Department of Water & Sanitation

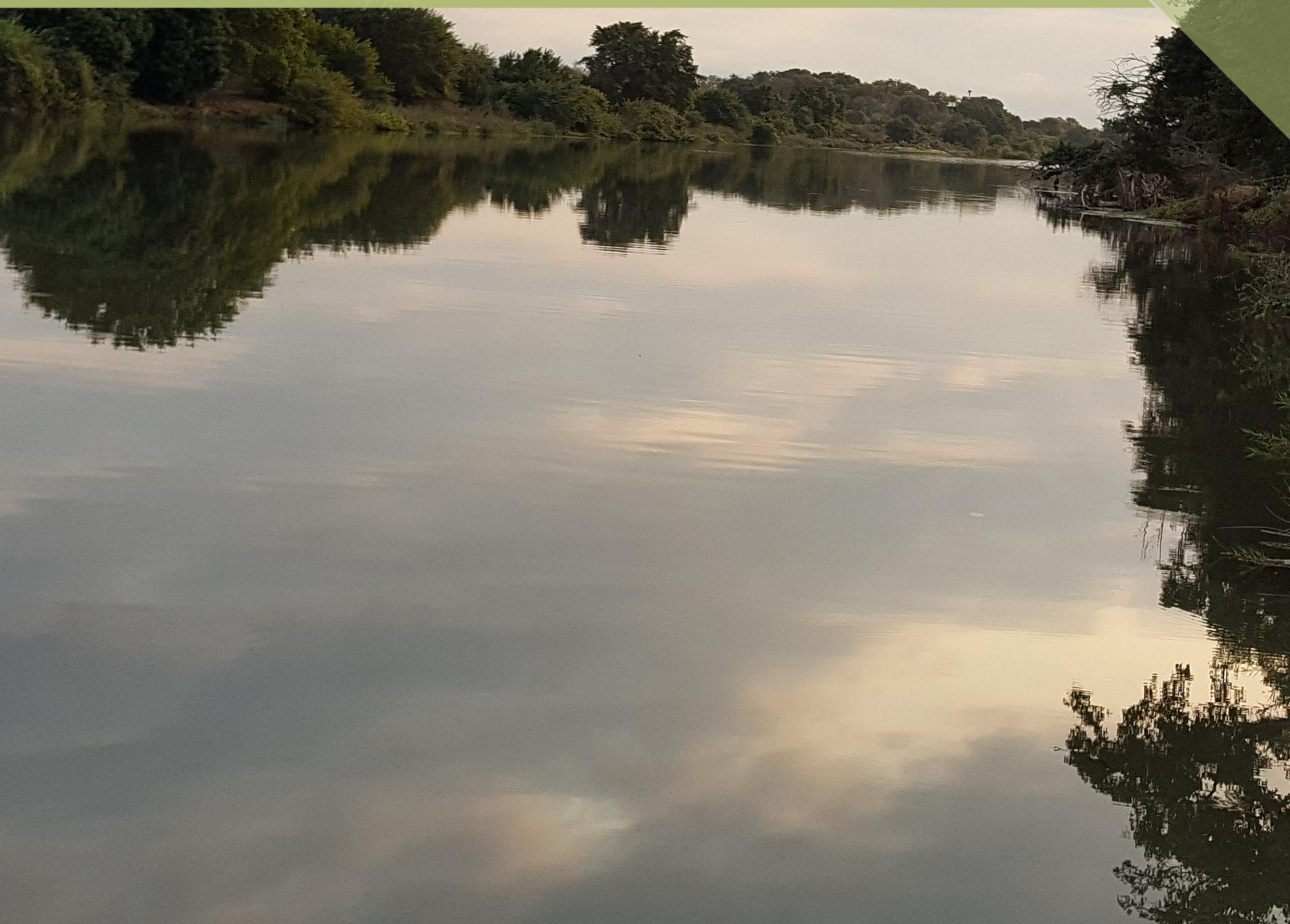
Report Number 3

Edition 2

REPORT

Integrated Water Quality Management Plan for the Olifants River System

Water Quality Planning Limits Report



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DEPARTMENT OF WATER AND SANITATION

Water Resource Planning Systems Series

Development of an Integrated Water Quality Management Plan for the Olifants River System

Water Quality Planning Limits Report

Study Report No. 3

P WMA 04/B50/00/8916/4

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APPROVAL

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EXECUTIVE SUMMARY

The quality of any body of surface water or groundwater is a function of both natural and human influences. If there were no human influences water quality would be determined by the weathering of bedrock minerals, by the atmospheric processes of evapotranspiration and the deposition of dust and salt by wind, as well as by natural leaching of organic matter and nutrients from soil, hydrological factors that lead to run-off and by biological processes within the aquatic environment that can alter the physical and chemical composition of water.

The water quality of a particular body of water is determined by measuring the physical, chemical, aesthetic and biological characteristics of the water and typically, the fitness for use of the water is determined by comparing these characteristics against water quality guidelines or standards for a particular water use. In South Africa, the South African Water Quality Guidelines series (DWAF, 1996) is essentially a series of documents that was developed based on different user specifications (including use by the following sectors: domestic, industrial, livestock watering, irrigation and aquatic ecosystems) and were based on scientifically assessed acceptable levels of toxicity to either humans or aquatic organisms.

Declining water quality has become a global issue of concern as human populations grow, industrial and agricultural activities expand, and climate change threatens to cause major alterations to the hydrological cycle.

The Olifants River system faces a number of water quality challenges impacting on both surface water and groundwater including salinization, sedimentation, nutrient enrichment and microbial and agrochemical pollution, all at different scales within the sub-catchments of the WMA.

Over the years significant catchment development, including industrial growth and power stations, widespread mining activities, especially in the upper catchments, irrigation and formal and informal urbanisation has impacted on the surface water and groundwater resources of the Olifants River System.

The water quality data downloaded from the Departments WMS during the situation assessment in March 2016 (Appendix B), ranged from 1965 to February 2016, depending on the site. In the calculations, where available, the last 10 years of data were used, however there are sites where longer periods of data were used due to limited sampling events, or shorter periods where monitoring only started later. The 5%, 50% and 95% percentile values were used to assess the degree of compliance against the South African Water Quality Guidelines for domestic, irrigation, industrial, livestock watering and ecosystems. Seasonal variation and when exceedances may have occurred is also important, as it is these extreme events that may cause the real concerns, not the average or median values.

Proposed WQPLs have subsequently been set based on the data assessment and refined after further consultation with stakeholders.

Currently, the water quality in the Upper Olifants will not meet the WQPLs proposed. Management actions will therefore need to be set to reduce the associated loads in this sub-catchment in the short- to medium-term to levels that are acceptable and then maintain and improve these over the longer term with further management actions. As the TDS is high throughout the catchment, all sectors (mining, urban and agriculture, but especially mining because the mines appear to be the largest and most persistent contributors to TDS) will need to contribute to the load reduction. The highest limit proposed is 500 mg/L which is aligned to the RQOs for the Olifants. While this value is still high it is important to start with a value that will not intimidate users into 'doing nothing' because they feel that the limit is unrealistic. Achieving the 500 mg/L will reduce the load by more than 50% in certain catchments. The main area of concern in respect of TDS at this level will be the damage to irrigation equipment and salinization of the soil that could lead to reduced crop yields and crop damage to sensitive crops. This will need to be assessed over the longer term by the agricultural sector to be able to inform the need for the WQPLs to be reduced further, albeit in a phased manner over time.

Sulphate WQPLs are high in the Upper Olifants, but reduce moving downstream until the river reaches Phalaborwa where the severe impacts of the industries and mines in the area are seen and have an impact into the KNP. There are certain management units in the Upper Olifants and around Phalaborwa where the current status will not meet the WQPLs. The WQPLs set may be above the current TWQR for domestic use (the strictest requirement), however the limit for drinking water (SANS 241: 2015) is set at 400 mg/L and based on the World Health Organisation (WHO) Guidelines for drinking water in 2017, except for taste and odour concerns, existing data do not identify a level of sulphate in drinking-water that is likely to cause adverse human health effects. In this respect even if communities use water directly from the river at these points, the elevated sulphate concentrations (if ≤400 mg/L) are not likely to impact on human health.

In MU 80 (Phalaborwa) and downstream in the KNP (MU 53), the proposed 500 mg/L is not expected to have impacts on the animals in the KNP, with the limit for livestock watering being 1 000 mg/L. The impacts on the aquatic organisms are however not known as sulphate limits for aquatic ecosystems are not set. Again, it is important to note that the proposed WQPL limit is not cast in stone and should be updated in a phased manner as progress is made in achieving load reduction in the impacted areas.

Orthophosphate WQPLs have been set at limits that will limit the eutrophication potential, particularly in the Middle and Lower Olifants. The concerns are downstream of Witbank into Loskop Dam as well as downstream of the dam and in the Phalaborwa area and into the KNP. These are linked closely to the unacceptably high concentrations of nutrients in effluents emanating from the Emalahleni municipal area. Downstream of Loskop Dam (and Flag Boshielo Dam) nutrient concentrations are lower because the two major dams act as nutrient (plus salts and sediment) traps. Consideration of whether to reduce these limits to the limit at which the potential for eutrophication is low (< 0.015) needs to be discussed and economic considerations assessed.

WQPLs for the tributaries have been set at limits less than or equal to those of the main stem Olifants River System so they will support the achievement of the WQPLs of the main stem.

Except for orthophosphate and nitrate to a lesser extent the WQPLs for the lower catchments of the Letaba and Shingwedzi sub-catchments are in most cases well below those of the Olifants River. The concerns are related more to eutrophication due to run-off and and poorly treated domestic wastewater effluent from poorly managed urban areas. The Shingwedzi sub-catchment is also on the whole a dry surface water catchment with rivers being non-perennial.

It was noted that it would be very difficult to set WQPLs for groundwater, as groundwater, unlike surface water, with a certain chemical quality, cannot easily be changed, for example by dilution. It is therefore important to represent groundwater as having a particular fitness for use and to note that the water may then require treatment if used for a different use, and even to consider setting protection zones around abstraction points. It should also be noted that during the dry season of each year, a large portion of the visible surface water flows in rivers have a groundwater origin.

The groundwater quality fitness for use, domestic water supply, is described and a Quality Index is based on the DWAF, 1998 Domestic Water Quality Classification and the available water quality data. The groundwater quality status/ trend in terms of long-term sustainability describes specific groundwater quality signatures and should help as an indicator of management measures to address these water quality trends. Some of the trends are regional impacts, such as the elevated nitrate values in irrigated areas (Springbok Flats) and rural villages in the Upper/ Middle Olifants and upper Letaba regions. Considering that the larger proportion of groundwater is used for irrigation, rather than domestic use, the Class 0 and I water quality would be acceptable for irrigation use, however the Class II water may be high in TDS and could cause problems with irrigation equipment.

The way forward will be to take the WQPLs for each of the sub-catchments and derive further detail on the sources that contribute to the pollution loads – this will be done in consultation with the relevant Proto-CMA and DWS Regional Offices. Ongoing stakeholder participation will take place giving feedback and getting inputs at the different stages of the project. Modelling will determine what loads need to be removed in those management units where non-compliance has been noted. This will allow the various relevant management options to be assessed for possible implementation, and will form part of the sub-catchment water quality management plans.

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LIST OF ACRONYMS

AMD	Acid Mine Drainage
COGTA	Co-operative Governance and Traditional Affairs
CMA	Catchment Management Agency
CMS	Catchment Management Strategy
DMR	Department of Mineral Resources
DT	Discharge Tables
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
GWP	Global Water Partnership
ICP-MS	Inductively coupled plasma mass spectrophotometry
IWRM	Integrated Water Resources Management
IWQM	Integrated Water Quality Management
IWQMP	Integrated Water Quality Management Plan
IWULA	Integrated Water Use Licence Application
KNP	Kruger National Park
NWA	National Water Act
NWRS	National Water Resource Strategy
ORS	Olifants River System
PAC	Project Administrative Committee
PMC	Project Management Committee
PSC	Project Steering Committee
PSP	Professional Service Provider
RDM	Resource Directed Measures
RQOs	Resource Quality Objectives
RWQOs	Resource Water Quality Objectives
SA	South Africa

SALGA	South African Local Government Association
SAWQG	South African Water Quality Guidelines
TDS	Total Dissolved Salts
TOR	Terms of Reference
TWQR	Target Water Quality Range
WET	Whole Effluent Toxicity
WDCS	Waste Discharge Charge System
WHO	World Health Organisation
WMA	Water Management Area
WMI	Water Management Institution (relating in this report to the CMA)
WMS	Water Management System
WQM	Water Quality Management
WQP	Water Quality Planning
WQPL	Water Quality Planning Limit
WRPM	Water Resource Planning Model

1. INTRODUCTION

In terms of the National Water Act (NWA) (Act 36 of 1998) and in line with the Department of Water and Sanitation's (DWS) obligation to ensure that the country's water resources are fit for use on an equitable and sustainable basis, DWS has adopted the approach of the progressive development and implementation of catchment management strategies (CMS) to fulfil this mandate. Each Catchment Management Agency (CMA) is responsible for the progressive development of a CMS for its respective Water Management Area (WMA), which needs to be developed in consultation with stakeholders within the area. The Department's eventual aim is to hand over certain water resource management functions to these CMAs. However, until such time as the CMAs are established and are fully operational, the Regional Offices of the Department or Proto CMA, referred to as Water Management Institution (WMI), will continue managing the water resources in their areas of jurisdiction with the support of the national office.

The development of the integrated water quality management plan (IWQMP) for the Olifants WMA is being undertaken by DWS National Office in consultation with the WMI, DWS Provincial Office and stakeholders in the WMA. This will ultimately be a sub-strategy that will support the CMS.

1.1 Water Quality Planning Limits development

An important deliverable from the study will be a set of integrated Water Quality Planning Limits (WQPLs) which is the focus of this report. This will include development of WQPLs, adjustments to the existing WQPLs and alignment to Resource Quality Objectives (RQOs).

The following key aspects will follow on the WQPLs development:

- Evaluation of Management Options;
- Sub-catchment Integrated Water Quality Management Plans;
- Assessment and development of a Water Quality Monitoring Programme;
- Compilation of an overall IWQMP including the sub-catchment management plans; and
- A practical and detailed implementation plan.

The following aspects are also fundamental to the study and will inform and support the IWQMP development during the study execution phase:

- Legal considerations that inform the IWQMP and its implementation (sub-catchment and overarching);
- External Drivers, Considerations and Influences to water quality and WQM including the multi-dimensional facets to water quality and WQM such as international and transboundary obligations, water quantity aspects, water resource planning priorities, resource directed measures (Classification, RQOs and the Reserve), ecosystems, water services related aspects, waste

management, water resource economics and integrated water resources management;

- Integration of stakeholder issues and technical aspects; and
- Integration/ alignment with other processes/ initiatives.

1.2 Study area

As described in detail in Report Number: P WMA 04/B50/00/8916/3, the study area is the Olifants Water Management Area, also referred to as the Olifants River System (Figure1), and includes:

- Olifants River catchment: tertiary drainage regions B11, B12, B20, B31, B32, B41, B42, 52, B52, B60, B71, B72 and B73;
- Letaba River catchment: tertiary drainage regions B81, B82 and B83; and
- Shingwedzi River catchment: tertiary drainage region B90.

The area has been sub-divided into the following sub-catchments (Figure 1):

- Upper Olifants;
- Middle Olifants;
- Steelpoort;
- Lower Olifants;
- Letaba; and
- Shingwedzi.

The Olifants River flows northwards through Witbank Dam down to Loskop Dam. The confluences of the Klein Olifants, Spookspruit, Klipspruit and Wilge Rivers with the Olifants River are between the Witbank and Loskop dams. From Loskop Dam the Olifants River flows some 80 km to Flag Boshielo Dam. The Moses and Elands Rivers join the Olifants River downstream of Loskop Dam from the west while the Bloed River joins from the east. The Steelpoort River confluences with the Olifants about 50 kilometres before the confluence of the Olifants and Blyde rivers after which it confluences with the Ga-Selati on the border of the Kruger National Park (KNP). The Letaba River joins the Olifants River upstream of the border into Mozambique in the KNP, after which it flows into the Massingir Dam about six (6) kilomteres from the border, before it joins the Limpopo River which eventually discharges into the Indian Ocean. The Shingwidzi River flows south east through the KNP becoming the Rio Shingwidzi in Mozambique where it confluences with the Rio Elefantes downstream of the Massingir Dam.

This study focusses on the South African sector of the Olifants River system and does not deal with the Mozambique sector, however the improvement in the South Africa portion of the Olifants River system, will ultimately have a positive impact on the Massingir Dam and the lowest reaches of the Rio Elephantes which is controlled by inflows from upstream (South Africa).

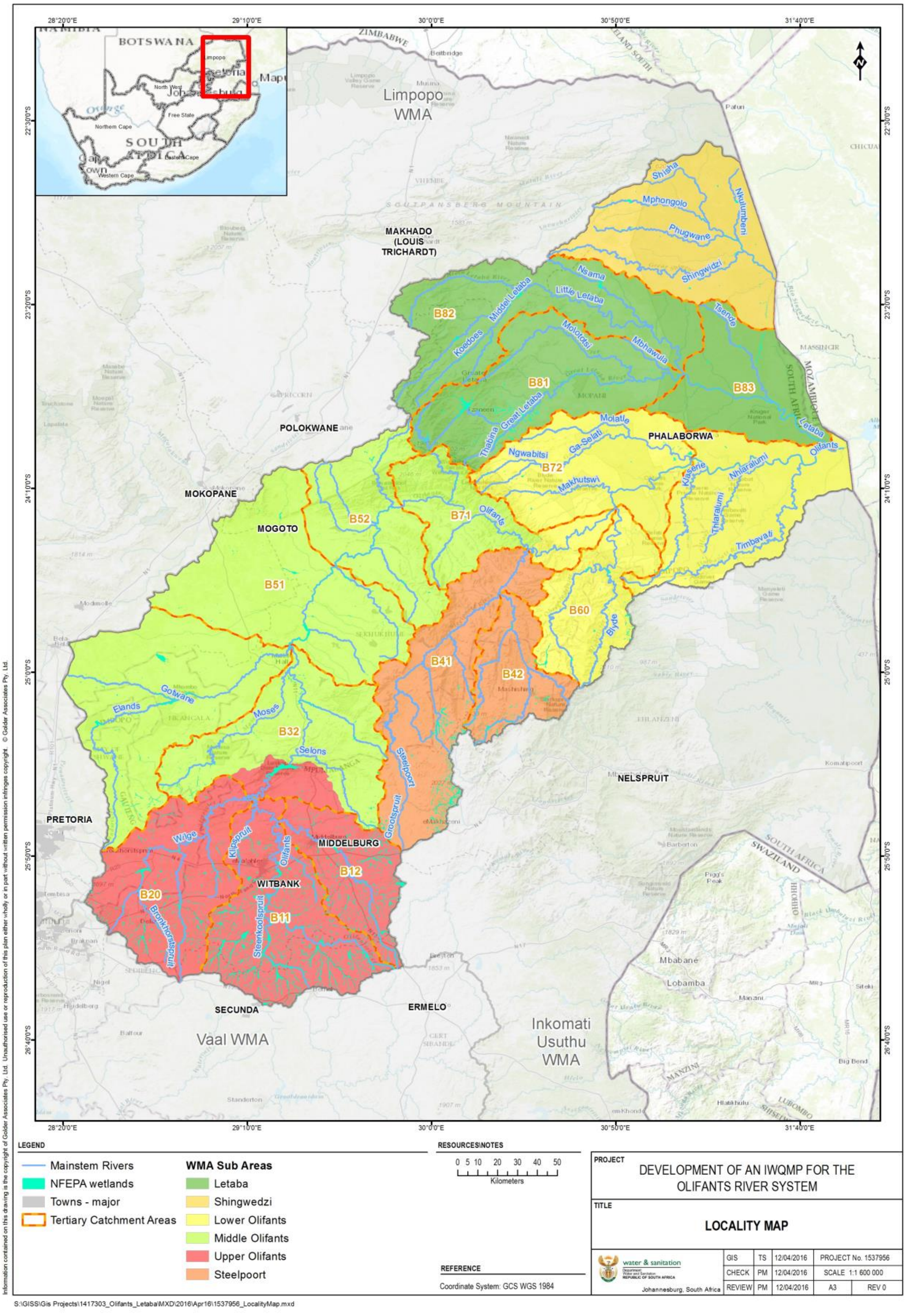


Figure 1: Study area

1.3 Water Users

The water users in the sub-catchments include:

- Mining, industry, irrigation and domestic use in the Upper Olifants;
- Irrigation, limited mining and domestic use in the Middle Olifants;
- Mining, industry, irrigation and domestic use in the Steelpoort;
- Irrigation, limited mining and domestic use in the Lower Olifants
- Irrigation, limited mining and domestic use in the Letaba; and
- Irrigation, potential future mining and domestic use in the Shingwedzi.

In all cases, recreation and aquatic ecosystems will need to be considered as tourism is a key economic driver for all the areas.

1.4 Strategic monitoring points

In the situation assessment task, monitoring points were assessed for location, frequency of monitoring, variables analysed and quality of data. From this assessment, strategic monitoring points on the main stem Olifants as well as on major tributaries were identified.. These are described in Section 3 of this report and have been used in the development of the WQPLs. The data used for each point were retrieved from the DWS Water Management System (WMS) and in a few cases data collected as part of the Controlled Release Scheme.

1.5 Objective of the integration of the water quality planning limits task

As part of the Department's approach to the management of water quality, WQPLs (previously referred to as Resource Water Quality Objectives, RWQO) were set in 2003 and updated in 2009 when developing the Integrated Water Resource Management Plan (DWS Report No: P WMA 04/000/00/6607)(DWAF 2009) for the Upper Olifants sub-catchment and upper portions of the Middle Olifants sub-catchment. Currently no WQPLs exist for the lower portion (below Flag Boshielo Dam) of the Middle Olifants, the Steelpoort, Lower Olifants, Letaba and Shingwedzi sub-catchments.

Typically WQPLs were set defining concentrations for different water quality variables for identified management units. These WQPLs were often set in isolation without consideration of downstream WQPLs.

As part of setting the WQPLs it will be important to assess whether or not the WQPLs on the main stem and on the major tributaries make sense and are aligned and integrated with the various objectives that have been set. It does not make sense to set an upstream WQPL that a particular user will be able to achieve if it will be detrimental to users downstream, as this may have human and ecological health impacts, as well as contributing to physical impacts, such as clogging of irrigation systems and decreased crop yields; all of which would have adverse economic impacts for the region.

1.6 Stakeholder collaboration

It is important to note that as part of the setting of the WQPLs, consultation was done at the following levels:

- Project Management Committee: 17 November 2016;
- Project Steering Committee: 23 November 2016; and
- Broader Stakeholders: 24 November 2016.

In addition, ongoing consultation with focus groups (encompassing Provincial and WMI officials as well as the mining, agricultural, industrial and local government sectors) has allowed for refinement as the process has progressed so that the sub-catchment plans have the full set of finalised WQPLs for that particular area, and the overall IWQMP for the Olifants WMA contains the full set of WQPLs.

2. RATIONALE FOR REVIEWING AND DEVELOPING NEW WATER QUALITY PLANNING LIMITS

Chapter 3 of the National Water Act (Act 36 of 1998) relates to the protection of water resources fundamentally related to their use, development, conservation, management and control.

Part 1 of the NWA provides for the first stage in the protection process, which is the development, by the Minister, of a system to classify the nation's water resources. The system provides guidelines and procedures for determining different classes of water resources. Once the classification has been done, the Minister is required to use the classification system established to determine the class and resource quality objectives (RQO) of all or part of water resources considered to be significant. The purpose of the RQO is to establish clear goals relating to the quality, quantity and ecological components of the relevant water resources. In determining RQOs a balance must be sought between the need to protect and sustain water resources on the one hand, and the need to develop and use them on the other.

In the Olifants WMA the classification and development of RQOs has been completed and gazetted (GN 466, National Water Act, 1998 (Act No.36 Of 1998) Classes And Resource Quality Objectives Of Water Resources For The Olifants Catchment, 22 April 2016). As part of the classification and development of RQOs a visioning exercise was undertaken for the WMA which is a collective statement from all stakeholders of their future aspirations of the relationship between the stakeholders (in particular relating to their quality of life) and the water resources in the catchment.

During the classification study the following provisioning, regulating and cultural aspects were taken into consideration and need to be considered further when developing the WQPLs:

Provisioning services:

- River water for domestic use;
- Livestock watering and grazing;
- Sand and clay harvesting and use;
- Use of plant resources;
- Harvesting and use of wild food and medicinal products;
- Hunting resources; and
- Fishing resources.

Regulating services:

- Value of flood attenuation;
- Value of base flow maintenance;
- Value of water purification; and
- Carbon sequestration values.

Cultural services:

- Value of river based adventure tourism;
- Value of recreational angling;
- Ecotourism value;
- Property values; and
- Scientific and educational value.

Considering the classes set for the Olifants catchment, the vision is a for a catchment that will include management of water quality using source directed measures, plus regulatory and institutional structures, with concerted and regular monitoring and compliance management, to ensure the successful implementation of the management classes and RQOs.

Setting of WQPLs will therefore help to achieve the management class and RQOs for particular areas, as they are set at a finer resolution, and take local users and uses into account.

For example, WQPLs at a finer spatial scale will assist the Environmental Official to for example, assess an Integrated Water Use Licence Application (IWULA) as well as set relevant conditions and manage and control the water users in the sub-catchment in a manner that will allow for sustainable use and development.

The objective of using WQPLs is to provide a mechanism through which the balance between sustainable and optimal water use and protection of the water resource can be achieved. What is important is that WQPLs are aligned to the RQOs and do not contradict the objectives gazetted.

Setting WQPLs and ultimately achieving them will allow for the realisation of the catchment vision by giving effect to the water quality component of the gazetted RQOs.

2.1 Overarching Policy

The Department of Water and Sanitation's policy (DWAF, 2006) regarding WQPLs is that they should:

- Ultimately allow realisation of the catchment vision;
- Give effect to the water quality component of gazetted RQOs;
- Where necessary, express more detailed stakeholder requirements than those accounted for by the RQOs;
- Equal the gazetted RQO, however, they may be set at a finer spatial/ or temporal resolution; and
- Dictate the tolerable level of impact collectively produced by upstream users.

The Department recognises the importance of a strong technical basis for defining WQPLs and in this respect a detailed situation assessment was undertaken (Report No P WMA 04/B50/00/8916/3) and on which this WQPL report is based.

2.2 Guiding Principles

The determination of WQPLs is underpinned by the principle of sustainable development and is also informed and guided by the principles that formed the foundation for the following (DWAF, 2006a):

- *The Precautionary Principle*: a risk averse and cautious approach that recognizes the limits of inadequate current knowledge about the environmental consequences of decisions or actions.
- The default rule described in the *Resource Directed Measures documentation*: the management class is determined in relation to the present state, but at a level which represents a goal of no further degradation for water resources that are slightly to largely modified, and at least a move toward improvement for water resources that have been critically modified.
- The *National Water Resource Strategy*: any water resource which demonstrates 'unacceptable' conditions is deemed to be unsustainable. In these cases the management class will be determined as a minimum of 'heavily used/ impacted' (the lowest management class), and management will aim to rehabilitate the water resources to this state or better.

  Water required to meet basic human needs and to maintain environmental sustainability will be guaranteed as a right, while water use for all other purposes will be subject to a system of administrative authorisation, such as an integrated water use licence or General Authorisation.
- *Environmental rights* as described in the South African Constitution (Act 108 of 1996):

Everyone has the right:

a. To an environment that is not harmful to their health or well-being; and

b. To have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that:

  - Prevent pollution and ecological degradation;
  - Promote conservation; and
  - Secure ecologically sustainable development and use of natural resources, while promoting justifiable economic and social development.

- *Waste Discharge Charge System (WDCS)*: The WDCS will ultimately be designed to be adopted where the desired state for the WQPL is not being met (or is threatened) and provides an economic instrument to assist other regulatory tools in moving towards (or maintaining) the desired state over a pre-defined time period. In this situation, adaptive management (monitoring and review) of the waste discharges, charges and targets (interim WQPLs) will be conducted, in order to achieve WQPLs.

2.3 Balancing the needs of downstream water users with upstream water use and development

In setting WQPLs, the Department strives to achieve a balance between protecting the water resource for downstream users and allowing reasonable use and development of the water resource upstream of the river reach selected for the WQPLs. For the downstream water users, the focus is on protecting the water quality in order to ensure a healthy functional aquatic ecosystem, while also meeting the water quality requirements of the other recognised water user groups such as domestic, agricultural, industrial, recreation and aquatic ecosystems downstream of the WQPLs point.

However, the particular WQPL that is set may also restrict the type and extent of water use upstream of the point, where water uses refer to those described in Section 21 of the NWA (Act 36 of 1998).

As mentioned in the previous section, it should be noted the WQPLs will be used as the basis for the setting of waste discharge standards (Section 26 (1)(h) of the NWA) and waste discharges charges in each catchment. Thus the setting of RQOs and WQPLs become central to balancing the needs of the upstream “impactors” with downstream user requirements.

2.4 Fitness for use

Water quality is interpreted to mean ‘fitness for use’. In other words, those aspects of water that would allow a certain user to use the water for a particular purpose without causing harm, such as a human health impact due to a specific variable or combination of variables in the water.

Fitness for use is a scientific judgement that has been determined by evaluating specific evidence, and determining how suitable the quality of the water is for its intended use. Water quality can therefore only be expressed in terms of fitness for particular uses. Water quality assessment to determine fitness for use is based on using limits, in this case, WQPL, that have been set for the water resource and that have been based on the needs of specific water users of that area.

In South Africa, the South African Water Quality Guidelines (SAWQGs) (DWAF, 1996) were developed as specific values for a suite of variables for different water use sectors (domestic industrial, irrigation, livestock watering, aquatic ecosystems, recreation and aquaculture) that depict the change from one category of fitness for use to another. Currently the SAWQGs recognise only the Target Water Quality Range (TWQR). This is the range of concentrations or levels at which the presence of that constituent would have no known or anticipated adverse effect on the fitness of water for a particular use or on the protection of aquatic ecosystems. In the 1996 SAWQGs these ranges were determined by assuming long-term continuous use (life-long exposure) and incorporated a margin of safety.

Above this value/ range (and in certain cases such as pH, below a specified value/ range) the categories describe an ever increasing negative impact with respect to the use of the water. Thus, for any water resource it is necessary to determine whether or not the effect is acceptable to the user (DWAF, 2006a).

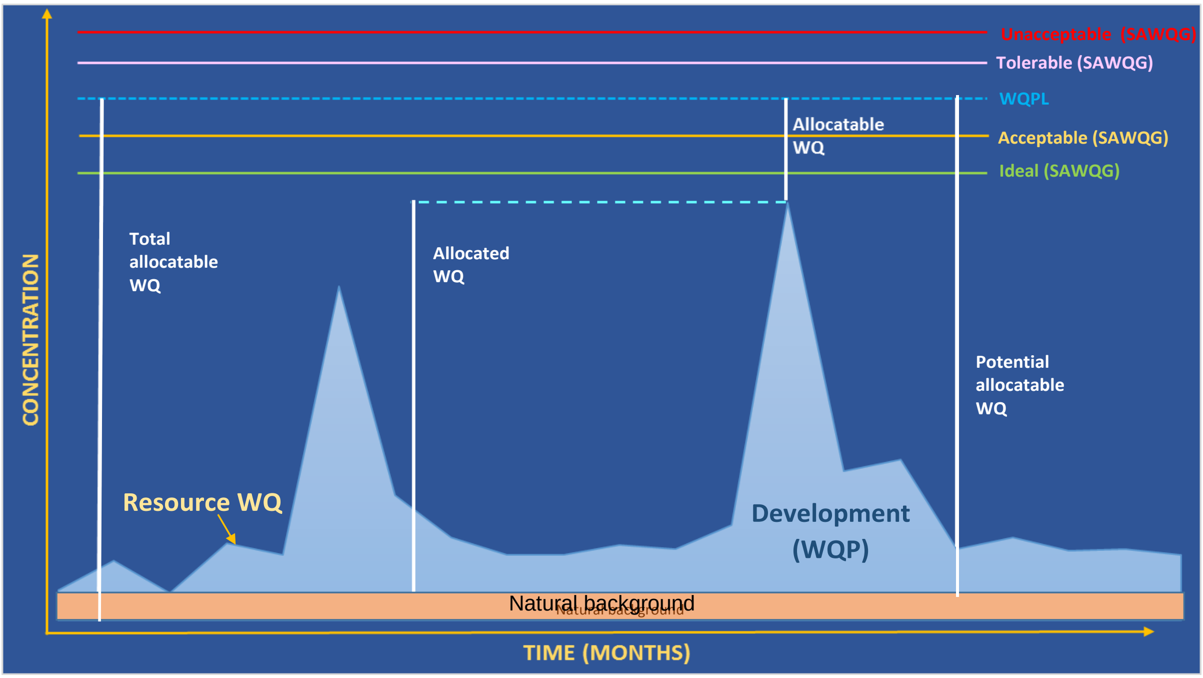
In this respect the water quality guidelines describe the fitness for use of a water resource, while a water quality objective defines a management action that needs to be in place to achieve the fitness for use goals for a particular water resource. The following fitness for use categories are linked to the SAWQGs (DWAF, 1996):

- *Ideal* – based on current knowledge the use of water is not affected in any way; 100% fit for use by all users at all times; desirable water quality (TWQR);
- *Acceptable* – based on current knowledge there may be slight to moderate problems encountered on occasion or for short periods of time;
- *Tolerable* – based on current knowledge moderate to severe problems are encountered; usually for a limited period only. It should be noted that in some cases this short period may in fact span a part of or even a full dry season when river flows are lowest and dilution is at a minimum; and
- *Unacceptable* – based on current knowledge water cannot be used for its intended use under normal circumstances at any time (DWAF, 2006a).

In the SAWQGs the TWQR defines the Ideal category, while the upper limit of where negative effects are seen is defined as the tolerable category. Assuming that a linear distribution in the data was used to derive the TWQRs (DWAF, 1996), the acceptable category was interpolated to be the average of the Ideal category (*i.e*. TWQR) and the tolerable level. The unacceptable category is regarded as any concentration/ level above the upper limit (*i.e.* Tolerable) (DWAF, 2006a).

Figure 2 illustrates the potential for allocation of water quality within a resource using this approach. However, it has been noted that in many cases in the Olifants WMA, this illustration will show that the current data is well above the WQPL and considerable effort will be needed to implement management actions to reduce this scenario.

The assessment of the water resource to rate its current water quality status in terms of fitness for use, supports or links to water quality management related targets and goals, a management action or objective that is required to either maintain or improve water quality at a desired level. This can range from no action (ideal) to immediate intervention (unacceptable).



ACRONYMS

WQPLS	Water Quality Planning Limits (non-gazetted objectives)
SAWQG	South African Water Quality Guidelines
WQ	Water quality
WQP	Water Quality Planning

NOTE: While the WQPLs are positioned below the Tolerable SAWQG, it could be that they are determined at any level below the unacceptable SAWQG according to catchment specific needs

Figure 2: Illustration of water quality allocation (DWAF, 2006)

3. MANAGEMENT UNITS

Based on factors such as land use and water users, climatic, hydrogeological and geographical zones, management units were proposed for each of the six sub-catchments.

In the Upper Olifants sub-catchment and the portion of the Middle Olifants sub-catchment upstream of Flag Boshielo Dam, management units had already been delineated (DWAF, 2009). These were assessed and minor changes made which included:

- An additional management unit in the Upper Olifants sub-catchment, MU 31 which is the catchment of the Vaalbankspruit that confluences with the Klein Olifants River downstream of the Middelburg Dam; and
- Amalgamation of the management units of the Elands River and associated tributaries (B31): MU 32. The reason for this amalgamation is that the water users and land use in the area are very similar throughout the sub-catchment.

The following aspects were also taken into consideration when looking at the management units' delineation:

- Presence of large dams and the way they are operated,
- Presence of water transfer schemes and the way they are operated,
- Presence of large scale irrigation and pumping schemes with their associated return flows that enter the river,
- Presence of point sources of pollution,
- River reaches being used as a conduit with resulting unseasonal flow, and
- Locality and type of planned developments.

4. WATER QUALITY PARAMETERS

The section to follow describes the parameters that have been included as part of the suite of water quality parameters that will be measured to assess compliance against the water quality planning limits.

4.1 Status Quo of WQPL parameters

As described in Section 1.5 as part of the development of an Integrated Water Resources Management Plan for the Upper and Middle Olifants (DWAF, 2009) Resource Water Quality Objectives (RWQO) were proposed for surface water. The existing RWQOs, now referred to as WQPLs, were developed for management units in the Upper Olifants sub-catchment as well the Middle Olifants down to Flag Boshielo Dam. Limits were also set for the major dams in the area. The limits set at the time are included in Appendix A.

The variables included those listed in Table 1. Proposed changes are included in the third column.

Table 1: Water quality parameters to be measured for the Olifants WQPLs

Variable	Units	Proposed changes with reason	
Calcium (dissolved)	mg/L	mg/L	No change
Chloride (dissolved)	mg/L	mg/L	No change
Total Dissolved Solids	mg/L	mg/L	No change
Electrical Conductivity	mS/m	mS/m	No change
Fluoride (dissolved)	mg/L	mg/L	No change
Potassium (dissolved)	mg/L	mg/L	No change
Magnesium (dissolved)	mg/L	mg/L	No change
Sodium (dissolved)	mg/L	mg/L	No change

Variable	Units	Proposed changes with reason	
Ammonia (unionised)	mg/L	mg/L	Propose to report as ionised ammonia - ammonium (NH_4 - N) as proposed in DWA, 2011 status assessment report (DWA, 2011) and as currently reported on WMS
Nitrate as N	mg/L	mg/L	No change
Total Phosphorus	mg/L	mg/L	No change
pH	mg/L	mg/L	No change
Ortho-phosphate as P	mg/L	mg/L	No change
Sulphate (dissolved)	mg/L	mg/L	No change
Total Alkalinity (as $CaCO_3$)	mg/L	mg/L	No change
Dissolved Organic Carbon	mg/L	mg/L	No change
Dissolved Oxygen	% sat	mg/L	DO is most important for aquatic ecosystems. The SAWQG (1996) uses mg/L as the unit of measurement. DO is also important in determining the oxidation-reduction potential of many ions. It is especially important in the case of metal ions.
Sodium Absorption Ratio			No change
Suspended Solids	mg/L	mg/L	No change
Chlorophyll a	mg/L	µg/L	To align with the National Microbiological Monitoring Programme (NMMP), it proposed to change to µg/L. The Reserve also uses µg/L as the unit of measurement.
Escherichia coli	CFU/ 100mL	CFU/ 100mL	No change
Faecal coliforms	CFU/ 100mL	CFU/ 100mL	No change
Aluminium (dissolved)	mg/L	mg/L	No change
Boron (dissolved)	mg/L	mg/L	No change
Chromium (VI) (dissolved)	mg/L	µg/L	To align with SANS 241, it proposed to change to µg/L. The Reserve also uses µg/L as the unit of measurement.
Iron (dissolved)	mg/L	mg/L	No change
Manganese (dissolved)	mg/L	mg/L	No change

Where no data exists on the DWS WMS system, such as for several of the metals and agrochemicals, recommendations regarding improved monitoring will be made as part of the monitoring and implementation plan and confirmed during consultation with stakeholders. This is further described in Section 4.3.

4.2 Variable descriptions

The section to follow describes, briefly, the importance of the variables included and the main concerns related to the major water user: domestic, aquatic ecosystems, irrigation, recreation and livestock watering, as taken from the South African Water Quality Guideline Series (DWAF, 1996).

Calcium (dissolved)

Calcium occurs naturally in varying concentrations in most waters and, together with magnesium, is one of the main components of water hardness. Soft waters contain low, while hard waters contain high, concentrations of calcium. Calcium is an essential element for all living organisms and is an important constituent of the bony skeleton of mammals, fishes, reptiles and amphibians, which consists of phosphates of calcium.

The solubility of calcium in water is usually governed by the carbonate/ bicarbonate equilibrium and is therefore influenced by pH and temperature. Metabolically, calcium interacts with cations, especially those of magnesium, and with both inorganic anions (bicarbonate, sulphate and phosphate) and organic anions (acetate and organic acids).

Biologically, calcium exerts an influence on the integrity of cell membranes and thereby strongly influences the absorption and toxicity of heavy metals.

Major impacts of calcium to society relate to scaling, rather than health or aquatic impacts.

Calcium and carbonate are also important in the “inactivation” of many metal ions in water bodies, being precipitated out of solution and deposited in/ on the sediments as double-ion carbonate salts. However, changing oxidation – reductions status can dissolve the calcium-bound metal ions and release the metal ions to the water again up to their solubility coefficient.

Chloride (dissolved)

Chloride is the anion of the gaseous element chlorine. The element chorine does not occur naturally in nature, but is found only as the chloride ion. The chloride forms of sodium, potassium, calcium and magnesium are all highly soluble in water. Chloride is of concern in domestic water supplies because elevated concentrations impart a salty taste to water and accelerate the corrosion rate of metals. High concentrations of chloride can also be detrimental to chloride-sensitive garden plants and certain commercial crops. When the accumulated chloride concentration in leaves exceeds the crop's tolerance, injury symptoms develop in the form of leaf burn. Chloride can be absorbed either through plant roots or plant foliage, or through a combination of both.

Maintaining chloride levels below 140 mg/L should prevent the accumulation of chloride to toxic levels in all but the most sensitive plants, when chloride uptake is through root absorption, that is, when water is applied to the soil surface, thereby excluding wetting of crop foliage.

Adverse human health effects are only observed at very high concentrations (> 600 mg/L) although water may have an objectionable taste.

Total Dissolved Solids and Electrical Conductivity

The total dissolved solids (TDS) concentration is a measure of the quantity of all of the various inorganic salts dissolved in water. The TDS concentration is directly proportional to the electrical conductivity (EC) of water. Since EC is much easier to measure than TDS, it is routinely used as an estimate of the TDS concentration. In the Olifants catchment: EC (ms/m at 25 °C) x 6.7 gives a good indication of the TDS (mg/L) value. However the factor may vary and should be confirmed by actual measured values and use of this “short-cut’ should rather be discouraged if possible.

The concentration of TDS is likely to accumulate in water as water moves downstream because salts are continuously being added through natural and manmade processes whilst very little is removed or diluted by precipitation or natural processes. Domestic and industrial effluent discharges and surface runoff from urban, industrial and cultivated areas are examples of the types of return flows that contribute to increased TDS concentrations.

High TDS concentrations in surface waters are also caused by evaporation in water bodies which are isolated from natural drainage systems, or during droughts. The saline pans in the Olifants catchment are examples of such water bodies.

The adverse impacts of elevated TDS levels are therefore mostly related to aesthetic (such as taste) impacts and economic impacts due to crop damage where elevated TDS concentrations may cause leaf burn, and decreased crop yields, caused by soil salinisation. Humans can tolerate considerable high levels of TDS (1 000 mg/L).

Fluoride (dissolved)

Fluoride either occurs as the fluoride ion or in combination with calcium, potassium and phosphates. Fluoride occurs in the earth's crust at an average concentration of 0.3 g/kg, most often as a constituent of fluorite (CaF), often known as fluorspar or calcium fluoride, in sedimentary rocks. Other important occurrences of fluoride are cryolite and fluorapatite in igneous rocks. Traces of fluoride (< 1 mg/L) occur in many aquatic ecosystems although unpolluted surface water resources are mostly around, 0.1 mg/L, while higher concentrations (often > 10 mg/L) can be found in ground waters derived from igneous rocks.

In ecosystems, all measurements should be below the Chronic Effect Value (CEV < 1.5 mg/L) to ensure protection of aquatic ecosystems. Acute toxicity effects will occur if fluoride exceeds the Acute Effect Value (AEV > 2.5 mg/L).

For human health, a level of < 1.5 mg/L should be maintained to ensure limited tooth damage (WHO, 2017). Skeletal and dental fluorosis may start to occur at levels > 4 mg/L.

Potassium (dissolved)

Potassium always occurs in water in association with anions, usually chloride, but can also occur with sulphate, bicarbonate, or nitrate and is ubiquitous in the environment occurring in fresh water within the range of 2 – 5 mg/L. Potassium is the main intracellular cation in living organisms and is an essential dietary element. Potassium interacts with sodium to regulate membrane process in cells, most notably controlling membrane permeability. Disruption of membrane permeability causes many adverse effects in plants, animals and humans, especially those linked to osmotic effects and transfer of toxic components into cells.

High concentrations of potassium may occur in runoff from irrigated lands, and from fertilizer production and domestic wastes. For human health levels of up to 100 mg/L can be tolerated in healthy individuals.

Health concerns would be related to the consumption of drinking-water treated by potassium-based water treatment (principally potassium chloride for regeneration of ion exchange water softeners), affecting only individuals in high-risk groups (i.e. individuals with kidney dysfunction or other diseases, such as heart disease, coronary artery disease, hypertension, diabetes, adrenal insufficiency, pre-existing hyperkalaemia; people taking medications that interfere with normal potassium-dependent functions in the body; and older individuals or infants).

Magnesium (dissolved)

Magnesium is a common constituent of water and occurs as a double-positively-charged magnesium (II) ion. The solubility of magnesium in water is governed by the carbonate/ bicarbonate equilibrium and hence, the pH. Magnesium, together with calcium, is responsible for the hardness of water. Magnesium is also an essential nutritional element, and the normal dietary intake is approximately 250 mg/day. Magnesium in water can make a significant contribution to the total dietary intake.

Magnesium has a bitter taste. This property serves as a natural protection against the ingestion of potentially harmful concentrations. As excess magnesium is readily excreted by the kidney, adverse effects such as the suppression of the central nervous system and heart function are rarely seen. Excess magnesium intake, particularly as the sulphate, results in diarrhoea. Magnesium, together with calcium, is responsible for scaling problems caused by deposits of carbonates in appliances using heating elements and plumbing which transports hot water, and also for inhibiting the lathering of soap which results in scum formation. For human health levels of up to 100 mg/L can be tolerated in healthy individuals.

Sodium (dissolved)

Sodium is an essential dietary element important for the electrolyte balance and the maintenance of many essential physiological functions. Sodium is present in all food to varying degrees. In minute quantities sodium is beneficial to the growth of some plants. At higher concentrations it is, however, toxic to many plants, especially woody plants. Sodium also has a potentially detrimental effect on soil physical conditions.

Sodium Absorption Ratio

The sodium adsorption ratio (SAR) is an index of the potential of a given water to induce sodic soil conditions. Soil sodicity is usually measured by the percentage of a soil's cation exchange capacity that is occupied by sodium ions. SAR is calculated from the concentrations of sodium, calcium and magnesium in water, and gives an indication of the level at which the exchangeable sodium percentage (ESP) of the soil will stabilise after prolonged irrigation.

$$SAR = [sodium]/ ([calcium] + [magnesium])*0.5$$

where the concentrations of sodium, calcium and magnesium in solution are measured in mmol/L or meq/L of sodium, calcium and magnesium in solution.

And, meq/L x molecular weight (MW) = mg/L;

Therefore: mg/L/ MW = meq/L

The SAR values are however mostly reported without units.

Although SAR is only one factor in determining the suitability of water for irrigation, in general, the higher the sodium adsorption ratio, the less suitable the water is for irrigation. Irrigation using water with high sodium adsorption ratio may require soil amendments to prevent long-term damage to the soil.

According to the SAWQGs for Agricultural Use: Irrigation (Volume 4)(DWAF, 1996) a SAR of < 2 should prevent sodium toxicity from developing in plants sensitive to sodium provided that crop foliage is not wetted and water is applied only to the soil surface.

Ammonia (un-ionised)

Un-ionized ammonia (NH_3) is a colourless, acrid-smelling gas at ambient temperature and pressure. It is produced naturally by the biological degradation of nitrogenous matter and provides an essential link in the nitrogen cycle. Ammonia may be present in the free, un-ionized form (NH_3) or in the ionized form as the ammonium ion (NH_4^+). Both are reduced forms of inorganic nitrogen derived mostly from aerobic and anaerobic decomposition of organic material. The toxicity of ammonia is directly related to the concentration of the un-ionized form (NH_3), the ammonium ion (NH_4^+) having little or no toxicity to aquatic biota.

Ammonia is a common pollutant and is one of the nutrients contributing to eutrophication through the nitrogen cycle. Commercial fertilizers contain highly soluble ammonium salts. Following applications of fertilizer, if the concentration of such compounds exceeds the immediate requirements of the plant, transport *via* the atmosphere or irrigation waters can carry these nitrogen compounds into aquatic systems. Other sources of ammonia include:

- fish-farm effluent as well as effluent from chicken, pig and cattle feed-lot operations (un-ionized ammonia);
- sewage discharge;
- discharge from industries that use ammonia or ammonium salts in their cleaning operations;
- manufacture of explosives and use of explosives in mining and construction; and
- atmospheric deposition of ammonia from distillation and combustion of coal, and the biological degradation of manure.

The most significant factors that affect the proportion and toxicity of un-ionized ammonia in aquatic ecosystems are water temperature and pH. An increase in either results in an increase in the relative proportion of un-ionized ammonia in solution, resulting in an increase in toxicity to aquatic organisms.

Other factors that affect ammonia toxicity are the concentrations of dissolved oxygen, carbon dioxide and total dissolved solids, as well as the presence of other toxicants, such as metal ions. The acute toxicity of ammonia to fish increases as dissolved oxygen decreases. Ammonia is oxidized to nitrate in well oxygenated waters. Ammonia may also be adsorbed onto suspended and bed sediments and to colloidal particles. At low to medium pH values, the ammonium ion dominates, but as pH increases ammonia is formed. At very high pH values, the gaseous ammonia (NH_3-N) can exceed its solubility coefficient and be released from water as gas bubbles.

To prevent loss of aquatic ecosystems, all un-ionised ammonia (NH_3) measurements should be below the Chronic Effect Value (CEV < 0.015 mg/L). It is important to note that conventional water quality analysis techniques measure ammonium ion and not ammonia. Accurate measurements of un-ionized ammonia are notoriously difficult to achieve when concentrations are low.

It is also well known for decades that ammonium (NH_4-N) is also a nitrogen source available for plant and algal growth, and should be considered. Algae and higher plants take up ammonium more easily (using less energy) than nitrate. Nitrate uptake by plants requires the action of nitrate reductase enzyme which is ‘costly’ to plants in terms of energy requirements.

