None			Not sampled	South Africa	26.44681	-30.70364	26.46516	-30.65017
OSAEH_26_14	Orange	D1H003 / WMS D14_101789 (1968-2015); WMS D14_191415 (2013-2014); WMS D14_191414 (2013-2014)			Not sampled	South Africa	26.45305	-30.57305	26.45166	-30.57142
OSAEH_26_15	Orange	D3H013 / WMS D34_101828 (1976-2014)			Not sampled	South Africa	25.22555	-30.50305	25.24003	-30.50378
OSSWQ_15_1	Mohokare	D2H035 / WMS D22_101815	Mohokare at Lifemeng (CQ18)			Lesotho	28.36000	-28.69030	27.89076	-28.91251
OSSWQ_15_2	Mohokare	D2H012 / WMS D21_101808	Mohokare at Mabine (CQ05)			Lesotho	27.89090	-28.91090	28.36762	-28.68582
OSSWQ_11_1	Mohokare at Ratjomose	D2H11/WMS D22_101807/D2H011Q01(1981-1944) D2H20/WMS D22_101809/D2HQ01 (1982-1991)	Mohokare (Caledon) Ratjomose			South Africa	27.43947	-29.33280	27.40529	-29.37106
OSSWQ_15_3	Makhaleng at Maphohloane	Lesotho Data MQ10 Mohales Hoek; D1H006/ WMS D15_101791 (1975-2015)	Makhaleng @ Maphohloane (MQ10 Mohales Hoek)			Lesotho	27.43361	-30.09040	27.43446	-30.08881
OSSWQ_15_4	Senqu at Seaka Bridge	Lesotho Data SQ82 Quthing D1H031 / WMS D18_86280 (One point 2002);	Senqu @ Seaka (SQ82 Quthing)			Lesotho	27.57540	-30.36400	27.57665	-30.36438
OSSWQ_26_2	Orange at Marksdrift	D3H8/WMS D33_101824/D3H008Q01 (1966-2015)				South Africa	23.69639	-29.16170	23.69191	-29.14207
OSAEH_26_4	Orange/ Hartbees	No water quality analysis (Zero flows)/ No monitoring stations			Not sampled	Namibia	20.61190	-28.84095	20.64283	-28.85738
OSAEH_26_7	Orange/ Brak	No water quality analysis (Zero flows)/ No monitoring stations			Not sampled	South Africa	23.17031	-29.91500	23.01667	-29.62299
OSAEH_26_16	Orange	D7H2/WMS D72_101874/D7H002Q01 (1952-2014)			Not sampled	South Africa	22.75574	-29.66075	22.74464	-29.65519
OSAEH_26_17	Orange	D7H5/WMS D73_101877/D7H005Q01 (1952-2014)			OSAEH 26.17 Gifkloof - Orange (D7ORANGIFKL)	South Africa	21.40583	-28.43861	21.40106	-28.43735