Therefore, when looking at nitrogen availability, it may be better to work with the total inorganic nitrogen (TIN) concentration available, *i.e.* the nitrate plus ammonium concentrations. It is proposed that ammonium limits are ideally maintained at 0.05 mg/L or below 0.15 mg/L as an acceptable limit. Anything > 0.25 is deemed unacceptable.

Nitrate as N

Nitrate is the end product of the oxidation of ammonia (NH_3) or nitrite (NO_2^-). Nitrates and nitrites occur together in the environment and under teh correct conditions, interconversion readily occurs. Under oxidising conditions nitrite is converted to nitrate, which is the most stable positive oxidation state of nitrogen and far more common in the aquatic environment than nitrite.

Nitrate in drinking water is primarily a health concern in that it can be readily converted in the gastrointestinal tract to nitrite as a result of bacterial reduction. Nitrates are ubiquitous in soils and in the aquatic environment, especially in association with the breakdown of organic matter and eutrophic conditions. A significant source of nitrates in natural water results from the oxidation of vegetable and animal debris and of animal and human excrement. Treated sewage wastes most often also contain elevated concentrations of nitrate.

Nitrate tends to increase in shallow ground water sources in association with agricultural and urban runoff, especially in densely populated areas. Nitrate together with phosphates stimulates plant growth often giving rise to unwanted aquatic plants such as water hyacinth, and in aquatic systems elevated concentrations generally give rise to accelerated growth of algae with resultant algal blooms which may subsequently cause problems associated with malodours and tastes in water, as well as the possible occurrence of toxicity due to toxins released by the blue-green algae, also known as cyanobacteria.

pH

The pH of natural waters is an index of the acid-base equilibrium of various dissolved compounds, and is a result of the carbon dioxide-bicarbonate-carbonate equilibrium which involves various constituent equilibria, all of which are affected by temperature.

Conditions which favour production of hydrogen ions result in a lowering of pH, and are referred to as an acidification process. Alternatively, conditions which favour neutralisation of hydrogen ions result in an increase in pH, referred to as an alkalinisation process. The pH of water does not indicate the ability to neutralise additions of acids or bases without appreciable change. This characteristic, termed buffering capacity, is controlled by the amounts of acidity and alkalinity present.

The pH of water does not have direct consequences except at extremes. The adverse effects of pH result primarily from the solubilisation of toxic heavy metals and the protonation or deprotonation of other ions.

Ortho-phosphate as P

Phosphorus can occur in numerous organic and inorganic forms, and may be present in waters as dissolved and particulate species. Elemental phosphorus does not occur in the natural environment. Orthophosphates, polyphosphates, metaphosphates, pyrophosphates and organically bound phosphates are found in natural waters. Of these, orthophosphate species H_2PO_4 and HPO_4^{2-} are the only forms of soluble inorganic phosphorus directly utilizable by aquatic biota. Soluble Reactive Phosphate (SRP), or orthophosphate, is that phosphorus fraction which is immediately available to aquatic biota and which can be transformed into an available form by naturally occurring processes.

The forms of phosphorus in water are continually changing because of processes of decomposition and synthesis between organically bound forms and oxidised inorganic forms.

The phosphorus cycle is influenced by the exchange of phosphorus between sedimentary and aqueous compartments. In turn this is affected by various physical, chemical and biological modifying factors such as mineral-water equilibria, water pH values, sorption and desorption processes, oxygen-dependent redox interactions, and the activities of living organisms.

Phosphorus is an essential macronutrient, and is accumulated by a variety of living organisms. It has a major role in the building of nucleic acids and in the storage and use of energy in cells. In un-impacted waters it is readily utilized by plants and converted into cell structures by photosynthetic action. Phosphorus is considered to be the principal nutrient controlling the degree of eutrophication in aquatic ecosystems.

Elevated levels of phosphorus may result from point-source discharges such as domestic and industrial effluents, and from diffuse sources (non-point sources) in which the phosphorus load is generated by surface and subsurface drainage. Non-point sources include atmospheric precipitation, urban runoff, and drainage from agricultural land, in particular from land on which fertilizers have been applied.

In dams, inorganic phosphorus concentrations of less than 0.005 mgP/L are considered to be sufficiently low to limit the likelihood of excessive algal and other plant growth. At levels > 0.025 mgP/L eutrophic conditions are expected to occur and algal blooms with the possibility of toxin production are likely. Adverse health impacts to humans, livestock and wildlife are possible. In rivers, the acceptable limit for orthophosphate is 0.075 mgP/L (although may still promote nuisance weeds and filamentous algae growth) with the unacceptable limit being >0.125 mgP/L (DWA, 2011).

Sulphate (dissolved)

Most often sulphur in geological systems occurs as the sulphide ion, usually bound to metal ions. Sulphate occurs rarely as the sulphate ion in undisturbed ecological systems, except in deposits of some minerals such as gypsum. Probably the commonest way in which sulphate is formed is from the oxidation of metal sulphides in rocks.

Since most sulphates are soluble in water, and calcium sulphate relatively soluble, especially when pH is relatively low, sulphates when added to water tend to accumulate to progressively increasing concentrations. Sulphates are discharged from acid mine wastes and many other industrial processes such as tanneries, textile mills and processes using sulphuric acid or sulphates. Sulphate concentrations should also be interpreted in conjunction with the major associated cations, as well as the pH.

High concentrations of sulphate (> 500mg/L) exert predominantly acute health effects (diarrhoea). These are temporary and reversible since sulphate is rapidly excreted in the urine. Individuals exposed to elevated sulphate concentrations in their drinking water for long periods, usually become adapted and cease to experience these effects. Sulphate concentrations of 600 mg/L and more cause diarrhoea in most individuals and adaptation may not occur.

Sulphate imparts a salty or bitter taste to water. The taste threshold for sulphate falls in the range of 200 - 400 mg/L and depends on whether the sulphate is predominantly associated with either sodium, potassium, calcium or magnesium, or mixtures thereof. Elevated sulphate concentrations also increase the corrosion rate of metal fittings in distribution systems.

Dissolved Organic Carbon

Dissolved organic carbon (DOC) is the organic carbon present in water in the dissolved form, able to pass through a 0.45 µm membrane filter. The DOC content of water includes both low molecular weight volatile organic compounds and moderate to high molecular weight organic compounds.

The presence of DOC can have adverse aesthetic implications (taste, odour and colour), which may be associated with both naturally-occurring organic carbon and organic carbon that originates from domestic or industrial effluent discharges.

The origin of the DOC found in water largely determines the effect it has in the water system, and can range from harmless to highly toxic. For example, DOC from natural humic acids of soil origin are not usually toxic and only of aesthetic concern. However, if the DOC content includes synthetic organic compounds, usually found in agricultural runoff after pesticide application, it may be associated with significant toxicity. Industrial effluents and domestic runoff entering the water also affect the character of the DOC. Endocrine disrupting chemicals, as well as pharmaceutical products such as antibiotics and hormones are present in many domestic effluents as well as effluents emanating from feed-lot operations. These all contribute to DOC concentrations in water but also have separate important adverse effects on ecosystems and humans.

The DOC concentration in unpolluted water is typically less than 5 mg/L, but in waters receiving organic wastes from runoff, significantly higher concentrations may be encountered.

The rate of breakdown of organic carbon compounds varies and depends on the intrinsic stability of the compound and associated environmental conditions. Low molecular weight organic carbon compounds may be released into the atmosphere, whereas high molecular weight compounds tend to be associated with suspended solids and ultimately accumulate in sediments or are taken up by plants and animals. The oxidation of DOC compounds also contributes to oxygen depletion in water.

The DOC concentration in water *per se* has no direct health implications but, it is an indicator of the organic material content of the water.

Dissolved Oxygen

Gaseous oxygen (O_2) from the atmosphere dissolves in water and is also generated during photosynthesis by aquatic plants and phytoplankton.

The maintenance of adequate dissolved oxygen (DO) concentrations is critical for the survival and functioning of the aquatic biota because it is required for the respiration of all aerobic organisms. Therefore, the DO concentration provides a useful measure of the health of an aquatic ecosystem.

In unpolluted surface waters, dissolved oxygen concentrations are usually close to saturation. Typical saturation concentrations at sea level, and at TDS values below 3 000 mg/L, are: 12.77 mg/L at 5 °C; 10.08 mg/L at 15 °C; 9.09 mg/L at 20 °C. There is a natural diel variation (24 hour cycle) in dissolved oxygen associated with the 24-hour cycle of photosynthesis and respiration by aquatic biota. Concentrations decline through the night to a minimum near dawn, then rise to a maximum by mid-afternoon. Seasonal variations arise from changes in temperature and biological productivity.

Suspended Solids

Suspended solids in water consist of inorganic and organic matter, such as clay, particles or suspended mineral matter, and a combination of decay products and living organisms respectively. In clear non-turbid waters, like spring water, the amount of suspended matter is low or absent, while in muddy waters the amount of suspended matter is high to very high. The amount of suspended matter found in the rivers draining a catchment area usually reflects the degree of soil erosion in teh catchment. Activities which result in accelerated soil erosion will therefore increase the suspended matter load in the draining rivers.

The settleable fraction of the suspended solids accumulates as sediment in lakes, dams and rivers. Scouring action during high flow periods in rivers can re-suspend settled matter and finer particles can remain in suspension for long periods. Suspended solids give rise to turbidity in water. Suspended solids may be abrasive and cause failure of pump seals, bearings or valves and controls.

Suspended solids promote microbial growth and the consequent build-up of slime which acts as a sediment trap. Such microbial slimes often contain sulphate-reducing bacteria (SRB) responsible for microbially-influenced / induced corrosion (MIC), which results in serious damage to metal pipelines and equipment.

Chlorophyll a (Algae)

Algae is a term referring collectively to a wide range of pigmented, oxygen-producing, photosynthetic organisms usually present in surface waters and measurement is mostly by means of chlorophyll-a. Algae range from microscopically small unicellular forms, the size of bacteria, to larger filamentous forms which can be metres in length. Like other plants, algae are primary producers requiring light, carbon dioxide, water, nutrients such as nitrate and phosphate, and trace elements for growth. Algae are common inhabitants of surface water exposed to sunlight.

Algae play an important role in the natural purification of surface waters through the assimilation of nitrogen species (ammonia and nitrate) during photosynthesis. Algal photosynthesis also releases oxygen as a by-product into the aquatic environment. Algae often form the basis for aquatic food webs. Algal overgrowths or the presence of noxious algal species can, however, become a nuisance and interfere with the desirable uses of a water body. This can be a natural phenomenon, but is often the result of accelerated eutrophication (nutrient enrichment) caused by human activities.

There are several types of algae that produce toxins. In fresh waters, the blue-green algae also referred to as cyanobacteria, are often responsible for the occurrence of toxic algal blooms. In South Africa the most common bloom-forming toxic species are *Microcystis spp* and *Anabaena spp*, although a number of other species may also produce toxins on occasion.

These toxins have been associated with a number of livestock and game deaths, and with widespread gastroenteritis in human populations. Skin irritations have also been reported in swimmers. The amount of algae in surface waters is usually limited by the concentration of nutrients, in particular nitrogen and phosphorus. In turbid waters light availability and other physical conditions can also influence the growth of algae.

Photosynthetic uptake of CO_2 by day and release of CO_2 by night can cause pH fluctuations, particularly in poorly buffered water. Dense algal growth and the resultant collapse of algal populations may lead to rapid oxygen depletion, often responsible for fish-kills and the death of other aquatic organisms.

Faecal coliforms and Escherichia coli

Faecal coliforms, and more specifically *Escherichia coli (E.coli)*, are the most commonly used bacterial indicators of faecal pollution. The presence of *Escherichia coli* is used to confirm the presence of faecal pollution by warm-blooded animals (often interpreted as human faecal pollution). Some organisms detected as faecal coliforms may not be of human faecal origin but are almost definitely from warm-blooded animals.

Faecal coliforms are primarily used to indicate the presence of bacterial pathogens such as *Salmonella spp*., *Shigella spp*. *Vibrio cholerae, Campylobacter jejuni, Campylobacter coli, Yersinia enterocolitica* and pathogenic *E. coli*. These organisms can be transmitted via the faecal/oral route by contaminated or poorly-treated drinking water and may cause diseases such as gastroenteritis, salmonellosis, dysentery, cholera and typhoid fever.

The risk of being infected by microbial pathogens correlates with the level of contamination of the water and the amount of contaminated water consumed. Higher concentrations of faecal coliforms in water will indicate a higher risk of contracting waterborne disease, even if small amounts of water are consumed.

Aluminium (dissolved)

Aluminium is the third most abundant element in the earth's crust. It occurs primarily as aluminosilicate minerals which are too insoluble to participate readily in bio-geochemical reactions. Aluminium is a strongly hydrolysing metal and is relatively insoluble in the neutral pH range. Under acidic (pH < 6.0) or alkaline (pH > 8.0) conditions, or in the presence of complexing ligands, elevated concentrations may be mobilised to the aquatic environment.

Aluminium can be mobilised from soils and sediments by both natural weathering and accelerated acidification processes, resulting in detectable concentrations in surface waters.

Although aluminium is found in waters made naturally acidic by humic and fulvic acids, it usually adsorbs onto these and is therefore not available in soluble form in such waters, even at low pH.

Aluminium is found in soluble forms mainly in acid mine drainage waters and is also of concern in natural waters affected by acid rain. Aluminium is one of the principal particulates emitted from the combustion of coal, and aluminium fluoride is emitted from aluminium smelters.

Boron (dissolved)

Boron is found in nature in the form of various borates and borosilicate minerals. Boron tends to occur in association with saline conditions. Once in solution, boron is not easily removed and tends to concentrate in solution on evaporation of water. Hence, the ubiquitous finding of elevated boron concentrations in conjunction with saline hydrogeological conditions.

Boron is an essential plant nutrient (in the µg/L range), but becomes toxic to plant growth at higher concentrations (in the mg/L range). Due to the fact that boron concentrations in the soil solution are largely buffered by sorption to and desorption from the soil, several seasons may be required before the effects of boron in irrigation water manifest in plant responses. Plants respond to root uptake of boron and are not sensitive to short-term variations in the concentration of boron in irrigation water. However, they are very dependent on the boron-supplying capacity of the soil, which, in turn, is largely determined by soil properties and previous boron applications

Chromium (VI) (dissolved)

Chromium is a relatively scarce metal, and the occurrence and amounts thereof in aquatic ecosystems are usually very low. Elevated concentrations of chromium (VI) found in the environment are due to industrial pollution. Because chromium (VI) is highly water soluble, it is very mobile in the environment and readily moves through the soil profile, resulting in contamination of ground water supplies. Chromium (VI) can be reduced to chromium (III) under suitable pH and reducing conditions.

Chromic acid or hexavalent chromium salts are used in alloys in the metal pickling and plating industry, in the leather industry and in the manufacture of paints, dyes, explosives, ceramics and paper.

The equilibrium between the chromium (VI) and chromium (III) is strongly influenced by pH and redox potential. The presence of oxidizable organic matter and iron (II) salts encourages reduction to lower, less toxic oxidation states.

Water hardness and pH affect the toxicity of both chromium (III) and chromium (VI). Limited data available indicate that acute toxicity decreases as water hardness and pH increase. There are reports that sodium chromate is more toxic in water with low concentrations of dissolved oxygen.

Chromium(VI) when ingested is associated with taste effects and nausea when the concentration exceeds 1 mg/L. Definitive evidence of carcinogenesis via the oral route is equivocal, and chromium(VI) has also been implicated in the cause of gastrointestinal cancer.

Given the technical difficulties in determining chromium (VI), the additional use of Chromium (Total) may be considered, noting that many international guidelines revert to a Total Chromium guideline, which when exceeded, triggers a test for chromium (VI).

Iron (dissolved)

Iron is the fourth most abundant element and constitutes five percent of the earth's crust. Iron is found in three oxidation states, namely, 0, II and III of which the III oxidation state is the most common. In water, iron can be present as dissolved ferric iron, Fe (III), as ferrous iron, Fe(II) or as suspended iron hydroxides and oxyhydroxides. Biologically, iron is an essential micronutrient required by all living organisms.

Iron is naturally released into the environment from weathering of sulphide ores (pyrite, FeS) and igneous, sedimentary and metamorphic rocks. Leaching from sandstones releases iron oxides and iron hydroxides to the environment. Iron is also released into the environment by human activities, mainly from the burning of coke and coal, acid mine drainage, mineral processing, sewage, landfill leachates and the corrosion of iron and steel.

High concentrations of iron are predominantly an aesthetic concern since ferrous salts are unstable under the pH conditions prevailing in drinking water and precipitate as insoluble ferric hydroxide, which settles out as a rust-coloured silt.

The major effects of the presence of iron in domestic water are aesthetic, but in some cases distribution systems may also be affected. Health effects may occur at extremely high concentrations.

In the aquatic environment the iron concentration should not be allowed to vary by more than 10 % of the background dissolved iron concentration for a particular site or case, at a specific time.

Manganese (dissolved)

Manganese is a relatively abundant element, constituting approximately 0.1 % of the earth's crust.

The aquatic chemistry of manganese is closely associated with that of iron chemistry. Both elements tend to behave synergistically in their dissolution from sediments under anaerobic conditions and re-precipitation under aerobic conditions. Manganese, once in solution, is more readily stabilised by complexation than iron is, and is often difficult to remove from solution except at high pH, where it precipitates as the hydroxide. Like iron, manganese can be utilised by metallophilic bacteria.

Other water constituents and properties that govern the action of manganese in water are pH, redox potential, turbidity, suspended matter and the concentration of aluminium.

Manganese is a normal soil constituent. Its concentration in the soil solution is largely determined by soil pH and oxidation-reduction reactions. This is further modified by sorption and desorption reactions with the soil exchange complex. Manganese is reduced (and the solubility increased) under waterlogged conditions in association with low pH. Under these conditions the manganese concentration in the soil solution can increase to levels toxic to plant growth. The effect of soil pH is to decrease the manganese concentration in the soil solution as soil pH increases. Manganese toxicity seldom occurs at soil pH (water) above 5.5 - 6.0. In practice the concentration of manganese in irrigation water is therefore relatively unimportant in determining the concentration in soil solution.

Manganese supports the growth of certain nuisance organisms in water distribution systems, giving rise to taste, odour and turbidity problems.

Plants vary in their sensitivity to manganese and toxicity has been observed at a fraction of a mg/L in nutrient solution. At fairly low concentrations manganese can cause the clogging of irrigation pipelines, drip and microjet emitters, and sand filter systems at water treatment works.

4.3 Additional monitoring requirements

The following aspects need to be considered, potentially as indicators of problems to be encountered, even though they may currently not be included in the WQPL parameter list described in Section 4.

Temperature (°C)

The temperature of a water body is simply a measure of the heat content of that water body. Water temperature is a key feature that governs the rates of reactions (physical, chemical and biological). The propensity of that water body to absorb more heat, or to lose heat to another environmental component, is not really a characteristic of temperature *per se*, it is simply a natural consequence of temperature differentials between adjacent media. The greater the temperature differential, the higher/ faster the potential rate of heat transfer.

Temperature is most important to the aquatic environment. As temperature increases viscosity, surface tension, compressibility, specific heat, the ionization constant and the latent heat of vaporization decrease, whereas thermal conductivity and vapour pressure increase. The solubility's of the gasses: H_2, N_2, CO_2 and O_2 decrease with increasing temperature.

Temperature therefore plays an important role in water by affecting the rates of chemical reactions and therefore also the metabolic rates of organisms. Temperature is therefore one of the major factors controlling the distribution of aquatic organisms. Natural variations in water temperature occur in response to seasonal and diel cycles and organisms use these changes as cues for activities such as migration, emergence and spawning. Artificially-induced changes in water temperature can thus impact on individual organisms and on entire aquatic communities. While there is not necessarily a limit, a variation of 2˚C or 10% from the background average temperature is proposed as part of the aquatic guidelines.

Turbidity

Turbidity is a measure of the light-scattering ability of water and is indicative of the concentration of suspended matter in water. The turbidity of water is also related to clarity, a measure of the transparency of water and settleable material, which refers to suspended matter which settles after a defined time period as opposed to that which remains in suspension.

Micro-organisms are often associated with turbidity, hence low turbidity minimises the potential for transmission of infectious diseases. The probability of the presence of carcinogenic asbestos fibres in water is also reduced under conditions of low turbidity. Turbidity also affects the aesthetic quality of water.

Contaminants associated with power stations

There are a number of contaminants that are discharged from power stations and may pose a threat to human health. Specifically, bromide discharges from coal-fired power stations and related activities pose a significant concern to public health due to the consequential challenge posed to drinking water disinfection due to the formation of brominated disinfection byproducts with well described adverse health endpoints, effectively yielding household disinfection with chlorine unacceptable.

Additional key pollutants noted in the local and scientific literature that should be included in the WQPLs include:

- Antimony
- Arsenic
- Barium
- Beryllium
- Bromide
- Cadmium
- Cobalt
- Lead
- Mercury
- Nickel
- Selenium
- Thallium
- Uranium
- Vanadium

4.4 Use of ratios

Sulphate to Anion Ratio

In a CSIR project led by Dr Peter Ashton (Ashton et al, 2011), a calculation was included for the ratio of sulphate to chloride anions. The report stated that while sulphate on its own has insignificant health effects even at 400 mg/l, an increase in the ratio of sulphate to chloride indicates a human disturbance – such as an effluent discharge – with high to very high ratio values indicating the strong likelihood that acid mine drainage was occurring. A low ratio value indicates strongly that very little human disturbance is taking place.

Dr Ashton used a SO_4/Cl ratio, however this was amended by Dr M Silberbauer from the DWS RQIS who uses SO_4/[total anions]. By determining the SO_4/[total anions] ratio, this provides a more convenient number in the range 0.0 to 1.0 and avoids bias when total alkalinity is very high or low. A high SO_4/[total anions] ratio is considered indicative of AMD and suggests that further investigation and analysis are needed.

It is intended as a rough filter and where hotspots are identified in this manner it follows that sampling and analysis should be done to confirm whether there has been a significant change in the water quality.

Based on the 95 percentile data, the following (arbitrary) ranges (Table 2) could be applied to produce a risk category. Note that the calculation of the relative concentrations of the anions – in any ratio of this nature that is considered as a basis for action - should always be in the milliequivalents per litre form and NOT the simple milligram per litre form.

Table 2: Example Risk potential table

0 – <0.2	No risk potential	Blue
0.2 – <0.4	Small risk potential	Green
0.4 – <0.6	Perceptible risk potential	Yellow
0.6 – <0.8	High Risk potential	Orange
0.8 – 1	Severe Risk potential	Red

Nitrogen to phosphorus ratios

Imbalances in nutrient ratios cause widespread changes in the structure and functioning of ecosystems, which, in turn, have generally negative impacts on habitats, food webs and species diversity, including economically important ones (UNEP/ GPA, 2006).

Organic matter from aquatic algae and macrophytes contains nitrogen (N) and phosphorus (P) in approximately the ratio 7N:1P (mass) or 16:1 on a molar basis, also called the Redfield ratio (Wetzel, 1983). This implies that at an N: P ratio of less than 7 in the environment, N could be limiting and at an N: P greater than 7, P could be limiting to algal or macrophyte growth. Several investigators have used ratios of nitrogen to phosphorus (N: P) to indicate which of these essential nutrients potentially limits production (Grimm & Fisher, 1986).

However , it should be noted that neither of the two (N or P) will be limiting when, for example, you have a situation like Loskop Dam, where the respective concentrations are in the high microgramme per litre or low to moderate milligramme per litre range. In such cases, light is usually the limiting factor.

However, the threshold is not clear-cut in practice and there is region of ambiguity about this threshold. It is probably best to consider ratios in the range 4 – 14 as ambiguous. This broad range is not surprising because algal assemblages consist of many species, each with different optimal N: P requirements (Grimm & Fisher, 1986).

Davis & Koop (2006), stated that nitrogen (N) appears to limit algal growth as often as phosphorus (P) in Australian waters especially where nitrogen concentrations are very low. However, many studies now indicate that both N and P appear to be jointly limiting in rivers (Davis & Koop, 2006). Other nutrients can also limit growth for a few weeks, such as silicon during a diatom bloom. The likelihood is that the nutrient limiting algal growth probably changes depending on the algal type and the instantaneous prevalent conditions.

A low ratio between N and P concentrations may favour the development of cyanobacterial blooms (WHO, 1999). Phosphorus enrichment will reduce the N: P ratio, which can favour growth of nitrogen-fixing cyanobacteria (UNP, 2000)

Waters not impacted by human influence usually have an N: P ratio greater than 25:1, while most impacted (i.e. eutrophic or hypertrophic) system have an N: P ratio of less than 10:1.

The inorganic N: P (DIN: DIP) ratio in the Olifants River ranged between 0.4 and 22.8 with a fairly low average of 7.6 and the median at 5.0 (Table 3).

Table 3: Nutrient concentrations (mg/L)(averages) and ratios of nitrogen and phosphorus in the main stem of the Olifants River

Sample site ID	NO_3-N	NH_4-N	DIN	DIP (PO_4-P)	DIN:DIP	NO_3:NH_4
B11 188428	0.090	0.173	0.263	0.327	0.8	0.5
B11 188423	0.203	0.411	0.614	0.675	0.9	0.5
B11 188424	0.732	0.182	0.914	0.439	2.1	4.0
B11 188420	0.065	0.128	0.193	0.047	4.1	0.5
B11 188588	0.149	0.101	0.25	0.0795	3.1	1.5
B11 188536	0.271	0.054	0.325	0.0485	6.7	5.0
B11 90410	0.281	0.053	0.334	0.021	15.9	5.3
B11 88607	0.340	0.101	0.441	0.0193	22.8	3.4
B11 90412	0.115	0.043	0.158	0.358	0.4	2.7
B11 188530	4.945	0.419	5.364	1.028	5.2	11.8
B32 90455	0.194	0.0824	0.2764	0.026	10.6	2.4
B32 88595	0.812	0.047	0.859	0.283	3.0	17.3
B32 191682	1.047	0.062	1.109	0.254	4.4	16.9
B32 193742	1.438	0.05	1.488	0.01		28.8
B32 90444	0.411	0.048	0.459	0.0227	20.2	8.6
B32 191684	0.855	0.025	0.88	0.503	1.7	34.2
B51 90486	0.169	0.054	0.223	0.0194	11.5	3.1
B71 1000009801	0.691	0.324	1.015	0.32	3.2	2.1
B71 1000009772	0.548	0.345	0.893	0.178	5.0	1.6
B71 90506	0.294	0.047	0.341	0.025	13.6	6.3
B72 1000009786	0.412	0.314	0.726	0.314	2.3	1.3
B72 90503	0.270	0.0495	0.3195	0.0195	16.4	5.5
B72 192539	0.417	0.374	0.791	0.35	2.3	1.1
B73 90512	0.454	0.069	0.523	0.0335	15.6	6.6
B73 90515	0.169	0.056	0.225	0.0234	9.6	3.0
Min	0.065	0.025	0.158	0.01	0.4	0.5

Sample site ID	NO_3-N	NH_4-N	DIN	DIP (PO_4-P)	DIN:DIP	NO_3:NH_4
Max	4.945	0.419	5.364	1.028	22.8	34.2
Average	**0.615**	0.144	0.759	0.217	**7.6**	**7.0**
Median	**0.376**	0.0655	0.491	0.064	**5.0**	**3.7**

Generally water bodies with N: P <4 indicating probable N limitation and N: P >14 indicating probable P limitation, and if N: P is between 4 and 14, phytoplankton would be stimulated by addition of both N and P (Jassby & Goldman, 2003), provided that the actual concentrations of N and P are already high. Therefore, with an overall average N: P ratio in the Olifants River of 7.6 (median, 5.0) suggests both N and P limitation to phytoplankton growth.

However, the relationships between river and dam phosphorus sensitivity, environmental drivers and catchment characteristics within the upper Olifants River and Loskop Dam were studied over a period of four years to derive mitigation and management strategies (CSIR, 2013). Using modified indices, it was evident that the best strategy for improving the trophic state of Loskop Dam was to drastically reduce the external nutrient loading coming from the upper Olifants River catchment. According to the Dam phosphorus sensitivity index (LPSI) developed, Loskop Dam was phosphorus sensitive and will likely respond to reduced phosphorus loads in its upper catchment.

The relatively low N concentrations in the Olifants River can partially be ascribed to the effective denitrification that is apparently taking place in the river. As denitrification is an anaerobic process, the presence of denitrification therefore suggests very strongly that dissolved oxygen concentrations will be lowered.

It is widely suggested that the ratios of N: P can influence the types of organisms that occur and provide important information about the extent to which individual species or whole communities might become N or P limited (Jarvie *et al.*, 2006).

N-fixing Cyanobacteria do better under conditions of low DIN: DIP ratios (<25) especially when N and P concentrations are high, or when N concentrations are low. On the other hand, green algae and diatoms prefer higher DIN: DIP ratios (between 25 and 50) (Janse van Vuuren & Pieterse, 2005b). The relative low N: P ratios in the Olifants River are favourable for cyanobacteria and between 30 and 50 % cyanophyte dominance can be expected.

4.5 Other chemicals for consideration

Experience from researchers in the catchment has indicated that frequently the source analysis is lacking and there are insufficient data about all the potentially problematic pollutants entering the groundwater and surface water resources (communication Dr J Meyer, November 2016 with specific reference to quaternary catchments B20E and B20F).

In this respect it is proposed that a comprehensive ICP-MS list of inorganic trace elements be included as part of the monitoring plan to be developed as part of the sub-catchment management plans. This will allow a baseline database to be set up for those chemicals where data is lacking. It is noted that without this key potential pollutants linked to activities such as the coal-fired power stations and related activities as well as agrochemicals and endocrine disrupting chemicals emanating from amongst other activities, domestic wastewater treatment works, will simply fail to be observed.

Key pollutants noted in the local and international scientific literature that should be included are:

- Antimony
- Arsenic
- Barium
- Beryllium
- Bromide
- Cadmium
- Cobalt
- Lead
- Mercury
- Nickel
- Selenium
- Thallium
- Uranium
- Vanadium
- Zinc

It is noted that there are deposits of uranium and thorium in the Middle Olifants sub-catchment and some of these have been – or are being – mined. Research needs to be undertaken to assess whether there is radioactive products contamination in the streams and rivers located near known mining operations.

Further specific agrochemicals should also be included based on the recent research undertaken by Dr J Dabrowsky (WRC, 2015). The most common pesticides used (based on kilogrammes used) in the Limpopo and Mpumalanga Provinces are:

- Glyphosate
- Petroleum-oil
- Mancozeb
- Atrazine
- Copper-oxychloride
- Acetochlor
- Terbuthylazine
- Metolachlor

4.6 Toxicity monitoring

Aquatic Toxicity data are useful to monitor and control the pollution of water bodies by setting site specific guidelines, investigating the effects of single variable and/or whole effluents, and including toxicological end-points in discharge licenses.

The receiving water type, location, and available dilution are important factors that need to be considered when determining the appropriate Whole Effluent Toxicity (WET) requirements for a given situation. Samples should be collected upstream and downstream of the discharge of concern. Where possible, an additional sample should be collected as close to the effluent release point as possible. In order to evaluate the effects in a river resource, additional samples should be collected upstream and downstream of confluences.

Additionally, any points of concern that are identified through chemical analysis should be included in the Toxicological Monitoring Program, with toxicity tests used to determine if the particular waters pose a risk to humans or the environment.

Whole Effluent Toxicity Tests (utilising biotests) are used in a number of countries to evaluate the biological toxicities of effluents released from Industrial and Agricultural processes. Previously the quality of the water released was mainly regulated by the concentration of the individual chemical toxicities; however the chemical and physical analyses of samples is not able to detect all the chemicals present in polluted water, let alone the synergistic and antagonistic reactions between them and the products formed by these chemicals reactions (Mankiewicz-Boczek *et al.*, 2008).

The use of WET tests, using different test organisms, provides a rapid and replicable measure of the potential ecological effect as a result of released effluents. These tests form an integrated tool that measures the toxicity of effluents and accounts for the uncharacterised sources of toxicity as well as their toxic interactions.

Toxicity has an inverse relationship to effect concentration (the lower the effect concentration, the higher the toxicity of an effluent). If effluents show a high degree of toxicity, it is possible to assign an Acute Toxicity Unit (TUa) and toxicity group (Table 7). If there is insufficient toxicity in a sample to enable the determination of an EC50/LC50 value, then an acute toxicity unit of <1 is assigned to the sample.

Table 4: Toxicity Units and Grouping (Tonkes & Baltus, 1997)

Toxicity Unit	Conclusion
< 1	Limited to Not Acutely Toxic
1 - 2	Negligibly Acute Toxic
2 - 10	Mildly Acutely Toxic
10 - 100	Acutely Toxic
> 100	Highly Acutely Toxic

The major advantage of using toxicity units to express toxicity test results is that toxicity units increase linearly as the toxicity of a sample increases. Toxicity unit (TUa) for each test performed is calculated as 100% (full strength effluent expressed as percentage) divided by the effective concentration or LC50 expressed as percentage sample dilution (e.g. *Daphnia pulex* and *Poecilia reticulata* acute toxicity tests) and EC50 (e.g. *Vibrio fischeri* bioluminescent test and *Selenastrum capricornutum* growth inhibition test) (Tonkes & Baltus, 1997). Toxicity units make it easier to specify water quality criteria based on toxicity and the toxicity grouping can be correlated to the biotic integrity of a site.

Table 5: Acute Hazard Classification system for natural waters (Persoone *et al.* 2003)

	Class	Hazard	Percentage Effect
	I	No acute hazard	None of the tests show a toxic effect (i.e. an effect value that is significantly higher than that in the controls).
	II	Slight acute hazard.	A statistically significant PE is reached in at least one test, but the effect level is below 50%.
	III	Acute hazard.	The 50% Percentage Effect (PE50) is reached or exceeded in at least one test, but the effect level is below 100%.
	IV	High acute hazard tolerant taxa present.	The PE100 is exceeded in at least one test.
	V	Very high acute hazard.	The PE100 is exceeded in all tests.

Various types of toxicity classification systems have been developed by scientists in different countries to be able to assign a hazard score to polluted environments (Persoone *et al.* 2003). Using a hazard classification system developed by Persoone *et al.* (2003) one can classify sites using the toxicity data of the non-diluted samples. The percentage effect of toxicity (PE) (Mortality or inhibition of growth, luminescence, reproduction or feeding) is used to rank the water sample into one of five classes (Table 6) based on the highest toxic response shown in at least one of the tests applied (Persoone *et al.* 2003).

Additionally a weight score (Table 4) can be calculated for each determined hazard class in order to indicate the quantitative importance (weight) of the toxicity within that sample. The combined weight score of the sample is then converted to a percentage. The toxic hazard of the water is expressed with a higher weighted score percentage (Persoone *et al.* 2003). A class weight score below 20% can indicate that the quantitative importance of the hazard is not relevant and that the toxicity of the sample is actually lower than what the acute hazard class indicates (Mankiewicz-Boczek *et al.*, 2008).

Table 6: Weight score allocation for each test type (Persoone *et al.* 2003)

Score	Category
0	Statistically significant PE not reached
1	Statistically significant PE reached but less than PE50
2	The PE50 is reached or exceeded but the effect level is below 100%.
3	The PE100 is reached

Calculation of class weight Score:

Class weight score = (∑ all test scores)/n (n = number of tests performed)

Calculation of class weight Score as a percentage:

Class weight score in % = (class score) / (maximum class weight score) x 100

5. WATER QUALITY PLANNING LIMITS FOR THE OLIFANTS WATER MANAGEMENT AREA

5.1 Quality of data

As part of the project *Review, Evaluation and Optimisation of the South African Water Resources Monitoring Network* undertaken by the DWS, Chief Directorate Information Management a data integrity assessment report was produced.

Definition of data quality

The ISO 9000 (International Organization for Standardization, 2008) definition of data quality is defined as: *the degree to which a set of characteristics of data fulfils requirements*. Examples of these characteristics used in the above-mentioned project were:

- ***Completeness***: A long complete record of data offers a better chance of providing a wider range of observed variability on what is being measured, making the time series more representative;
- ***Validity***: A record should be valid for what is intended to be measured;
- ***Accuracy***: The accuracy of a record is crucial to ensure that the data correctly reflect the status and the magnitude in changes of what is being measured;
- ***Consistency***: The measurement of data should be done in a consistent manner to ensure that different periods of the data record are comparable;
- ***Availability***: The data should be available at the required time to ensure that actions dependant on the delivery of the data, can happen on time; and
- **Timeliness**: The data should be available and measured at the appropriate frequency to make the data set applicable for its intended purpose.

The following aspects were noted and are important in light of the data intensive nature of determining water quality planning limits, as well as determining loads in the different sub-catchments. Some concerns noted included:

Surface water quantity data

- Poorly maintained weirs. This is important as measurement of flows is highly dependent on the actual infrastructure and its' state;
- Inadequate number of weirs;
- In the Olifants WMA, of the 79 stations, only 4% had discharge tables (DT) updated and reservoir surveys (4% of 23) loaded after 2010. It is important for many users to get good data at various flow boundaries. Whenever a DT of a gauging station is exceeded, the data quality of the flow record and value are greatly reduced; and
- Of 103 stations in the Olifants 70% have more than 95% of the daily data flagged as being reliable, 23% between 80 to 95% reliable, and 7% with <80% reliable data.

Groundwater level data

- Still using manual methods like dip meters;
- Inadequate number of stations in respect of operational needs and water use. In Mpumalanga, only 59 stations are active with the longest data record being 13.9 years; and
- Inadequate/ disparity in frequency of recording. In Mpumalanga monitoring appears to be monthly. In Limpopo the frequency is unknown.

Water Quality data

The DWS Water Management System (WMS) undertakes quality assurance of the monitoring processes for all Water Resource Quality Data. The intention is to do quality assurance of all data captured into the system before the data is released to the National Water Quality Database for the benefit of water resource quality management practices.

The quality assurance on WMS does not only focus on water quality analysis but includes the needed information associated with water samples such as the method of sampling, depth at which the sample was taken, and quality assurance of the sampling processes such as use of correct containers and preservatives.

Sampling and analysis parameters are specified by means of monitoring programmes or registration of unscheduled samples. The information requirements and business rules are identical for all sampling and analysis undertaken.
Business rules determine what monitoring action (sampling method), analysis methods (instrumentation or preparation method) as well as what sampling equipment (containers and preservative) and sample type grouping are valid. In this regard an action type is specified which defines a sample as “physical sample” or an “observation”.

Monitoring variables can be “Fundamental” (measured) or “Derived” (calculated). Monitoring Actions or Monitoring Variables determine the kind of data capture requirements needed: “Single” result answer per variable, “Multiple” answers per variable, “Depth Profile” kind of answers or “Time Interval” kind of answers. Result capture templates with all the required information are generated with the above kind of information and given to the sampler.

All sampling and analysis requirements are scheduled. A unique identification number (Consolidation ID) is allocated to distinguish between different sampling requirements. Monitoring and analysis schedules are generated to indicate where, what, how and by whom the sampling or analysis should be done.

The following concerns were recorded for water quality data for the national Monitoring Programme (specifics were not given per WMA):

- Monitoring not always done at relevant points: The low monitoring compliance illustrates serious constraints to collection, transport and analysis of samples. The root cause is a lack of adequate finances for samplers, sampler training, equipment, vehicles, delivery and analysis of samples.
- Poor sampling techniques due to inadequate sampler training and no follow-up refresher courses;
- There are a number of critical fields which are not recorded during sample collection and analysis: GPS coordinates, name of sampler, date of sample collection and analysis. It is critical that new and innovative methods are implemented that can enable capture of the required fields such as cell phone apps for GPS coordinates.
- Reason for sample rejection is not recorded;
- A central repository should be developed to record results of all proficiency tests and failure response reports which can be linked to each data analysis. In addition, each analysis should be evaluated against all the tests in the WMS system to ensure the root cause for rejection is captured and can be reviewed in the event of repeated failures for the same sample point.

While earlier studies such as Ashton & Dabrowski (2011) showed that many of the DWS water quality data were unreliable, this project did not allow for detailed scrutiny of the data quality, however where data were noted to be anomalous, values were removed. The assumption was made that these data have been internally (DWS) verified.

The sections to follow set out the approach taken in determining WQPLs. The data used was taken from the WMS as well as to a limited extent the data captured during the controlled release scheme project.

5.2 Approach for the review of existing WQPLs and setting of new WQPLs for surface water

The water quality data downloaded from the Departments WMS during the situation assessment in March 2016, ranged from 1965 to February 2016, depending on the site (Appendix B sets out the period for each site). In the calculations, where available, the last 10 years of data were used, however there are sites where longer periods of data were used due to limited sampling events, or shorter periods where monitoring only started later.

WQPLs were set in the Upper Olifants and upper parts of the Middle Olifants sub-catchments (DWAF, 2009). A summary of these are included in the spreadsheets included as Appendix A to this report, for the relevant management units.

Based on the assessment undertaken as part of the situation assessment:

- Water users were identified including the following sectors: recreational, aquatic ecosystem, industrial use, domestic and agriculture;
- Relevant monitoring points were identified in each management unit;
- Statistical data (5, 50 and 95 percentiles) were calculated and compared against the South African Water Quality Guidelines (DWAF, 1996) to determine the fitness for use at each point:
  - 95 %: salts and metals;
  - 50%: nutrients (nitrates, ortho-phosphate and total phosphorus);
  - 5% and 95% for pH
  - Time-series graphs per variable were drawn and examples are included as Appendix C to this report where adequate data were available.
- It is noted that this approach may obscure seasonal changes where the concentration of a particular constituent may exceed desirable limits for a period of one to several months, however this approach does give a good indication of the situation and will give some guidance.
- Where no data exists on the DWS WMS system, such as for several of the metals and agrochemicals that have been included as part of the water quality component of the RQOs, recommendations regarding monitoring will be made as part of the monitoring and implementation plan and confirmed during consultation;
- Where available, existing WQPLs were assessed to see whether they are still relevant or need to be adjusted; and
- Amended or new WQPLs were proposed based on criteria/ numeric or descriptive in-stream objectives; to protect by maintaining or improving the fitness for use of the water resource, and

- WQPLs were assessed to see that they are aligned to the classification and RQOs.

5.3 Approach to the groundwater component

It would be very difficult to set WQPLs for groundwater, as groundwater, unlike surface water, with a certain chemical quality, cannot easily be changed, for example by dilution. It is therefore important to represent groundwater as having a particular fitness for use and to note that the water may then require treatment if used for a different use.

The assessment of groundwater quality was undertaken against the Department's Quality of Domestic Water Supplies Guidelines (DWAF, 2008) and classed as Classes 0 – 4 (Figure 3). These guidelines compare as follows to the SAWQGs for domestic use:

Class 0: Ideal	Class I: Acceptable
Class II: Tolerable	Class III and IV: Unacceptable

However, groundwater is also used for irrigation and livestock watering. Use of these water quality guidelines would still allow some interpretation of the fitness for use of the supply for irrigation and livestock watering as the parameters important for these two activities are in most cases, except for copper, the allowable concentrations are lower than those required for domestic use.

The availability of groundwater quality is however significantly limited to a few time-series water quality monitoring sites in the area, approximately 20 sites over the study area. This is not a representative sample and recommendations will be made as part of the monitoring programme component of this project, specifically in the sub-catchment management plans, so that where groundwater is the key water source, such as in the Shingwedzi and parts of the Middle Olifants sub-catchments, they are given more attention.

CLASS/COLOUR	DESCRIPTION	EFFECTS
Class 0 B	Ideal water quality	***Drinking Health:*** No effects, suitable for many generations. ***Drinking Aesthetic:*** Water is pleasing. ***Food preparation:*** No effects. ***Bathing:*** No effects. ***Laundry:*** No effects.
Class 1 G	Good water quality	***Drinking Health:*** Suitable for lifetime use. Rare instances of sub-clinical effects. ***Drinking Aesthetic:*** Some aesthetic effects may be apparent. ***Food preparation:*** Suitable for lifetime use. ***Bathing:*** Minor effects on bathing or on bath fixtures. ***Laundry:*** Minor effects on laundry or on fixtures.
Class 2 Y	Marginal water quality	***Drinking Health:*** May be used without health effects by the majority of individuals of all ages, but may cause effects in some individuals in sensitive groups. Some effects possible after lifetime use. ***Drinking Aesthetic:*** Poor taste and appearance are noticeable. ***Food preparation:*** May be used without health or aesthetic effects by the majority of individuals. ***Bathing:*** Slight effects on bathing or on bath fixtures. ***Laundry:*** Slight effects on laundry or on fixtures.
Class 3 R	Poor water quality	***Drinking Health:*** Poses a risk of chronic health effects, especially in babies, children and the elderly. ***Drinking Aesthetic:*** Bad taste and appearance may lead to rejection of the water. ***Food preparation:*** Poses a risk of chronic health effects, especially in children and the elderly. ***Bathing:*** Significant effects on bathing or on bath fixtures. ***Laundry:*** Significant effects on laundry or on fixtures.
Class 4 P	Unacceptable water quality	***Drinking Health:*** Severe acute health effects, even with short-term use. ***Drinking Aesthetic:*** Taste and appearance will lead to rejection of the water. ***Food preparation:*** Severe acute health effects, even with short-term use. ***Bathing:*** Serious effects on bathing or on bath fixtures. ***Laundry:*** Serious effects on laundry or on fixtures.

B = Blue	G = Green	Y = Yellow	R = Red	P = Purple

Figure 3: Groundwater classes used (DWAF, 1998)

5.4 Proposed WQPLs for surface water

Appendix A (included as electronic spreadsheets) sets out the fitness for use assessment for each of the management units, considering the main tributaries. As the water users in the catchment are mostly related to domestic, irrigation, aquaculture and recreation - in most cases the acceptable limit for these uses has been used as the limit against which compliance was undertaken. It should also be noted that SANS 241: 2015 contains adjusted values for certain parameters such as sulphate, which could then be used at an acceptable limit.

Based on the assessment the sections to follow set out the proposed surface water WQPLs for the Olifants WMA sub-catchment areas.

It is important to note:

- In the case where a present state (5, 50 or 95 percentile) was considerably lower than the acceptable or even the ideal water quality guideline value, it did not automatically assume that the limit was set as being equal to the guideline, rather the present value was used, with a small buffering margin; and
- In the case where the present state was higher (in certain cases considerably higher) than the ideal or acceptable water quality guideline (TWQR), the tolerable levels were considered, although not always implemented. More often than not the 50 - 75 percentile data was used.

In the case where the present state was at an unacceptable level it may be necessary to bring in a phased approach. In these unacceptable cases the load modelling will give a better indication of what load needs to be removed, which will allow the determination of what management measures will need to be implemented to reduce the load to an acceptable level, and at what cost. Seasonal trends will also need to be evaluated in these cases.

It is important to note that the WQPLs set in this project will need to be re-assessed in the next 5 – 10 years, especially for those areas where the TDS and suphate limits have been set at a value that should be lowered in future.

5.4.1 Upper Olifants sub-catchment

Management Units

Table 7 sets out the management units delineated for the Upper Olifants sub-catchment of the study area. Figure 4 maps the management units for each of the sub-catchments including the strategic monitoring points used in setting the WQPLs.

Those management units specifically linked to the main stem Olifants River are shown in the purple colour.

Table 7: Management Units description for Upper Olifants sub-catchment

MU	Quaternary catchments	Main River/ tributary	WQ Monitoring points	Weirs
1	B11D	Trichardspruit	90420 90411	B1H22 B1H6
2	B11E	Rietspruit and Blesbokspruit	No monitoring	1000003173
3	B11B	Koringspruit	90418	B1H20
4	B11G	Olifants	88607	
5	B11F	Klippoortjiespruit Tweefonteinspruit	189430	
6	B11G	Noupoortspruit	188537 90417 188538	B1H19
7	B11C B11D	Steenkoolspruit Dwars in-die-Weg Spruit	90415 188589 188447 188448	B1H17

MU	Quaternary catchments	Main River/ tributary	WQ Monitoring points	Weirs
			191615	
8	B11A B11B	Olifants Bankspruit Joubertvleispruit Viskuile Leeufonteinspruit Olifants Leeuwfontein Spruit	188428 188423 188424 188420 90416 188430 188431 188588	B1H18
9	B11F B11G	Unnamed tributary of Klippoortjiespruit	189438 188536	
10	B12A	Klein Olifants	188596 188595	
11	B12B	Rietkuilspruit	188397	
12	B12B	Bosmanspruit	90421	B1H23
13	B12B	Woestalleenspruit		
14	B12C	Klein Olifants	88506 (ZKOHA06)	
15	B12C	Goeiehoopspruit	188390	
16	B11K	Brugspruit	188539 188547 185085 185084	
17	B11K	Blesbokspruit	90430	B1H32
18	B11K	Klipspruit	90408	B1H4
19	B20G	Saalboomspruit/ (Saalklapspruit)	189465 189464	
20	B20G	Saalboomspruit/ (Saalklapspruit)	188545	
21	B20G	Saalboomspruit/ (Saalklapspruit) Kromdraaispruit	88821	
22	B20E B20F	Wilge River	189565 189470 189469 189412 90441	B2H14
23	B20A B20B B20C	Bronkhorstspruit Unnamed tributaries Koffiespruit Osspruit	189562 90438 90437 90436 90434	B2H8 B2H7 B2H6 B2H4
24	B20D	Honde River Bronkhorstspruit	90433	B2H3
25	B20H; B20J	Grootspruit Wilge River	90442 188223	B2H15 B2H16
26	B11H	Spookspruit	90407	B1H2
27	B12E	Keeromspruit	No monitoring points	

MU	Quaternary catchments	Main River/ tributary	WQ Monitoring points	Weirs
28	B11J	Olfants River	188530 90412	B1H10 (d/s Witbank Dam)
29	B11L	Klip Olifants	No monitoring points	
30	B32A	Kranspoortspruit Olifants	No monitoring points, except in Loskop Dam	
31	B12D	Vaalbankspruit	188574	

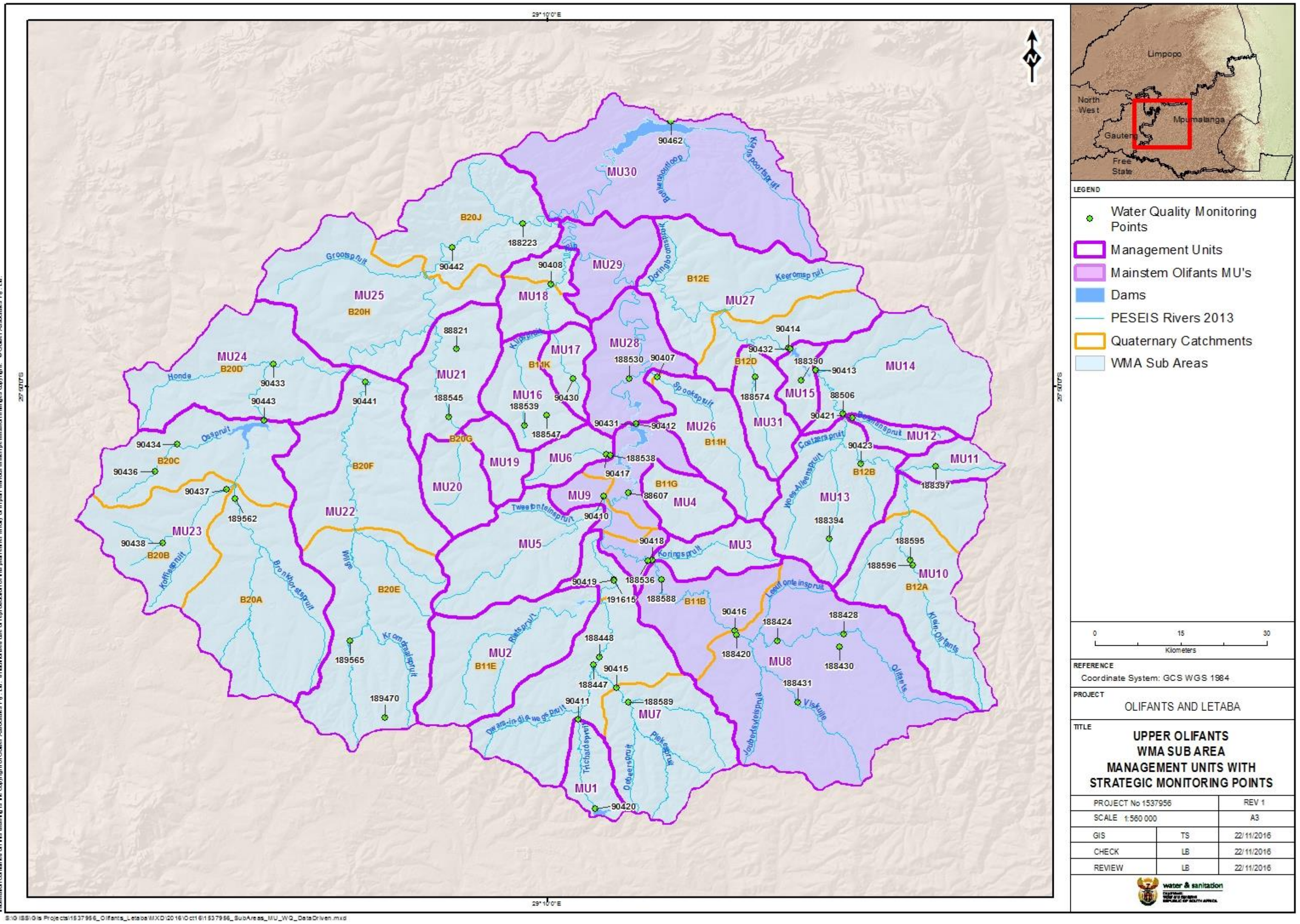


Figure 4: Upper Olifants sub-catchment Management Units showing monitoring points used for the determination of WQPLs

Water Quality Planning Limits

Because of the complexity, the Upper Olifants sub-catchment has been divided into the following sub-drainage areas:

- Witbank Dam (MU 1, 2, 3, 4, 5, 6, 7, 8, 9, 26 including Rietspruit and Witbank dams);
- Middelburg Dam (MU 10, 11, 12, 13, 14, 15 including Middelburg Dam);
- Wilge catchments to Loskop Damn (MU 20, 21, 22, 23, 24 and 25 including Bronkhorstspruit and Wilge dams); and
- Catchments draining to the Loskop Dam downstream of Middelburg and Witbank Dams (MU 16, 17, 18, 27, 28, 30 and 31 including Loskop Dam).

Table 8, Table 9, Table 10, Table 11 set out the proposed WQPLs for the Upper Olifants sub-catchment.

Areas of concern

There are concerns around several of the management units in the Upper Olifants sub-catchment that are considerably higher in salts than allowed for in the RQOs as indicated in the statistical data included in Appendix A.

Consideration will need to be given on how to deal with these parameters. Can a phased approach be used and should the WQPLs reflect the stricter limit that will be strived for or should there be two limits, the first being the more relaxed value which can be achieved with limited interventions, and the second being the stricter limit which would need to be achieved after implementation of some management measure.

In the upper catchments the pH is for the most part in the acceptable range of 6.5 to 8.4. The Wilge River catchment is mostly in compliance except for MU 25 (Grootspruit) which shows some increased levels of TDS and the Saalboomspruit (MUs 20 and 21) showing increased levels of sulphate.

Notes for where no monitoring sites available:

- MU 27: used data from upstream MU 31;
- MU29: considered data from MU 28, 18 and 25;
- MU30: considered data from MU 28, 18, 25 and the Loskop Dam site.

In addition to the WQPLs set out in tables Table 8, Table 9, Table 10 and Table 11 it is recommended that additional variables are included for the Upper Olifants. This is specifically in relation to the bromide discharges from coal-fired power stations and related activities. These contaminants pose a significant concern to public health due to the consequential challenge posed to drinking water disinfection due to the formation of brominated disinfection byproducts with well described adverse health endpoints, effectively yielding household disinfection with chlorine unacceptable. Key pollutants noted in the local and scientific literature that should be included in the WQPLs at least for:

- MU2: Matla and Kriel power stations;
- MU3: Komati power station;
- MU9: Duvha power station;
- MU11: Arnot power station
- MU13: Hendrina power station; and
- MU 22: Kendal and Kusile power stations.

The following variables should be considered and measured using ICP-MS:

- Antimony
- Arsenic
- Barium
- Beryllium
- Bromide
- Cadmium
- Cobalt
- Lead
- Mercury
- Nickel
- Selenium
- Thallium
- Uranium
- Vanadium

The proposed limit values are set out in Table 12.

Table 8: Proposed WQPLs for catchments in the Witbank Dam catchments of the Upper Olifants

Variable	Units	Management Units draining to the Witbank Dam										
		1	2	3	4	5	6	7	8	9	Witbank Dam	Riet-spruit Dam
Calcium (dissolved)	mg/L	24	120	110	80	110	110	55	50	90	50	80
Chloride (dissolved)	mg/L	20	120	50	30	50	50	65	40	25	20	120
Total Dissolved Solids	mg/L	240	500	500	500	500	500	450	350	500	400	500
Electrical Conductivity	mS/m	35	70	90	90	35	90	70	90	90	75	70
Fluoride (dissolved)	mg/L	0.75	1	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.7	0.75
Potassium (dissolved)	mg/L	25	15	25	10	25	25	25	25	9	15	15
Magnesium (dissolved)	mg/L	30	70	70	50	70	80	70	30	50	40	80
Sodium (dissolved)	mg/L	70	70	70	50	70	70	70	50	50	40	70
Ammonium (NH_4-N)	mg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate	mg/L	0.5	0.2	0.2	0.5	0.05	0.3	0.3	0.5	0.5	0.5	0.1
Total Phosphorus	mg/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
pH		6.5-8.4	6.5-8.4	6.5-8.5	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.6	6.5-8.4
Ortho-phosphate	mg/L	0.025	0.025	0.02	0.05	0.06	1	1.25	0.02	0.02	0.02	0.025
Sulphate (dissolved)	mg/L	50	200	300	50	380	380	250	150	300	220	400
Total Alkalinity	mg/L	120	230	120	120	120	120	120	120	120	120	120
Dissolved Organic Carbon	mg/L	10	10	10	10	10	10	10	10	10	10	10
Dissolved Oxygen	mg/L	9	9	9	9	9	9	9	9	9	9	9
Sodium Absorption Ratio		2	5	2	1.5	2	2	2	2	2	2	2
Suspended Solids	mg/L	25	25	25	25	25	25	25	5	25	5	25
Chlorophyll a	µg/L	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Escherichia coli	CFU/ 100mL	130	130	130	130	130	130	130	130	130	130	130
Faecal coliforms	CFU/ 100mL	130	130	130	130	130	130	130	130	130	130	130
Aluminium	mg/L	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Variable	Units	Management Units draining to the Witbank Dam										
		1	2	3	4	5	6	7	8	9	Witbank Dam	Riet-spruit Dam
Boron	mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chromium (VI)	µg/L	7	7	7	7	7	7	7	7	7	7	7
Iron	mg/L	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Manganese	mg/L	0.02	0.15	0.15	0.15	0.15	0.18	0.15	0.05	0.15	0.02	0.02

Table 9: Proposed WQPLs for catchments in the Middelburg Dam catchments of the Upper Olifants

Variable	Units	Management Units draining to the Middelburg Dam						
		10	11	12	13	14	15	Middelburg Dam
Calcium (dissolved)	mg/L	32	60	60	60	70	24	40
Chloride (dissolved)	mg/L	70	50	50	50	30	20	25
Total Dissolved Solids	mg/L	260	260	260	260	400	200	260
Electrical Conductivity	mS/m	40	40	40	40	60	20	40
Fluoride (dissolved)	mg/L	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Potassium (dissolved)	mg/L	25	25	25	25	20	10	15
Magnesium (dissolved)	mg/L	25	25	25	25	50	20	30
Sodium (dissolved)	mg/L	70	125	70	70	30	30	30
Ammonium (NH_4-N)	mg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate	mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.1
Total Phosphorus	mg/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25
pH		6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.5	6.5-8.4	6.5-8.4	6.5-8.4
Ortho-phosphate	mg/L	0.025	0.025	0.025	0.025	0.025	0.1	0.025
Sulphate (dissolved)	mg/L	50	300	50	50	300	40	400
Total Alkalinity	mg/L	120	190	190	190	130	120	120
Dissolved Organic Carbon	mg/L	10	10	10	10	10	10	10

Variable	Units	Management Units draining to the Middelburg Dam						
		10	11	12	13	14	15	Middelburg Dam
Dissolved Oxygen	mg/L	9	9	9	9	9	9	9
Sodium Absorption Ratio		2	2	2	2	2	2	2
Suspended Solids	mg/L	25	25	25	25	25	25	25
Chlorophyll a	µg/L	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Escherichia coli	CFU/ 100mL	130	130	130	130	130	130	130
Faecal coliforms	CFU/ 100mL	130	130	130	130	130	130	130
Aluminium	mg/L	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Boron	mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chromium (VI)	µg/L	7	7	7	7	7	7	7
Iron	mg/L	0.1	0.3	0.3	0.3	0.1	0.1	0.1
Manganese	mg/L	0.02	0.18	0.02	0.02	0.02	0.02	0.02

Table 10: Proposed WQPLs for catchments in the Wilge catchments of the Upper Olifants

Variable	Units	Management Units In the Wilge catchment of the Upper Olifants							
		19, 20	21	22	23	24	25	Bronkhorst-spruit Dam	Wilge Dam
Calcium (dissolved)	mg/L	80	80	32	32	24	70	32	32
Chloride (dissolved)	mg/L	45	20	20	20	20	20	20	20
Total Dissolved Solids	mg/L	260	260	260	260	260	350	260	260
Electrical Conductivity	mS/m	125	40	40	40	40	55	40	40
Fluoride (dissolved)	mg/L	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Potassium (dissolved)	mg/L	25	25	10	10	25	10	10	10
Magnesium (dissolved)	mg/L	50	30	20	15	25	25	15	20
Sodium (dissolved)	mg/L	70	70	30	30	30	30	30	30
Ammonium (NH_4-N)	mg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate	mg/L	0.5	0.05	0.5	0.2	0.1	0.5	0.2	0.5

Variable	Units	Management Units In the Wilge catchment of the Upper Olifants							
		19, 20	21	22	23	24	25	Bronkhorst-spruit Dam	Wilge Dam
Total Phosphorus	mg/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
pH		6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4
Ortho-phosphate	mg/L	0.025	0.025	0.025	0.025	0.025	0.06	0.025	0.025
Sulphate (dissolved)	mg/L	400	400	70	30	50	100	30	70
Total Alkalinity	mg/L	120	120	120	140	140	70	140	120
Dissolved Organic Carbon	mg/L	10	10	10	10	10	10	10	10
Dissolved Oxygen	mg/L	9	9	9	9	9	9	9	9
Sodium Absorption Ratio		2	2	2	2	2	2	2	2
Suspended Solids	mg/L	5	5	5	5	5	5	5	5
Chlorophyll a	µg/L	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Escherichia coli	CFU/ 100mL	130	130	130	130	130	130	130	130
Faecal coliforms	CFU/ 100mL	130	130	130	130	130	130	130	130
Aluminium	mg/L	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Boron	mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chromium (VI)	µg/L	7	7	7	7	7	7	7	7
Iron	mg/L	0.1	0.3	0.1	0.1	0.1	0.3	0.1	0.1
Manganese	mg/L	0.02	0.18	0.02	0.02	0.02	0.02	0.02	0.02

Table 11: Proposed WQPLs for catchments in the Loskop Dam catchments of the Upper Olifants (downstream Middelburg and Witbank Dams)

Variable	Units	Management Units in the Loskop Dam catchment (downstream MD and WD)									
		16	17	18	27	28	29	30	26	31	Loskop Dam
Calcium (dissolved)	mg/L	80	80	80	32	60	55	45	80	32	40
Chloride (dissolved)	mg/L	80	100	100	20	25	15	20	20	20	20
Total Dissolved Solids	mg/L	500	500	500	240	400	350	350	500	240	260
Electrical Conductivity	mS/m	90	90	90	40	60	75	55	90	40	40

Variable	Units	Management Units in the Loskop Dam catchment (downstream MD and WD)									
		16	**17**	**18**	**27**	**28**	**29**	**30**	**26**	**31**	**Loskop Dam**
Fluoride (dissolved)	mg/L	1	0.75	1	0.75	0.75	0.7	0.75	1	0.75	0.75
Potassium (dissolved)	mg/L	30	25	25	25	20	2	20	25	25	10
Magnesium (dissolved)	mg/L	50	70	40	30	25	30	40	30	30	25
Sodium (dissolved)	mg/L	70	70	170	70	30	15	50	70	70	30
Ammonium (NH_4-N)	mg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate	mg/L	6	0.1	6	0.2	2	0.5	0.5	1	0.2	0.5
Total Phosphorus	mg/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
pH		6.5-8.4	6.5-8.4	6.5-8.4	6.5 - 8.4	6.5-8.4	6.5-8.4	6.5-8.4	6.5*-8.4	6.5 - 8.4	6.5-8.4
Ortho-phosphate	mg/L	0.05	0.025	0.025	0.025	0.1	0.1	0.02	0.02	0.025	0.01
Sulphate (dissolved)	mg/L	400	400	400	50	200	150	190	400	50	150
Total Alkalinity	mg/L	120	120	120	120	120	130	120	180	120	90
Dissolved Organic Carbon	mg/L	10	10	10	10	10	5	10	10	10	10
Dissolved Oxygen	mg/L	9	9	9	9	9	9	9	9	9	9
Sodium Absorption Ratio		2	2	2	2	2	2	2	2	2	2
Suspended Solids	mg/L	5	5	5	5	5	25	5	25	5	5
Chlorophyll a	µg/L	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Escherichia coli	CFU/ 100mL	130	130	130	130	130	130	130	130	130	130
Faecal coliforms	CFU/ 100mL	130	130	130	130	130	130	130	130	130	130
Aluminium	mg/L	0.02	0.02	0.02	0.02	0.02	0.15	0.02	0.02	0.02	0.15
Boron	mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chromium (VI)	µg/L	7	7	7	7	7	7	7	7	7	7
Iron	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.15	0.1	0.1
Manganese	mg/L	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.18	0.02	0.02

Table 12: Additional WQPLs for the Upper Olifants sub-catchment

Variable	Units	Proposed limit
Antimony (Sb)	mg/L	0.01
Arsenic (As)	mg/L	0.01
Barium (Ba)	mg/L	0.02
Beryllium (Be)	mg/L	0.02
Bromide (Br)	mg/L	0.02
Cadmium (Cd)	mg/L	0.01
Cobalt (Co)	mg/L	0.02
Lead (Pb)	mg/L	0.01
Mercury (Hg)	mg/L	0.01
Nickel (Ni)	mg/L	0.02
Selenium (Se)	mg/L	0.01
Thallium (Th)	mg/L	0.01
Uranium (U)	mg/L	0.02
Vanadium (V)	mg/L	0.02

5.4.2 Middle Olifants sub-catchment

Management Units

Table 13 sets out the management units delineated for the Middle Olifants sub-catchment of the study area. Figure 5 maps the management units for each of the sub-catchments including the strategic monitoring points used in setting the WQPLs.

Table 13: Management Units description for Middle Olifants sub-catchment

MU	Quaternary catchments	Main River/ tributary	WQ Monitoring points	Weirs
32	B32B B32C	Klipspruit Kruis Selons	191822	
33	B32E B32F	Bloed River		B3H18 and B3H6 – no longer monitored
34	B32D	Olifants River from Selons confluence to Bloed River	88595	
35	B32G B32H	Moses River; Mametse	189553 189423	B3H7
36	B31A B31B B31C B31D B31E B31F B31G B31H B31J	Elands River Hartbeesspruit Enkeldoringspruit Gotwane	189424 189567 189551 189417 191683 (at FBD)	B3H3 and B3H9 – no longer monitored
37	B51E excluding the Zebediela	Grass Valley River	No monitoring points	

MU	Quaternary catchments	Main River/ tributary	WQ Monitoring points	Weirs
	portion running from the R519 to the Nkumpi River in B51G			
38	B32J	Rulokwane Olifants	191684 (Upstream FBD)	B3H25 B3H1
39	B51C B51H B52A B52B B52E	Mokotswane Motseleope Madibjaneng Motsemohlaba Ngwaritsi Ngwaritsane Lepellane Mohlaletsi Pelangwe	1000009810	
40	B51F B51G plus the Zebediela portion running from the R519 road in B51E to the Nkumpi River in B51G	Doring Nkumpi	No monitoring points	
41	B52C B52D	Chunies River	188349	
42	B71E	Moopetsi Matadi Mabogwane Motse	1000009844 (L26)	
43	B52F B52G B52J B52H B71A B71C B71B	Hlakaro Thlabasane Masokuditsi Mpbogodima Paardevlei Tongwane Monametsi	1000009843 (L25)	B5H2
44	B71B	Olifants Mohlapitse Kgotswane	192537 (L56)	
45	B71F	Olifants	No monitoring points	
46	B51B B51A	Puleng Ga-Makatle Motsephiri	No monitoring points	

Water Quality Planning Limits

Table 14Table 15 set out the proposed WQPLs for the management units delineated for the Middle Olifants sub-catchment:

- upstream of Flag Boshielo Dam; and
- downstream of Flag Boshielo Dam.

On the whole the data in this sub-catchment are limited and this will need to be addressed in the monitoring plan.

Areas of concern

There are concerns around several of the management units that are considerable higher in salts than allowed for in the RQOs as indicated in the statistical data included in Appendix A.

These include the two management units (MU 34 and 38) immediately downstream of Loskop Dam as well as MU 36 (Elands River) where it appears that there are considerable impacts from irrigated lands and limited mining in the Marble Hall area.

Downstream of Flag Boshielo Dam the water quality is mostly acceptable for irrigation and domestic use, except for TDS which is on the high side. This will be discussed with the sector as well as the Proto - CMA and DWS Regional Office to get consensus on what relaxations could be given.

Notes for MUs where no monitoring data were available:

- MU33: considered data from MU34;
- MU37: considered data from MU46;
- MU40: considered data from MU39 and MU41; and
- MUs 42, 44 and 45: considered data based on monitoring point B71 192537.

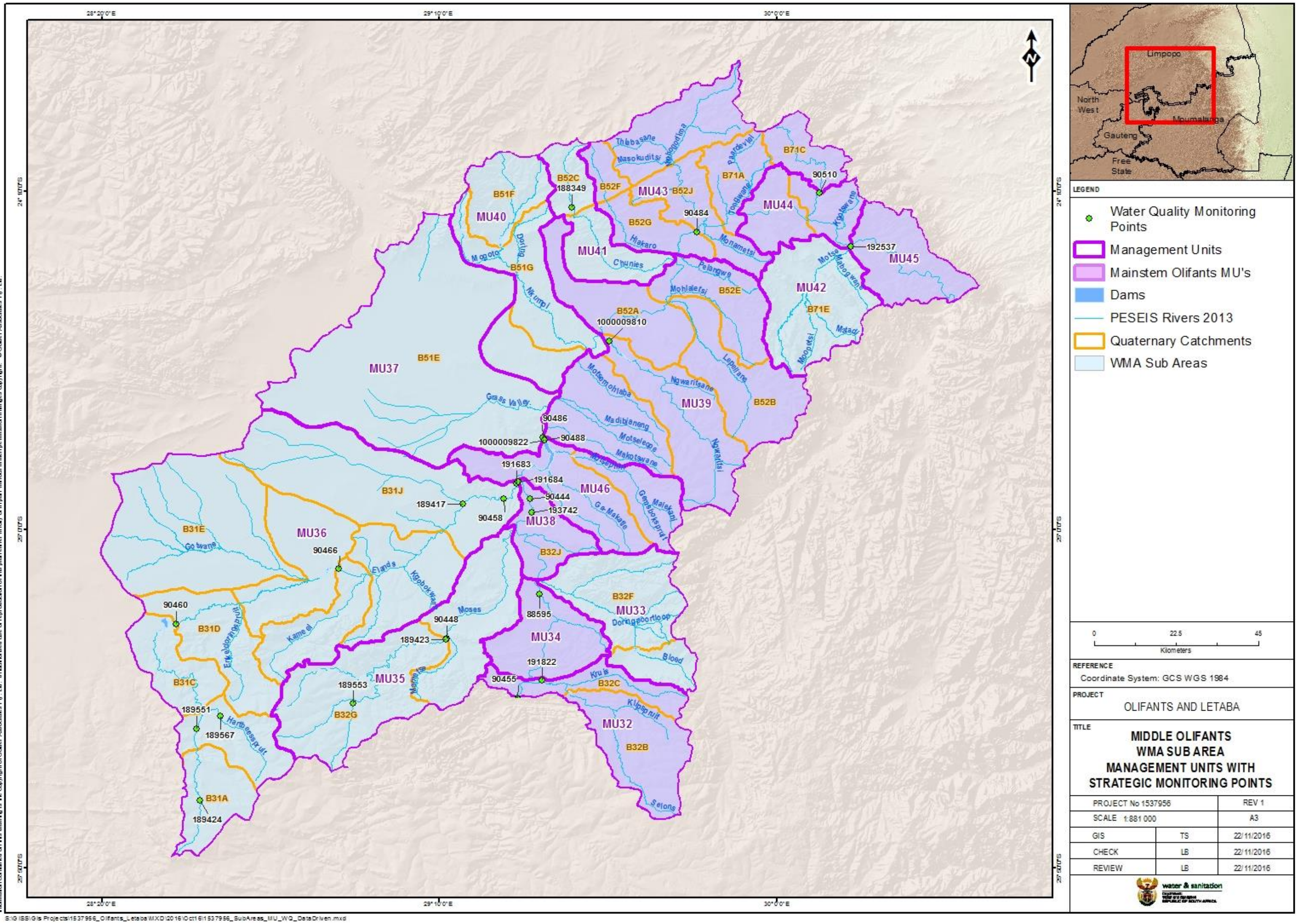


Figure 5: Middle Olifants sub-catchment Management Units showing monitoring points used for the determination of WQPLs

Table 14: Proposed WQPLs for catchments in the Flag Boshielo Dam catchments of the Middle Olifants sub-catchments

Variable	Units	Management Units in the Middle Olifants to Flag Boshielo Dam									
		32	33	34	35	36	38	46	Rhenoster kop Dam	Rust de Winter Dam	Flag Boshielo Dam
Calcium (dissolved)	mg/L	20	25	40	24	80	50	32	20	20	40
Chloride (dissolved)	mg/L	20	7	20	30	100	70	70	25	25	50
Total Dissolved Solids	mg/L	260	180	260	240	500	500	450	180	180	430
Electrical Conductivity	mS/m	40	25	40	40	90	75	70	30	30	70
Fluoride (dissolved)	mg/L	0.75	0.7	0.75	1	1	0.75	0.75	0.75	0.75	0.75
Potassium (dissolved)	mg/L	10	2	10	50	20	10	50	10	10	10
Magnesium (dissolved)	mg/L	25	15	25	30	30	40	30	10	10	30
Sodium (dissolved)	mg/L	30	5	30	70	70	70	70	25	25	90
Ammonium (NH_4-N)	mg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate	mg/L	0.5	0.5	0.5	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Total Phosphorus	mg/L	0.25	0.1	0.25	0.25	0.25	0.25	0.25	0.1	0.1	0.25
pH		6.5-8.4	6.5-8.4	6.5-8.4	6.5 - 8.4	6.5 - 8.4	6.5-8.4	6.5 - 8.4	6.5-8.4	6.5-8.4	6.5-8.4
Ortho-phosphate	mg/L	0.01	0.02	0.01	0.025	0.05	0.02	0.005	0.025	0.025	0.01
Sulphate (dissolved)	mg/L	150	25	150	30	300	150	180	200	200	100
Total Alkalinity	mg/L	90	90	90	120	150	120	120	80	120	120
Dissolved Organic Carbon	mg/L	10	5	10	5	5	10	5	10	10	10
Dissolved Oxygen	mg/L	9	9	9	9	9	9	9	9	9	9
Sodium Absorption Ratio		2	2	2	2	2	2	2	1.5	1.5	2
Suspended Solids	mg/L	5	25	5	25	25	5	25	25	25	5
Chlorophyll a	µg/L	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Escherichia coli	CFU/ 100mL	130	130	130	130	130	130	130	130	130	130
Faecal coliforms	CFU/ 100mL	130	130	130	130	130	130	130	130	130	130
Aluminium	mg/L	0.15	0.1	0.15	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Boron	mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Variable	Units	Management Units in the Middle Olifants to Flag Boshielo Dam									
		32	33	34	35	36	38	46	Rhenoster kop Dam	Rust de Winter Dam	Flag Boshielo Dam
Chromium (VI)	µg/L	7	7	7	7	7	7	7	7	7	7
Iron	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manganese	mg/L	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

The management units downstream of Flag Boshielo Dam are lacking in data. Monitoring point 192537 on the Olifants has been used to propose WQPLs for these management units, all of which have similar water uses.

Table 15: Proposed WQPLs for catchments downstream of the Flag Boshielo Dam catchments of the Middle Olifants sub-catchments

Variable	Units		Management Units in the Middle Olifants downstream Flag Boshielo Dam						
		37	39	40	41	42	43	44	45
Calcium (dissolved)	mg/L	32	32	32	32	32	32	32	35
Chloride (dissolved)	mg/L	85	85	85	85	85	20	65	65
Total Dissolved Solids	mg/L	355	355	355	355	355	260	260	450
Electrical Conductivity	mS/m	55	55	55	55	55	40	40	75
Fluoride (dissolved)	mg/L	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Potassium (dissolved)	mg/L	50	50	50	50	50	10	10	10
Magnesium (dissolved)	mg/L	30	30	30	30	30	35	40	40
Sodium (dissolved)	mg/L	70	70	70	70	70	20	30	30
Ammonium (NH_4-N)	mg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate	mg/L	3	3	3	3	3	0.5	0.5	0.5
Total Phosphorus	mg/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
pH		6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4
Ortho-phosphate	mg/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Sulphate (dissolved)	mg/L	30	90	30	30	30	60	60	60
Total Alkalinity	mg/L	120	120	120	120	120	120	120	120

Variable	**Units**		**Management Units in the Middle Olifants downstream Flag Boshielo Dam**						
		37	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Dissolved Organic Carbon	mg/L	5	5	5	5	5	5	5	5
Dissolved Oxygen	mg/L	9	9	9	9	9	9	9	9
Sodium Absorption Ratio		2	2	2	2	2	2	2	2
Suspended Solids	mg/L	25	25	25	25	25	25	25	25
Chlorophyll a	µg/L	0.001	1	0.001	0.001	0.001	1	1	1
Escherichia coli	CFU/ 100mL	130	130	130	130	130	130	130	130
Faecal coliforms	CFU/ 100mL	130	130	130	130	130	130	130	130
Aluminium	mg/L	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Boron	mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chromium (VI)	µg/L	7	7	7	7	7	7	7	7
Iron	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manganese	mg/L	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

5.4.3 Steelpoort sub-catchment

Management Units

Table 16 sets out the management units delineated for the Steelpoort sub-catchment of the study area. Figure 6 maps the management units for each of the sub-catchments including the strategic monitoring points used in setting the WQPLs.

Table 16: Management Units description for the Steelpoort sub-catchment

MU	Quaternary catchments	Main River/ tributary	WQ Monitoring points	Weirs
59	B41A	Lakensvleispruit Kleinspruit Langspruit Grootspruit	188911 193279 (both near Belfast Dam)	
60	B41B B41D (excluding Mapochs) B41E	Steelpoort to De Hoop Dam Laersdrift	1000009852 (L42) 188910 193090 1000009854 (L44) 192623 (L80)	B4H24 B4H3
61	B41C and small portion of B41D up to where the Masala River confluences with the Olifants	Tonteldoos Vlugkraal Masala	1000009848 (L31) 90476 1000009858 (L49) 1000009848 (L31)	B4H17
62	B41F	Draaikraalspruit Klip	190142	
63	B42A B42B B42C B42D B42E	Dorps Hoppe se Spruit Doringspruit Potloodspruit Kliprots Spekboom	1000009780 (L37) 1000009778 (L36) 90472 1000009808 (L19) 90470	B4H10 B4H7
64	B42F B42G	Potspruit Buffelskloof Waterval	90469	B4H5 B4H21
65	B41H B41J	Steelpoort Tubatsane Hodupong	188915 1000009856 (L46)	
66	B41G B41H (Dwars to confluence with Olifants)	Klein Dwars Groot Dwars Dwars	192609 (L77) 90471	B4H9
67	B42H	Eloffspruit Spekboom	192622 (L62) 188912 (L74)	
68	B41K	Steelpoort	192529 (L75) 90473 193091	B4H11 B4H25

Water Quality Planning Limits

Table 17 and Table 18 set out the proposed WQPLs for the management units delineated for the Steelpoort sub-catchment:

- upstream of De Hoop Dam (MU 59, 60, 61, 62 and 81 including De Hoop Dam); and
- downstream of De Hoop Dam (MU 63, 64, 66, 67 and 68).

Areas of concern

The water quality in this sub-catchment is on the whole fairly good except for MU 81 (Dwars River) which shows impacts from the upstream mines.

Elevated TDS is also noted in the Steelpoort just upstream of the confluence with the Olifants River.

Notes for MUs where monitoring data were not available:

- sites available in each MU.

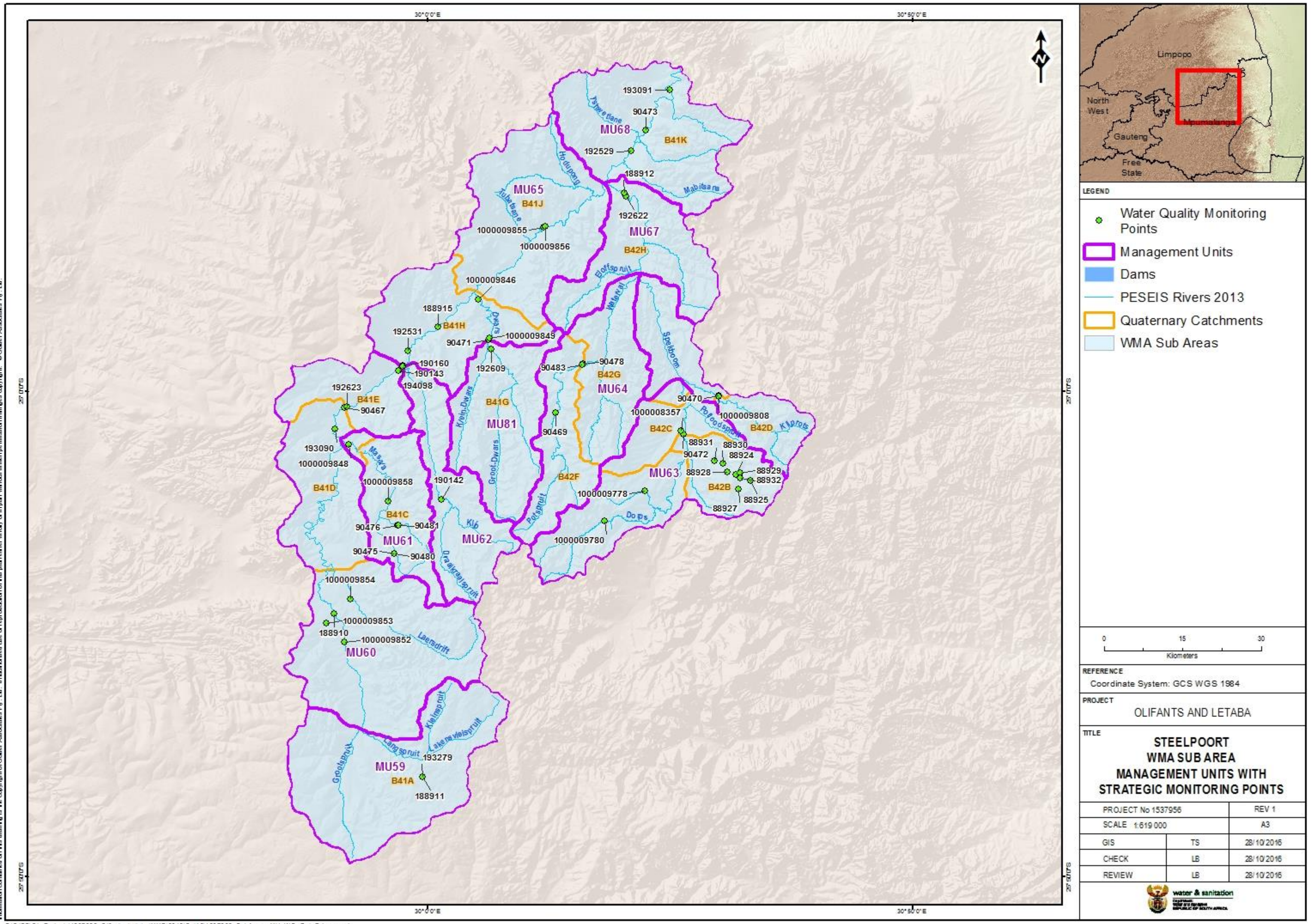


Figure 6: Steelpoort sub-catchment Management Units showing monitoring points used for the determination of WQPLs

Table 17: Proposed WQPLs for catchments upstream of De Hoop Dam catchments of the Steelpoort sub-catchment

Variable	Units	Management Units in Steelpoort sub-catchment upstream of De Hoop Dam					De Hoop Dam
		59	60	61	62	81	
Calcium (dissolved)	mg/L	15	15	15	32	45	32
Chloride (dissolved)	mg/L	25	25	25	20	20	20
Total Dissolved Solids	mg/L	260	260	260	260	400	280
Electrical Conductivity	mS/m	30	30	50	45	60	45
Fluoride (dissolved)	mg/L	0.75	0.75	0.75	0.75	0.75	0.75
Potassium (dissolved)	mg/L	50	10	10	10	10	10
Magnesium (dissolved)	mg/L	30	30	50	20	50	20
Sodium (dissolved)	mg/L	70	20	20	25	30	25
Ammonium (NH_4-N)	mg/L	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate	mg/L	0.5	0.5	0.5	0.5	0.5	0.5
Total Phosphorus	mg/L	0.25	0.25	0.25	0.25	0.25	0.25
pH		6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4
Ortho-phosphate	mg/L	0.01	0.01	0.01	0.005	0.025	0.005
Sulphate (dissolved)	mg/L	20	20	40	30	20	30
Total Alkalinity	mg/L	70	120	170	150	300	150
Dissolved Organic Carbon	mg/L	5	5	5	5	5	5
Dissolved Oxygen	mg/L	9	9	9	9	9	9
Sodium Absorption Ratio		2	2	2	2	2	2
Suspended Solids	mg/L	25	25	25	25	25	25
Chlorophyll a	µg/L	1	1	1	1	1	1
Escherichia coli	CFU/ 100mL	130	130	130	130	130	130
Faecal coliforms	CFU/ 100mL	130	130	130	130	130	130
Aluminium	mg/L	0.01	0.01	0.01	0.01	0.01	0.01
Boron	mg/L	0.5	0.5	0.5	0.5	0.5	0.5
Chromium (VI)	µg/L	7	7	7	7	7	7
Iron	mg/L	0.1	0.1	0.1	0.1	0.1	0.1
Manganese	mg/L	0.02	0.02	0.02	0.02	0.02	0.02

Table 18: Proposed WQPLs for catchments downstream of De Hoop Dam catchments of the Steelpoort sub-catchment

Variable	Units	Management Units in Steelpoort sub-catchment downstream of De Hoop Dam				
		63	64	66	67	68
Calcium (dissolved)	mg/L	32	20	20	20	40
Chloride (dissolved)	mg/L	20	10	10	10	50
Total Dissolved Solids	mg/L	120	160	160	160	290
Electrical Conductivity	mS/m	45	40	30	40	45
Fluoride (dissolved)	mg/L	0.75	0.75	0.75	0.75	0.75
Potassium (dissolved)	mg/L	10	10	10	10	10
Magnesium (dissolved)	mg/L	45	30	15	15	40
Sodium (dissolved)	mg/L	10	10	10	10	40
Ammonium (NH_4-N)	mg/L	0.05	0.05	0.05	0.05	0.05
Nitrate	mg/L	0.5	0.5	0.5	0.5	1.5
Total Phosphorus	mg/L	0.25	0.25	0.25	0.25	0.25
pH		6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.7
Ortho-phosphate	mg/L	0.005	0.02	0.02	0.02	0.02
Sulphate (dissolved)	mg/L	20	30	10	10	50
Total Alkalinity	mg/L	120	140	100	100	200
Dissolved Organic Carbon	mg/L	5	5	5	5	5
Dissolved Oxygen	mg/L	9	9	9	9	9
Sodium Absorption Ratio		2	2	2	2	2
Suspended Solids	mg/L	25	25	25	25	25
Chlorophyll a	µg/L	1	1	1	1	1
Escherichia coli	CFU/ 100mL	130	130	130	130	130
Faecal coliforms	CFU/ 100mL	130	130	130	130	130
Aluminium	mg/L	0.01	0.01	0.01	0.01	0.01
Boron	mg/L	0.5	0.5	0.5	0.5	0.5
Chromium (VI)	µg/L	7	7	7	7	7
Iron	mg/L	0.1	0.1	0.1	0.1	0.1
Manganese	mg/L	0.02	0.02	0.02	0.02	0.02

5.4.4 Lower Olifants sub-catchment

Management Units

Table 19 sets out the management units delineated for the Lower Olifants sub-catchment of the study area. Figure 7 maps the management units for each of the sub-catchments including the strategic monitoring points used in setting the WQPLs.

Table 19: Management Units description for the Lower Olifants sub-catchment

MU	Quaternary catchments	Main River/ tributary	WQ Monitoring points	Weirs
47	B60E B60F B60G B60H to Blyderivierspoort Dam	Kranskloofspruit Ohrigstadt Mantshibi Vyehoek	1000009804 (L15) 100000980 (L14)	B6H6 B6H11 (Ohrigstadt Dam
48	B60A B60B B60C B60D to Blyderivierspoort Dam	Blyde River Lisbon Treur	1000009806 (L17) 1000009805 (L16) 1000009807 (L18)	B6H1 B6H3
49	B71G B71H B71J	Tswenyane River	1000009802 (L13) 1000009801 (L12)	B7H9
50	B60J	Blyde River Rietspruit Sandspruit	1000009799 (L10)	B6H5 B6H4
51	B73A	Klaserie	100000979 (L9)	B7H4
52	B73E (portion around Acornhoek outside the KNP)	Timbavati	No monitoring points	
53	B73B B73C B73D B73F B73G B73H B73J B73E (portion in KNP)	(Tributaries all flowing to Olifants) Monwana Tsiri Tharalumi Macharton Ga-Sekgobela Nyameni Nhlaralumi Shisakashanghondo Timbavati	No monitoring points	
54	B72A B72B B72C	Makhutswi Moungwane Malomanye Molomahlapi Mosomeetse Ga-Matombane	1000009795 (L2)	B7H7
55	B72D	Olifants to Phalaborwa barrage Sedumoni Mohlabetsi	1000009786 (L8)	B7R2
56	B72K (portion at Phalaborwa)	Ga-Selati (portion at Phalaborwa) to Mamba weir	192538 (L54) 1000009797 (L4)	B7H19 B7H15
57	B72E B72F B72G B72H B72K	Ngwabitsi Ga-Selati	1000009796 (L3)	B7H2 B7H10 B7H14

MU	Quaternary catchments	Main River/ tributary	WQ Monitoring points	Weirs
58	B72J	Molatle	No monitoring points	

Water Quality Planning Limits

Tables Table 20Table 21 set out the proposed WQPLs for the management units delineated for the Lower Olifants sub-catchment including:

- upstream of Blyderivierspoort Dam (MU 47, 48, 49, 50 and 54 including Ohrigstadt and Blyderivierspoort Dams); and
- downstream of Blyderivierspoort Dam to the Kruger National Park (MU 51, 52, 53, 55, 56, 57, 58 and 80 including the Phalaborwa Barrage).

Areas of concern

The management units of concern in this sub-catchment are MU 49, Olifants River just upstream of the confluence with the Blyde River that shows elevated TDS.

The water quality in MU 57 (Ngwabitsi River), MU 58 (Molatle River) and MU 56 (Ga-Selati River) show impacts from irrigation and urban use. MU 80 shows severe impacts from the mines and industries in the Phalaborwa area which continues into MU 53 in Kruger National Park.

Notes for MUS where data were not available:

- MU58: Used data from MU57 as land uses seem to be similar.

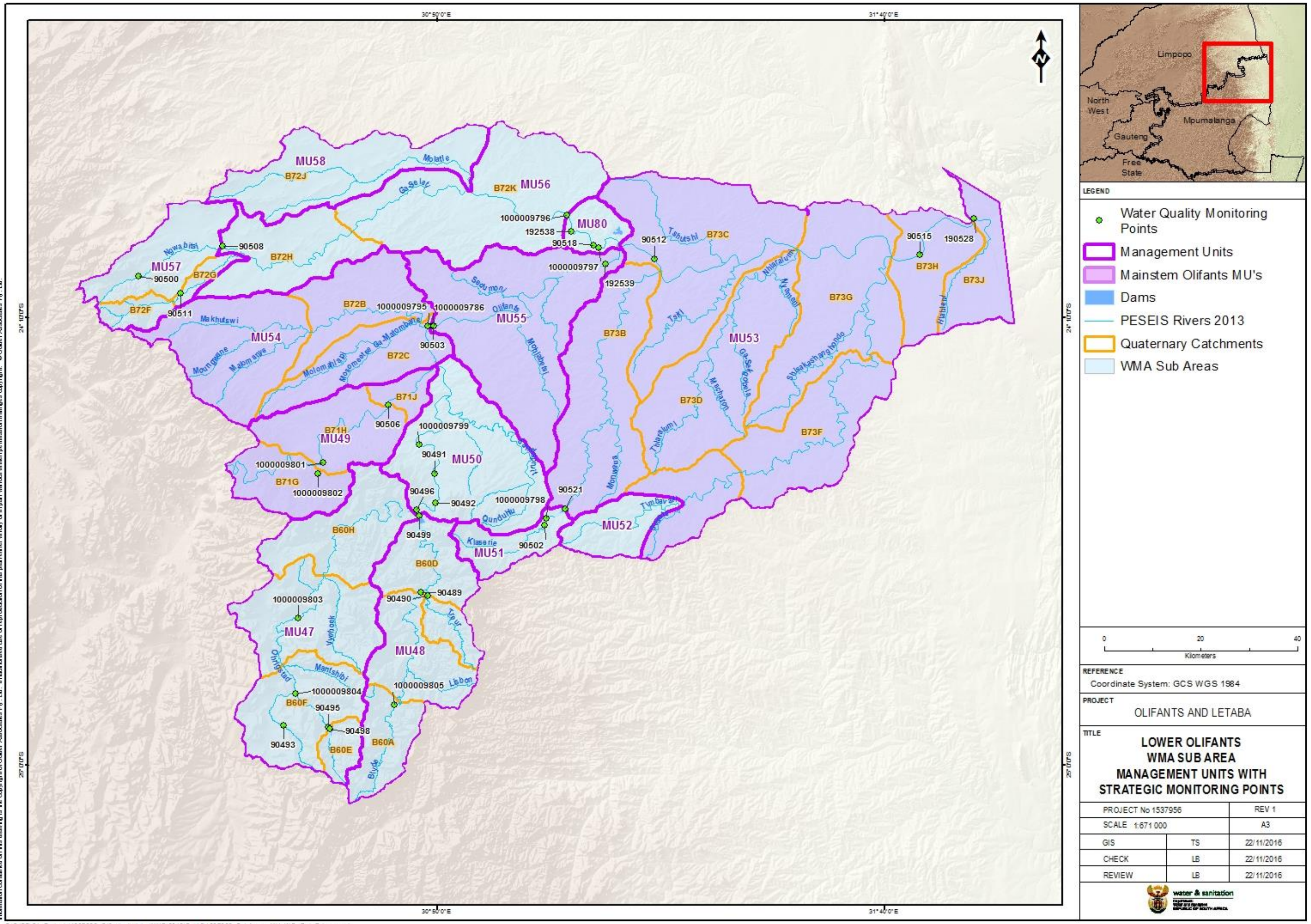


Figure 7: Lower Olifants sub-catchment Management Units showing monitoring points used for the determination of WQPLs

Table 20: Proposed WQPLs for catchments in the Lower Olifants sub-catchment upstream of Blyderivierspoort Dam

Variable	Units	Management Units in Lower Olifants sub-catchment upstream of Blyderivierspoort Dam						
		47	**48**	**49**	**50**	**54**	**Ohrigstad Dam**	**Blyderivier-poort Dam**
Calcium (dissolved)	mg/L	50	25	40	40	25	32	32
Chloride (dissolved)	mg/L	15	7	60	15	7	15	15
Total Dissolved Solids	mg/L	180	180	370	180	260	75	180
Electrical Conductivity	mS/m	25	25	60	30	25	25	25
Fluoride (dissolved)	mg/L	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Potassium (dissolved)	mg/L	2	2	10	10	2	2	2
Magnesium (dissolved)	mg/L	30	15	45	45	15	20	20
Sodium (dissolved)	mg/L	15	5	35	15	5	15	15
Ammonium (NH_4-N)	mg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate	mg/L	0.5	0.5	0.5	0.5	0.5	0.05	0.2
Total Phosphorus	mg/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25
pH		6.5-8.4	6.5-8.4	6.5-8.8	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4
Ortho-phosphate	mg/L	0.1	0.02	0.02	0.2	0.02	0.02	0.02
Sulphate (dissolved)	mg/L	15	25	70	25	25	10	10
Total Alkalinity	mg/L	130	90	160	100	90	40	120
Dissolved Organic Carbon	mg/L	5	5	10	5	5	5	5
Dissolved Oxygen	mg/L	9	9	9	9	9	9	9
Sodium Absorption Ratio		2	2	2	2	2	2	2
Suspended Solids	mg/L	25	25	5	25	25	25	25
Chlorophyll a	µg/L	1	1	1.5	1	1	1	1
Escherichia coli	CFU/ 100mL	130	130	130	130	130	130	130
Faecal coliforms	CFU/ 100mL	130	130	130	130	130	130	130
Aluminium	mg/L	0.15	0.15	0.02	0.15	0.15	0.15	0.15
Boron	mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chromium (VI)	µg/L	7	7	7	7	7	7	7
Iron	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manganese	mg/L	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Table 21: Proposed WQPLs for catchments in the Lower Olifants sub-catchment to KNP

Variable		Management Units in Lower Olifants sub-catchment to KNP							
		51	52	55	56	57; 58	53	80	Phalaborwa Barrage
Calcium (dissolved)	mg/L	20	20	35	120	20	35	120	35
Chloride (dissolved)	mg/L	115	115	50	180	15	50	180	50
Total Dissolved Solids	mg/L	80	80	350	500	120	400	500	400
Electrical Conductivity	mS/m	15	15	55	90	30	60	90	60
Fluoride (dissolved)	mg/L	0.75	0.75	0.75	0.75	0.75	0.75	1.5	0.7
Potassium (dissolved)	mg/L	10	10	10	15	10	10	30	10
Magnesium (dissolved)	mg/L	15	15	35	70	15	35	70	35
Sodium (dissolved)	mg/L	15	15	45	70	15	45	70	45
Ammonium (NH_4-N)	mg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate	mg/L	0.5	0.5	0.5	2	0.5	0.5	0.7	0.5
Total Phosphorus	mg/L	0.25	0.25	0.25	0.25	0.25	0.25	0.55	0.25
pH		6.5 - 8.4	6.5 - 8.4	6.5-8.4	6.5 - 8.4	6.5 - 8.4	6.5-8.4	6.5 - 8.6	6.5-8.4
Ortho-phosphate	mg/L	0.2	0.2	0.005	2	0.02	0.01	0.3	0.005
Sulphate (dissolved)	mg/L	15	15	55	100	15	100	400	55
Total Alkalinity	mg/L	60	60	200	390	100	180	380	200
Dissolved Organic Carbon	mg/L	5	5	10	5	5	5	5	5
Dissolved Oxygen	mg/L	9	9	9	9	9	9	9	9
Sodium Absorption Ratio		2	2	2	2	2	2	2	2
Suspended Solids	mg/L	25	25	5	25	25	5	25	5
Chlorophyll a	µg/L	1	1	1.5	1	1	1.5	1	1.5
Escherichia coli	CFU/ 100mL	130	130	130	130	130	130	130	130
Faecal coliforms	CFU/ 100mL	130	130	130	130	130	130	130	130
Aluminium	mg/L	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.02
Boron	mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chromium (VI)	µg/L	7	7	7	7	7	7	7	7
Iron	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3
Manganese	mg/L	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

5.4.5 Letaba sub-catchment

Management Units

Table 22 sets out the management units delineated for the Letaba sub-catchment of the study area. Figure 8 maps the management units for each of the sub-catchments including the strategic monitoring points used in setting the WQPLs.