Site Number	Major River	Cross reference to Historical WQ data	Lesotho SASS and WQ Data	Namibian Monitoring Points	Cross reference to JBS 1 site	Member State	Proposed Long.	Proposed Lat.	Actual Long	Actual Lat
OSAEH_28_1	Orange	D8H8/WMS D81_101893/D8H008Q01 (1980-2015)			Not sampled	South Africa	19.14531	-28.96411	19.17281	-28.95826
OSAEH_28_2	Orange	186794/WMS D81_186794 (One sample 2002); D8H2/WMS D81_101887/D8H002Q01 (1968-2012)			EFR OR 3	South Africa	20.17482	-28.51115	20.17190	-28.51060
OSAEH_28_3	Orange	D8H5/WMS D82_101890/D8H005Q01 (1971-2003); 186827/WMS D82_186827 (One sample 2002)			Not sampled	South Africa	18.42036	-28.90205	18.39148	-28.89773
OSAEH_28_4	Orange	D8H3/WMS D82_101888/D8H003Q01 (1959-2015); 186829/WMS D82_186829 (One sample 2002)		OR1 Noordowever; OR2 Felix Unite	EFR OR 4	South Africa	17.61856	-28.73645	17.72510	-28.76204
OSAEH_28_5	Orange	D8H6/WMS D8_101891/D8H006Q01 (1980-1982) ; 186867/WMS D82_186867(One sample 2002)		OR8 Sendelingsdrif; OR7 Above new weir	OSAEH 28.5	South Africa	17.06967	-28.04051	16.94431	-28.07772
OSSWQ_26_1	Vaal at Douglas Barrage	C9R003 / WMS C92_101787 (1977-2014)				South Africa	23.68738	-29.05280	23.69077	-29.05697
OSSWQ_26_3	Orange at Irene	D7H11/ WMS D71_101880/D7H011Q01 (1989)				South Africa	23.57560	-29.18250	23.56933	-29.18915
OSSWQ_28_1	Orange at Blouputs	186794/WMS D81_186794 (One sample 2002); D8H2/WMS D81_101887/D8H002Q01 (1968-2012)				South Africa	20.14830	-28.49460	20.17190	-28.51060
OSSWQ_28_2	Orange at Vioolsdrift	D8H3/WMS D82_101888/D8H003Q01(1959-2015); 186829/WMS D82_186829 (One sample 2002)		OR1 Noordowever; OR2 Felix Unite		Namibia	17.72631	-28.76210	19.17281	-28.95826
OSSWQ_28_3	Orange at Sendelingsdrift	D8H6/WMS D8_101891/D8H006Q01 (1980-1982); 186867/WMS D82_186867(One sample 2002)		OR8 Sendelingsdrif; OR7 Above new weir		Namibia	16.88290	-28.09720	18.39148	-28.89773
OSAEH_26_18	Fish	NOT SAMPLED				Namibia	17.78942	-26.80313		
OSSWQ_28_4	Alexander Bay	NOT SAMPLED D8H012 / WMS D82_101894 (1995-2010); D8H007 / WMS D82_101892 (1971-2010)				South Africa	16.50728	-28.56690		
WW39840	Blumfelde					Namibia	18.99960	-24.56400	18.38873	-23.64748
WW40960	Stampriet					Namibia	19.99940	-25.16510	20.61719	-26.46936
BH5229	Two Rivers					Botswana	21.80930	-26.65440	20.61719	-26.46936
BH9087	Tsabong					Botswana	21.96100	-25.77270	22.37459	-25.76361
BH1255	Mokatako					Botswana	26.10820	-24.69720	25.22608	-25.76361
42477	Tswalu					South Africa	22.59320	-27.24150	22.48868	-27.28592

APPENDIX B

Table App B. 1. Recommendations from JBS1 for sites not included in the list of 56 sites originally provided by the ORASECOM Programmes (AEH, Surface Water and Groundwater Quality). ✓ = recommended, ✗ = not recommended, - = no recommendation made.

VAAL CATCHMENT		
EWR1	Indications that there are water quality problems as the fish show signs of serious bacterial infection and quality sensitive macroinvertebrates are absent.	-
EWR2	The site is located just below Grootdraai Dam. Due to flow modification originating from Grootdraai Dam, habitat may be altered and the site is too high in the catchment to detect impacts lower downstream and not considered as a high priority site. However, as there are indications that water quality is deteriorating, this site should be included as a water quality monitoring site.	✓
EWR3	EWR 3 is upstream of the Waterval River confluence and therefore the deteriorated water quality entering the Vaal River from the Waterval catchment will not be detected. OSAEH 11.2 is downstream of this confluence but may be influenced by inundation from the Vaal Dam which would make sampling difficult. Based on the data availability and level of analysis undertaken at EWR 3, this site is a preferred biomonitoring site.	✓
EWR4	This site is situated just below the Vaal Dam and represents critical habitat in the reach as the rest of the reach is inundated by the Vaal Barrage. This site is however too close to the Vaal Dam to detect any major impacts and access to the site is difficult as Rand Water controls access.	✗
EWR5	EWR 5 is situated at the end of the WMA 10 km upstream of the Mooi River confluence and the farthest EWR site in the Vaal River. It is impacted by major upstream anthropogenic activities upstream. This site is situated downstream of the Vredefort Dome World Heritage area and is therefore a very high priority monitoring site.	✓
EWR6	Considering the importance of this tributary as well as data availability and the level of analysis undertaken at EWR 6, this site is a preferred biomonitoring site.	✓
EWR8	The site is impacted by WWTWs (Harrismith, Industriqwa, Warden and Tshiane) and receives diffuse runoff from agricultural, urban (Harrismith) and industrial activities (Industriqwa). Weirs occur in the system for the purposes of abstraction for purification purposes, fish dams and abstraction by tankers. This site could be valuable for detecting upstream anthropogenic activities. Sterkfontein releases impact on turbidity levels, habitat loss, decreased temperature and oxygen levels.	✓
EWR9	OSAEH 11.15 is at the same locality as EWR 9 and considering that the lower reaches of the Suikerbosrand is impacted by mining and other industrial activities this site should be included in a monitoring programme.	✓
EWR12	EWR 12 is situated in quaternary catchment C24A, upstream of the confluence with the Koekemoerspruit at Vermaasdrift on the main stem of the Vaal River but downstream of the Rhenoster and Mooi river. The site is adequate for biotic monitoring and an important future monitoring site as it is important to understand the influence of the Upper Vaal WMA.	✓
EWR13	OSAEH 11.1 is situated approximately 5 km downstream of EWR 13 in quaternary catchment C24J. Both sites are adequate as future monitoring sites. However OSAEH 11.1 may be more suitable as there are more unique habitats present and the site is located further downstream in quaternary catchment C24J. As both sites occur within the same EcoRegion and MRU and as the PES results were similar, the data collected at both these sites are valid. However within MRU Vaal G the presence of a Nature Reserve would warrant a further delineation of the MRU into Reserve Assessment Units as the habitat at OSAEH 11.1 is more unique and more responsive to flow changes than EWR 13, although the EWR site is more representative of the reach.	✗
EWR14	EWR 14 is at the same location as OSAEH 11.5 and is the only site that has been identified in the Vals River. The data collated during the Reserve study is important and adequate.	✓