Table 22: Management Units description for the Letaba sub-catchment

MU	Quaternary catchments	Main River/ tributary	WQ Monitoring points	Weirs
69	B81A B81B B81C B81D B81E	Broederstroom Babs Thabina Nwanedzi Groot Letaba	90546 187689 190450 90525	B8H53 B8H9 B8H10
70	B82E B82F B82G	Soeketse Klein Letaba	90539 183879	B8H33
71	B81G B81F B81H B81J	Molototsi Lerwatlou Merekome Groot Letaba Leshogole Makwena	90528 90524	B8H17 B8H8
72	B82H	Nsama Magobe	90581 (at Nsami Dam)	
73	B82J	Nalatsi Byashishi Klein Letaba	90536	B8H28
74	B83A B83B B83C B83D B83E	Letaba Shipikani Tsende Nharhweni Ngwenyeni Nwanedzi	No monitoring points	B8H18
75	B82A B82B B82C B82D	Brandboontjies Middle Letaba Lejelebore	90580 (at MLD)	B8H54 (canal at Middle Limpopo Dam)

Water Quality Planning Limits

Table 23 sets out the proposed WQPLs for the management units delineated for the Letaba sub-catchment including the area in the Kruger National Park (MU 53) and including the Middle Letaba, Magoebaskloof, Ebenezer and Tzaneen Dams.

Areas of concern

Water quality in the upper catchments of the Letaba sub-catchment is very good. The areas around the towns show impacts from urbanisation, especially in MUs 79, 70, 71 and 72.

Data in the sub-catchment are limited so will need to be addressed as part of the monitoring plan development. Data for MU70 has also been considered for MUs 72, 73 and 79.

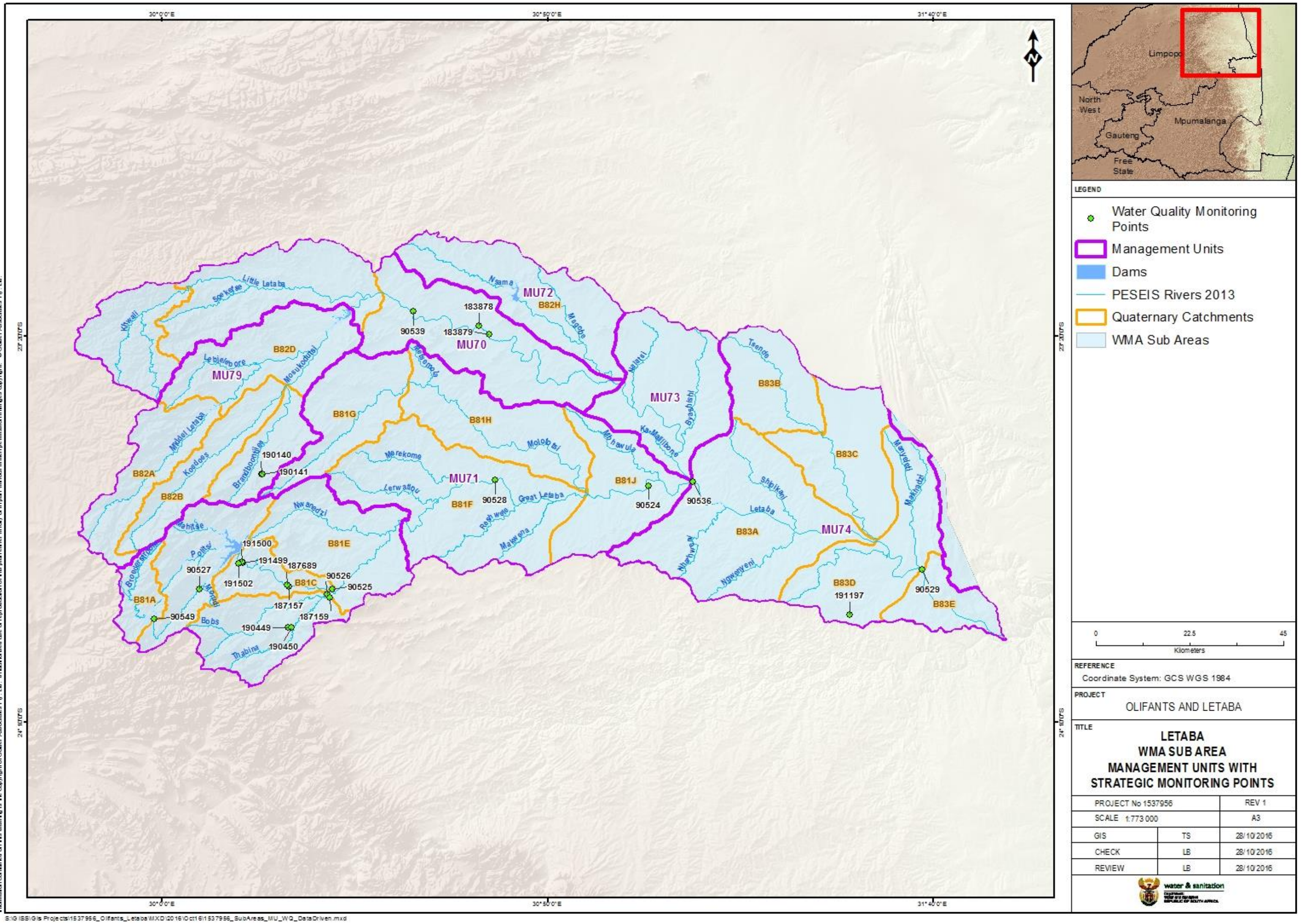


Figure 8: Letaba sub-catchment Management Units showing monitoring points used for the determination of WQPLs

Table 23: Proposed WQPLs for catchments in the Letaba sub-catchment

Variable	Units	Management Units in the Letaba sub-catchment								
		69	70	71; 73	74	79	Middle Letaba Dam	Magoebaskloof Dam	Ebenezer Dam	Tzaneen Dam
Calcium (dissolved)	mg/L	20	50	40	60	35	35	10	10	10
Chloride (dissolved)	mg/L	30	100	180	150	60	60	10	10	20
Total Dissolved Solids	mg/L	120	260	500	300	380	260	60	80	100
Electrical Conductivity	mS/m	20	40	90	50	60	40	10	15	25
Fluoride (dissolved)	mg/L	0.75	0.75	0.75	0.75	0.75	0.75	0.2	0.2	0.2
Potassium (dissolved)	mg/L	10	20	10	10	10	50	5	5	5
Magnesium (dissolved)	mg/L	10	50	35	60	40	30	5	5	5
Sodium (dissolved)	mg/L	20	80	120	115	50	40	10	10	10
Ammonium (NH_4-N)	mg/L	0.05	2	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate	mg/L	0.5	2	0.5	0.5	0.5	0.5	0.5	0.5	0.3
Total Phosphorus	mg/L	0.25	2.5	0.25	0.25	0.25	0.25	0.25	0.25	0.25
pH		6.5 - 8.4	6.5 - 9.2	6.5 - 8.4	6.5 - 8.4	6.5 - 8.7	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4
Ortho-phosphate	mg/L	0.02	1	0.02	0.02	0.02	0.005	0.02	0.02	0.2
Sulphate (dissolved)	mg/L	10	30	35	10	20	30	15	15	35
Total Alkalinity	mg/L	70	300	180	120	180	210	40	40	40
Dissolved Organic Carbon	mg/L	5	5	5	5	5	5	5	5	5
Dissolved Oxygen	mg/L	9	9	9	9	9	9	9	9	9
Sodium Absorption Ratio		2	2	2	2	2	2	2	2	2
Suspended Solids	mg/L	25	25	25	25	25	25	25	25	25
Chlorophyll a	µg/L	1	1	1	1	1	1	1	1	1
Escherichia coli	CFU/ 100mL	130	130	130	130	130	130	130	130	130
Faecal coliforms	CFU/ 100mL	130	130	130	130	130	130	130	130	130
Aluminium	mg/L	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Boron	mg/L	5	5	5	5	5	5	5	5	5
Chromium (VI)	µg/L	7	7	7	7	7	7	7	7	7

Variable	**Units**	**Management Units in the Letaba sub-catchment**								
		69	**70**	**71; 73**	**74**	**79**	**Middle Letaba Dam**	**Magoebaskloof Dam**	**Ebenezer Dam**	**Tzaneen Dam**
Iron	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manganese	mg/L	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

5.4.6 Shingwedzi sub-catchment

Management Units

Table 24 sets out the management units delineated for the Shingwedzi sub-catchment of the study area. Figure 9 maps the management units for each of the sub-catchments including the strategic monitoring points used in setting the WQPLs for the Shingwedzi sub-catchment.

Table 24: Management Units description for the Shingwedzi sub-catchment

MU	Quaternary catchments	Main River/ tributary	WQ Monitoring points	Weirs
76	B90F	Shingwidzi	No monitoring points	
77	B90C	Phugwane	No monitoring points	
78	B90B	Mphongolo	193797	
79	B90A B90E B90D B90G B90H	Shisa Phugwane Nkulumbeni Bububu Drombo	188499	B9H2 B9H3

Water Quality Planning Limits

Table 25 sets out the proposed WQPLs for the Shingwedzi sub-catchment.

Table 25: Proposed WQPLs for catchments in the Shingwedzi sub-catchment

Variable	Units	Management Units in the Shingwedzi sub-catchment	
		75; 76; 77	78
Calcium (dissolved)	mg/L	60	32
Chloride (dissolved)	mg/L	100	30
Total Dissolved Solids	mg/L	280	340
Electrical Conductivity	mS/m	40	45
Fluoride (dissolved)	mg/L	0.70	0.70
Potassium (dissolved)	mg/L	20	20
Magnesium (dissolved)	mg/L	30	30
Sodium (dissolved)	mg/L	50	70
Ammonium (NH_4-N)	mg/L	0.07	0.06
Nitrate	mg/L	0.5	0.2
Total Phosphorus	mg/L	0.25	0.2
pH		6.5 - 8.4	6.5 - 8.4
Ortho-phosphate	mg/L	0.025	0.050
Sulphate (dissolved)	mg/L	30	40
Total Alkalinity	mg/L	150	185
Dissolved Organic Carbon	mg/L	5	5
Dissolved Oxygen	mg/L	9	9
Sodium Absorption Ratio		2	2
Suspended Solids	mg/L	25	25
Chlorophyll a	µg/L	1	1

Variable	Units	Management Units in the Shingwedzi sub-catchment	
		75; 76; 77	78
Escherichia coli	CFU/ 100mL	130	130
Faecal coliforms	CFU/ 100mL	130	130
Aluminium	mg/L	0.01	0.01
Boron	mg/L	5	5
Chromium (VI)	µg/L	7	7
Iron	mg/L	0.1	0.1
Manganese	mg/L	0.02	0.02

Areas of concern

The data in this sub-catchment are very limited due mostly to the non-perennial nature of the rivers, however the areas of concern are mostly around the urban areas, as for the Letaba catchment, and relate to urban run-off and poorly managed wastewater treatment works. In this respect ensuring implementation of good management practices would be more important than assessing compliance against the WQPLs.

For MUs 76 and 77, the data from monitoring point on the Shingwidzi River (MU75) has been used.

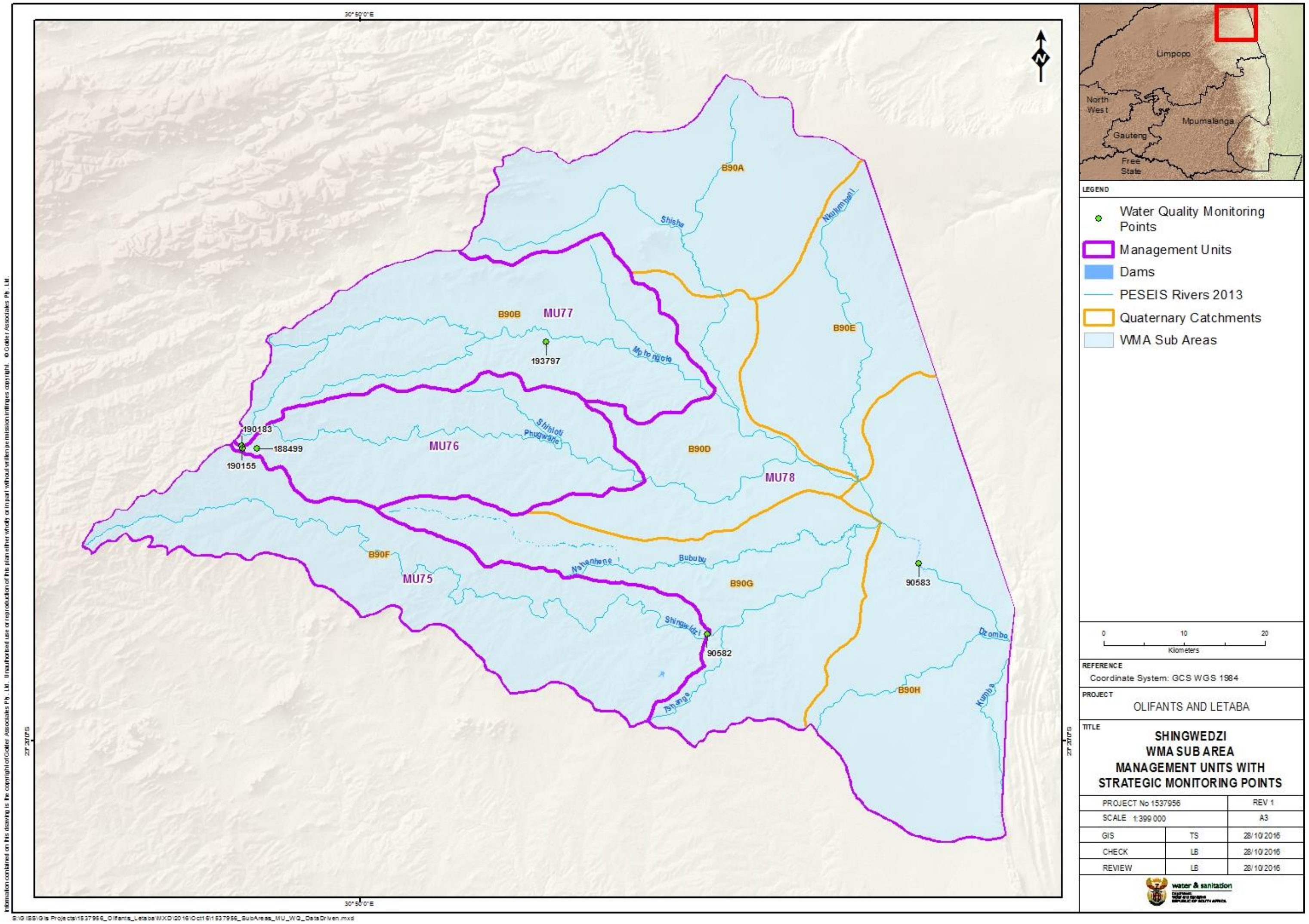


Figure 9: Shingwedzi sub-catchment Management Units showing monitoring points used for the determination of WQPLs

5.5 Alignment of Status Quo of Water Quality Planning Limits

5.5.1 Olifants River Main Stem

Figure 10 illustrates the main stem Olifants River and the main tributaries. Figure 11 shows the proposed TDS limits along the main stem Olifants River. Currently the TDS concentrations along the main stem will not meet the WQPLs proposed. Comparing the TDS to the sulphate and chloride graphs (Figure 12 and Figure 13) respectively shows the impacts from both mining and irrigation return flows. Management actions will therefore need to be set to reduce these in the short to medium term to a level that is acceptable and then maintain and improve over the longer term with further management actions. As the TDS is high throughout the catchment all sectors (mining, urban and agriculture) will need to contribute to the reduction. The highest limit proposed is 500 mg/L which is aligned to the RQOs for the Olifants.

Sulphate WQPLs are high in the Upper Olifants, but reduce further downstream until the river reaches Phalaborwa where the severe impacts of the industries and mines in the area are seen and have an impact well into the KNP. There are certain management units in the Upper Olifants and around Phalaborwa where the current status will not meet the WQPLs. The WQPLs set may be above the TWQR for domestic use (the strictest requirement), however the limit for drinking water (SANS 241: 2015) is set at 400 mg/L, so that even if communities use water directly from the river at these points, the elevated sulphate concentrations (if ≤400 mg/L) are not likely to impact on human health to a large extent. In MU 80 and 53 (Phalaborwa) and downstream in the KNP, the proposed 400 mg/L is not expected to have considerable impacts on the animals in the KNP, with the limit for livestock watering being 1 000 mg/L. The impacts on the aquatic organisms is however not known.

Potassium chloride and calcium chloride are commonly used in agriculture. Calcium chloride improves soil tilth and reduces crusting. It is used as a pre-harvest treatment (foliar applications) to reduce physiological disorders, such as bitter pit in apples and blossom-end rot in tomatoes. Calcium chloride may also be used as a post-harvest dip treatment to improve the shelf life of fruits and vegetables. The impacts of the use of these chemicals in the Middle Olifants is noticeable (Figure 13).

Many farmers apply gypsum (agricultural lime) to their soils in an attempt to counter acidification effects – especially those linked to acidic rainfall. Some farmers have also applied powdered power station ash and slag in place of gypsum. This latter practice has the effect of adding potentially harmful quantities of metal ions to the soils, with deleterious effects on plants and grazing animals.

Orthophosphate WQPLs (Figure 14) have been set at limits that will limit the eutrophication potential, particularly in the Middle and Lower Olifants. The concerns are downstream of Witbank Dam and Loskop Dam as well as in the Phalaborwa area and into the KNP. Consideration of whether to reduce these limits to the limit at which the potential for eutrophication is low (< 0.015) needs to be discussed, and the economic aspects assessed.

The proposed WQPLs for the main stem are summarised in Table 26.

Table 26: Proposed WQPLs for management units along the main stem Olifants River

Variable	Units	MU 8	MU 9	Wit-bank Dam	MU 28	MU 29	MU 30	Los-kop Dam	MU 34	MU 38	MU 46	Flag Bosh-ielo Dam	MU 39	MU 43	MU 44	MU 45	MU 49	MU 54	MU 55	MU 53
Calcium (dissolved)	mg/L	50	90	50	60	55	45	40	40	50	32	40	32	32	32	35	40	25	35	35
Chloride (dissolved)	mg/L	40	25	20	25	15	20	20	20	70	70	50	85	20	65	65	60	7	50	50
Total Dissolved Solids	mg/L	350	500	400	400	350	350	260	260	500	450	430	355	260	260	450	370	260	350	400
Electrical Conductivity	mS/m	90	90	75	60	75	55	40	40	75	70	70	55	40	40	75	60	25	55	60
Fluoride (dissolved)	mg/L	0.75	0.75	0.7	0.75	0.7	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Potassium (dissolved)	mg/L	25	9	15	20	2	20	10	10	10	50	10	50	10	10	10	10	2	10	10
Magnesium (dissolved)	mg/L	30	50	40	25	30	40	25	25	40	30	30	30	35	40	40	45	15	35	35
Sodium (dissolved)	mg/L	50	50	40	30	15	50	30	30	70	70	90	70	20	30	30	35	5	45	45
Ammonium (NH_4-N)	mg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate as N	mg/L	0.5	0.5	0.5	2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	3	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Phosphorus	mg/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
pH		6.5-8.4	6.5-8.4	6.5-8.6	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4	6.5-8.4	6.5 - 8.4	6.5-8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5 - 8.4	6.5-8.8	6.5-8.4	6.5-8.4	6.5-8.4
Ortho-phosphate as P	mg/L	0.02	0.02	0.02	0.1	0.1	0.02	0.01	0.01	0.02	0.005	0.01	0.025	0.025	0.025	0.025	0.02	0.02	0.005	0.01
Sulphate (dissolved)	mg/L	150	300	220	200	150	190	150	150	150	180	100	90	60	60	60	70	25	55	100
Total Alkalinity (as $CacO_3$)	mg/L	120	120	120	120	130	120	90	90	120	120	120	120	120	120	120	160	90	200	180
Dissolved Organic Carbon	mg/L	10	10	10	10	5	10	10	10	10	5	10	5	5	5	5	10	5	10	5
Dissolved Oxygen (at 20°C)	mg/L	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Sodium Absorption Ratio		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Suspended Solids	mg/L	5	25	5	5	25	5	5	5	5	25	5	25	25	25	25	5	25	5	5
Chlorophyll a	µg/L	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1	1	1	1	1.5	1	1.5	1.5
Escherichia coli	CFU/ 100mL	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130

Variable	**Units**	**MU 8**	**MU 9**	**Wit-bank Dam**	**MU 28**	**MU 29**	**MU 30**	**Los-kop Dam**	**MU 34**	**MU 38**	**MU 46**	**Flag Bosh-ielo Dam**	**MU 39**	**MU 43**	**MU 44**	**MU 45**	**MU 49**	**MU 54**	**MU 55**	**MU 53**
Faecal coliforms	CFU/ 100mL	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
Aluminium (dissolved)	mg/L	0.02	0.02	0.02	0.02	0.15	0.02	0.15	0.15	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.15	0.02	0.02
Boron (dissolved)	mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chromium (VI) (dissolved)	µg/L	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Iron (dissolved)	mg/L	0.3	0.3	0.3	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manganese (dissolved)	mg/L	0.05	0.15	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

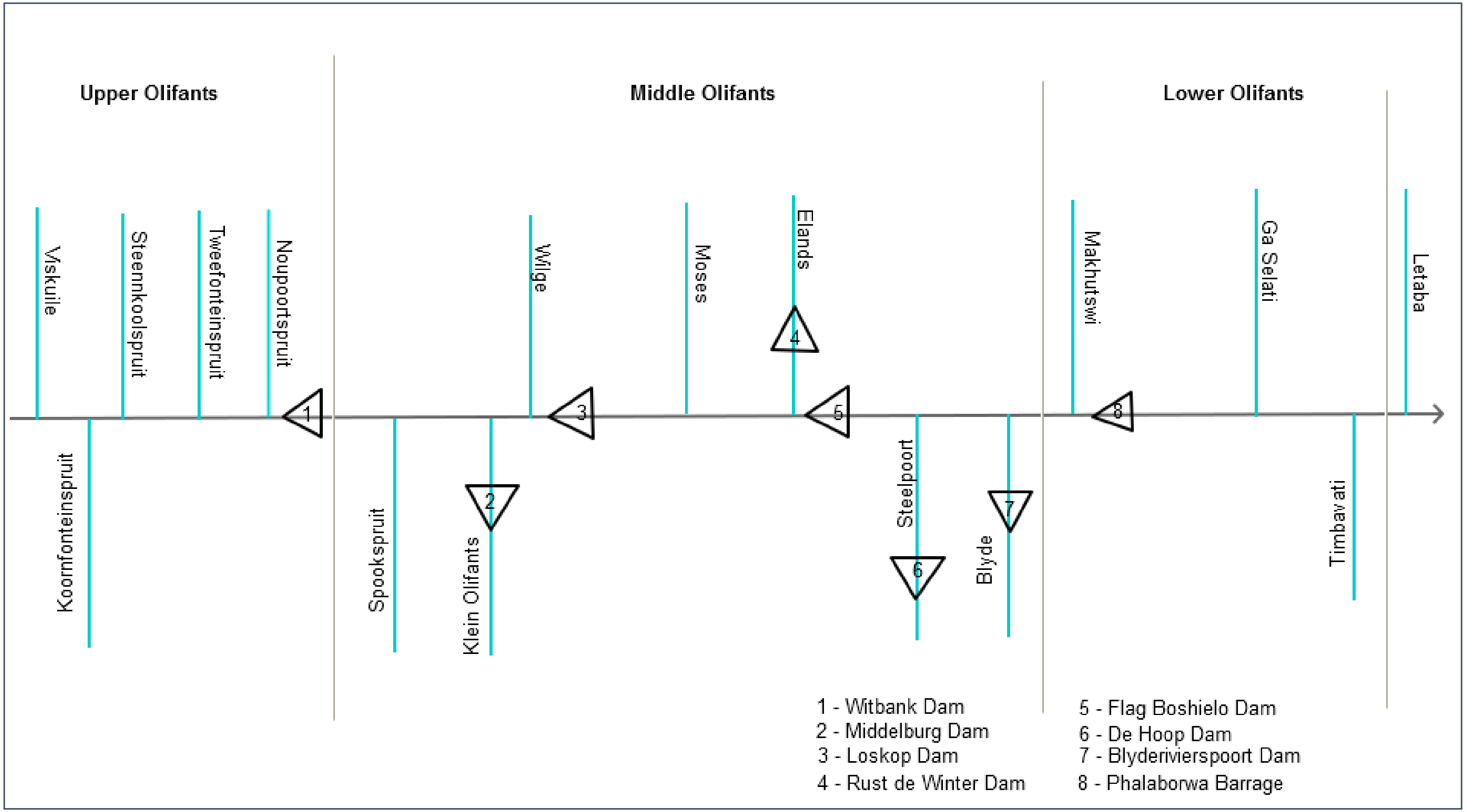


Figure 10: Illustration of the main stem Olifants River and major tributaries

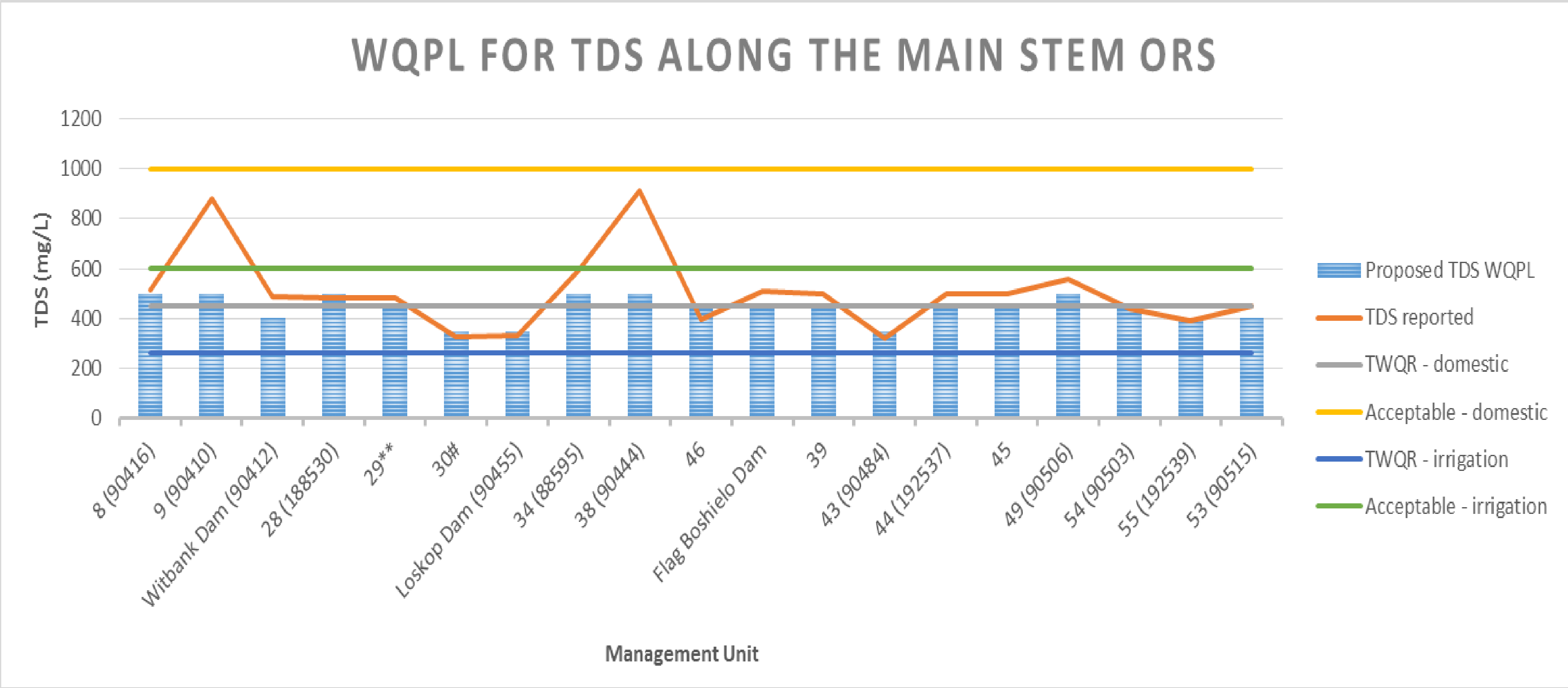


Figure 11: Proposed WQPLs for TDS along the main stem Olifants River

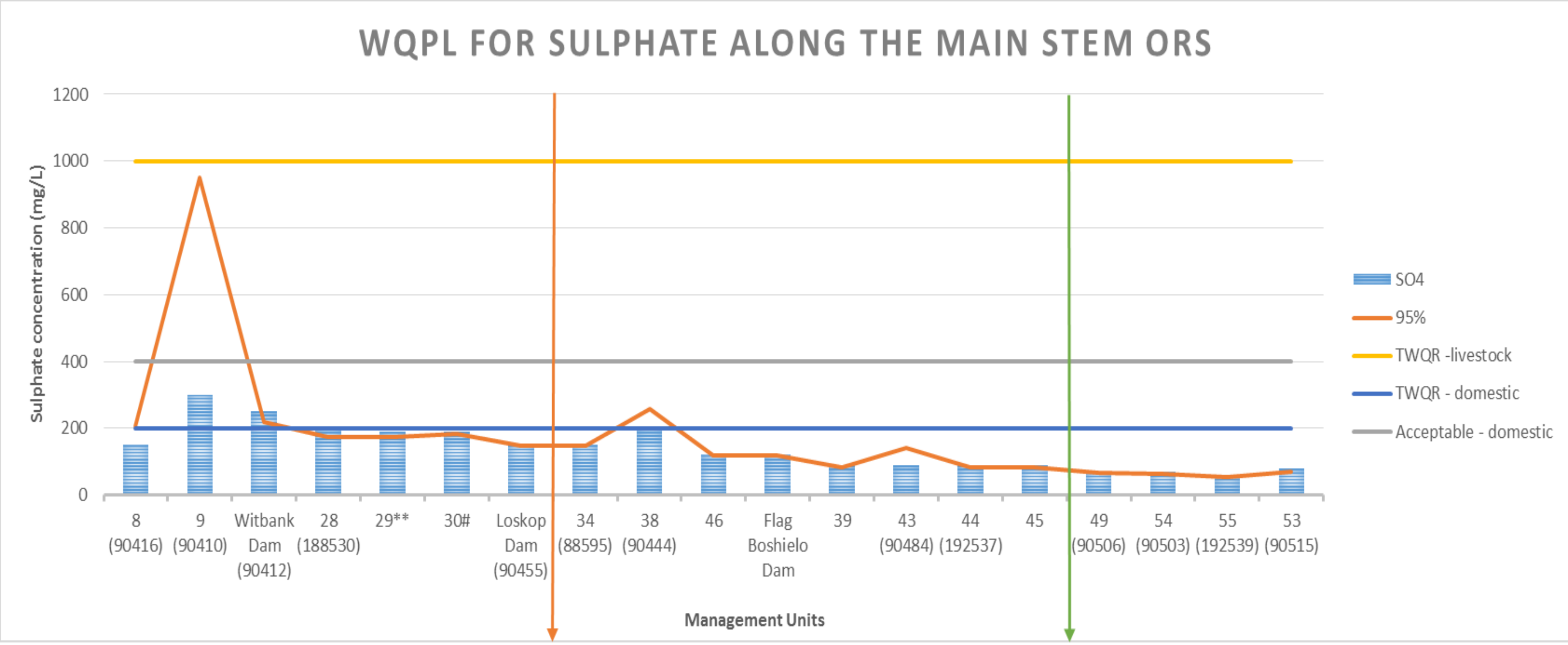


Figure 12: Proposed WQPLs for sulphate for the main stem Olifants River

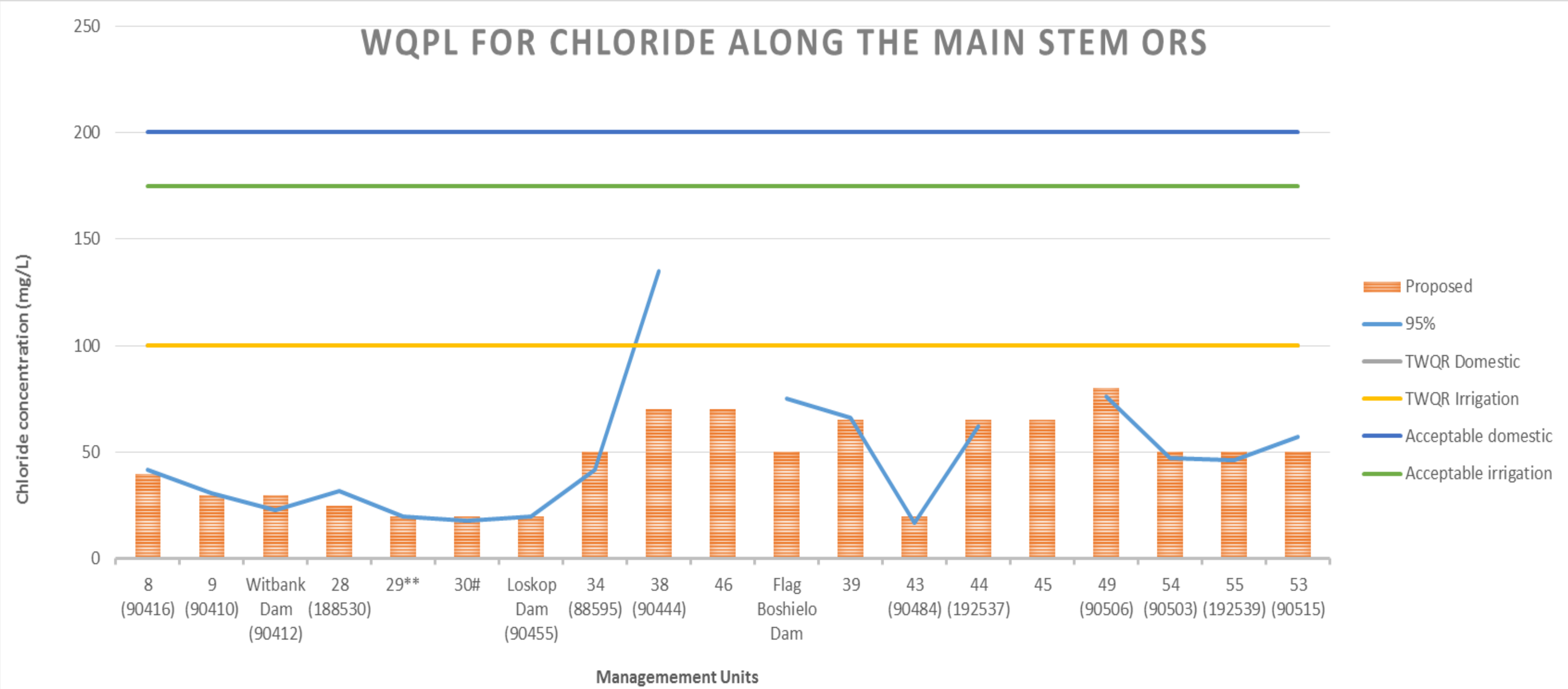


Figure 13: Proposed WQPLs for chloride for the main stem Olifants River

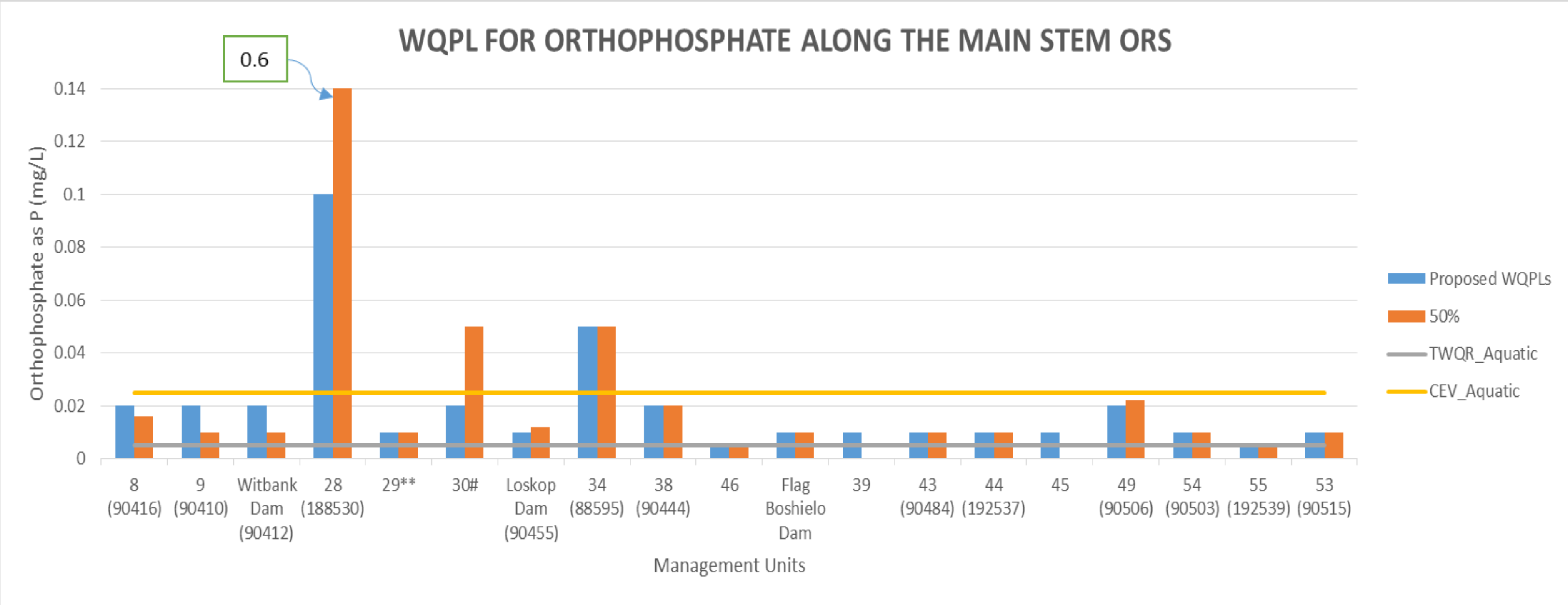


Figure 14: Proposed WQPLs for orthophosphate for the main stem Olifants River

5.5.2 Tributaries – alignment with Olifants River Main Stem

WQPLs for the tributaries have been set at limits less than or equal to those of the main stem Olifants River System so they will support the achievement of the WQPLs of the main stem and ultimately the RQOs for the WMA.

Except for orthophosphate, and nitrate to a lesser extent; the WQPLs for the lower catchments of the Letaba and Shingwedzi sub-catchments are in most cases well below those of the Olifants River. The concerns are related more to eutrophication from poorly managed urban areas.

6. GROUNDWATER

As described in Section 5.3 it would be very difficult to set WQPLs for groundwater, as groundwater, unlike surface water, with a certain chemical quality, cannot easily be changed, for example by dilution. It is therefore important to represent groundwater as having a particular fitness for use and to note that the water may then require treatment if it is used for a different use.

The groundwater quality fitness for use, domestic water supply, is described in Table 26. As indicated in Section 5.3 the Quality Index is based on the DWAF, 1998 domestic water quality classification and the available water quality data. The groundwater quality status/ trend in terms of long-term sustainability describes specific groundwater quality signatures and should help as an indicator of management measures to address these water quality trends. Some of the trends are regional impacts, such as the elevated nitrate (NO_3–N) values in irrigated areas (Springbok Flats) and rural villages in the upper/ middle Olifants and upper Letaba regions.

It should be noted however that a great proportion of the groundwater is used for irrigation and some for livestock watering. The Class 0 (Ideal) and Class I (Acceptable) water quality would be acceptable for irrigation use, however the Class II water may be high in TDS (> 1 000 mg/L) and could potentially impact crop yields. In all cases the water quality is acceptable for livestock watering.

A common method that is used world-wide to help protect groundwater quality is to establish areas or “protection zones” around groundwater abstraction points (and sometimes well fields and even whole aquifers) within which activities that may pollute groundwater are controlled (DWA, 2010). It is also obviously not enough merely to define a protection zone – of equal importance are the restrictions or rules that are made for activities within the protection zone, and the enforcement of these. This aspect will be further considered in specific areas in the sub-catchment plans.

Table 27: Groundwater quality class per quaternary catchment

Quaternary Catchment	Quality Index (Research Reports)	South Africa Water quality Guidelines (DWAF, 1996)			
		Domestic	Irrigation	Livestock watering	Groundwater Quality Status/Trend i.t.o long-term sustainability
B11A	Good (Class I)	Acceptable	Acceptable	Ideal	Largely acceptable levels of TDS, NO_3-N and SO_4.
B11B	Good (Class I)	Acceptable	Acceptable	Ideal	Local impacts on water quality due to agriculture practices and livestock farming.
B11C	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B11D	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B11E	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B11F	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B11G	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B11H	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B11J	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B11K	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B11L	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B12A	Good (Class I)	Acceptable	Acceptable	Ideal	
B12B	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B12C	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B12D	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B12E	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B20A	Marginal (Class II)	Tolerable	Acceptable	Ideal	In terms of TDS, nitrates and sulphates, water quality still within acceptable concentrations.
B20B	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B20C	Marginal (Class II)	Tolerable	Acceptable	Ideal	Impacted by local activities: waste disposal sites and agricultural practises (B20A and -B)
B20D	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B20E	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B20F	Marginal (Class II)	Tolerable	Acceptable	Ideal	

Quaternary Catchment	Quality Index (Research Reports)	South Africa Water quality Guidelines (DWAF, 1996)			
		Domestic	Irrigation	Livestock watering	Groundwater Quality Status/Trend i.t.o long-term sustainability
B20G	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B20H	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B20J	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B31A	Marginal (Class II)	Tolerable	Acceptable	Ideal	Dissolved solids within acceptable limits
B31B	Marginal (Class II)	Tolerable	Acceptable	Ideal	Dissolved solids within acceptable limits
B31C	Marginal (Class II)	Tolerable	Acceptable	Ideal	Dissolved solids within acceptable limits
B31D	Marginal (Class II)	Tolerable	Acceptable	Ideal	Salinity & nitrates elevated areas
B31E	Good (Class I)	Tolerable	Acceptable	Ideal	Local nitrate hot spots.
B31F	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local nitrate hot spots.
B31G	Marginal (Class II)	Tolerable	Acceptable	Ideal	Salinity & nitrates elevated areas
B31H	Marginal (Class II)	Tolerable	Acceptable	Ideal	Dissolved solids within acceptable limits
B31J	Marginal (Class II)	Tolerable	Acceptable	Ideal	Elevated NO_3-N, Mg and SO_4 (rising trend) levels
B32A	Good (Class I)	Acceptable	Acceptable	Ideal	Dissolved solids within acceptable limits
B32B	Good (Class I)	Acceptable	Acceptable	Ideal	
B32C	Good (Class I)	Acceptable	Acceptable	Ideal	
B32D	Good (Class I)	Acceptable	Acceptable	Ideal	In terms of TDS, nitrates and sulphates, water quality still within acceptable concentrations.
B32E	Good (Class I)	Acceptable	Acceptable	Ideal	Dissolved solids within acceptable limits
B32F	Good (Class I)	Acceptable	Acceptable	Ideal	
B32G	Good (Class I)	Acceptable	Acceptable	Ideal	Salinity & nitrates elevated areas
B32H	Good (Class I)	Acceptable	Acceptable	Ideal	Dissolved solids within acceptable limits
B32J	Marginal (Class II)		Acceptable	Ideal	
B41A	Good (Class I)	Acceptable	Acceptable	Ideal	
B41B	Good (Class I)	Acceptable	Acceptable	Ideal	

Quaternary Catchment	Quality Index (Research Reports)	South Africa Water quality Guidelines (DWAF, 1996)			Groundwater Quality Status/Trend i.t.o long-term sustainability
		Domestic	Irrigation	Livestock watering	
B41C	Good (Class I)	Acceptable	Acceptable	Ideal	
B41D	Good (Class I)	Acceptable	Acceptable	Ideal	
B41E	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local nitrate hot spots.
B41F	Marginal (Class II)	Tolerable	Acceptable	Ideal	Not impacted, head waters area.
B41G	Marginal (Class II)	Tolerable	Acceptable	Ideal	Long-term quality stable trends.
B41H	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B41J	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B42A	Good (Class I)	Acceptable	Acceptable	Ideal	Dissolved solids within acceptable limits
B42B	Good (Class I)	Acceptable	Acceptable	Ideal	Potential impact from local mines (TDS & SO_4)
B42C	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local nitrate hot spots. (Unfortunately limited time series dataset)
B42D	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B42E	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B42F	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B42G	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B42H	Marginal (Class II)	Tolerable	Acceptable	Ideal	
B51A	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local nitrate hot spots.
B51B	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local nitrate hot spots.
B51C	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local nitrate hot spots.
B51E	Good (Class I)	Acceptable	Acceptable	Ideal	Salinity & nitrates elevated areas
B51F	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local nitrate hot spots.
B51G	Good (Class I)	Acceptable	Acceptable	Ideal	Salinity & nitrates elevated areas
B51H	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local nitrate hot spots.
B52A	Good (Class I)	Acceptable	Acceptable	Ideal	Salinity & nitrates elevated areas
B52B	Good (Class I)	Acceptable	Acceptable	Ideal	Local nitrate hot spots.

Quaternary Catchment	Quality Index (Research Reports)	South Africa Water quality Guidelines (DWAF, 1996)			
		Domestic	Irrigation	Livestock watering	Groundwater Quality Status/Trend i.t.o long-term sustainability
B52C	Good (Class I)	Acceptable	Acceptable	Ideal	Local nitrate hot spots.
B52D	Good (Class I)	Acceptable	Acceptable	Ideal	Salinity & nitrates elevated areas
B52E	Good (Class I)	Acceptable	Acceptable	Ideal	Local nitrate hot spots.
B52F	Good (Class I)	Acceptable	Acceptable	Ideal	Local nitrate hot spots.
B52G	Good (Class I)	Acceptable	Acceptable	Ideal	Salinity & nitrates elevated areas
B52H	Good (Class I)	Acceptable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B52J	Good (Class I)	Acceptable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B60A	Ideal (Class 0)	Ideal	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B60B	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B60C	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B60D	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B60E	Ideal (Class 0)	Ideal	Acceptable	Ideal	Not impacted, head waters area.
B60F	Ideal (Class 0)	Ideal	Acceptable	Ideal	Not impacted, head waters area.
B60G	Ideal (Class 0)	Ideal	Acceptable	Ideal	Not impacted, head waters area.
B60H	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B60J	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local nitrate hot spots.
B71A	Good (Class I)	Acceptable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B71B	Good (Class I)	Acceptable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B71C	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B71D	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B71E	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B71F	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B71G	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated Salinity & nitrates levels.
B71H	Marginal (Class II)	Tolerable	Acceptable	Ideal	Salinity & nitrates hot spots, rising.

Quaternary Catchment	Quality Index (Research Reports)	South Africa Water quality Guidelines (DWAF, 1996)			Groundwater Quality Status/Trend i.t.o long-term sustainability
		Domestic	Irrigation	Livestock watering	
B71J	Marginal (Class II)	Tolerable	Acceptable	Ideal	Salinity & nitrates hot spots, rising.
B72A	Good (Class I) &	Acceptable to marginal	Acceptable	Ideal	TDS and SO_4 are largely at acceptable levels, although salinity and nitrate hot spots are present.
B72B	Marginal (Class II)		Acceptable	Ideal	
B72C			Acceptable	Ideal	
B72D			Acceptable	Ideal	
B72E			Acceptable	Ideal	
B72F			Acceptable	Ideal	
B72G			Acceptable	Ideal	
B72H			Acceptable	Ideal	
B72J	Marginal (Class II)	Tolerable	Acceptable	Ideal	Marginal (Class II)
B72K	Marginal (Class II)	Tolerable	Acceptable	Ideal	High salinity (Phalaborwa - B72K) & nitrate.
B73A	Good (Class I) &	Acceptable for domestic to tolerable (irrigation)	Acceptable	Ideal	TDS and SO_4 are largely at acceptable levels, although salinity and nitrate hot spots are present.
B73B					In QC's B73G, -F, -H & -J are potential elevated/rising nitrate areas.
B73C	Marginal (Class II)				
B73D					
B73E					
B73F					
B73G					
B73H					
B73J					
B81A	Ideal (Class 0)	Ideal	Ideal	Ideal	Not impacted, head waters area.
B81B	Ideal (Class 0)	Ideal	Ideal	Ideal	Salinity & nitrates hot spots, rising.
B81C	Ideal (Class 0)	Ideal	Ideal	Ideal	Not impacted, head waters area.

Quaternary Catchment	Quality Index (Research Reports)	South Africa Water quality Guidelines (DWAF, 1996)			
		Domestic	Irrigation	Livestock watering	Groundwater Quality Status/Trend i.t.o long-term sustainability
B81D	Ideal (Class 0)	Ideal	Ideal	Ideal	Marginal (Class II)
B81E	Ideal (Class 0)	Ideal	Acceptable	Ideal	Local salinity & nitrate hot spots.
B81F	Marginal (Class II)	Tolerable	Acceptable	Ideal	Salinity & nitrates hot spots, rising.
B81G	Good (Class I)	Acceptable	Acceptable	Ideal	Salinity & nitrates hot spots, rising.
B81H	Marginal (Class II)	Tolerable	Acceptable	Ideal	Salinity & nitrates elevated areas
B81J	Marginal (Class II)	Tolerable	Acceptable	Ideal	Salinity & nitrates elevated areas
B82A	Good (Class I)	Acceptable	Acceptable	Ideal	Local nitrate hot spots.
B82B	Ideal (Class 0)	Ideal	Acceptable	Ideal	Local nitrate hot spots.
B82C	Marginal (Class II)	Tolerable	Acceptable	Ideal	Salinity & nitrates elevated areas
B82D	Ideal (Class 0)	Ideal	Acceptable	Ideal	Not impacted, head waters area.
B82E	Good (Class I)	Ideal	Acceptable	Ideal	Salinity & nitrates hot spots, rising.
B82F	Good (Class I)	Ideal	Acceptable	Ideal	Salinity & nitrates hot spots, rising.
B82G	Poor (Class III)	Unacceptable	Acceptable	Ideal	Significant nitrate pollution (Giyani)
B82J	Marginal (Class II)	Tolerable	Acceptable	Ideal	Nitrates hot spots, rising.
B82H	Marginal (Class II)	Tolerable	Acceptable	Ideal	Significant nitrate pollution
B83A	Ideal (Class 0)	Ideal	Acceptable	Ideal	Not impacted, head waters area.
B83B	Ideal (Class 0)	Ideal	Acceptable	Ideal	Not impacted, head waters area.
B83C	Ideal (Class 0)	Ideal	Acceptable	Ideal	Not impacted, head waters area.
B83D	Ideal (Class 0)	Ideal	Acceptable	Ideal	Not impacted, head waters area.
B83E	Ideal (Class 0)	Ideal	Acceptable	Ideal	Not impacted, head waters area.
B90A	Good (Class I)	Acceptable	Acceptable	Ideal	Not impacted, head waters area.
B90B	Good (Class I)	Acceptable	Acceptable	Ideal	Local elevated salts (Na, Cl & TAL)
B90C	Good (Class I)	Acceptable	Acceptable	Ideal	Not impacted, head waters area.
B90D	Good (Class I)	Acceptable	Acceptable	Ideal	Local elevated salts (Na, Cl & TAL)

Quaternary Catchment	Quality Index (Research Reports)	South Africa Water quality Guidelines (DWAF, 1996)			
		Domestic	**Irrigation**	**Livestock watering**	**Groundwater Quality Status/Trend i.t.o long-term sustainability**
B90E	Good (Class I)	Acceptable	Acceptable	Ideal	Local elevated salts (Na, Cl & TAL)
B90F	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated salts and nitrates.
B90G	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated salts and nitrates.
B90H	Marginal (Class II)	Tolerable	Acceptable	Ideal	Local elevated salts and nitrates.