EWR15	EWR 15 is at the same location as OSAEH 29.3 and is situated in the Vet River downstream of the confluence with the Sand River. As this is the only site that has been identified in the Vet River, the data collated during the Reserve study is important and adequate.	✓
EWR16	Seems adequate for the full suite of biological components to be monitored. This site may be more valuable in a monitoring programme than EWR 16 as it is situated further downstream in the Vaal River and therefore more suitable to detect upstream impacts.	✓
UPPER ORANGE/SENQU CATCHMENT		
IFR2	On the Malibamatso River downstream of the Katse Bridge representing, the Malibamatso River from Katse Bridge to the confluence with the Matsoku River (IFR Reach 2). Same as OSAEH 15.1	✓
IFR3	On the Malibamatso River at Paray, representing the Malibamatso River from the confluence with the Matsoku River to the confluence with the Senqu River (IFR Reach 3).	✓
IFR4	On the Senqu River at Sehonghong, representing the Senqu River from the confluence with the Malibamatso River to the confluence with the Tsolike River (IFR Reach 4).	✓
IFR6	On the Senqu River at Seaka Bridge, representing the Senqu River from the confluence with the Senqunyane River to the Lesotho/South Africa border (IFR Reach 6).	✓
IFR7	On the Senqunyane River at Marakabei, representing the Senqunyane River from the site of the proposed Mohale Dam to the confluence with the Lesobeng River (IFR Reach 7).	✓

APPENDIX C

Table App C. 1. Results of water chemistry analyses from samples taken at all AEH sites sampled during JBS2 in the Orange-Senqu River Basin.