7. FINALISED WQPLS FOR THE OLIFANTS WMA

The approach was presents at the following meetings:

Project Management Committee: 17 November 2016;

Project Steering Committee: 23 November 2016; and

Broader stakeholder meeting: 24 November 2016.

The approach was debated and agreed upon. Comments received will be available in the comments and response report and have been and will be incorporated as the study progresses. This means that the WQPLs presented in this report may change after further in-depth assessment in the sub-catchment areas, determination of loads and feasibility of management options where loads may need to be removed, as well as if further recommendations are received from key role-players.

8. CONCLUSION

The water quality data downloaded from the Departments WMS during the situation assessment in March 2016, ranged from 1965 to December 2015, depending on the site. In the calculations, where available, the last 10 years of data were used, however there are sites where longer periods of data were used due to limited sampling events, or shorter periods where monitoring only started later. While earlier studies such as Ashton & Dabrowski (2011) showed that many of the DWS water quality data were unreliable, this project did not allow for detailed scrutiny of the data quality, however where data were noted to be anomalous, values were removed.

The 5%, 50% and 95% were used to assess the compliance against the South African Water Quality Guidelines for domestic, irrigation, industrial, livestock watering and ecosystems. It is also noted that this approach may obscure seasonal changes where the concentration of a particular constituent may exceed desirable limits for a period of one to several months, however, this approach does give a good indication of the situation and will give some guidance on realistic limits that should be set. Proposed WQPLs were subsequently set based on the data assessment and stakeholder consultation.

The way forward will be to take the WQPLs for each of the sub-catchments and get further detail on the sources contributing to the pollution loads – this will be done in consultation with the relevant WMI Officials and DWS Provincial Offices. Ongoing stakeholder participation will continue, even after the project. Modelling will determine what load needs to be removed in those management units where non-compliance has been noted. This will allow the various relevant management options to be assessed for possible implementation, and will form part of the sub-catchment water quality management plans. This will also support the proposed WQPLs or may necessitate amendments.

In respect of groundwater it was noted that it would be very difficult to set WQPLs, as groundwater, unlike surface water, with a certain chemical quality, cannot easily be changed, for example by dilution. It is therefore important to represent groundwater as having a particular fitness for use and to note that the water may then require treatment if used for a different use or even to include recommendation of protection zones around abstraction points.

9. REFERENCES

Ashton PJ and Dabrowski JM (2011) An overview of surface water quality in the Olifants River catchment. WRC Report No. KV 293/11. Water Research Commission

CSIR (2013) Risk Assessment of Pollution in Surface Waters of the Upper Olifants River System: Implications for Aquatic Ecosystem Health and the Health of Human Users of Water. Report Number: CSIR/NRE/WR/ER/2013/0053/B. Draft Technical Report: Phase 3

Davis JR and Koop K. (2006) Eutrophication in Australian rivers, reservoirs and estuaries – a southern hemisphere perspective on the science and its implications, Review. *Hydrobiologia,* **559:** 23 – 76.

Dabrowski JM (2015) Investigation of the Contamination of Water Resources by Agricultural Chemicals and the Impact on Environmental Health, Volume 2: Prioritizing human health effects and mapping sources of agricultural pesticides used in South Africa, WRC Report No. TT 642/15

Department of Water Affairs and Forestry (DWAF)(1996) *South African Water Quality Guidelines*. Second Edition. Volumes 1-8

Department of Water Affairs and Forestry (DWAF)(1998) Quality of Domestic Water Supplies, Second Edition, ISBN 1 86845 416 9

Department of Water Affairs and Forestry (DWAF)(2006a) Department of Water Affairs and Forestry. *Resource Directed Management of Water Quality: Management Instruments. Volume 4.2: Guideline for Determining Resource Water Quality Objectives (RWQOs), Allocatable Water Quality and the Stress of the Water Resource.* Edition 2. Water Resource Planning Systems Series, Sub-Series No. WQP 1.7.2. ISBN No. 0-621-36793-1. Pretoria, South Africa.

Department of Water Affairs and Forestry (DWAF)(2009) Development of an Integrated Water Resource Management Plan for the Upper and Middle Olifants catchment: RWQOs Report, Report Number: P WMA 04/000/00/6607

DWA, 2010. Groundwater Strategy.

Department of Water Affairs (DWA)(2011) Directorate Water Resource Planning Systems: Water Quality Planning. Resource Directed Management of Water

Quality. Planning Level Review of Water Quality in South Africa. Sub-series No. WQP 2.0. Pretoria, South Africa.

Department of Water and Sanitation (DWS)(2016) *Development of an Integrated Water Quality Management Plan for the Olifants River System: Water Quality Status Assessment and International Obligations Report.* Study Report No. 2, Report No: P WMA 04/B50/00/8916/3

Grimm NB and Fisher SG (1986) Nitrogen limitation in a Sonoran Desert stream, Journal of North American Benthological Society, 5 (1): 2-15

Jarvie HP, Neal C and Withers PJA (2006) Sewage-effluent phosphorus: A greater risk to river eutrophication than agricultural phosphorus? Science of the Total Environment 360(1 3): 246 253.

Jassby AD, Reuter JE and Goldman CR (2003) Determining long-term water quality change in the presence of climate variability: Lake Tahoe (USA), Canadian Journal of Fisheries and Aquatic Sciences

Mankiewicz-Boczek J and Nałęcz-Jawecki (2008) *Application of a microbiotests battery for complete toxicity assessment of rivers*. Ecotoxicity and Environmental Safety 71: 830 - 836

Persoone G, Marsalek B, Blinova I, Törökne A, Zarina D., Manusadzianas L, Nalecz-Jawecki G, Tofan L, Stepanova N, Tothova L and Kolar B (2003) *A practical and user-friendly toxicity classification system with micro-biotests for natural waters and wastewaters*. Environmental Toxicology and Chemistry 18: 395 - 402

Tonkes M and Baltus CAM (1997) *Praktijkonderzoek aan complexe efflenetenmet de Totaal Effluent Milieubezwaarlikheid (TEM) – metodiek*. RIZA – rapportnummer 97.033. RIZA, Lelystad, The Netherlands.

United Natiosn Environmental Programme (UNEP)(2006) Environmental Effects of Ozone Depletion and its Interactions with Climate Change: 2006 Assessment

UNP (United Nations Publications) (2000). Planning and Management of Lakes and Reservoirs: An Integrated Approach to Eutrophication. Technical Publication Series 11. UNEP/Earthprint, 375 pp

United States Environmental Protection Agency (US EPA)(2002) Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms. EPA-821-02-012, 5th Edition. Office of Research and Development, Washington DC 20460

Wetzel, RG (1983) Limnology, 2nd Edition

World Health Organisation (WHO)(2017) Guidelines for Drinking-water quality, Fourth Edition, ISBN 978-92-4-154995-0

APPENDIX A

Water Quality Statistics for priority sites (electronic)

APPENDIX B

Table showing data availability for priority sites

Site ID	n	First date	Last date	Latitude	Longitude
B11 1000003173	185	2005/08/04	2012/09/12	-26.1923	29.1826
B11 185084	181	2002/06/07	2014/12/11	-25.7682	29.121
B11 188420	41	2005/08/03	2014/12/02	-26.2228	29.46264
B11 188424	43	2005/08/03	2014/12/02	-26.2328	29.52644
B11 188428	78	2005/11/29	2015/02/16	-26.2219	29.63056
B11 188430	33	2005/08/04	2014/12/02	-26.2415	29.62375
B11 188431	34	2005/08/04	2014/12/02	-26.3281	29.55822
B11 188447	52	2005/08/04	2014/03/11	-26.2704	29.23769
B11 188448	73	2005/08/04	2014/12/02	-26.2575	29.24744
B11 188530	62	2005/08/30	2015/04/30	-25.8216	29.29419
B11 188536	40	2005/08/30	2014/12/02	-26.1073	29.32319
B11 188537	66			-25.9313	29.23647
B11 188538	120	2005/08/30	2015/11/09	-25.9418	29.26483
B11 188539	34	2005/08/31	2014/08/21	-25.8952	29.12944
B11 188547	79	2005/08/31	2015/05/14	-25.8785	29.16453
B11 188588	32	2005/10/04	2014/12/02	-26.1364	29.34495
B11 188589	42	2005/10/03	2014/12/02	-26.3282	29.2922
B11 189430	24	2009/04/23	2012/02/20	-26.0519	29.19806
B11 189438	22	2009/04/23	2012/02/20	-26.1333	29.17639
B11 191615	46	2009/04/20	2015/01/22	-26.1374	29.26992
B11 88607	179	1990/05/01	2014/12/11	-26.0008	29.29222
B11 90407	1610	1970/02/19	2015/08/20	-25.8183	29.33778
B11 90408	1457	1966/04/18	2015/08/20	-25.6733	29.17111
B11 90410	1087	1979/11/20	2015/10/30	-26.0064	29.25389
B11 90411	837	1982/10/13	2014/07/15	-26.3558	29.21417
B11 90412	723	1983/02/23	2015/07/22	-25.8917	29.30417
B11 90415	931	1990/01/02	2015/08/19	-26.3056	29.27417
B11 90416	700	1991/05/27	2015/08/19	-26.2167	29.45917
B11 90417	883	1990/05/09	2015/08/19	-25.9397	29.2575
B11 90418	865	1990/05/01	2015/08/19	-26.1058	29.33083
B11 90419	818	1990/07/02	2015/07/21	-26.1361	29.27
B11 90420	634	1990/04/30	2015/08/19	-26.495	29.24111
B11 90430	646	1998/10/05	2015/12/11	-25.8217	29.20611
B11 90431	1421	1972/01/04	2016/02/04	-25.8917	29.30417
B12 188390	45	2005/07/26	2014/12/01	-25.8241	29.56439
B12 188397	146	2005/07/27	2014/12/01	-25.9588	29.77514
B12 188595	77	2005/10/05	2014/12/01	-26.1058	29.73422
B12 188596	73	2005/10/05	2014/12/01	-26.1138	29.73875
B12 88506	101	1993/10/20	2014/12/01	-25.8767	29.62944
B12 90413	1326	1986/01/03	2015/07/22	-25.8081	29.58667
B12 90414	1357	1983/02/01	2015/10/30	-25.7733	29.54361
B12 90421	113	1993/10/20	2014/12/18	-25.8828	29.64333
B12 90432	1729	1978/11/13	2016/02/03	-25.775	29.54583
B20 188223	272	2005/05/18	2015/09/07	-25.5788	29.12747
B20 188545	159	2005/08/31	2014/12/08	-25.8811	29.01131

B20 189412	39	2009/03/30	2014/12/08	-25.8444	28.87167
B20 189464	72	2009/03/24	2015/05/13	-25.9678	29.02694
B20 189465	41	2010/01/19	2014/12/08	-25.9958	29.02917
B20 189469	49	2009/03/29	2014/12/11	-26.3453	28.90833
B20 189470	31	2011/01/24	2014/12/08	-26.3522	28.91056
B20 189565	30	2009/07/28	2015/05/13	-26.2322	28.85611
B20 88821	190	1991/10/19	2014/12/08	-25.7753	29.02389
B20 90433	668	1983/05/03	2015/08/18	-25.7989	28.73583
B20 90434	944	1984/10/27	2015/08/18	-25.9247	28.58556
B20 90436	869	1984/11/16	2015/07/20	-25.9667	28.55083
B20 90437	948	1985/08/26	2015/08/18	-25.9947	28.66278
B20 90438	607	1985/08/26	2015/08/18	-26.0789	28.56278
B20 90441	650	1991/01/30	2015/08/18	-25.8267	28.88083
B20 90442	799	1994/01/05	2015/11/16	-25.6161	29.01611
B20 90443	2683	1968/03/21	2016/02/08	-25.8869	28.72139
B31 189417	41	2009/03/30	2014/12/10	-24.9386	29.22333
B31 189424	32	2009/06/19	2015/04/29	-25.6681	28.57611
B31 189521	44	2009/03/30	2014/12/04	-25.6903	28.69472
B31 189568	50	2009/03/30	2015/04/30	-25.6867	28.68194
B31 191683	25	2009/11/14	2014/05/28	-24.8874	29.35656
B31 90458	729	1994/01/06	2015/07/14	-24.9253	29.32444
B31 90460	1130	1968/03/19	2016/01/26	-25.2343	28.5172
B31 90466	1059	1983/04/05	2016/01/13	-25.0983	28.9177
B32 189413	37	2009/04/29	2014/12/10	-25.1589	29.32833
B32 189423	36	2009/04/29	2014/12/10	-25.2722	29.18306
B32 189456	39	2009/03/30	2015/01/21	-25.0036	29.34528
B32 189553	29	2009/03/30	2012/03/22	-25.43	28.95361
B32 191682	48	2009/03/30	2014/12/10	-25.1281	29.40483
B32 191684	22	2009/11/14	2014/01/30	-24.8841	29.36064
B32 191822	28	2009/10/21	2014/12/10	-25.3735	29.41983
B32 193742	10	2014/07/18	2015/08/21	-24.9586	29.39528
B32 88595	67	2009/07/01	2014/12/10	-25.1617	29.41417
B32 90444	1052	1976/10/12	2015/04/23	-24.9267	29.38944
B32 90448	729	1992/08/19	2015/08/17	-25.2694	29.18472
B32 90455	637	1993/09/01	2015/08/21	-25.4167	29.35833
B32 90462	1649	1968/05/06	2015/11/26	-25.4183	29.3599
B41 1000009852	50	2004/04/30	2012/03/14	-25.4321	29.85653
B41 1000009854	231	2004/04/30	2015/12/08	-25.3575	29.86707
B41 188910	175	2005/12/06	2015/12/08	-25.383	29.83792
B41 188911	143	2005/12/06	2015/10/27	-25.6631	29.99092
B41 188915	176	2005/12/06	2015/12/08	-24.8907	30.01744
B41 190142	385	2007/11/21	2015/11/24	-25.1861	30.02297
B41 190143	360	2007/11/12	2015/02/05	-24.9658	29.94892
B41 190160	375	2007/11/21	2015/10/27	-24.9561	29.95706
B41 193090	59	2012/03/20	2015/12/14	-25.0655	29.84019
B41 193091	60	2012/03/22	2015/12/18	-24.4835	30.41502

B41 193279	136	2012/12/05	2016/02/03	-25.6627	29.99028
B41 194098	23	2015/03/05	2016/01/26	-24.9575	29.95629
B41 90467	1726	1977/11/13	2015/11/24	-25.0289	29.85667
B41 90471	1145	1977/05/11	2015/08/17	-24.9125	30.10333
B41 90473	907	1984/11/02	2015/12/18	-24.5528	30.37333
B41 90475	312	1983/03/11	2015/08/17	-25.2792	29.94167
B41 90476	315	1983/03/09	2015/08/17	-25.2303	29.9475
B41 90480	662	1980/01/30	2015/10/21	-25.2797	29.942
B41 90481	673	1972/01/05	2015/11/05	-25.2316	29.9493
B42 188912	185	2005/12/06	2015/12/08	-24.6601	30.33681
B42 90469	1015	1978/10/12	2015/08/17	-25.0378	30.21917
B42 90470	1340	1977/05/10	2015/08/18	-25.0081	30.49944
B42 90472	1020	1979/10/18	2015/08/17	-25.0753	30.43889
B42 90478	737	1983/02/28	2015/08/19	-24.9542	30.26667
B42 90483	858	1980/10/15	2015/11/19	-24.9552	30.2651
B51 90486	1043	1993/09/01	2015/11/26	-24.7744	29.42222
B51 90488	1100	1994/01/06	2015/11/26	-24.7809	29.4264
B52 188349	3	2014/01/17	2014/01/17	-24.2071	29.4937
B52 90484	227	1969/11/19	2015/04/30	-24.2675	29.80139
B60 1000009799	100	2004/03/24	2015/06/10	-24.4051	30.79821
B60 1000009803	69	2004/02/23	2015/01/21	-24.7282	30.57359
B60 1000009804	69	2004/02/23	2015/01/21	-24.8677	30.56852
B60 1000009805	69	2004/02/23	2015/01/21	-24.889	30.7519
B60 1000009806	120	2004/02/23	2015/06/10	-24.905	30.74586
B60 1000009807	75	2004/02/23	2015/01/21	-24.8864	30.76208
B60 90489	790	1966/04/23	2015/08/18	-24.6792	30.8025
B60 90490	787	1966/04/23	2015/08/18	-24.6861	30.815
B60 90491	1252	1978/04/12	2015/09/17	-24.4586	30.8275
B60 90492	217	1969/02/06	2015/12/17	-24.5139	30.82889
B60 90493	399	1966/04/22	2014/06/30	-24.9275	30.54611
B60 90495	146	1993/03/16	2015/08/21	-24.9303	30.62944
B60 90496	360	1996/01/08	2015/08/20	-24.5269	30.79361
B60 90498	653	1973/07/16	2015/10/28	-24.9333	30.6322
B60 90499	411	1978/04/13	2014/07/15	-24.5369	30.7982
B71 1000009801	108	2004/02/23	2015/06/08	-24.4375	30.61947
B71 1000009802	93	2004/02/23	2015/02/09	-24.4592	30.60978
B71 192537	12	2011/08/29	2013/08/15	-24.3039	30.18103
B71 90506	602	1962/02/25	2013/12/19	-24.3312	30.74164
B71 90510	293	1980/01/23	2015/08/21	-24.1725	30.10306
B72 1000009786	74	2004/03/24	2015/02/09	-24.1846	30.82616
B72 1000009795	47	2004/03/24	2015/02/09	-24.1833	30.81507
B72 1000009796	107	2004/03/24	2015/06/08	-23.9776	31.07371
B72 1000009797	81	2004/03/24	2015/06/08	-24.038	31.13331
B72 192538	23	2011/06/01	2014/01/13	-24.0085	31.08189
B72 192539	63	2011/06/01	2015/06/08	-24.0691	31.14528
B72 90500	433	1981/12/21	2015/08/20	-24.0919	30.27528

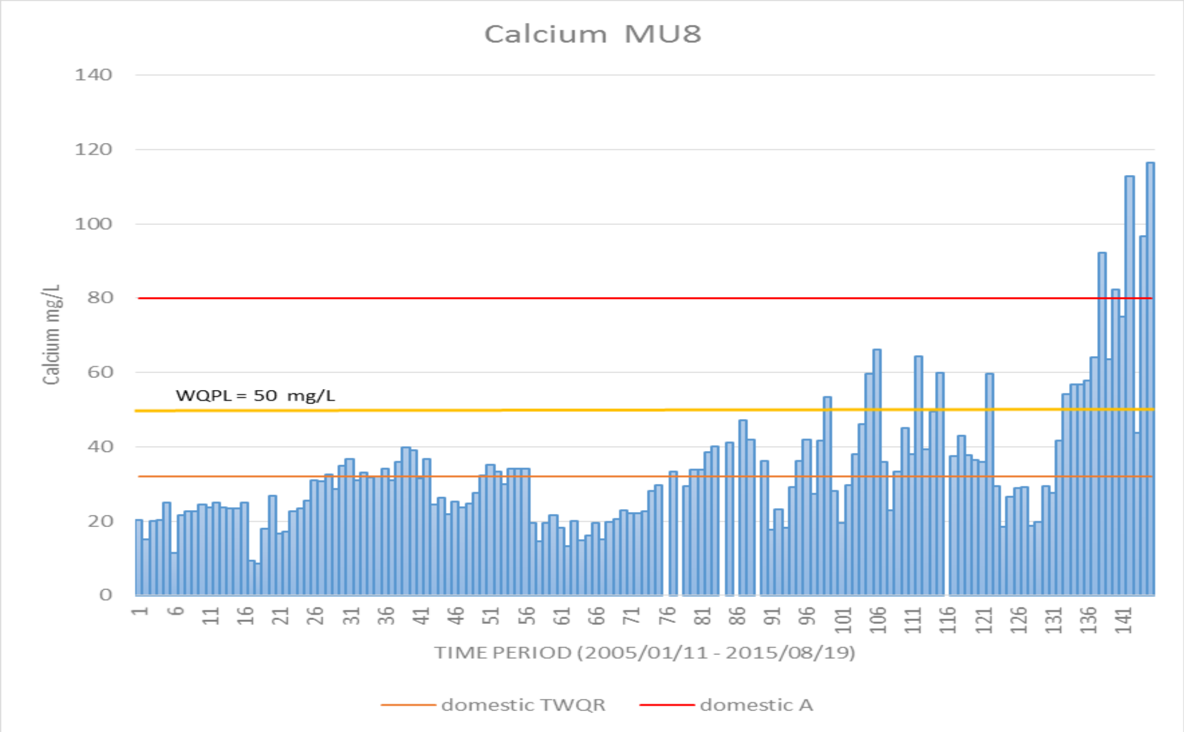
B72 90503	1184	1969/11/24	2015/12/14	-24.1839	30.82389
B72 90508	374	1969/11/20	2015/02/12	-24.035	30.43333
B72 90511	377	1977/05/05	2015/08/20	-24.1239	30.35361
B72 90518	543	1989/01/05	2015/08/26	-24.0342	31.12361
B73 1000009798	65	2004/03/24	2015/01/21	-24.5424	31.03523
B73 190528	13	2008/05/29	2014/08/15	-23.9847	31.83242
B73 90502	591	1969/11/28	2015/07/18	-24.5553	31.03222
B73 90512	1077	1983/10/18	2015/11/18	-24.0589	31.23722
B73 90515	691	1983/10/18	2015/08/05	-24.0517	31.73139
B81 90524	1036	1977/09/21	2015/10/06	-23.6581	31.05
B81 90525	785	1969/11/20	2015/07/07	-23.8803	30.36694
B81 90526	803	1969/11/20	2015/07/07	-23.8922	30.35583
B81 90527	553	1969/11/21	2015/07/13	-23.8806	30.07972
B81 90528	137	1980/03/10	2015/07/07	-23.6456	30.71861
B83 90529	321	1983/11/29	2015/02/09	-23.8386	31.64083
B83 90536	789	1983/11/09	2015/11/16	-23.6486	31.14722
B82 90539	144	1996/01/23	2015/02/10	-23.281	30.54306
B81 90549	177	1998/07/16	2015/07/08	-23.9458	29.98389
B82 183878	1043	2001/11/06	2015/07/29	-23.312	30.68342
B82 183879	887	2001/11/06	2015/07/29	-23.3299	30.7064
B81 187157	392	2003/08/13	2013/05/23	-23.8748	30.27303
B81 190450	105	2005/07/12	2015/07/29	-23.9628	30.27922
B81 90550	418	1968/05/02	2014/10/21	-23.9408	29.9851
B81 90576	252	1973/06/21	2015/07/13	-23.7492	30.1076
B81 90577	655	1975/11/19	2014/12/04	-23.8162	30.0554
B81 90578	597	1977/05/11	2015/07/17	-23.8	30.16667
B82 90580	425	1996/02/06	2016/01/07	-23.274	30.4037
B82 90581	422	1996/01/16	2016/01/22	-23.2545	30.77072
B81 177868	54	2009/03/31	2015/03/06	-23.5865	30.34954
B81 190778	25	2010/07/13	2014/12/01	-24.0288	30.16866

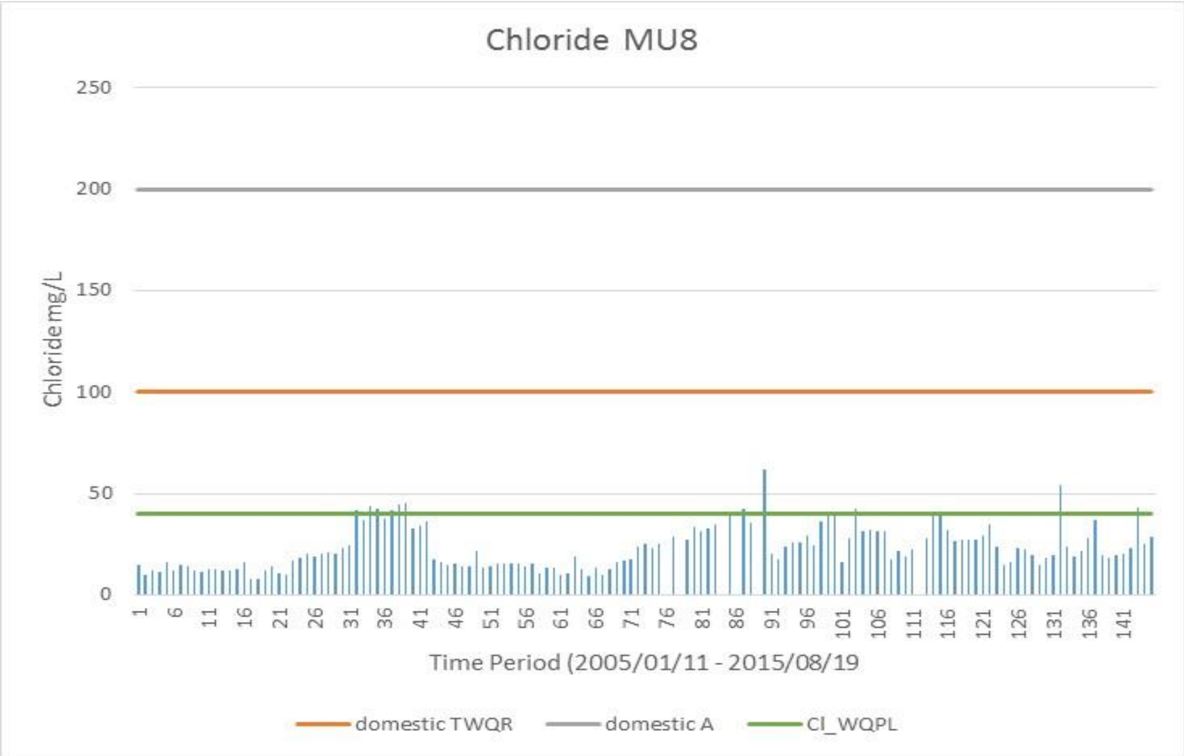
APPENDIX C

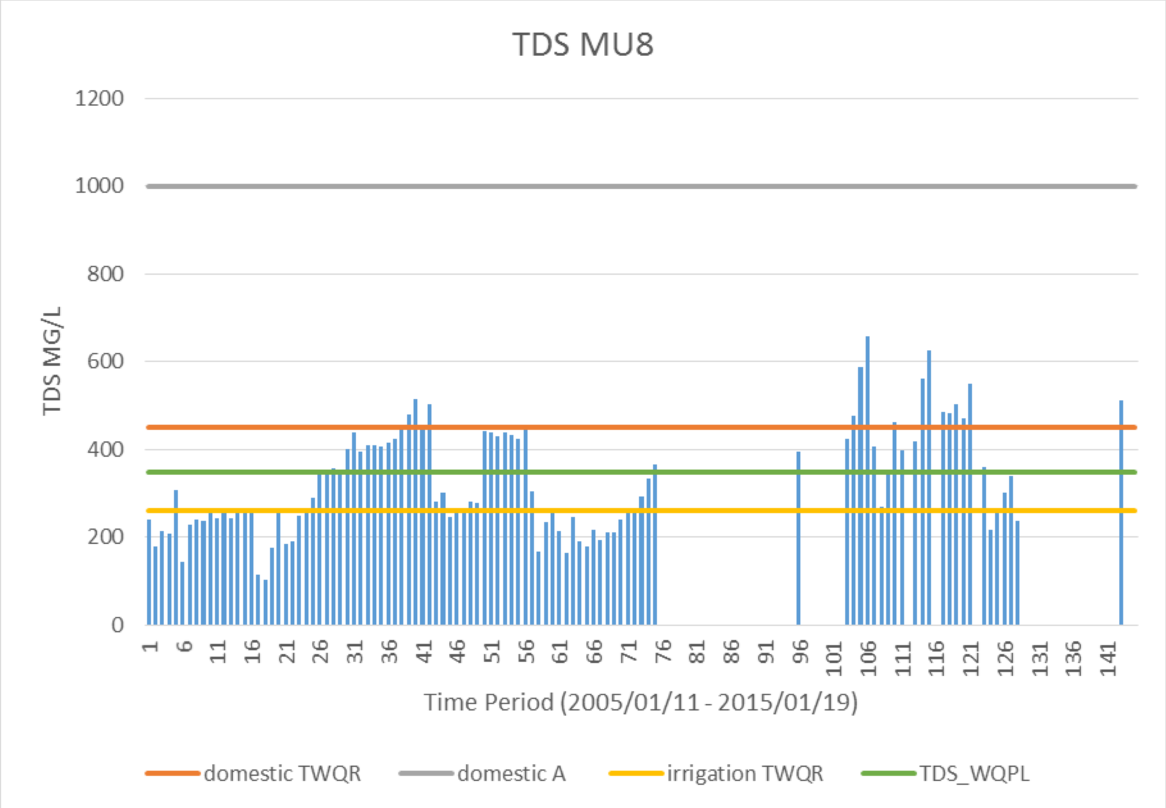
Examples of time series graphs for priority sites

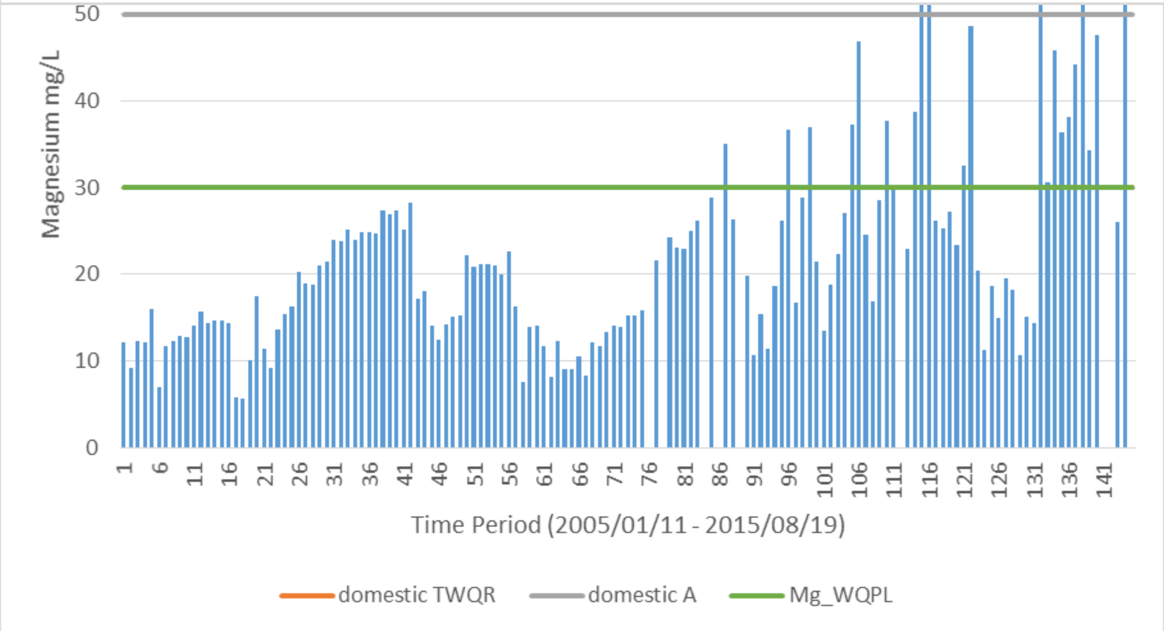
MAIN STEM OLIFANTS RIVER

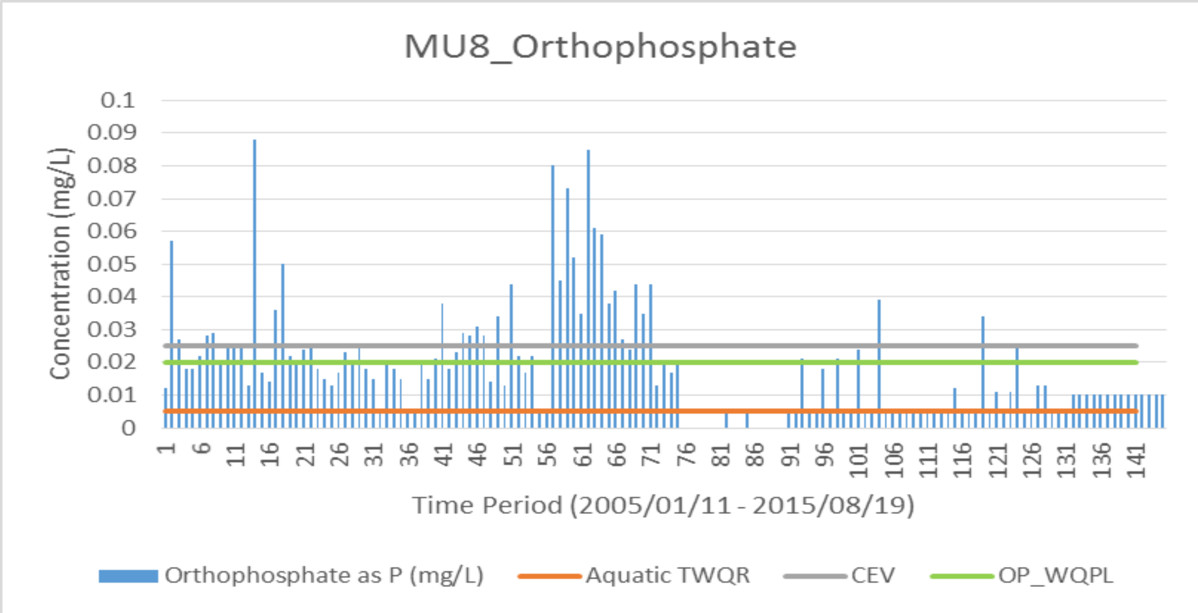
Management Unit 8

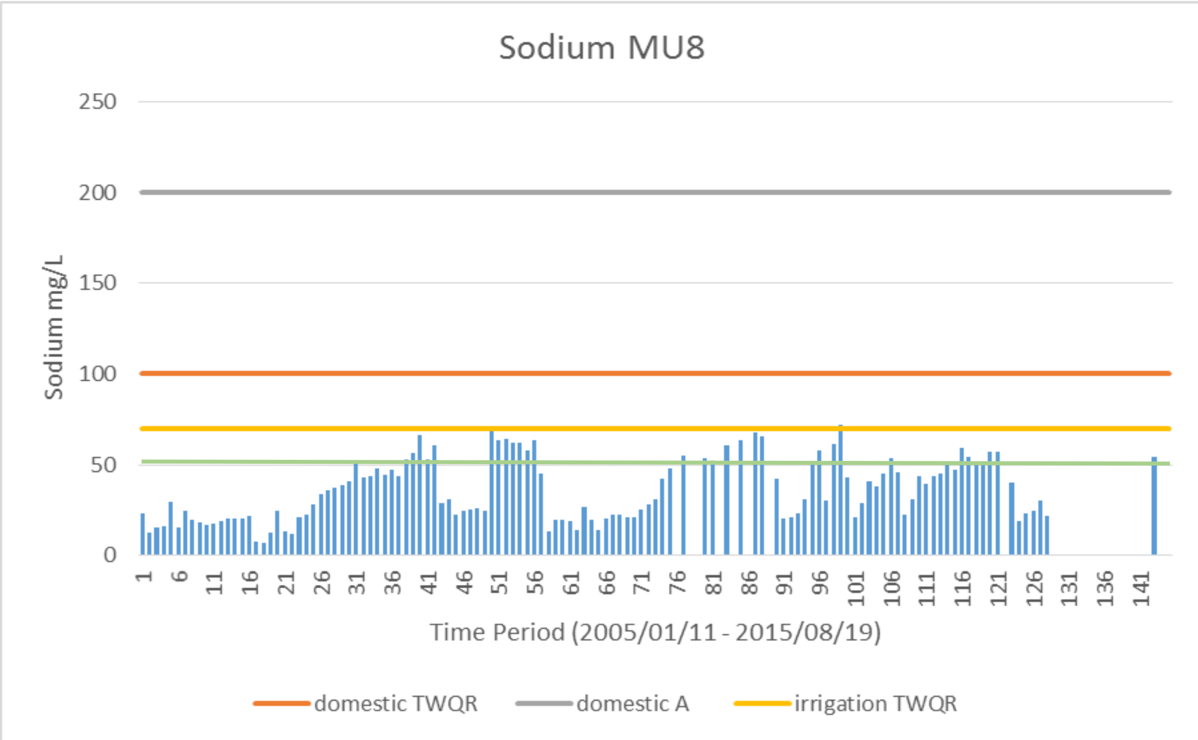


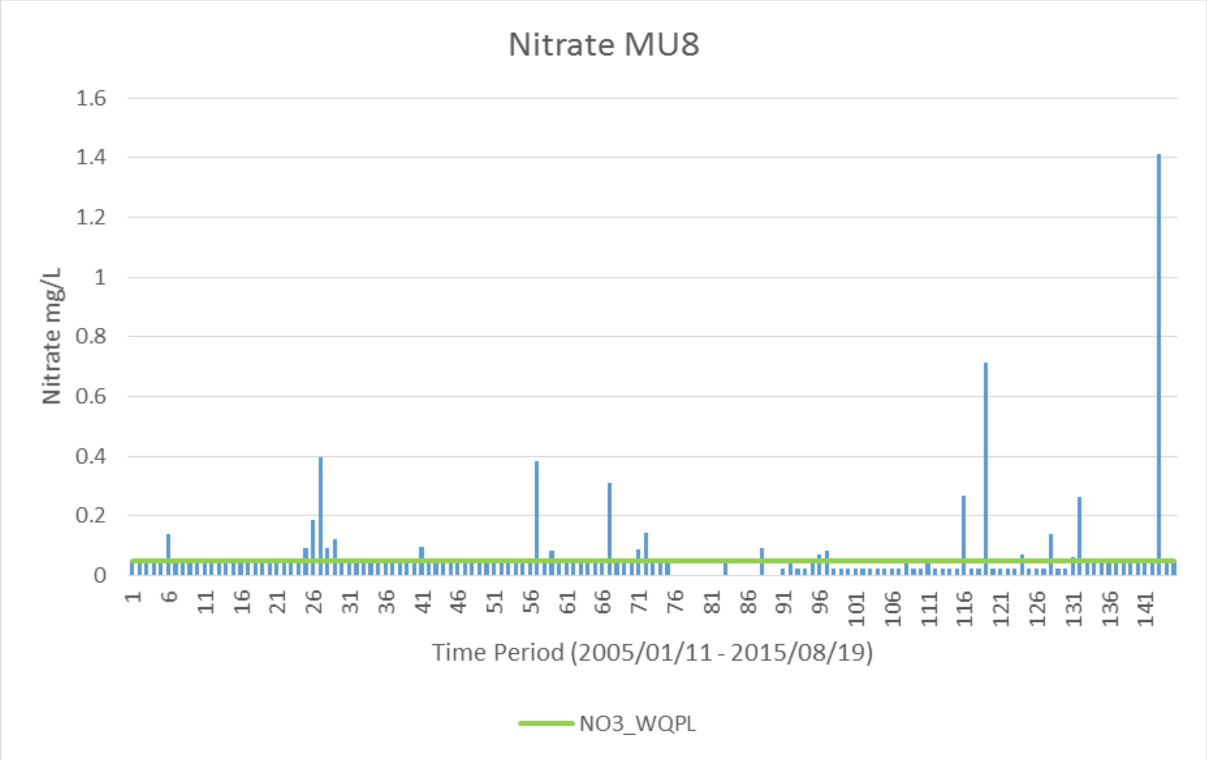


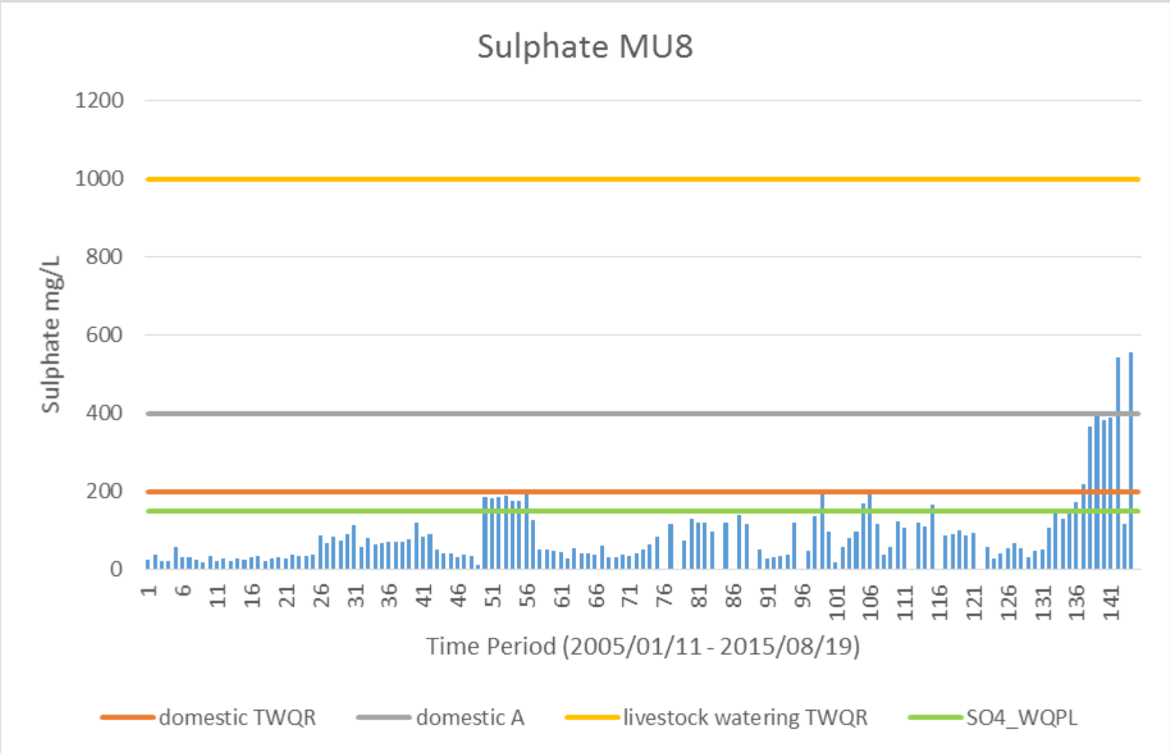

TDS MU8
TDS MG/L
Time Period (2005/01/11 - 2015/01/19)
domestic TWQR
domestic A
irrigation TWQR
TDS_WQPL

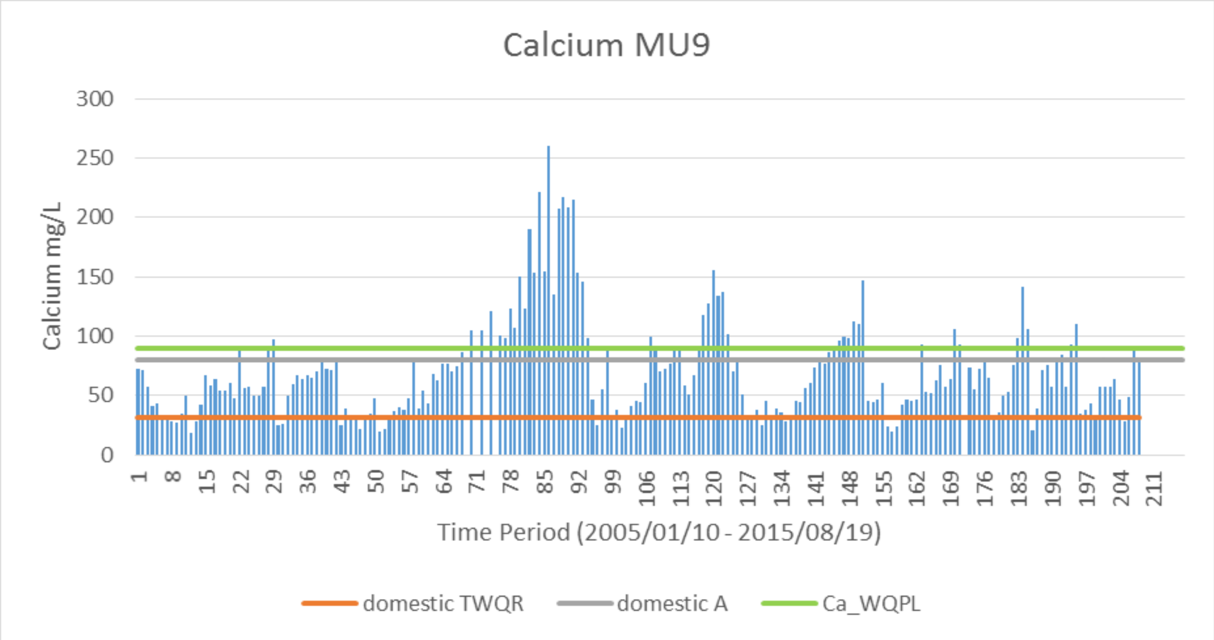

Magnesium mg/L
Time Period (2005/01/11 - 2015/08/19)
domestic TWQR
domestic A
Mg_WQPL

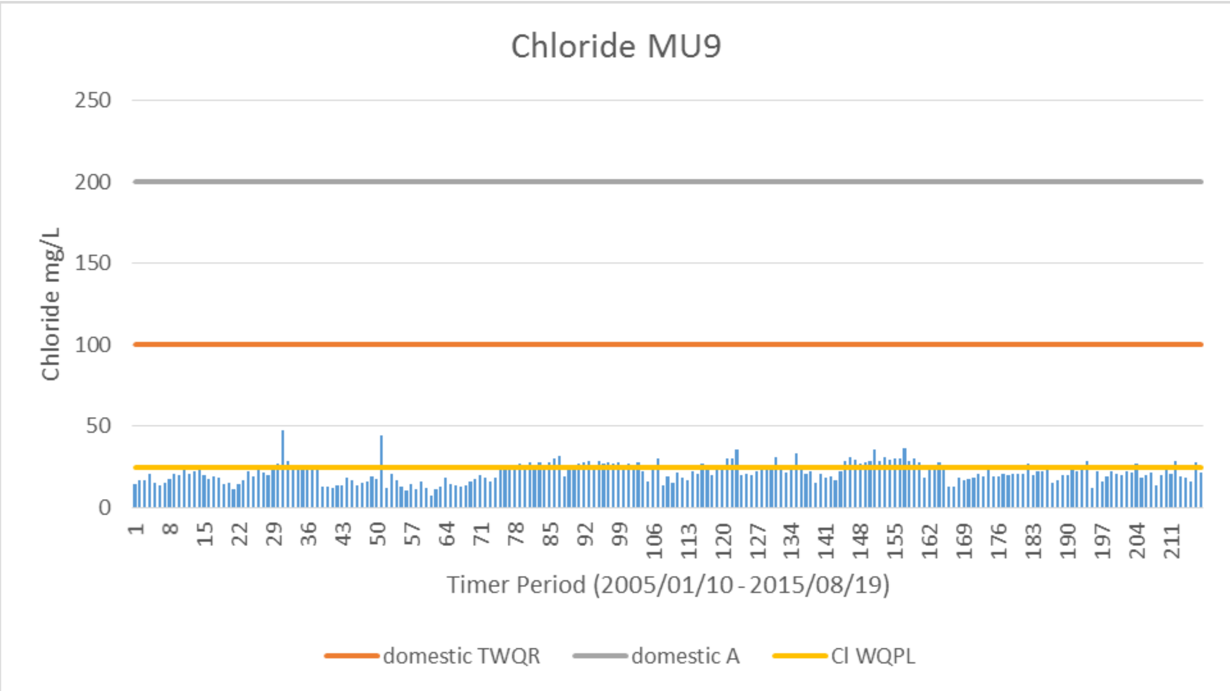

MU8_Orthophosphate
Concentration (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141
Time Period (2005/01/11 - 2015/08/19)
Orthophosphate as P (mg/L)
Aquatic TWQR
CEV
OP_WQPL

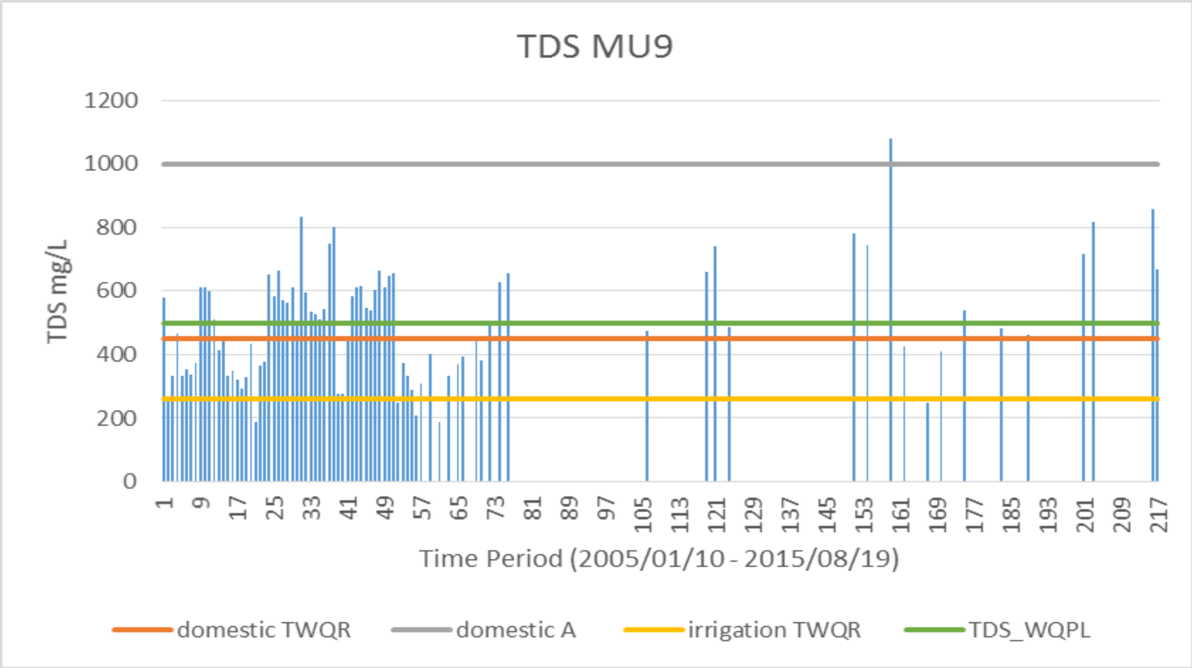

Sodium MU8
Sodium mg/L
250
200
150
100
50
0
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141
Time Period (2005/01/11 - 2015/08/19)
domestic TWQR
domestic A
irrigation TWQR