Site	Temp (°C)	DO (% saturation)	pH	(EC) (mS/m)	(TDS) (mg/l)	SS 105°C * (mg/l)	Turbidity (NTU)	Total Alkalinity as CaCO3 (mg/l)	Sodium as Na (mg/l)	Potassium as K (mg/l)	Calcium as Ca (mg/l)
OSAEH_11_1	16.3	116.4	8.26	56.4	462	12.7	12	92	62	9.5	45
OSAEH_11_3	16.3	106.1	7.53	52.6	494	<1.0	2.3	232	26	2	60
OSAEH_11_4	15.6	48.4	6.93	112.3	818	2.7	3.7	296	110	22	91
OSAEH_11_6	11.2	100.9	7.28	32.3	304	2.7	3.9	156	28	4.1	40
OSAEH_11_8	11.1	63.3	7.05	38.4	498	1.3	3.2	192	70	11.7	53
OSAEH_11_13	10.4	62.8	7.25	20.98	198	<1.0	25	152	21	6.9	19
OSAEH_11_14	12.4	87.1	7.29	52.8	446	12	9.2	176	65	9.8	49
OSAEH_11_18	12.2	76.5	8.74	22.4	192	13.3	16	132	21	5.4	29
OSAEH_11_20	9.04	70.2	7.9	28.67	254	3.3	3.4	208	28	4.8	32
OSAEH_11_21	10.7	75.6	7.63	32.8	298	5.3	4.8	240	25	4.5	45
OSAEH_11_22	11.72	108.5	8.42	11.39	102	57	64	76	5	<1.0	15
OSAEH_15_1	10.45	101.3	8.39	20.95	176	6	3.8	152	9	<1	28
OSAEH_15_2	9.42	100.6	7.96	9.77	88	61	21	48	2	<1	12
OSAEH_15_3	9.85	99.4	8.41	12.54	124	10.7	5.4	104	4	<1	23
OSAEH_15_5	9.89	104.4	8.54	14.28	108	<1.0	0.9	100	5	<1	24
OSAEH_15_6	9.82	108.8	8.48	23.84	208	27	29	120	22	3.1	25
OSAEH_26_1	12.5	101.4	6.33	56.3	336	4	5.6	132	40	4.7	34
OSAEH_26_2	10.31	97.9	8.65	14.9	136	6	14	92	8	1.3	22
OSAEH_26_3	12.2	86.08	7.99	14.92	150	6	8.9	96	9	1.3	21
OSAEH_26_8	9.28	101	8.56	24.44	218	3.3	4.9	156	17	2.1	36
OSAEH_26_10	9.1	69.5	8.06	184.6	1584	85	43	236	393	6.1	84
OSAEH_26_11	8.19	103.4	8.49	18.32	192	7.3	3.8	136	7	<1.0	31
OSAEH_26_12	9.56	90.3	9.54	58.53	560	1.3	1.5	280	95	3.3	21
OSAEH_26_13	8.36	90.6	8.37	36.45	340	16.7	17	264	36	3.1	50
OSAEH_26_14	9.42	101.3	8.41	16.35	160	23	23	112	7	<1.0	28
OSAEH_26_15	11.43	111.3	8.49	12.26	132	12	34	76	6	1.3	19
OSAEH_26_16	9.3	84.8	6.37	29.54	154	6.7	10	104	27	2.5	22
OSAEH_26_17	12.3	90.5	6.37	31.2	172	18.7	14	112	28	2.5	24
OSAEH_28_1	13.8	96.4	6.44	40.8	282	16	9	132	28	1	27
OSAEH_28_2	12.7	97.9	6.43	39.6	240	10.7	7.9	132	25	1	26
OSAEH_28_3	15.6	106.5	6.49	40.6	200	4	3.6	132	28	1	28
OSAEH_28_4	15.6	96.7	6.51	41	232	6	4.5	136	27	<1	26
OSAEH_28_5	17.1	130.7	6.56	41.7	238	6.7	3.9	140	30	<1	25
OSAEH_29_1	12.6	86.7	8.29	110.2	968	44	37	224	155	11.4	44
OSAEH_29_2	11.9	93.3	7.46	42	380	5.3	8	132	45	8.9	40
OSAEH_29_4	15.3	85.8	7.57	5.63	474	8	8.1	156	59	8.4	39
OSAEH_29_5	10.92	99.4	8.72	49.11	400	<1.0	1.1	152	60	1.9	36