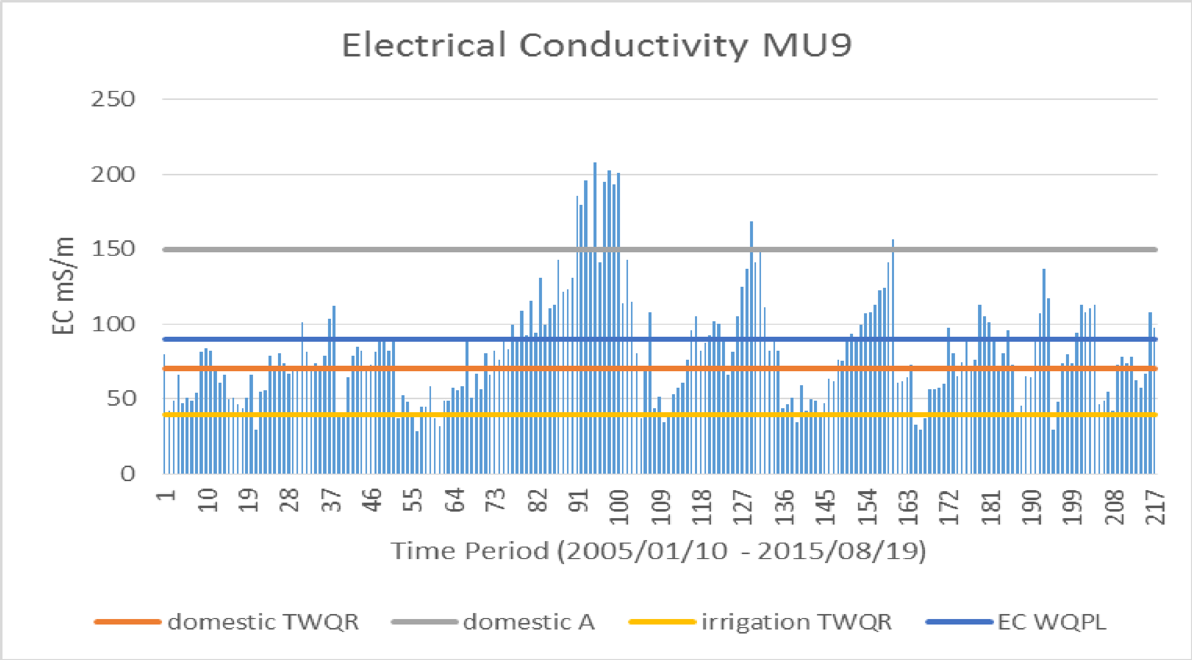

Nitrate MU8
Nitrate mg/L
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Time Period (2005/01/11 - 2015/08/19)
NO3_WQPL

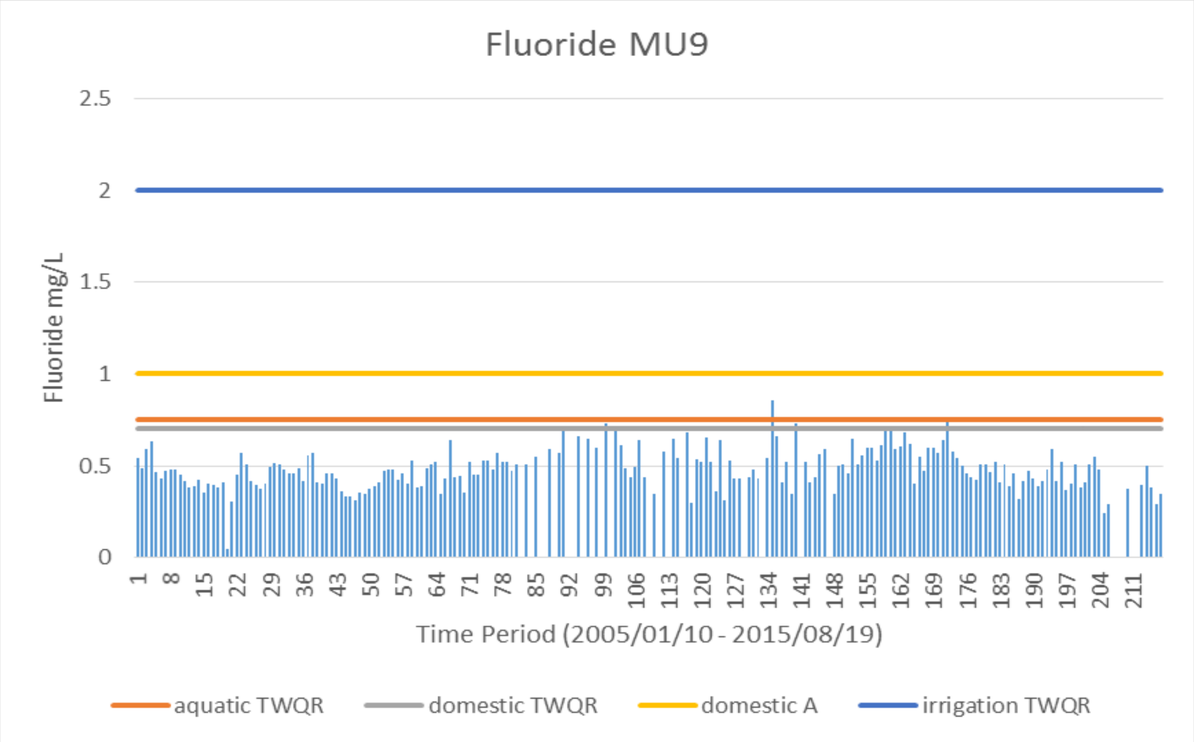

Sulphate MU8
Sulphate mg/L
1200
1000
800
600
400
200
0
Time Period (2005/01/11 - 2015/08/19)
domestic TWQR
domestic A
livestock watering TWQR
SO4_WQPL

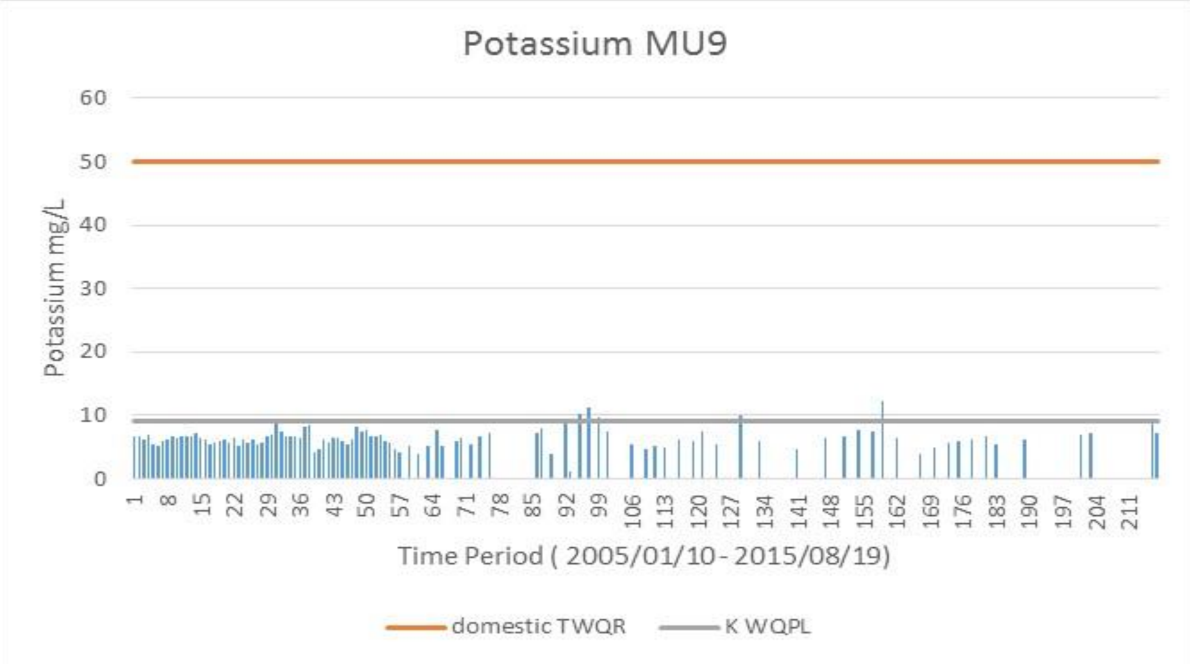

Calcium MU9
Calcium mg/L
300
250
200
150
100
50
0
Time Period (2005/01/10 - 2015/08/19)
domestic TWQR
domestic A
Ca_WQPL

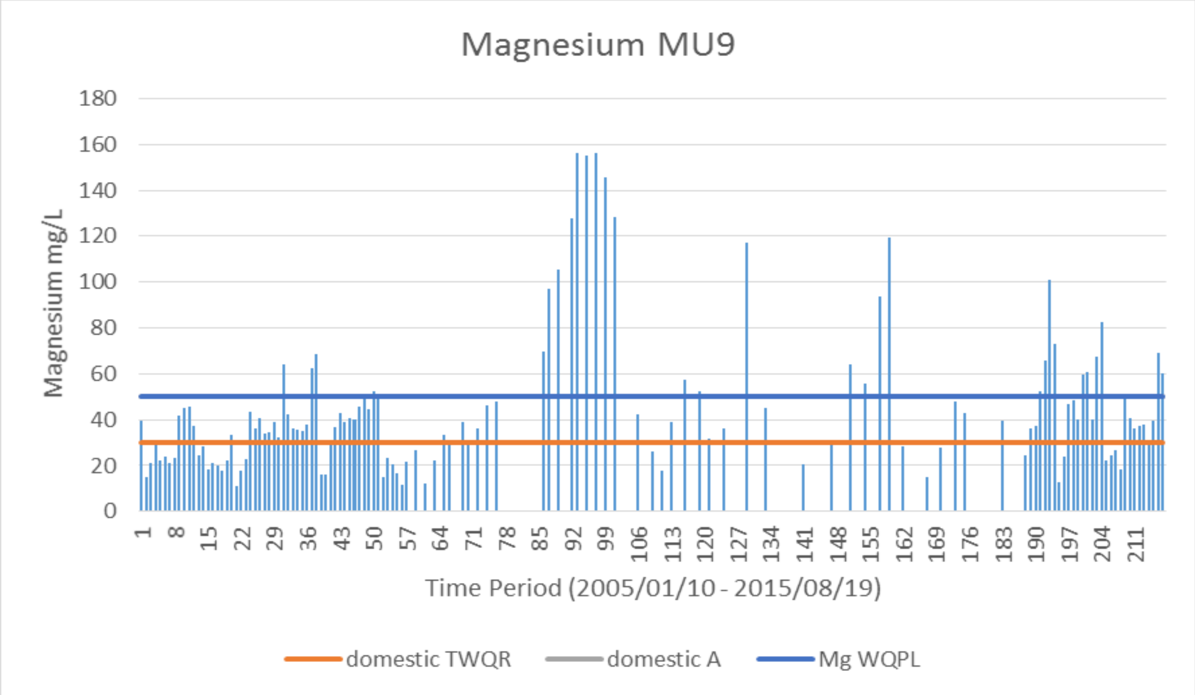

Chloride MU9
Chloride mg/L
250
200
150
100
50
0
Timer Period (2005/01/10 - 2015/08/19)
domestic TWQR
domestic A
Cl WQPL

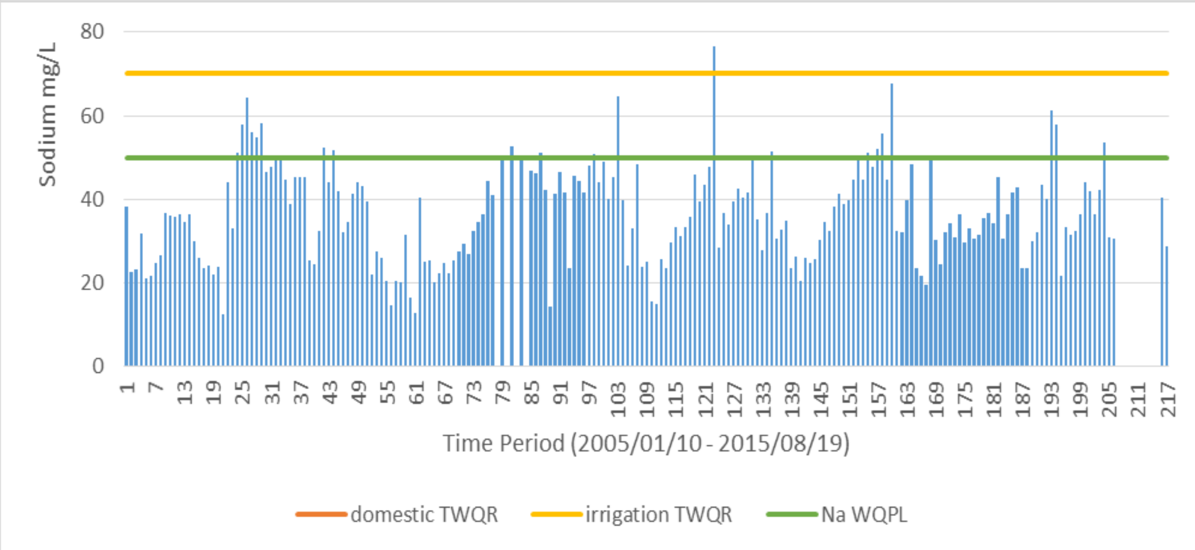

TDS MU9
TDS mg/L
Time Period (2005/01/10 - 2015/08/19)
domestic TWQR
domestic A
irrigation TWQR
TDS_WQPL

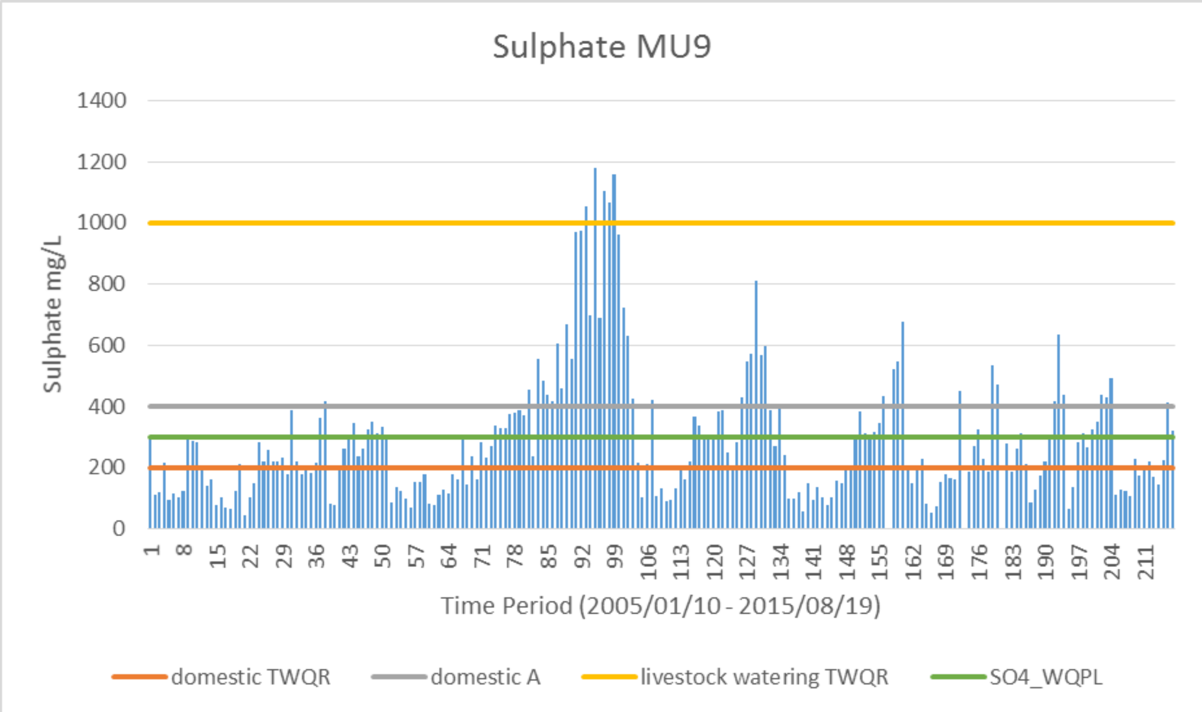

Electrical Conductivity MU9
EC mS/m
Time Period (2005/01/10 - 2015/08/19)
domestic TWQR
domestic A
irrigation TWQR
EC WQPL


Fluoride MU9
Fluoride mg/L
Time Period (2005/01/10 - 2015/08/19)
aquatic TWQR
domestic TWQR
domestic A
irrigation TWQR

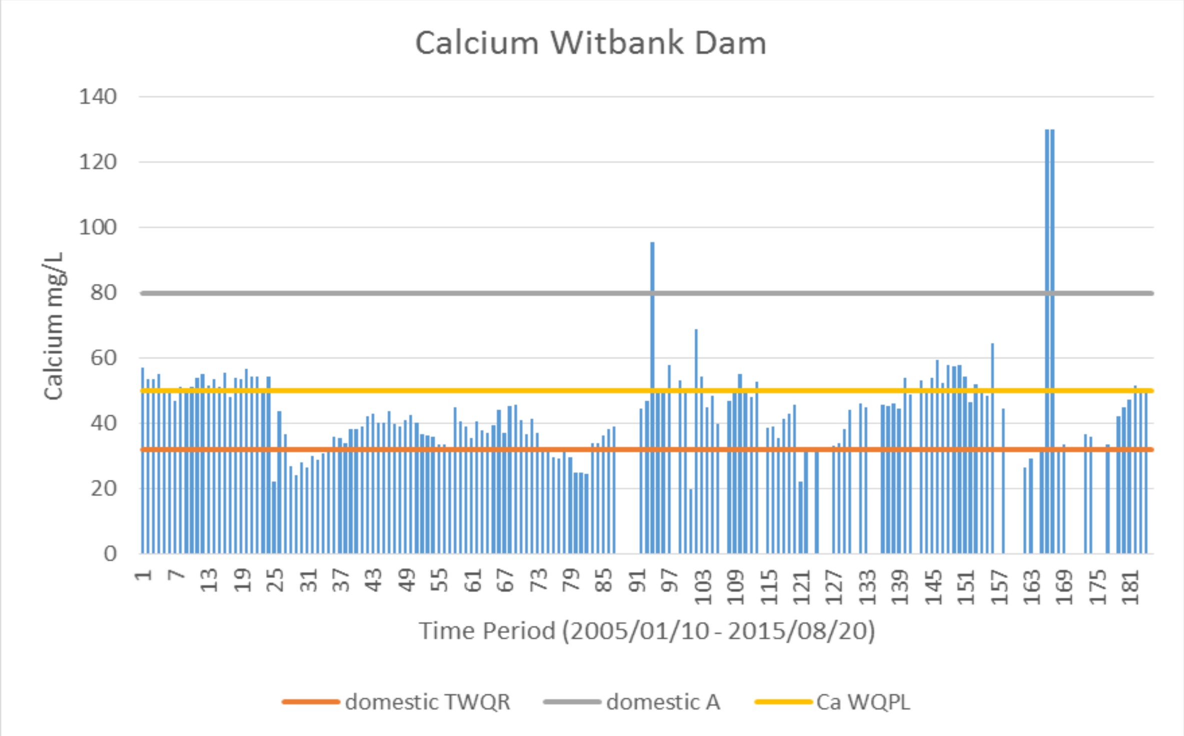

Potassium MU9
Potassium mg/L
Time Period (2005/01/10 - 2015/08/19)
domestic TWQR
K WQPL

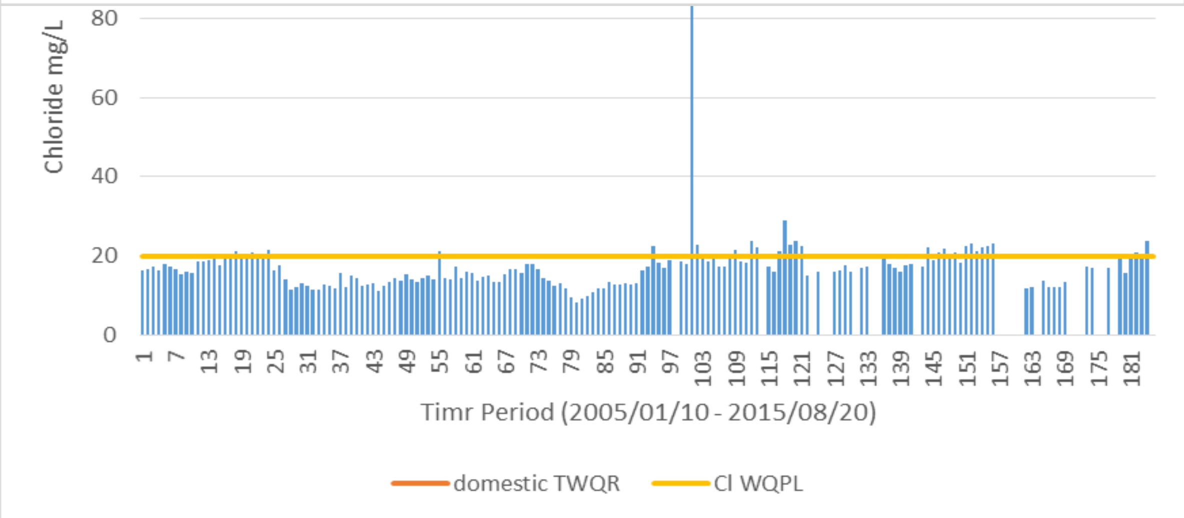

Magnesium MU9
Magnesium mg/L
Time Period (2005/01/10 - 2015/08/19)
domestic TWQR
domestic A
Mg WQPL

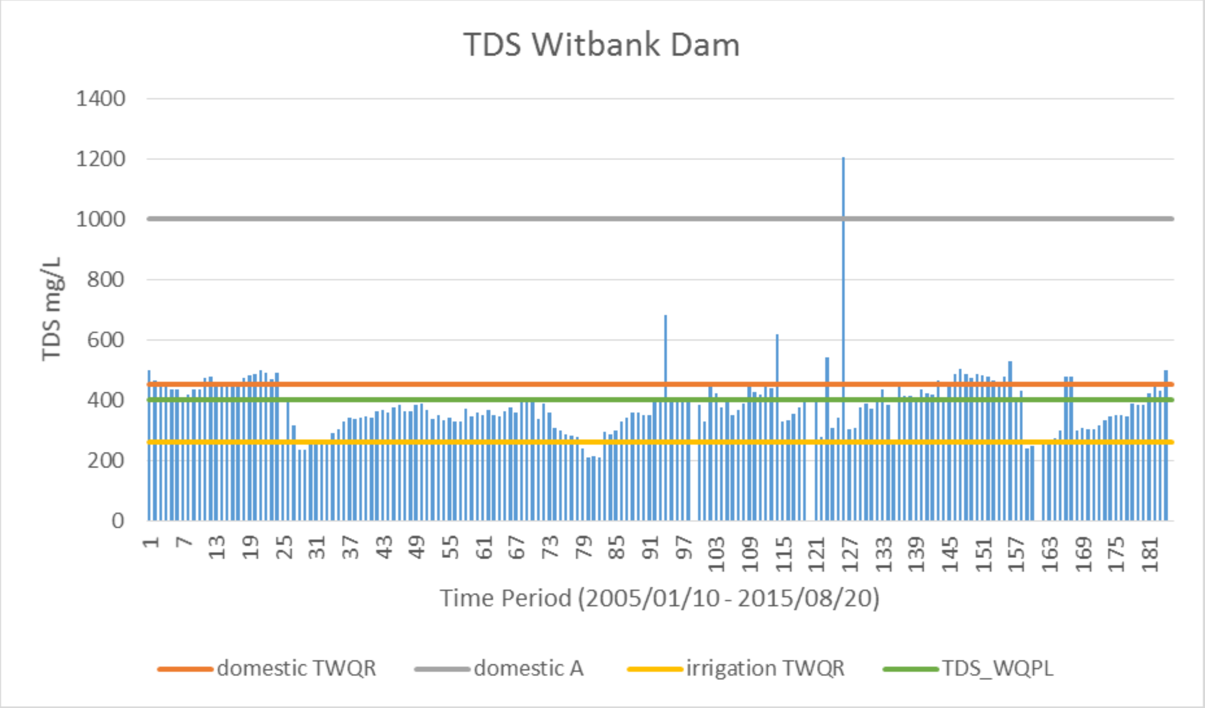

Sodium mg/L
Time Period (2005/01/10 - 2015/08/19)
domestic TWQR
irrigation TWQR
Na WQPL

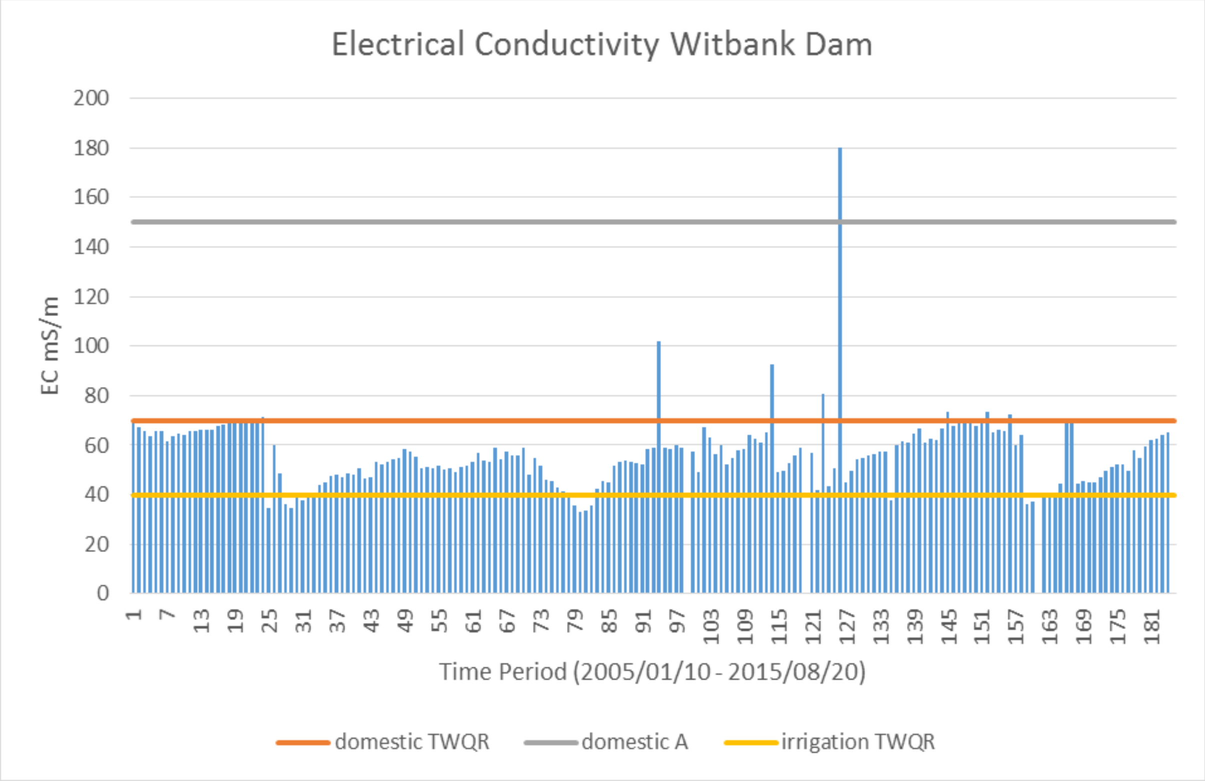

Sulphate MU9
1400
1200
1000
800
600
400
200
0
Sulphate mg/L
1
8
15
22
29
36
43
50
57
64
71
78
85
92
99
106
113
120
127
134
141
148
155
162
169
176
183
190
197
204
211
Time Period (2005/01/10 - 2015/08/19)
domestic TWQR
domestic A
livestock watering TWQR
SO4_WQPL

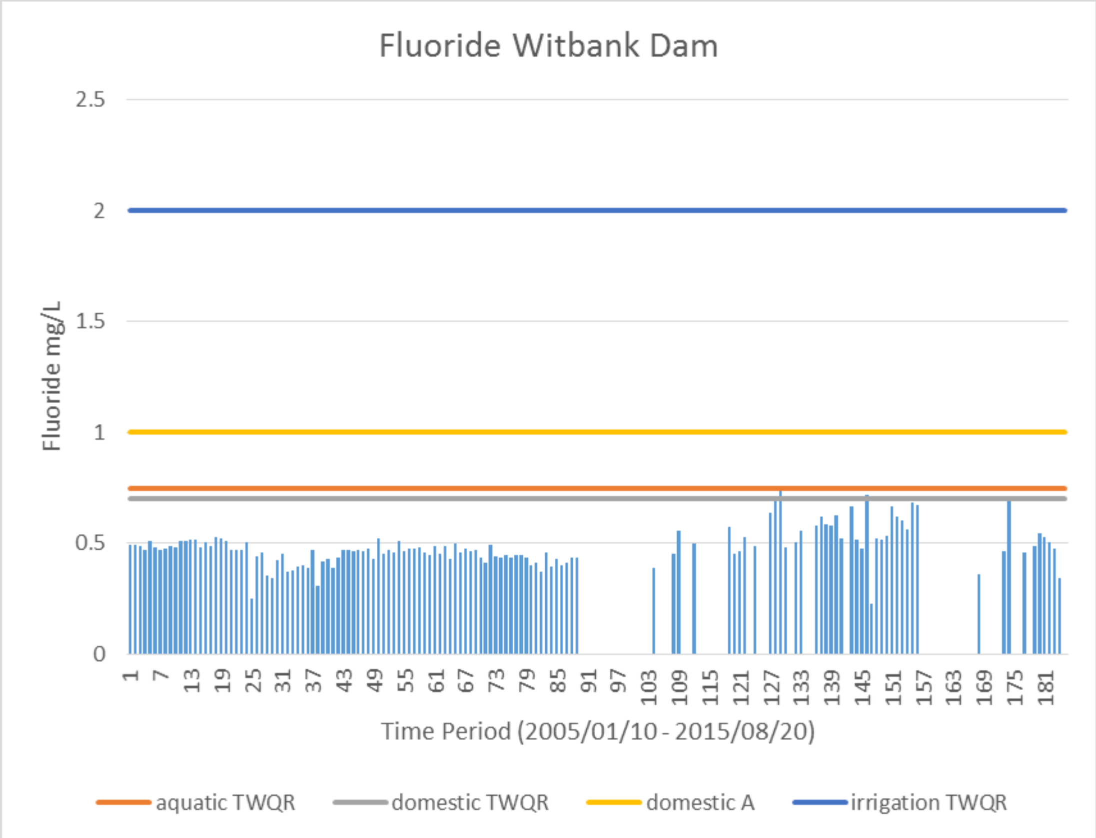
Witbank Dam

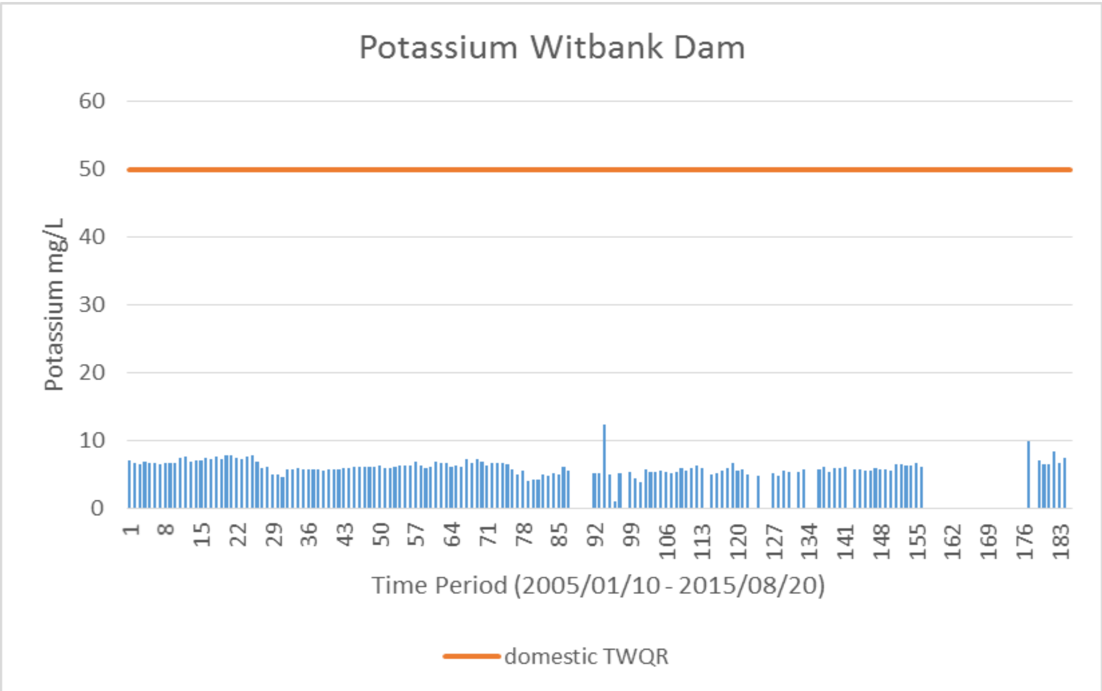

Calcium Witbank Dam
Calcium mg/L
0
20
40
60
80
100
120
140
Time Period (2005/01/10 - 2015/08/20)
domestic TWQR
domestic A
Ca WQPL

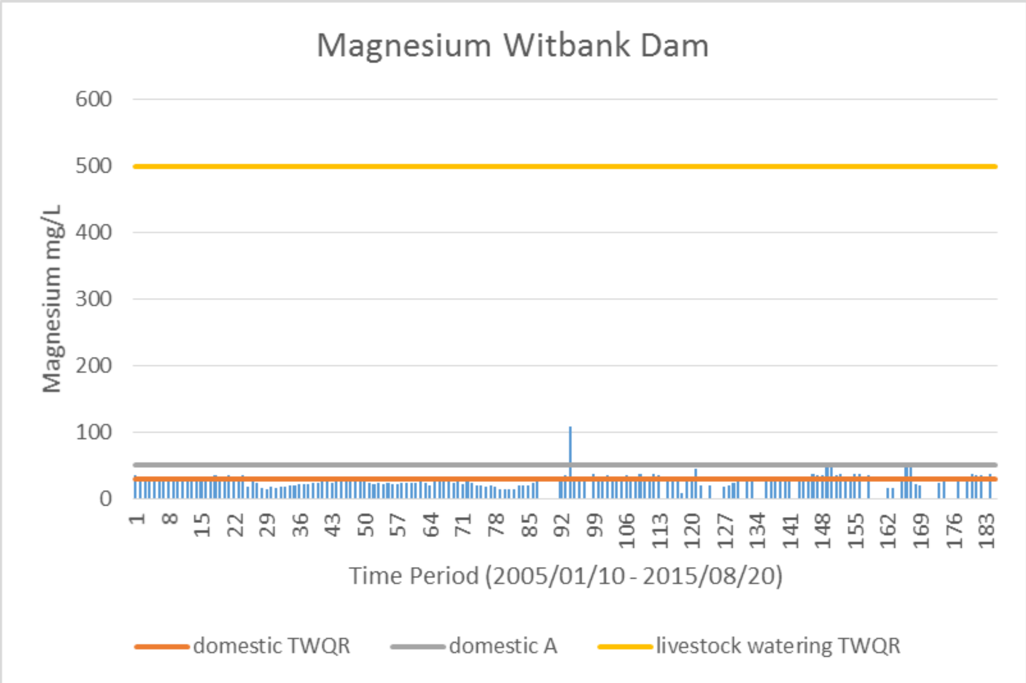

Chloride mg/L
0
20
40
60
80
Timr Period (2005/01/10 - 2015/08/20)
domestic TWQR
Cl WQPL

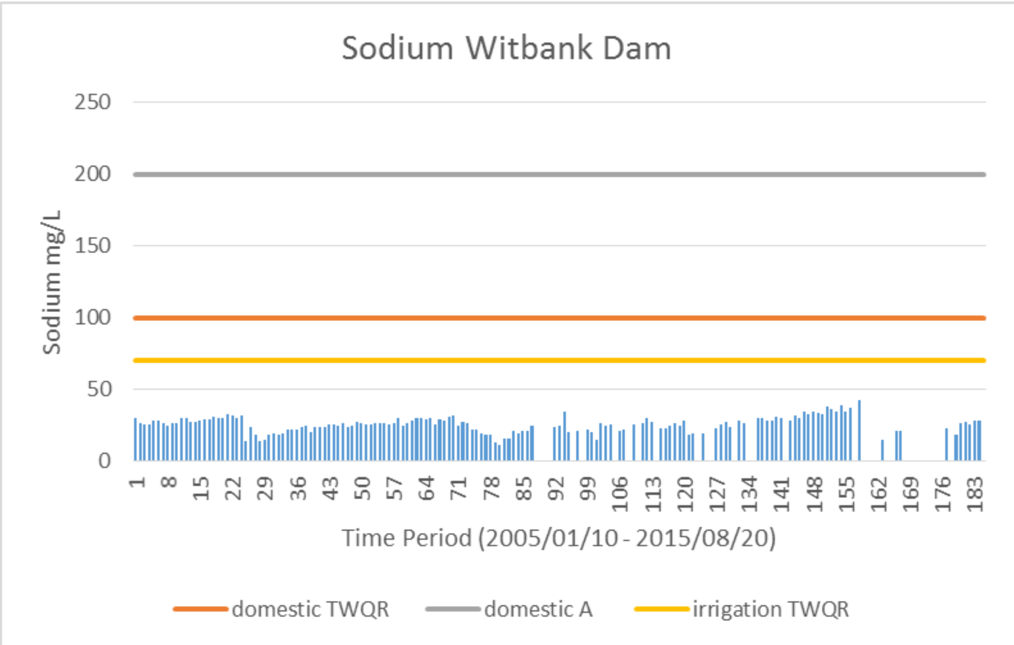

TDS Witbank Dam
TDS mg/L
1400
1200
1000
800
600
400
200
0
Time Period (2005/01/10 - 2015/08/20)
domestic TWQR
domestic A
irrigation TWQR
TDS_WQPL

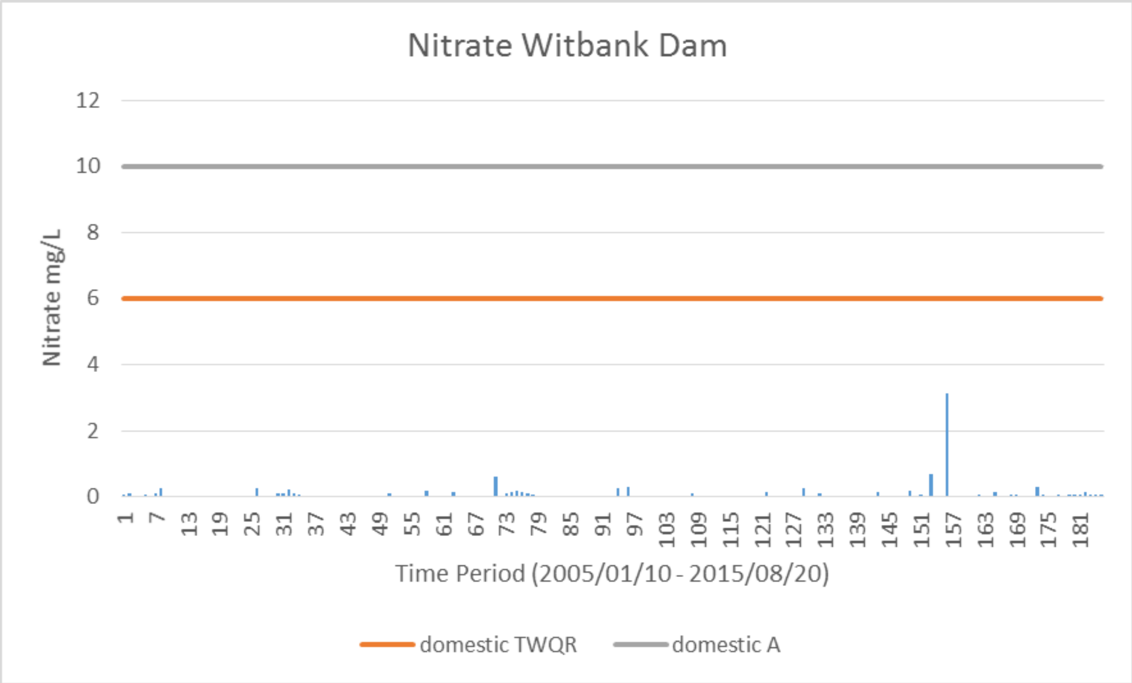

Electrical Conductivity Witbank Dam
EC mS/m
200
180
160
140
120
100
80
60
40
20
0
Time Period (2005/01/10 - 2015/08/20)
domestic TWQR
domestic A
irrigation TWQR

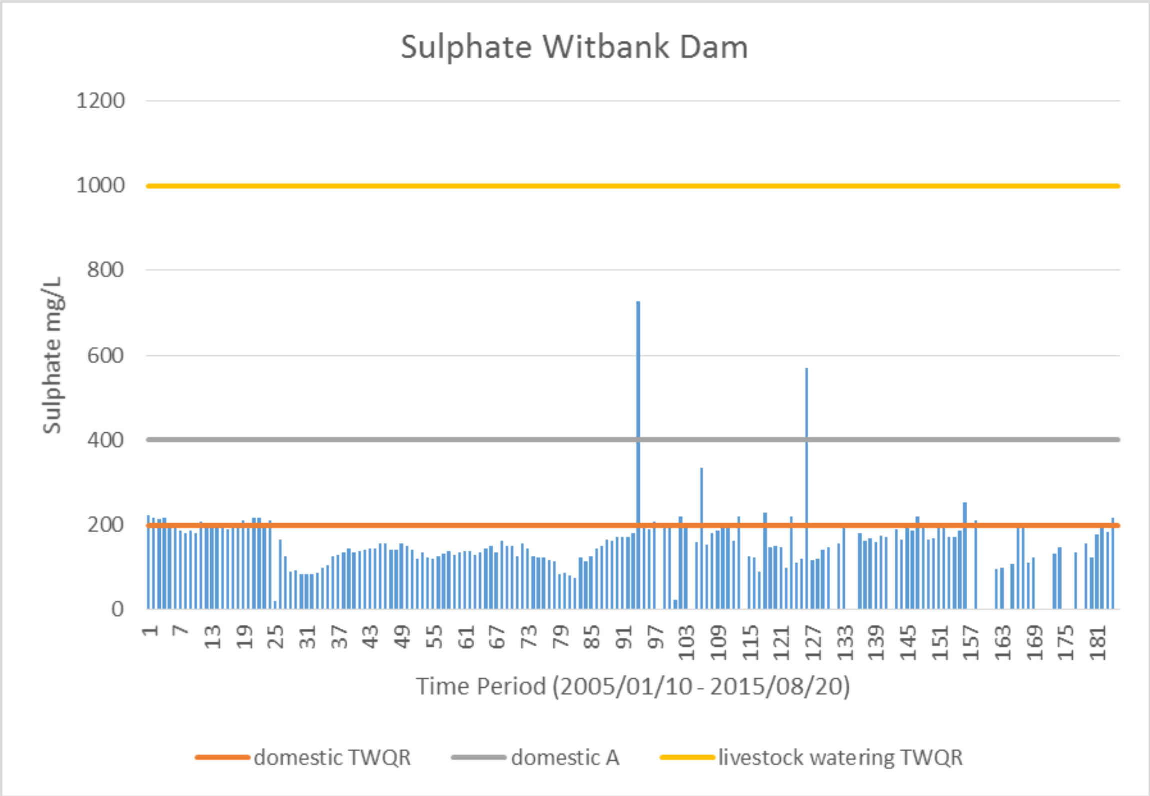

Fluoride Witbank Dam
Fluoride mg/L
2.5
2
1.5
1
0.5
0
Time Period (2005/01/10 - 2015/08/20)
aquatic TWQR
domestic TWQR
domestic A
irrigation TWQR


Potassium Witbank Dam
Potassium mg/L
60
50
40
30
20
10
0
Time Period (2005/01/10 - 2015/08/20)
domestic TWQR

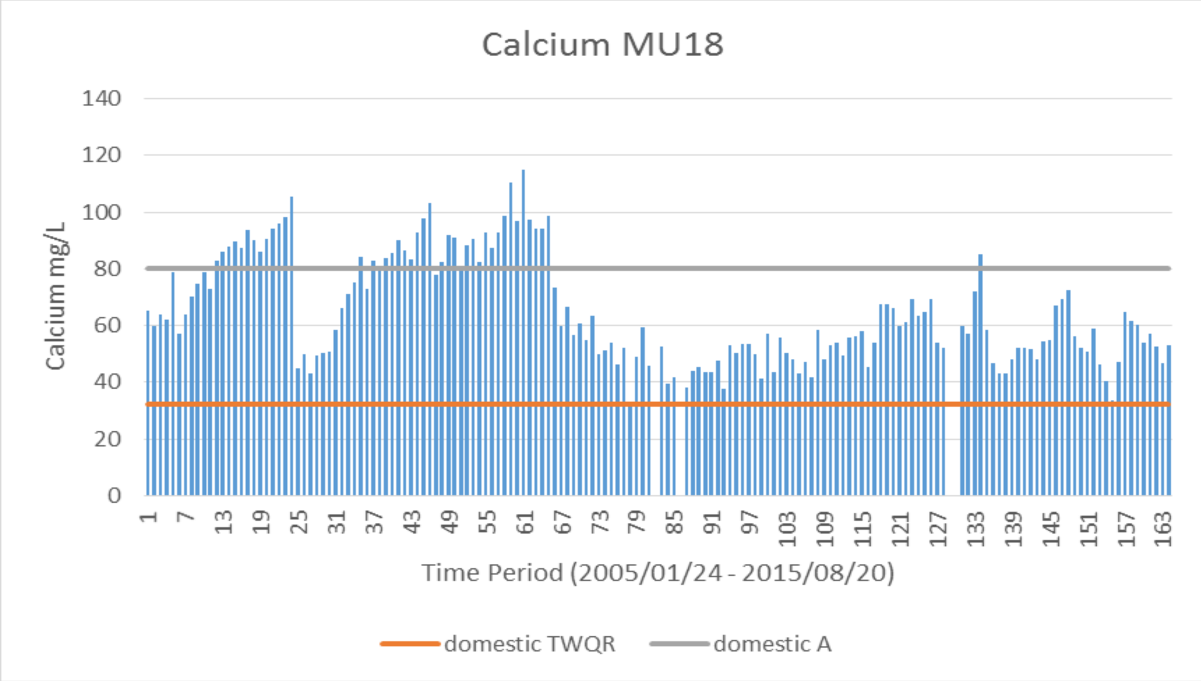

Magnesium Witbank Dam
Magnesium mg/L
600
500
400
300
200
100
0
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99 106 113 120 127 134 141 148 155 162 169 176 183
Time Period (2005/01/10 - 2015/08/20)
domestic TWQR
domestic A
livestock watering TWQR

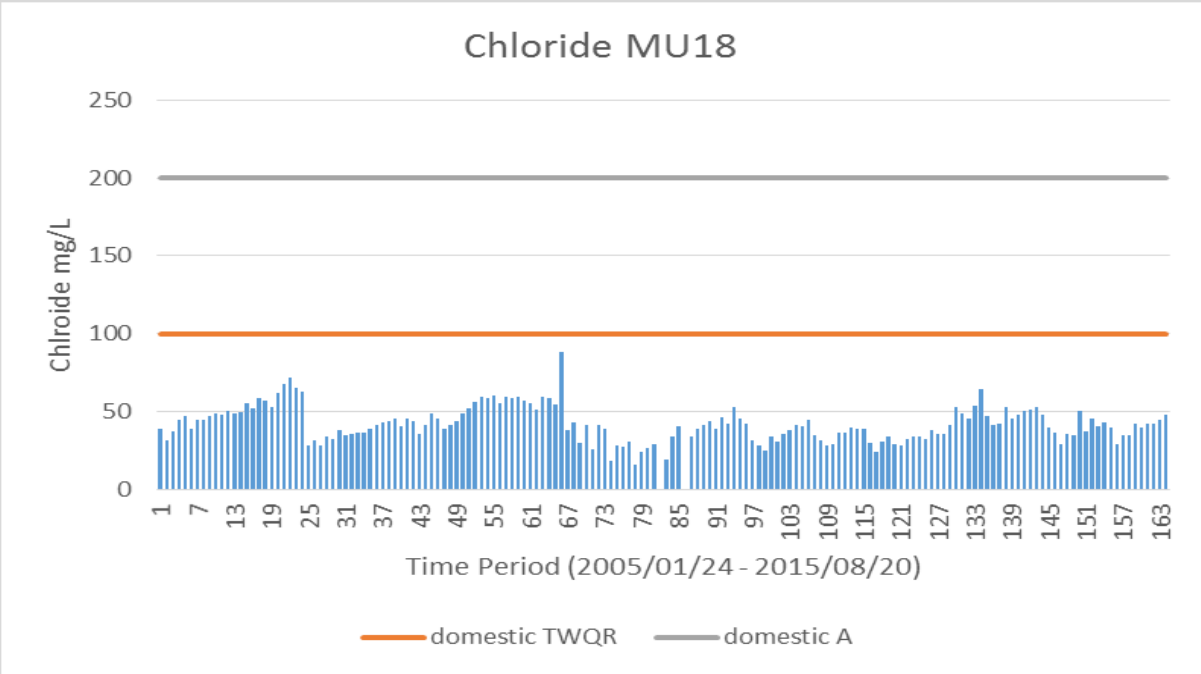

Sodium Witbank Dam
Sodium mg/L
250
200
150
100
50
0
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99 106 113 120 127 134 141 148 155 162 169 176 183
Time Period (2005/01/10 - 2015/08/20)
domestic TWQR
domestic A
irrigation TWQR

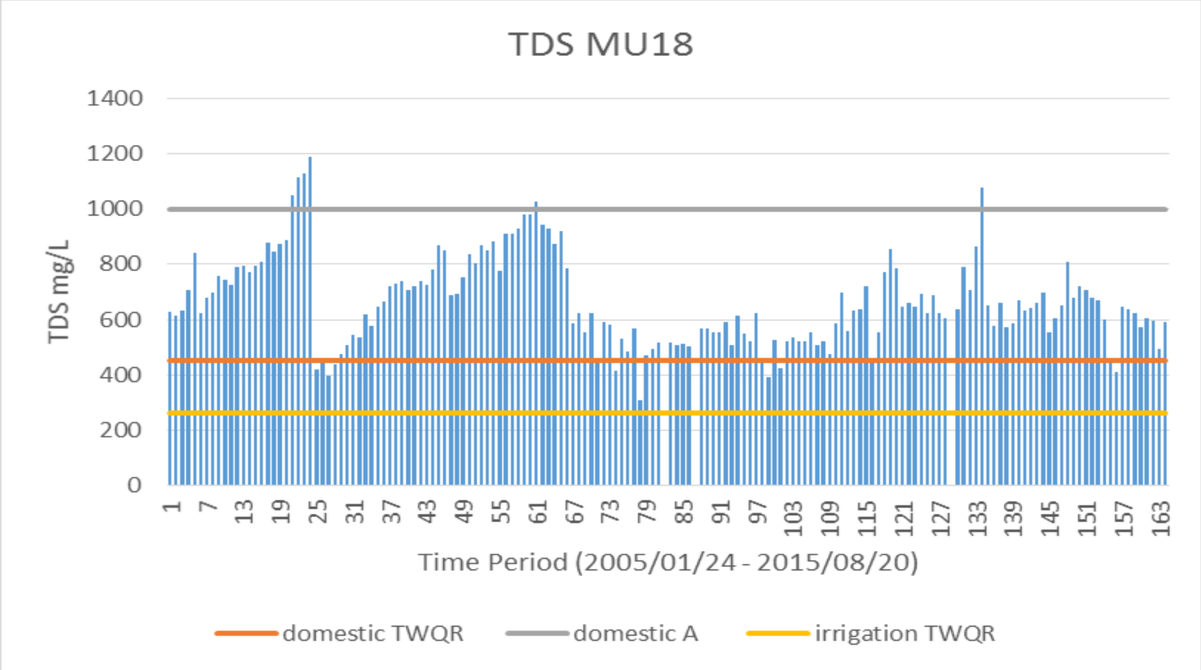

Nitrate Witbank Dam
Nitrate mg/L
12
10
8
6
4
2
0
Time Period (2005/01/10 - 2015/08/20)
domestic TWQR
domestic A

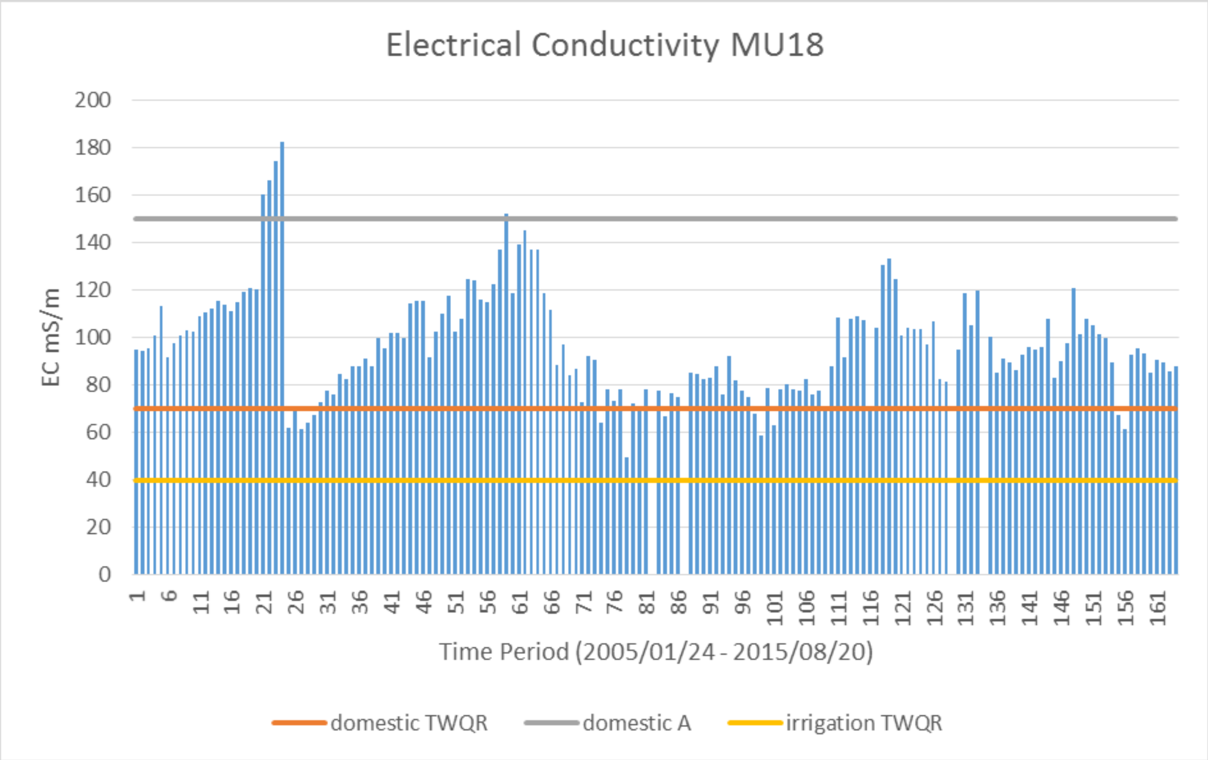

Sulphate Witbank Dam
Sulphate mg/L
1200
1000
800
600
400
200
0
Time Period (2005/01/10 - 2015/08/20)
domestic TWQR
domestic A
livestock watering TWQR

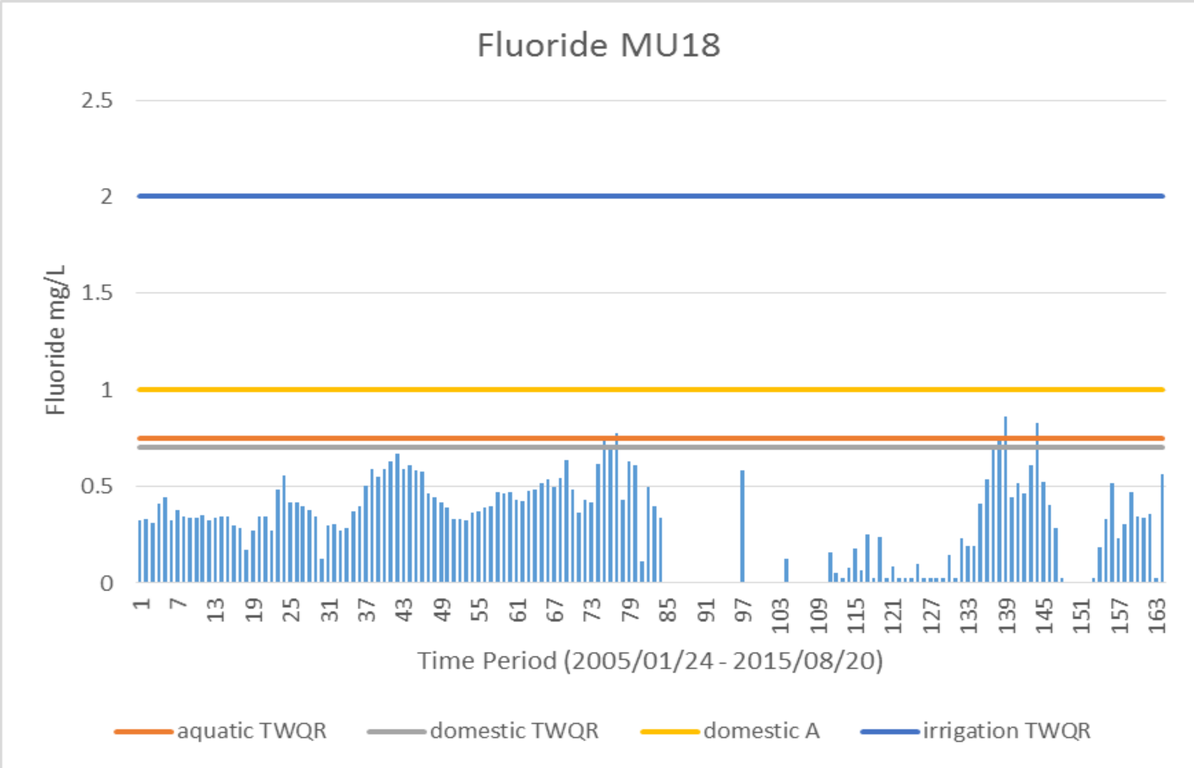
Management Unit 18

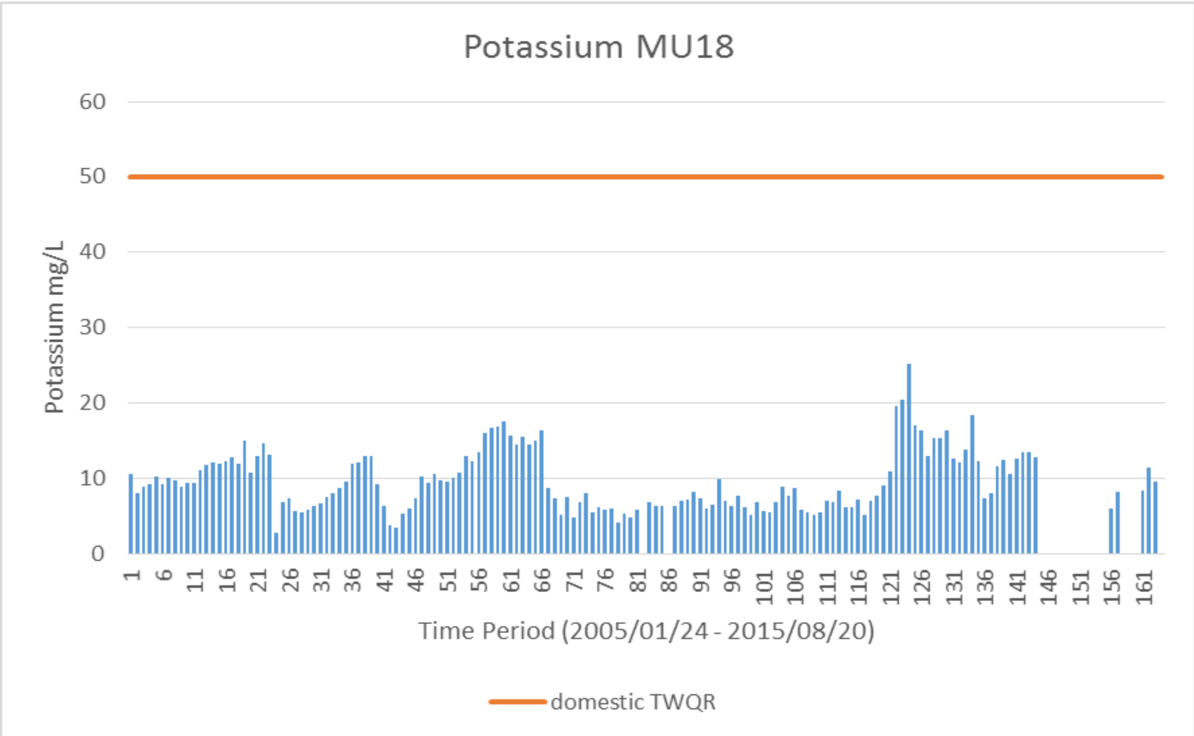


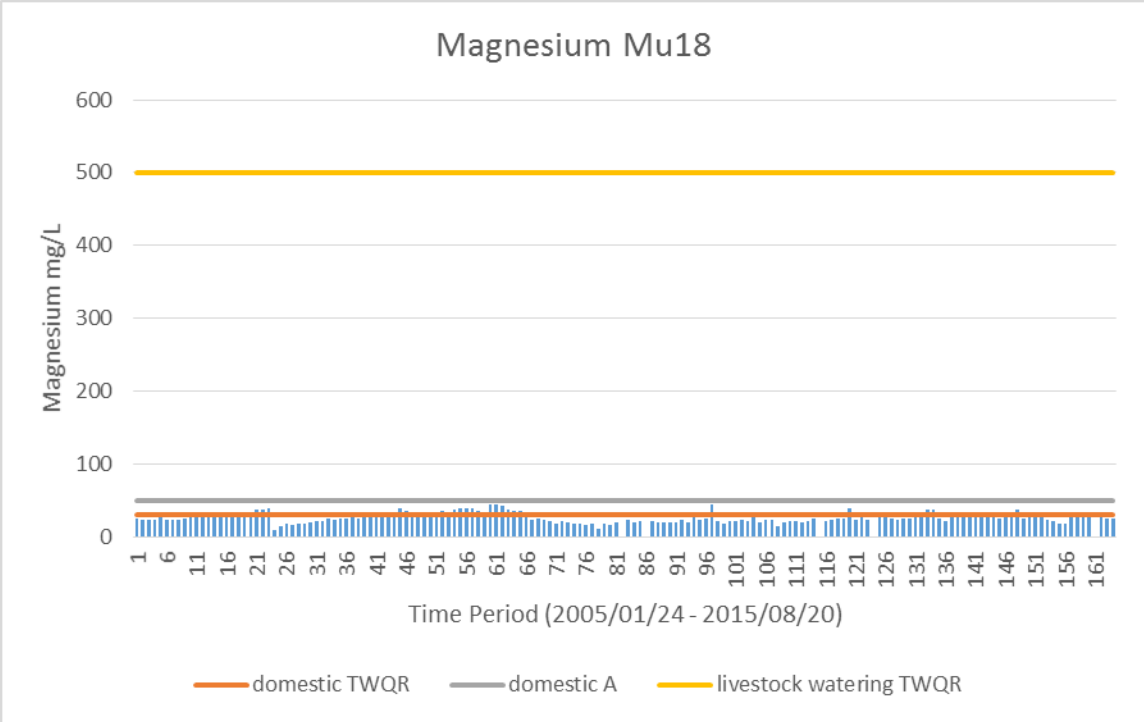


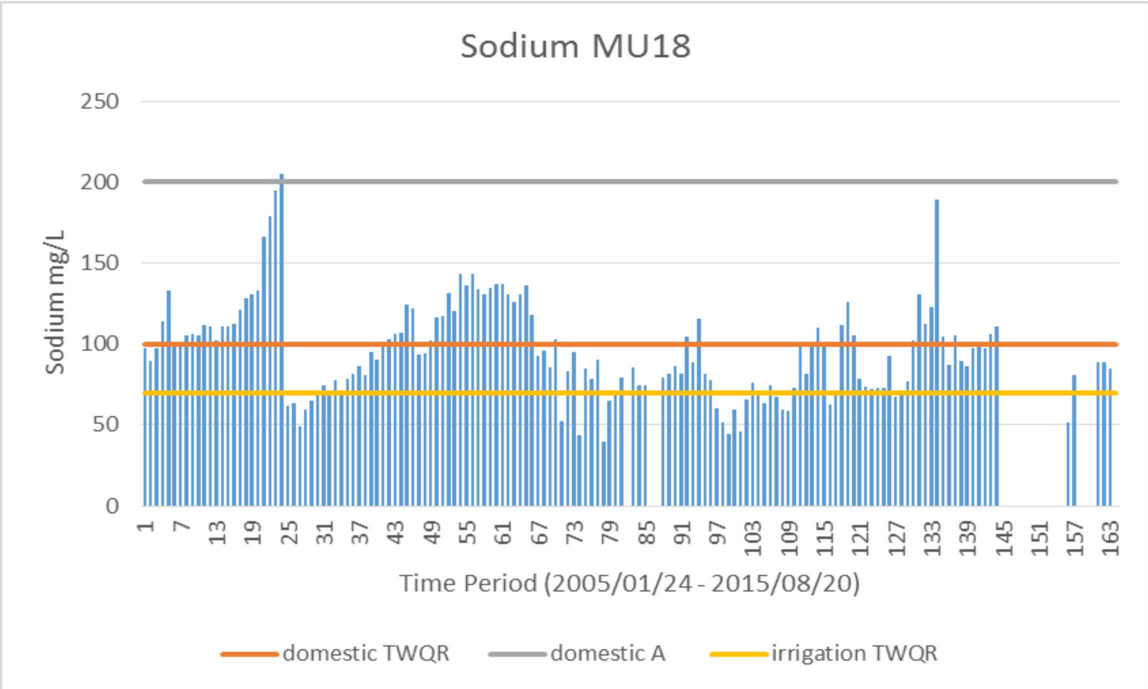

TDS MU18
TDS mg/L
Time Period (2005/01/24 - 2015/08/20)
domestic TWQR
domestic A
irrigation TWQR

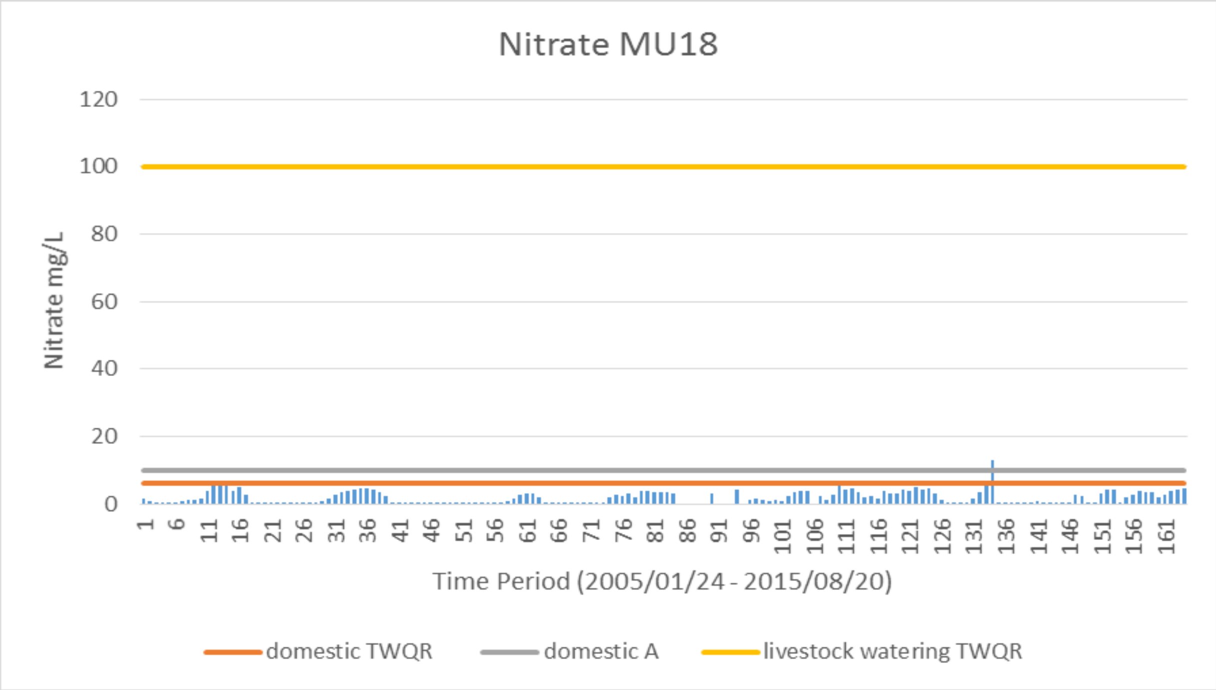

Electrical Conductivity MU18
EC mS/m
Time Period (2005/01/24 - 2015/08/20)
domestic TWQR
domestic A
irrigation TWQR

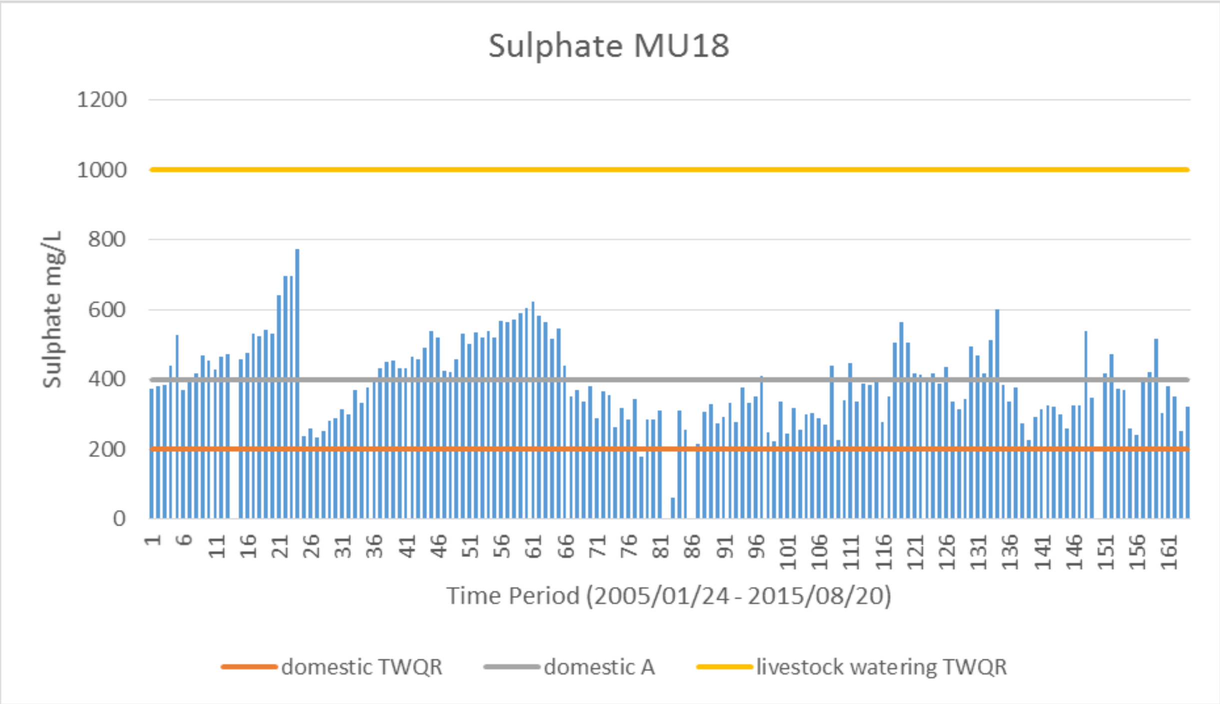

Fluoride MU18
Fluoride mg/L
2.5
2
1.5
1
0.5
0
1
7
13
19
25
31
37
43
49
55
61
67
73
79
85
91
97
103
109
115
121
127
133
139
145
151
157
163
Time Period (2005/01/24 - 2015/08/20)
aquatic TWQR
domestic TWQR
domestic A
irrigation TWQR


Potassium MU18
Potassium mg/L
60
50
40
30
20
10
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
136
141
146
151
156
161
Time Period (2005/01/24 - 2015/08/20)
domestic TWQR

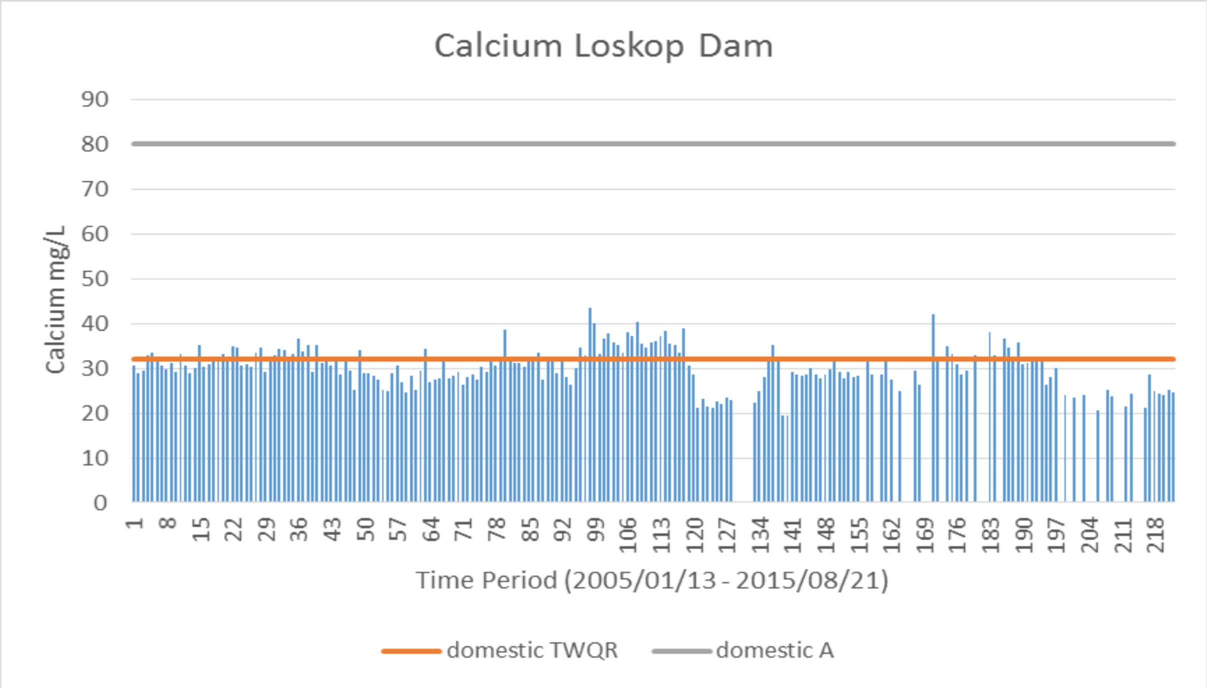

Magnesium Mu18
Magnesium mg/L
600
500
400
300
200
100
0
Time Period (2005/01/24 - 2015/08/20)
domestic TWQR
domestic A
livestock watering TWQR

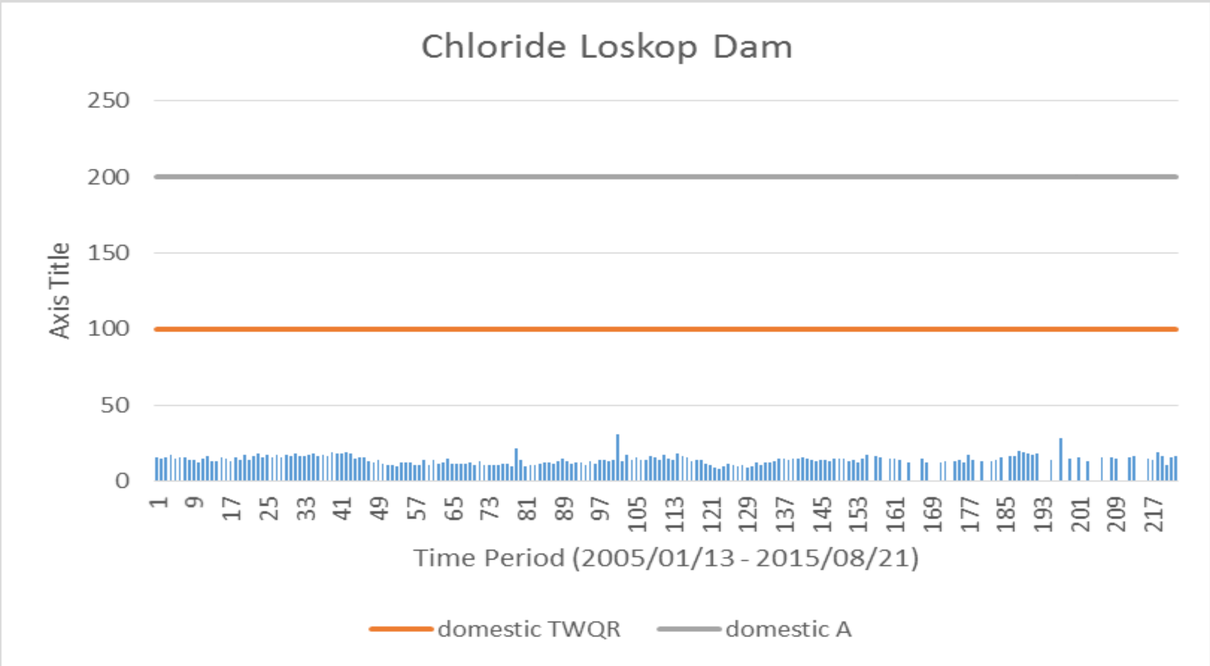

Sodium MU18
Sodium mg/L
250
200
150
100
50
0
Time Period (2005/01/24 - 2015/08/20)
domestic TWQR
domestic A
irrigation TWQR

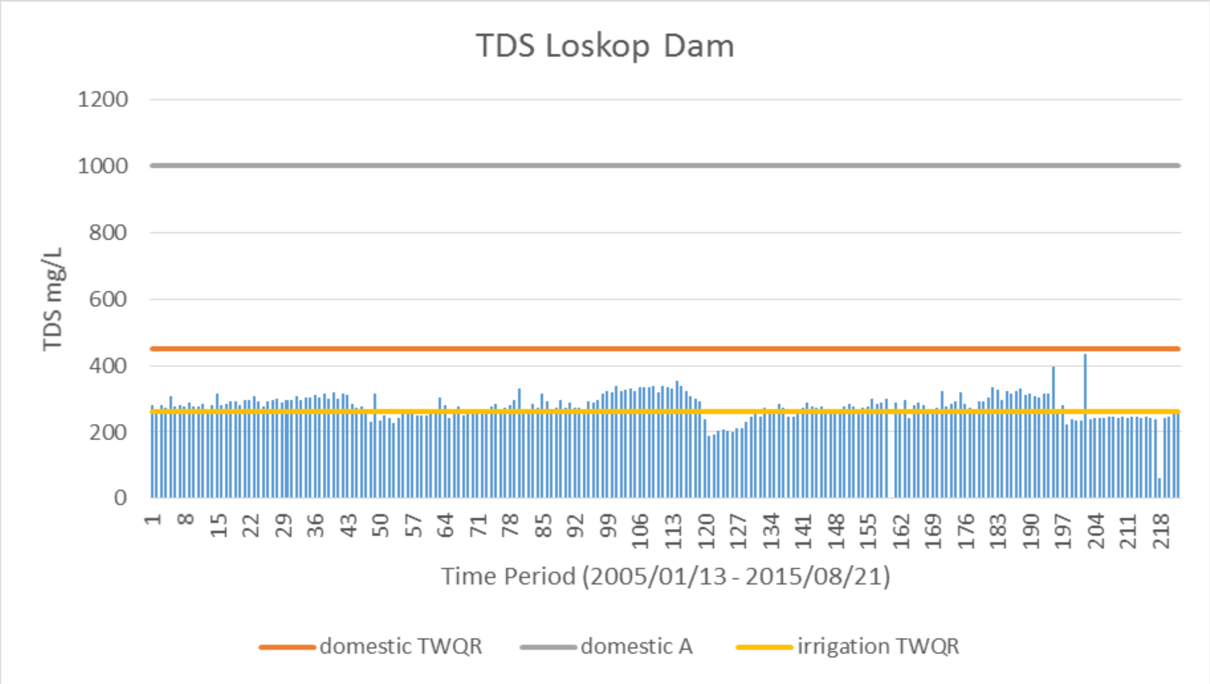

Nitrate MU18
Nitrate mg/L
120
100
80
60
40
20
0
Time Period (2005/01/24 - 2015/08/20)
domestic TWQR
domestic A
livestock watering TWQR

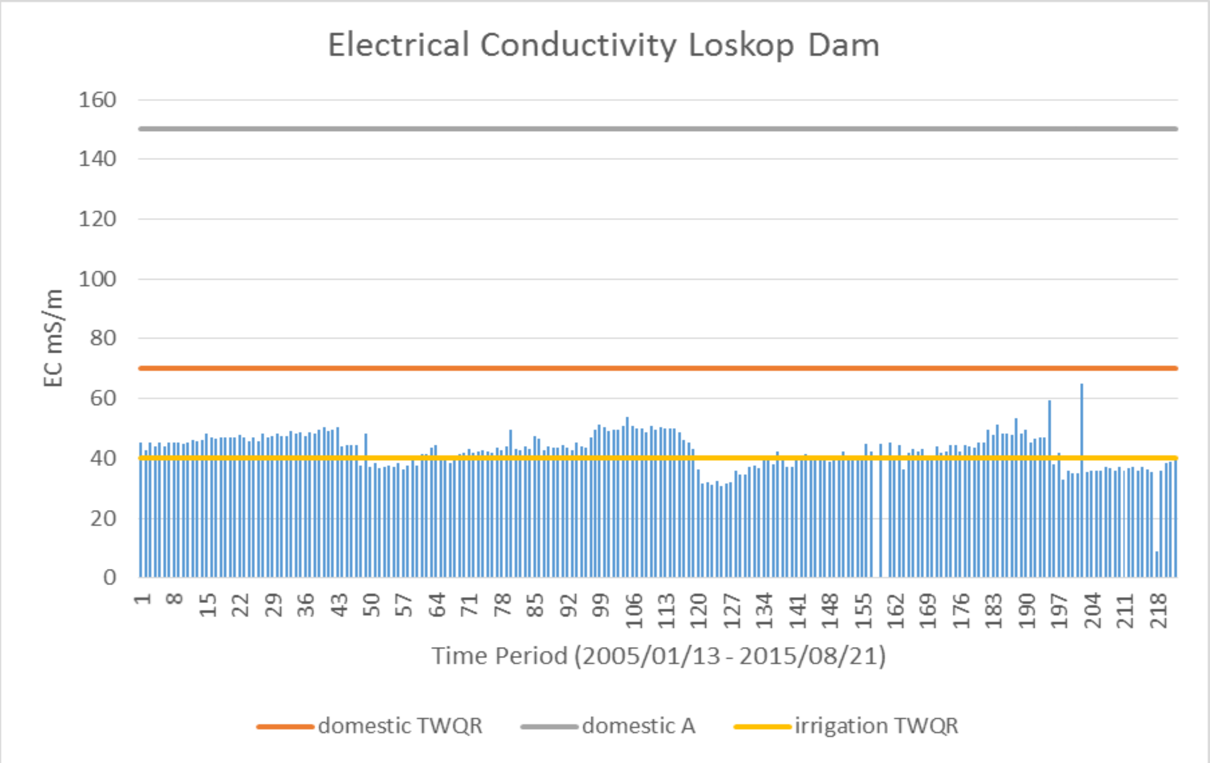

Sulphate MU18
Sulphate mg/L
1200
1000
800
600
400
200
0
Time Period (2005/01/24 - 2015/08/20)
domestic TWQR
domestic A
livestock watering TWQR

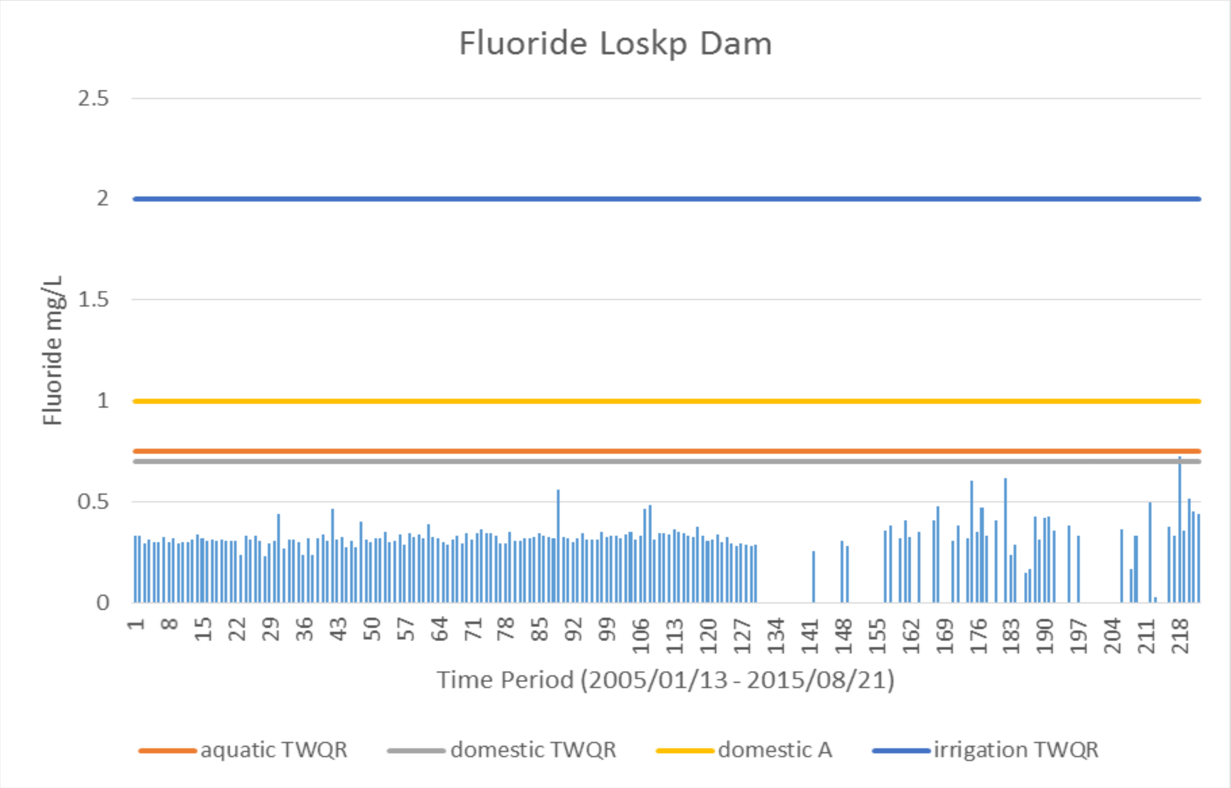
Loskop Dam

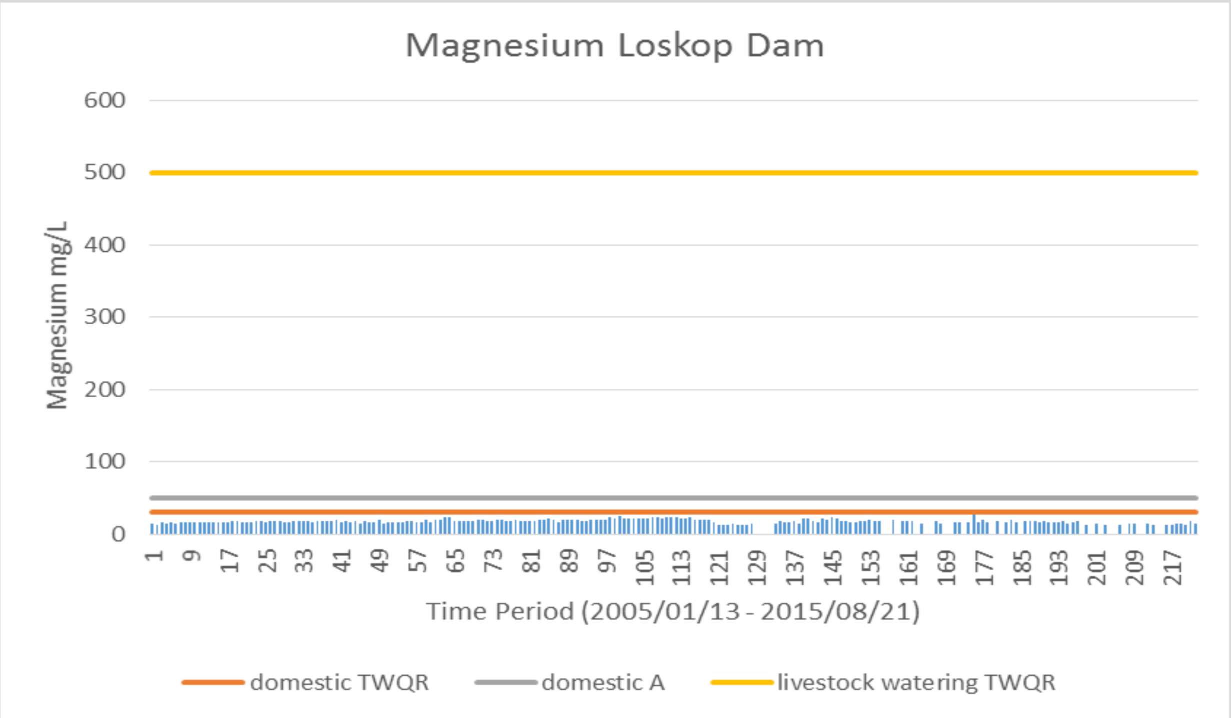

Calcium Loskop Dam
Calcium mg/L
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR
domestic A

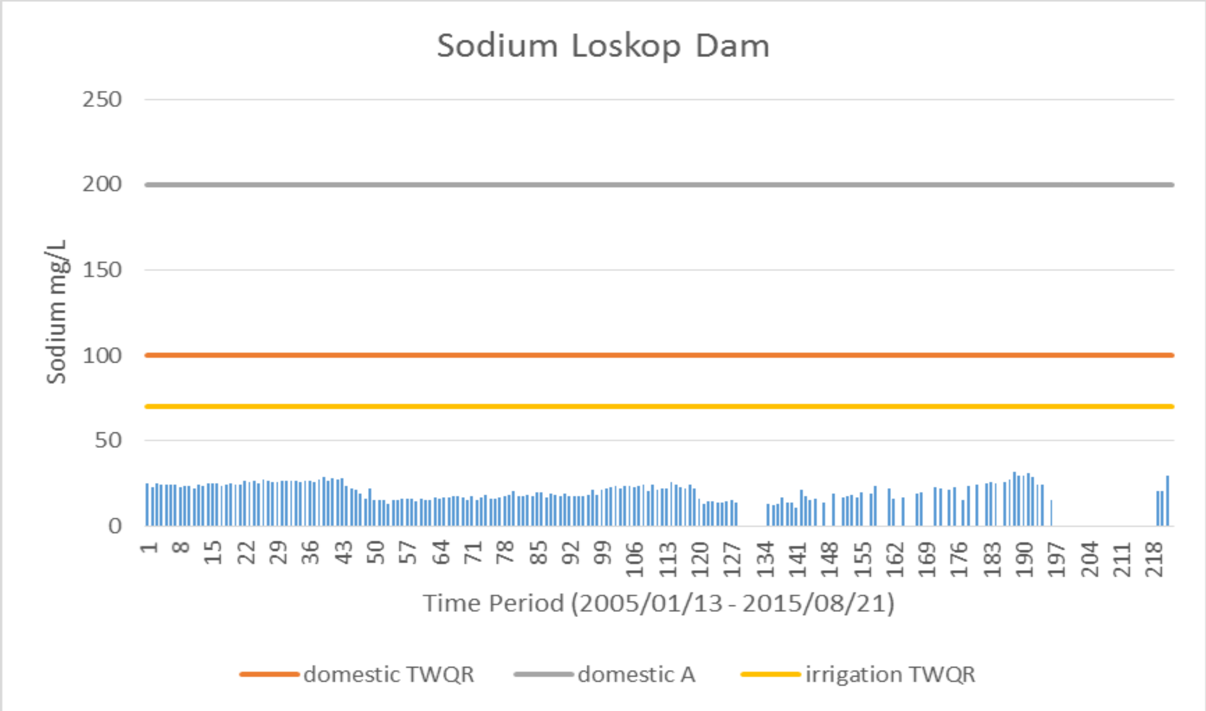

Chloride Loskop Dam
Axis Title
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR
domestic A

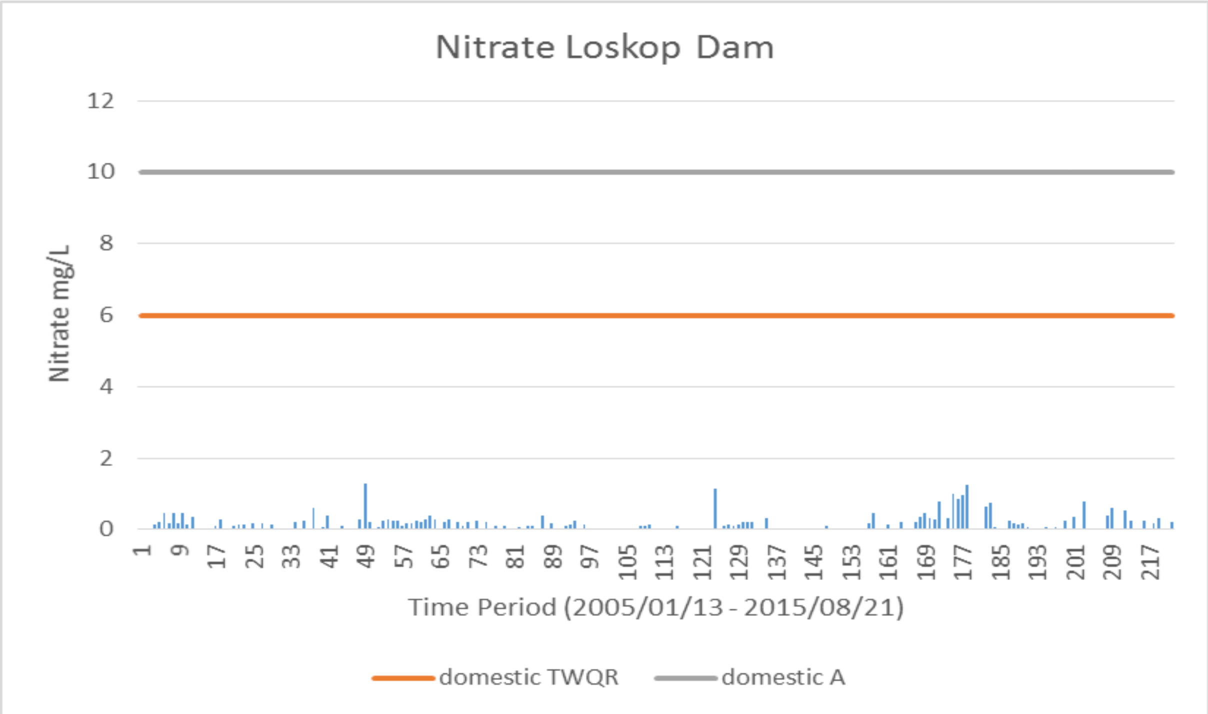

TDS Loskop Dam
TDS mg/L
1200
1000
800
600
400
200
0
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR
domestic A
irrigation TWQR

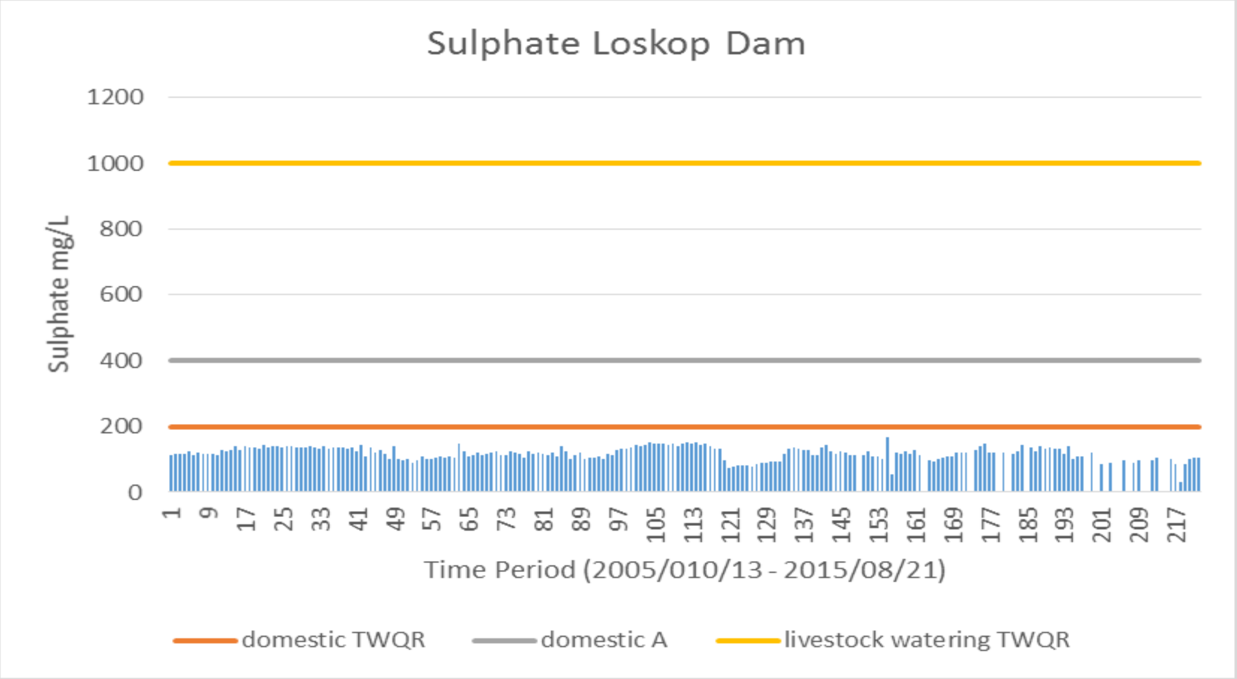

Electrical Conductivity Loskop Dam
EC mS/m
160
140
120
100
80
60
40
20
0
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR
domestic A
irrigation TWQR


Fluoride Loskp Dam
2.5
2
1.5
1
0.5
0
Fluoride mg/L
1
8
15
22
29
36
43
50
57
64
71
78
85
92
99
106
113
120
127
134
141
148
155
162
169
176
183
190
197
204
211
218
Time Period (2005/01/13 - 2015/08/21)
aquatic TWQR
domestic TWQR
domestic A
irrigation TWQR


Magnesium Loskop Dam
600
500
400
300
200
100
0
Magnesium mg/L
1
9
17
25
33
41
49
57
65
73
81
89
97
105
113
121
129
137
145
153
161
169
177
185
193
201
209
217
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR
domestic A
livestock watering TWQR


Sodium Loskop Dam
Sodium mg/L
250
200
150
100
50
0
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99 106 113 120 127 134 141 148 155 162 169 176 183 190 197 204 211 218
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR
domestic A
irrigation TWQR