Site	Magnesium as M (mg/l)	Chloride as Cl (mg/l)	Sulphate as SO4 (mg/l)	Fluoride as F (mg/l)	Nitrate as N (mg/l)	Nitrite as N (mg/l)	Total Nitrogen (mg/l)	Free & Saline Ammonia as N * (mg/l)	Kjeldahl Nitrogen * (mg/l)	Total Phosphate as P * (mg/l)	Ortho Phosphate as P * (mg/l)	Chlorophyll a (µg/l)
OSAEH_11_1	25	56	147	0.3	0.7	<0.1	0.95	0.2	0.8	<0.2	<0.2	85
OSAEH_11_3	48	33	104	<0.2	0.3	<0.1	0.45	<0.2	0.3	<0.2	<0.2	4
OSAEH_11_4	38	132	205	0.3	1.2	0.4	31.6	30	9	5	4.7	13
OSAEH_11_6	19	26	50	0.2	0.6	<0.1	0.75	<0.2	0.6	<0.2	<0.2	3
OSAEH_11_8	20	76	118	0.2	1.5	0.1	1.8	0.2	0.8	0.8	0.7	11
OSAEH_11_13	12	20	29	<0.2	0.2	0.1	0.6	0.3	-	0.2	<0.2	5
OSAEH_11_14	19	64	96	0.2	3.2	<0.1	3.35	<0.2	1.1	0.6	0.5	3
OSAEH_11_18	10	19	17	0.2	0.2	<0.1	0.35	<0.2	1.1	0.2	<0.2	<1
OSAEH_11_20	16	11	8	0.3	<0.2	<0.1	0.35	0.2	0.6	<0.2	<0.2	4
OSAEH_11_21	23	14	15	0.3	<0.2	<0.1	0.25	<0.2	0.6	<0.2	<0.2	1
OSAEH_11_22	6	<5	8	<0.2	0.3	<0.1	0.45	<0.2	0.3	0.5	<0.2	<1.0
OSAEH_15_1	15	7	15	<0.2	0.2	<0.1	0.35	<0.2	<0.2	<0.2	<0.2	<1.0
OSAEH_15_2	6	<5	12	<0.2	2.2	<0.1	2.35	<0.2	0.6	<0.2	<0.2	2
OSAEH_15_3	9	<5	11	<0.2	0.4	<0.1	0.65	0.2	<0.2	<0.2	<0.2	<1.0
OSAEH_15_5	10	<5	10	<0.2	0.2	<0.1	0.35	<0.2	<0.2	<0.2	<0.2	3
OSAEH_15_6	11	17	25	<0.2	1.7	<0.1	1.95	0.2	0.6	0.3	0.2	15
OSAEH_26_1	21	55	70	0.2	0.5	<0.1	0.65	<0.2	1.1	<0.2	<0.2	10
OSAEH_26_2	8	5	9	0.2	0.4	<0.1	0.55	<0.2	0.6	<0.2	<0.2	10
OSAEH_26_3	8	7	9	<0.2	0.4	<0.1	0.55	<0.2	3.1	0.2	<0.2	27
OSAEH_26_8	15	15	17	0.2	<0.2	<0.1	0.35	<0.2	0.6	<0.2	<0.2	<1.0
OSAEH_26_10	35	690	30	2.9	<0.2	<0.1	0.35	0.2	1.1	0.3	<0.2	6
OSAEH_26_11	13	5	9	<0.2	<0.2	<0.1	0.25	<0.2	0.3	<0.2	<0.2	<1.0
OSAEH_26_12	50	77	95	0.5	<0.2	<0.1	0.25	<0.2	1.1	<0.2	<0.2	<1.0
OSAEH_26_13	26	24	12	0.4	<0.2	<0.1	0.25	<0.2	<0.2	<0.2	<0.2	<1.0
OSAEH_26_14	11	7	9	<0.2	<0.2	<0.1	0.25	<0.2	6.7	0.2	<0.2	<1.0
OSAEH_26_15	7	<5	8	0.2	0.5	<0.1	0.65	<0.2	1.1	<0.2	<0.2	<1.0
OSAEH_26_16	11	17	27	0.2	0.6	<0.1	0.75	<0.2	<0.2	<0.2	<0.2	8
OSAEH_26_17	12	20	24	0.2	0.5	<0.1	0.75	0.2	0.2	<0.2	<0.2	17
OSAEH_28_1	16	28	40	0.3	<0.2	<0.1	0.35	0.2	0.6	0.2	<0.2	12
OSAEH_28_2	16	27	36	0.2	0.3	<0.1	0.45	<0.2	0.6	<0.2	<0.2	18
OSAEH_28_3	16	30	40	0.3	<0.2	<0.1	0.25	<0.2	<0.2	0.2	<0.2	7
OSAEH_28_4	16	30	40	0.2	<0.2	<0.1	0.25	<0.2	0.8	<0.2	<0.2	6
OSAEH_28_5	17	25	46	0.2	0.3	<0.1	0.45	<0.2	0.3	<0.2	<0.2	<1.0
OSAEH_29_1	71	202	238	0.5	0.4	<0.1	0.55	<0.2	1.4	<0.2	<0.2	13
OSAEH_29_2	22	51	94	0.3	<0.2	<0.1	0.45	0.3	1.7	0.2	<0.2	4
OSAEH_29_4	29	78	111	0.3	<0.2	<0.1	0.25	<0.2	0.8	<0.2	<0.2	4
OSAEH_29_5	25	75	79	0.2	0.5	<0.1	0.65	<0.2	2.5	<0.2	<0.2	<1