Nitrate Loskop Dam
Nitrate mg/L
12
10
8
6
4
2
0
1 9 17 25 33 41 49 57 65 73 81 89 97 105 113 121 129 137 145 153 161 169 177 185 193 201 209 217
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR
domestic A



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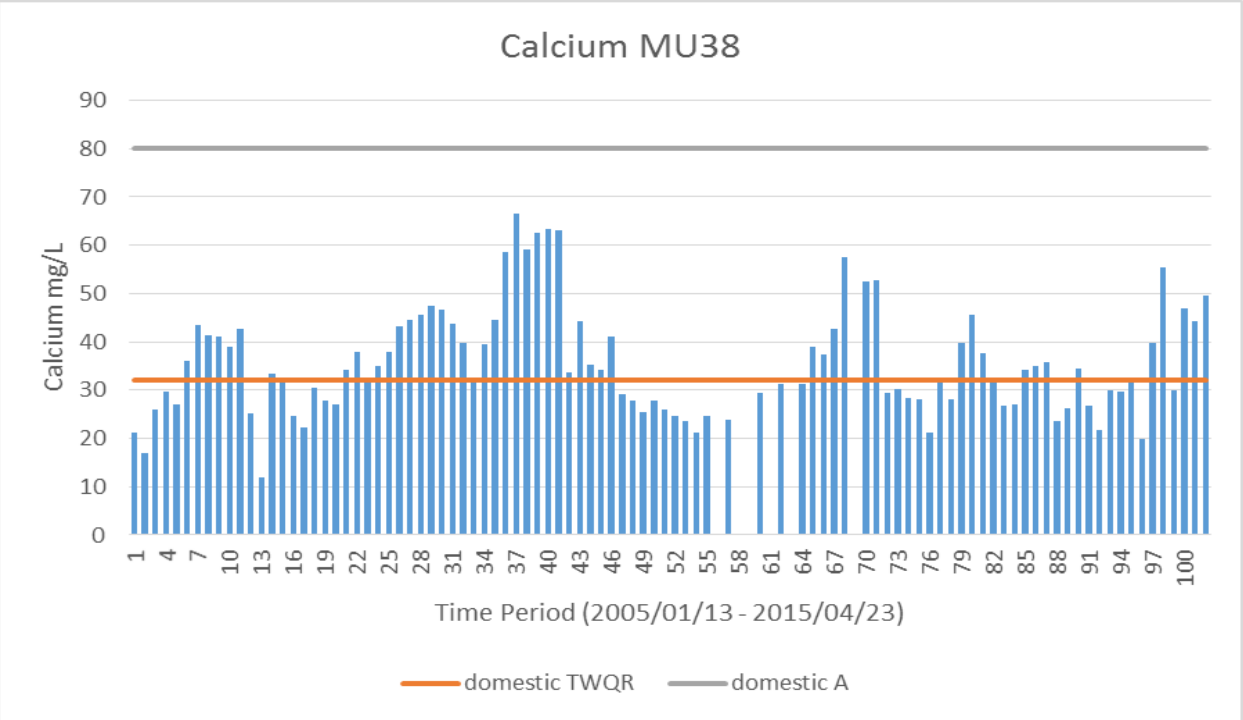
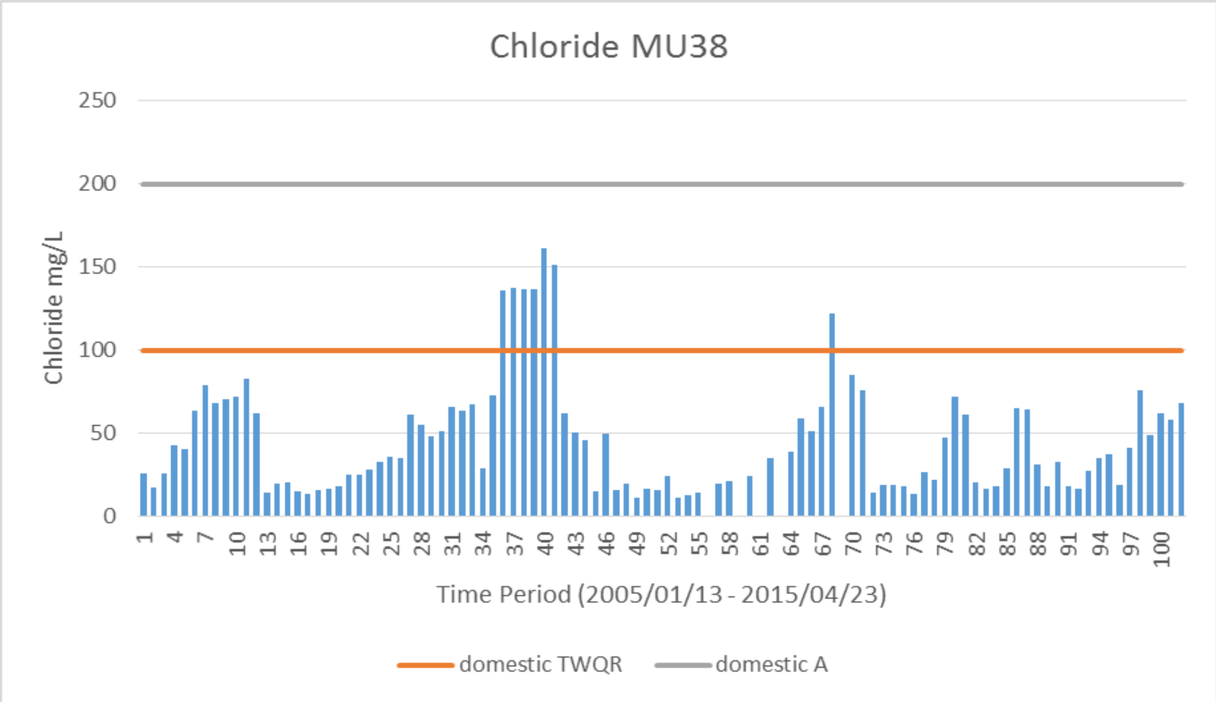
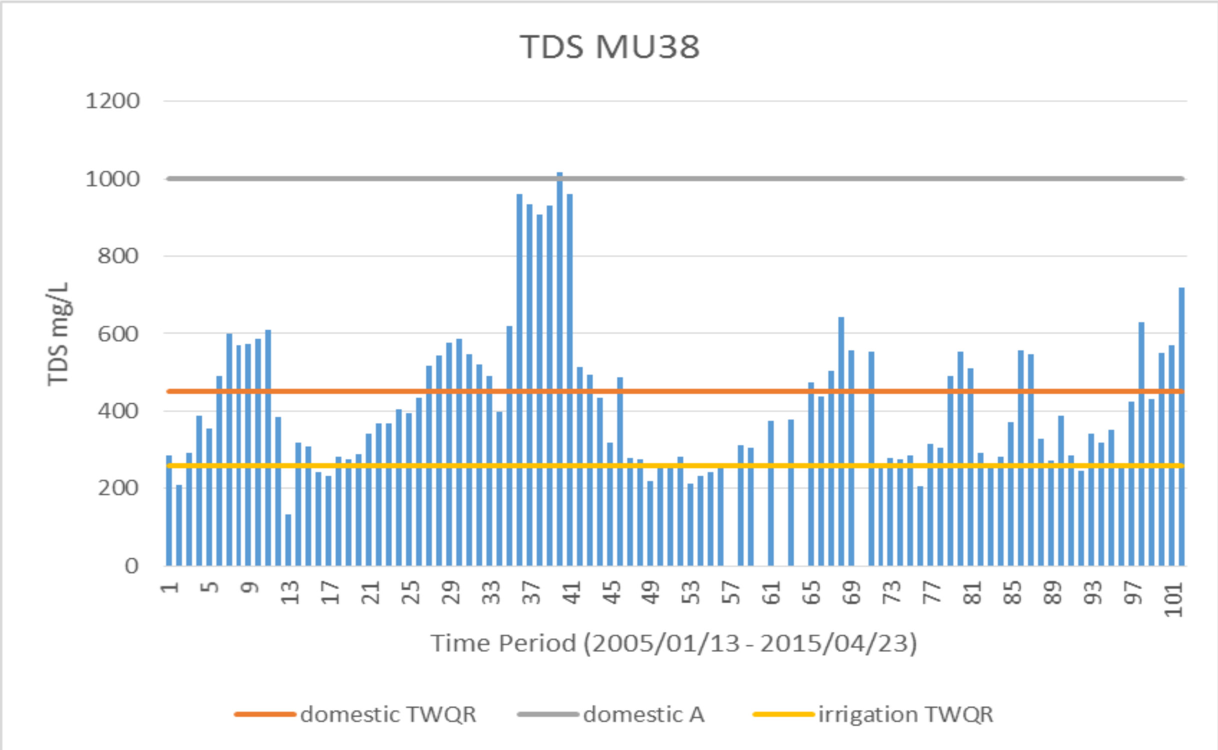
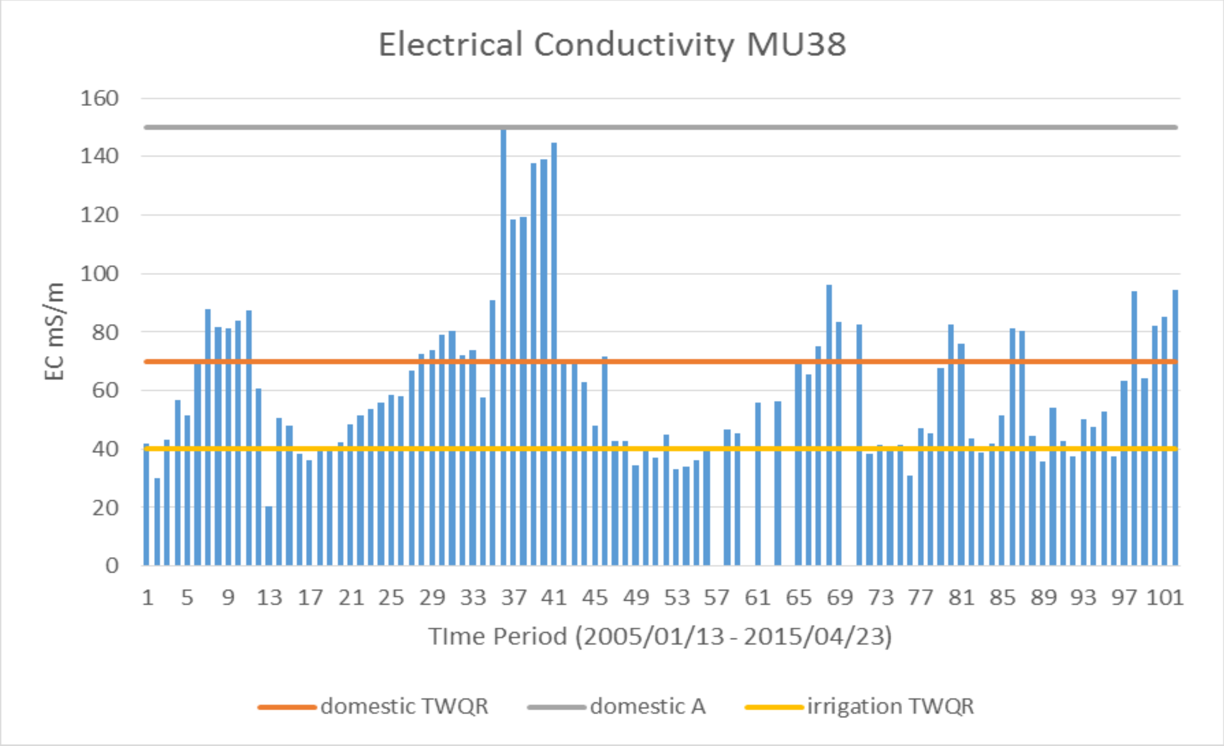
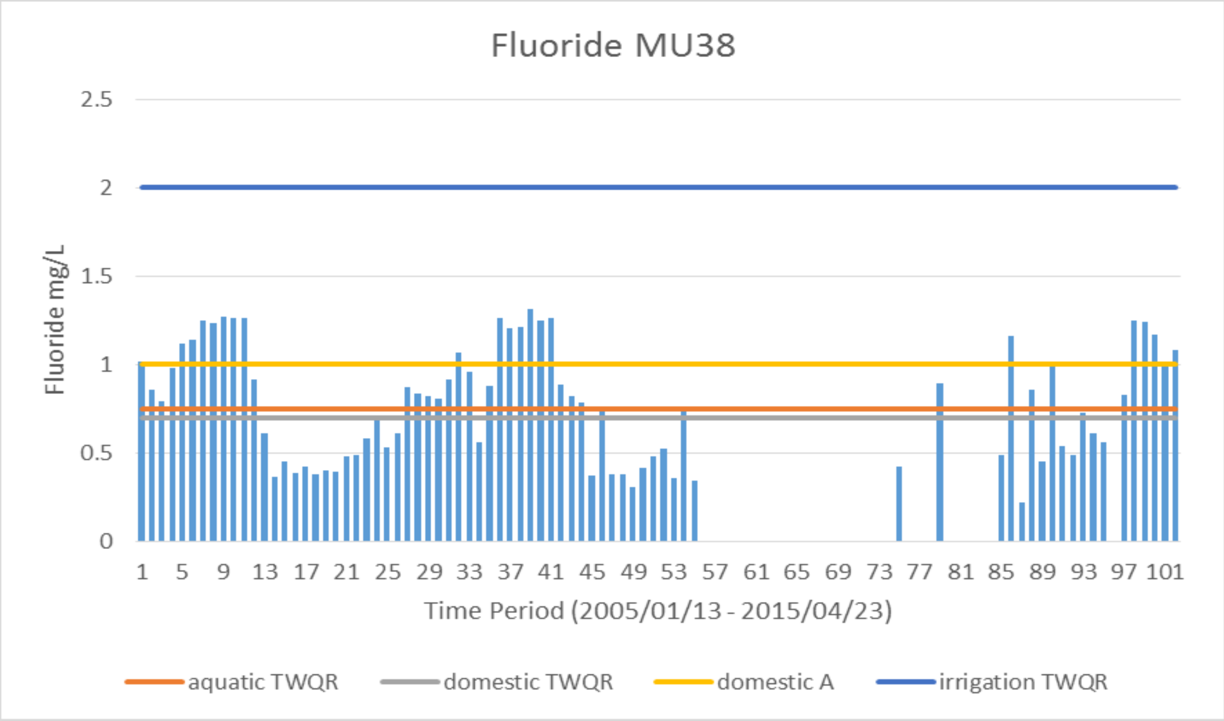
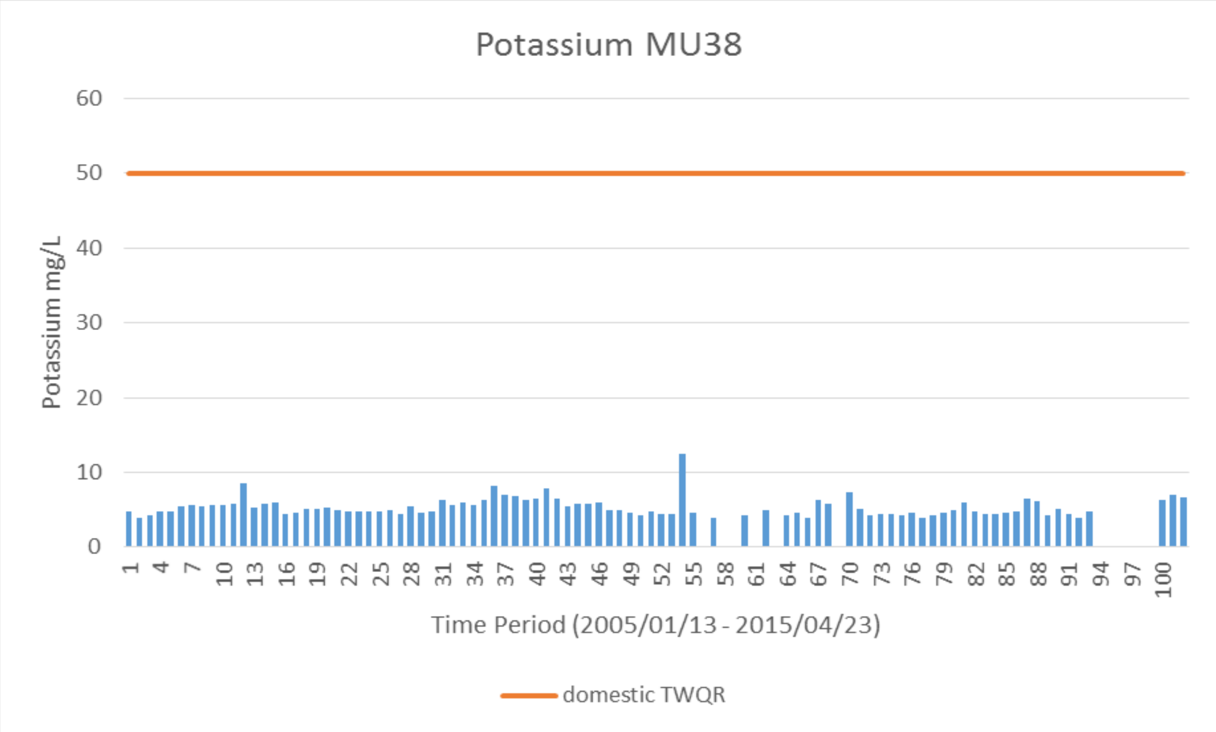


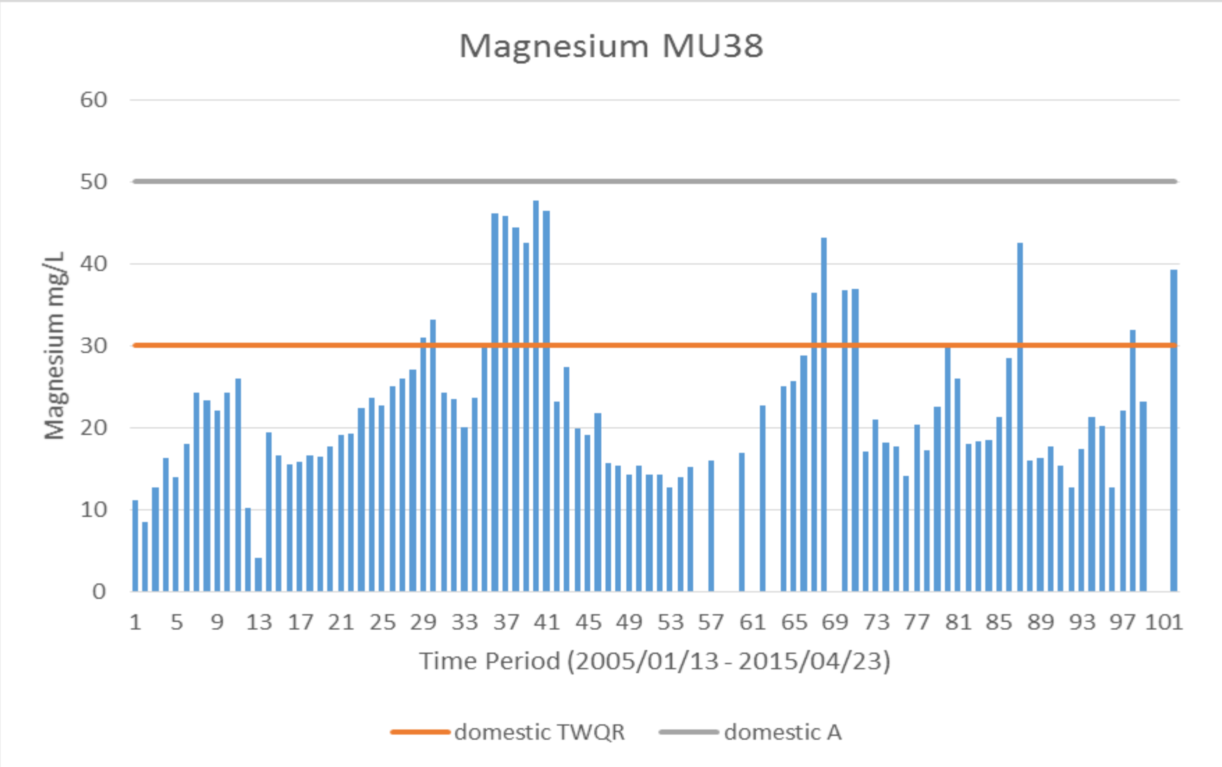

Chloride MU38
250
200
150
100
50
0
Chloride mg/L
Time Period (2005/01/13 - 2015/04/23)
domestic TWQR
domestic A


TDS MU38
1200
1000
800
600
400
200
0
TDS mg/L
Time Period (2005/01/13 - 2015/04/23)
domestic TWQR
domestic A
irrigation TWQR

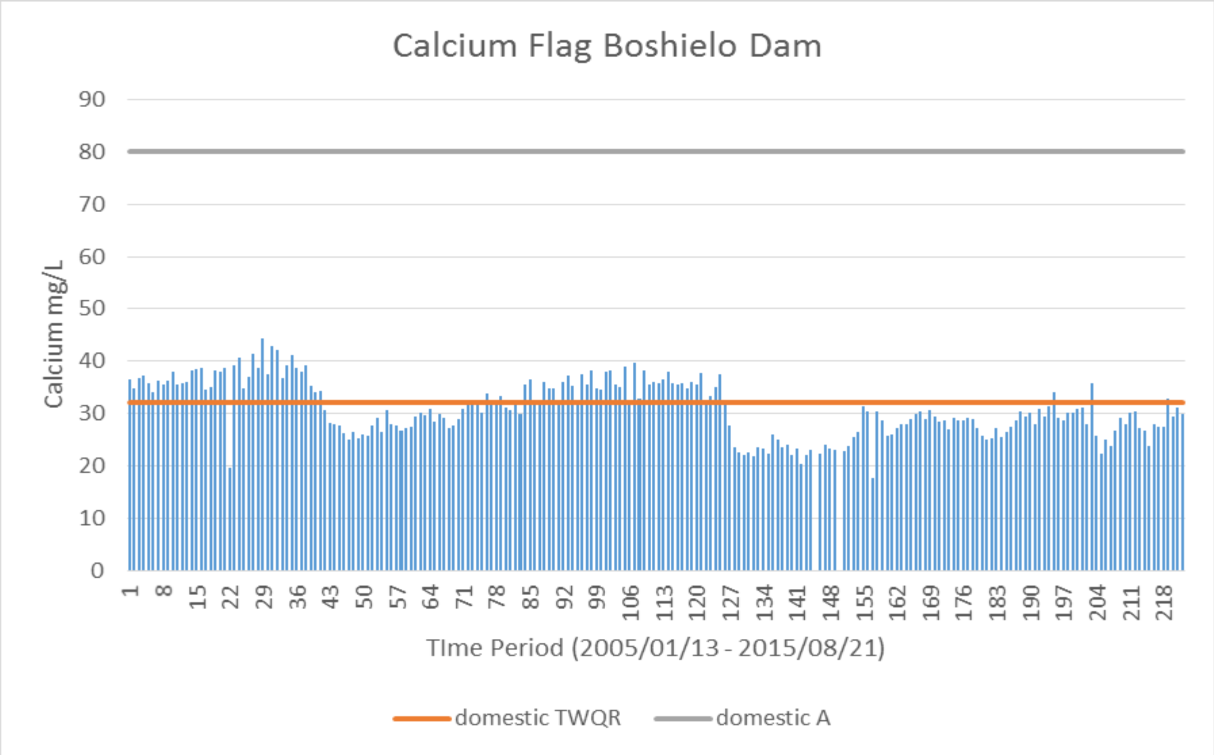

Electrical Conductivity MU38
EC mS/m
0
20
40
60
80
100
120
140
160
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101
TIme Period (2005/01/13 - 2015/04/23)
domestic TWQR
domestic A
irrigation TWQR

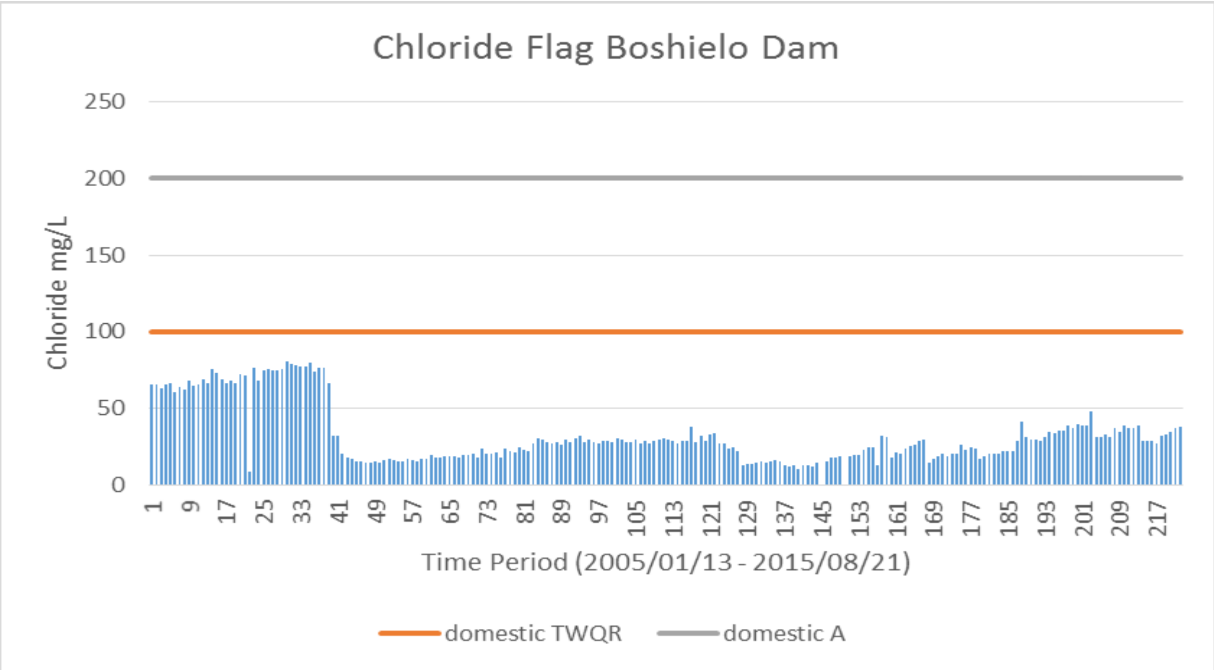

Fluoride MU38
Fluoride mg/L
0
0.5
1
1.5
2
2.5
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101
Time Period (2005/01/13 - 2015/04/23)
aquatic TWQR
domestic TWQR
domestic A
irrigation TWQR

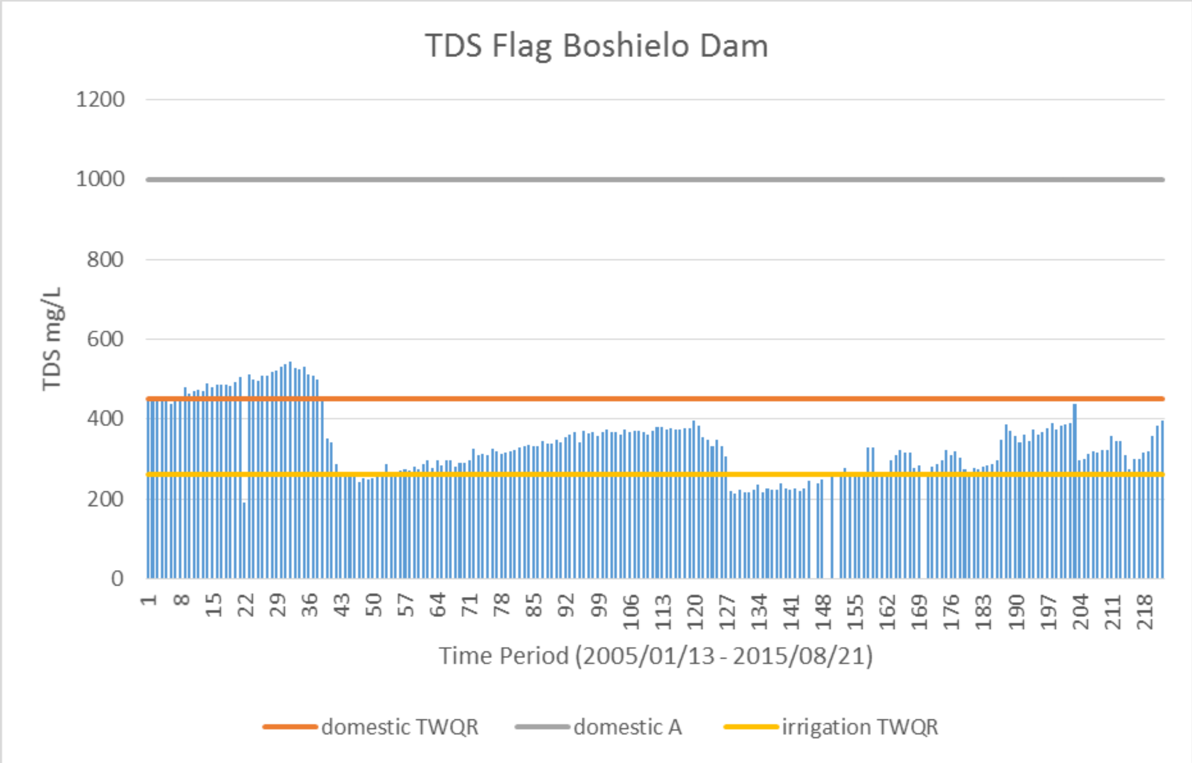

Potassium MU38
Potassium mg/L
0
10
20
30
40
50
60
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
Time Period (2005/01/13 - 2015/04/23)
domestic TWQR

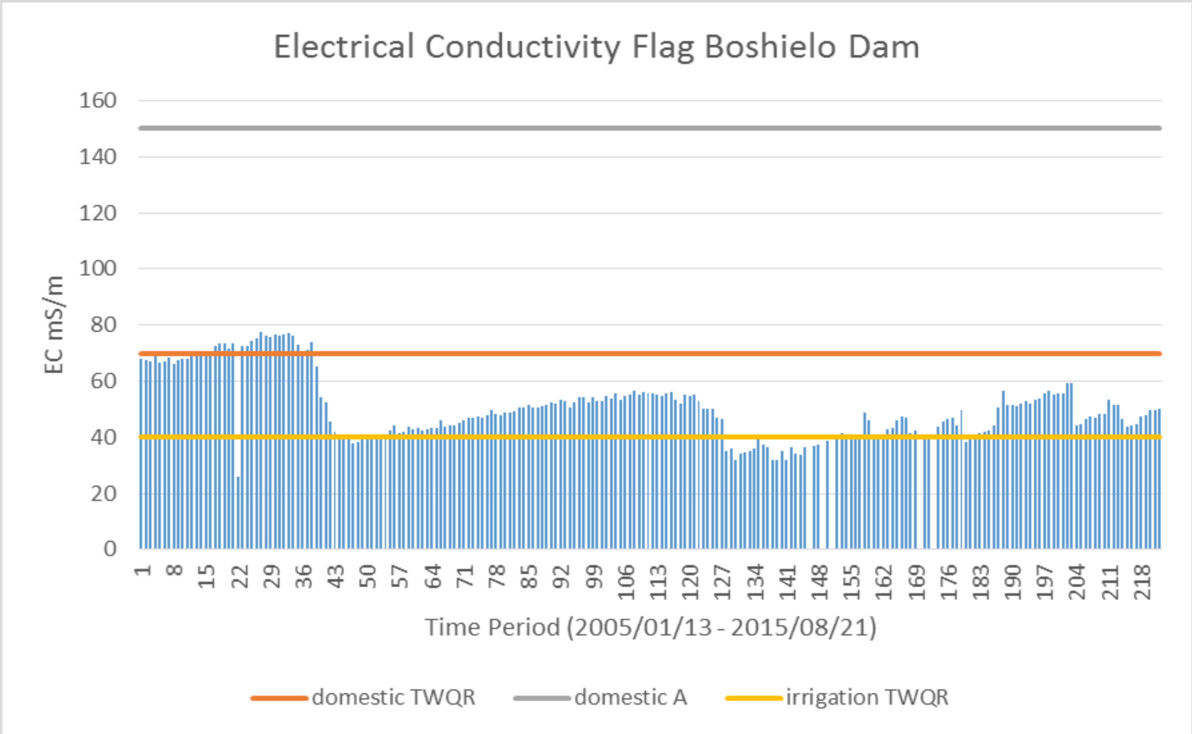

Magnesium MU38
Magnesium mg/L
0
10
20
30
40
50
60
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
Time Period (2005/01/13 - 2015/04/23)
domestic TWQR
domestic A

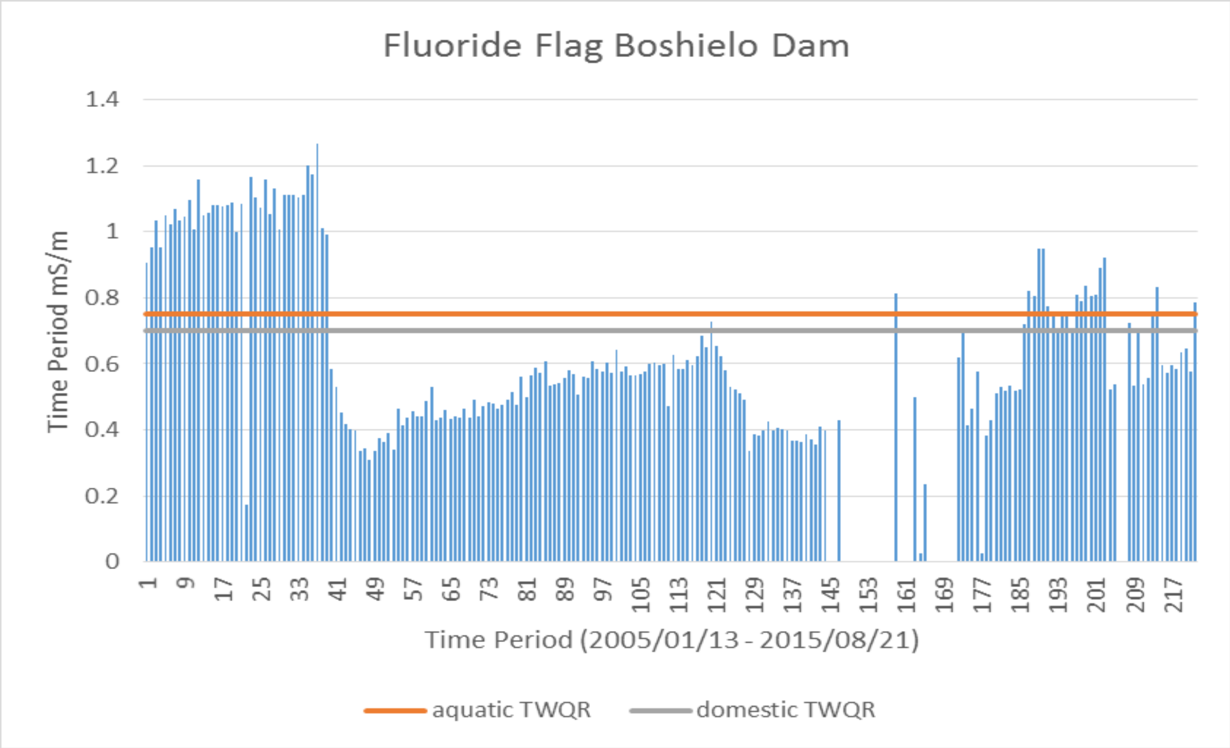
Flag Boshielo Dam

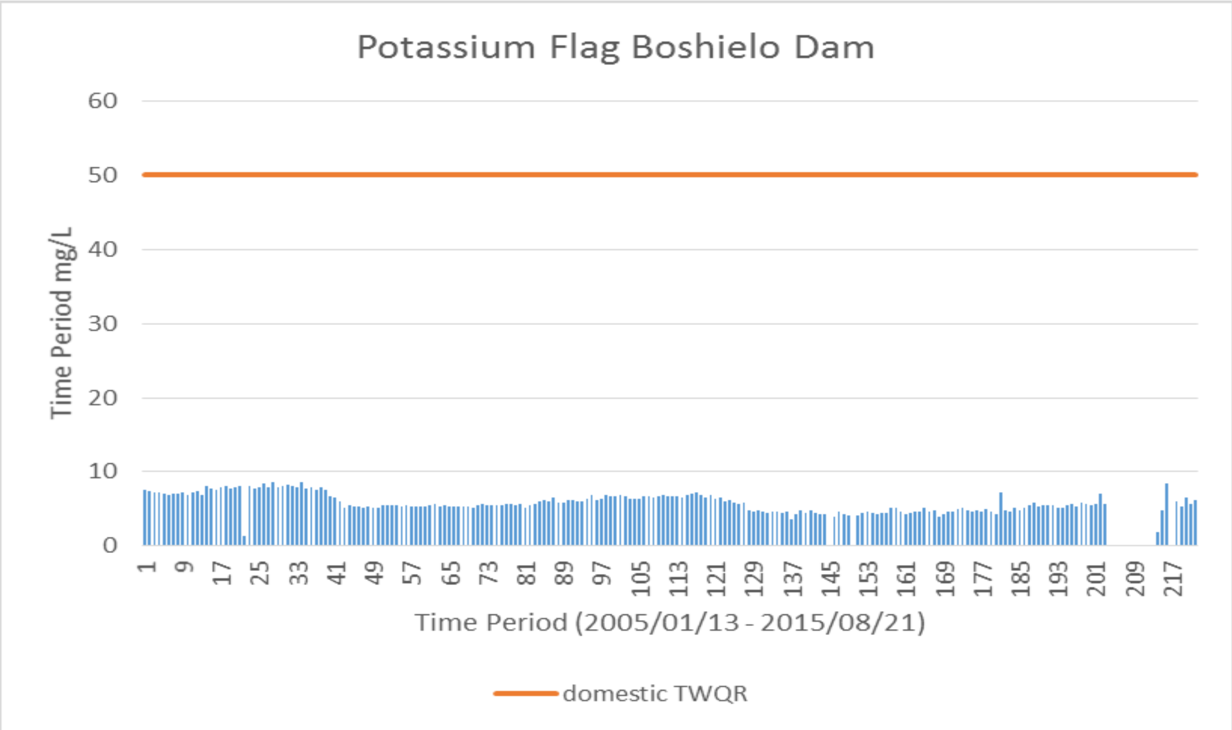


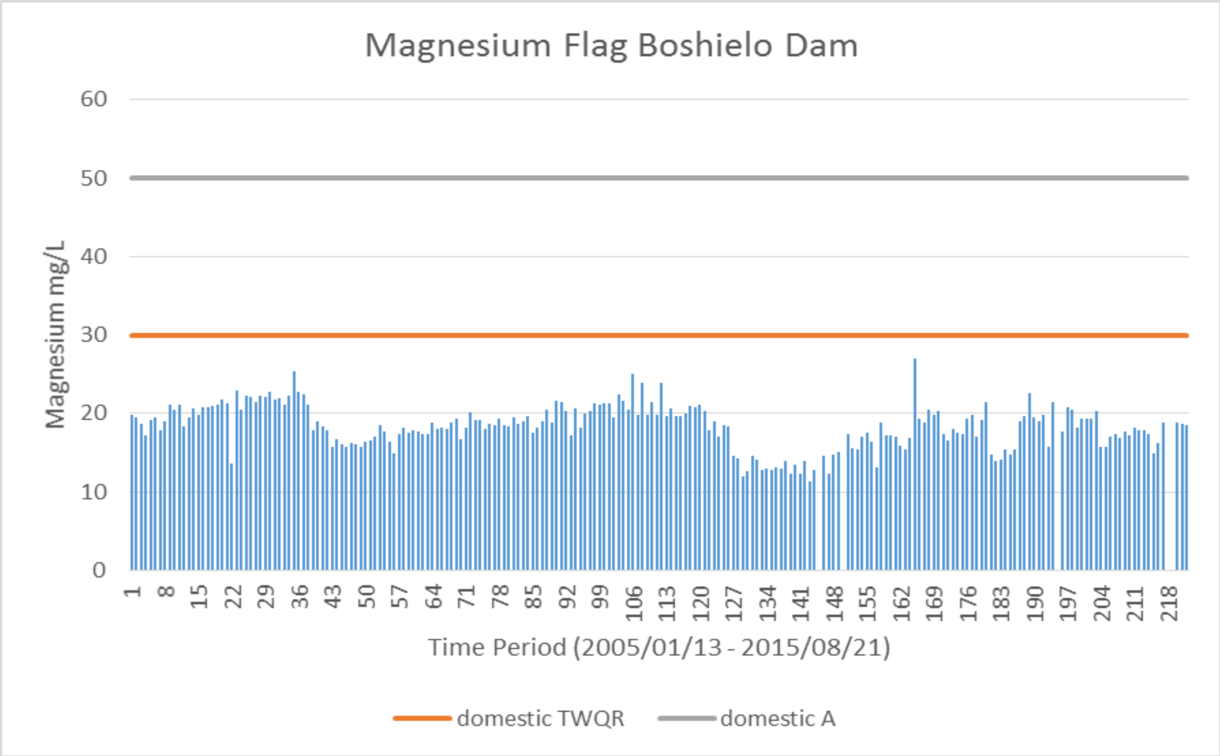


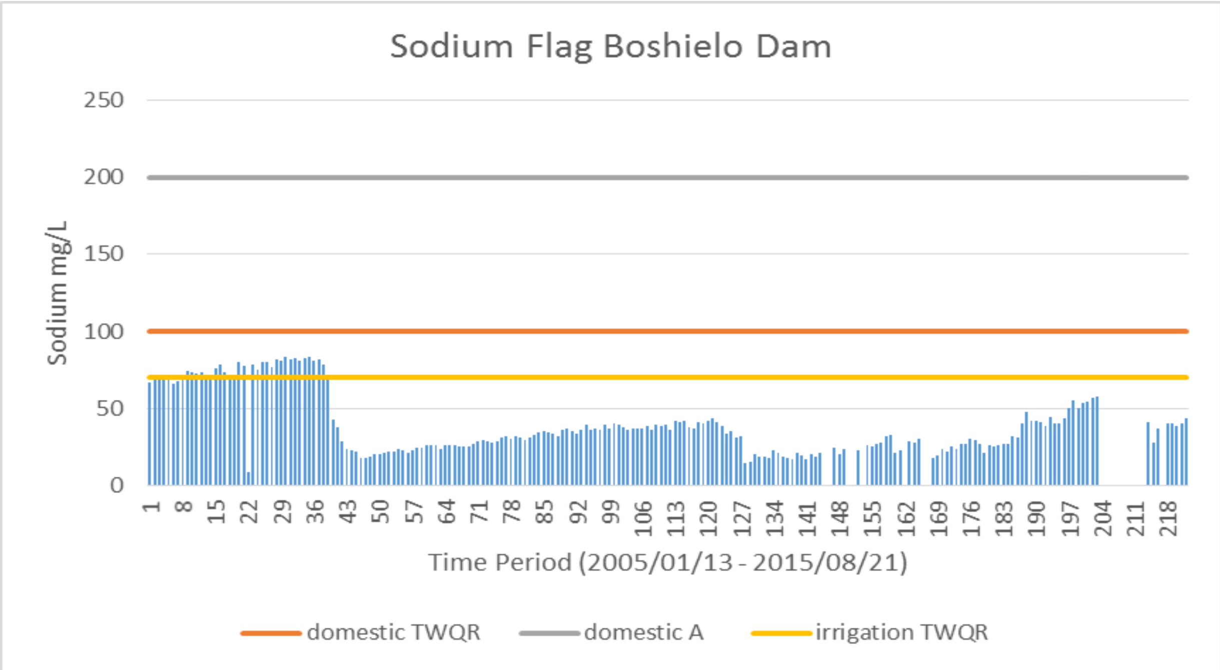

TDS Flag Boshielo Dam
TDS mg/L
1200
1000
800
600
400
200
0
1
8
15
22
29
36
43
50
57
64
71
78
85
92
99
106
113
120
127
134
141
148
155
162
169
176
183
190
197
204
211
218
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR
domestic A
irrigation TWQR

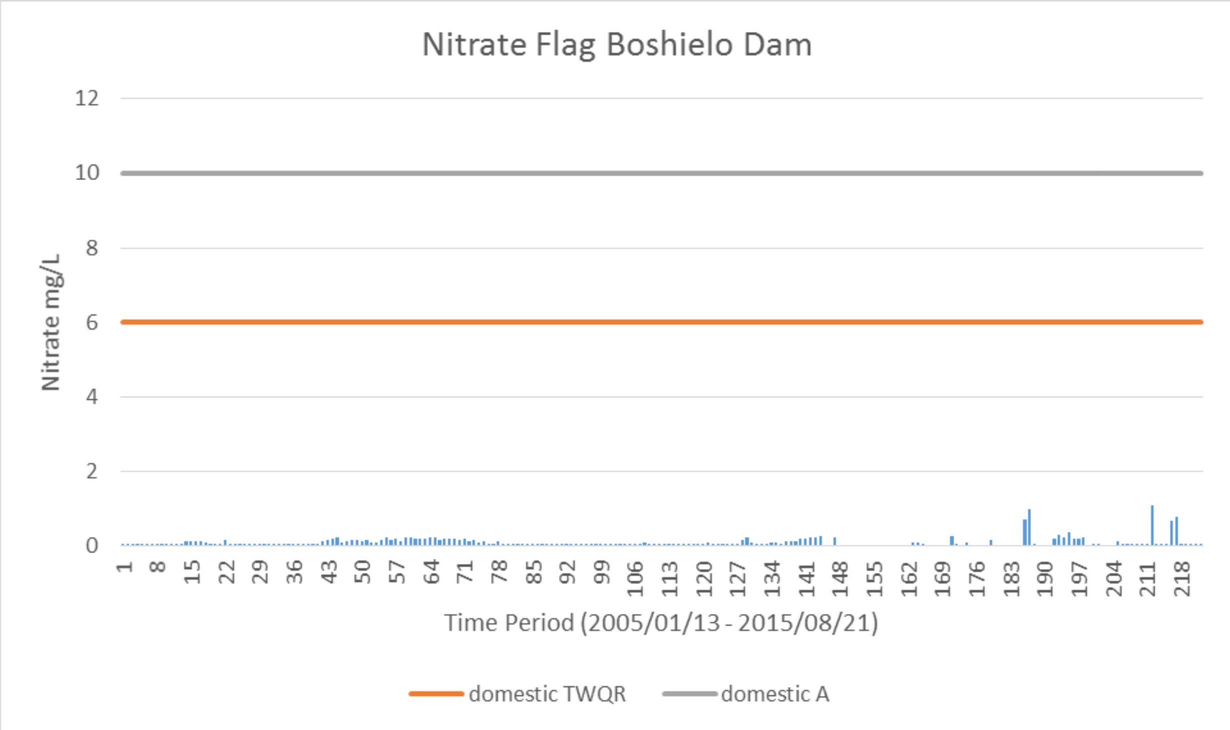

Electrical Conductivity Flag Boshielo Dam
EC mS/m
160
140
120
100
80
60
40
20
0
1
8
15
22
29
36
43
50
57
64
71
78
85
92
99
106
113
120
127
134
141
148
155
162
169
176
183
190
197
204
211
218
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR
domestic A
irrigation TWQR


Fluoride Flag Boshielo Dam
Time Period mS/m
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Time Period (2005/01/13 - 2015/08/21)
aquatic TWQR
domestic TWQR


Potassium Flag Boshielo Dam
Time Period mg/L
60
50
40
30
20
10
0
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR


Magnesium Flag Boshielo Dam
Magnesium mg/L
0
10
20
30
40
50
60
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR
domestic A


Sodium Flag Boshielo Dam
Sodium mg/L
0
50
100
150
200
250
Time Period (2005/01/13 - 2015/08/21)
domestic TWQR
domestic A
irrigation TWQR



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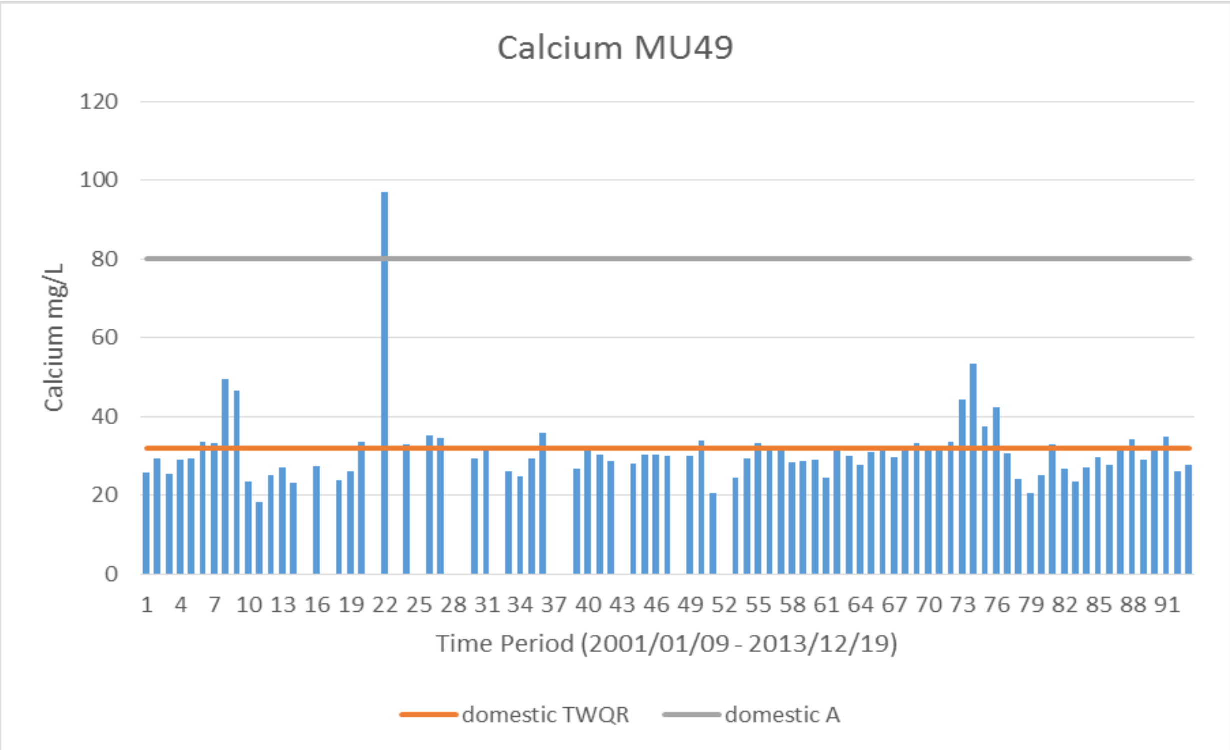
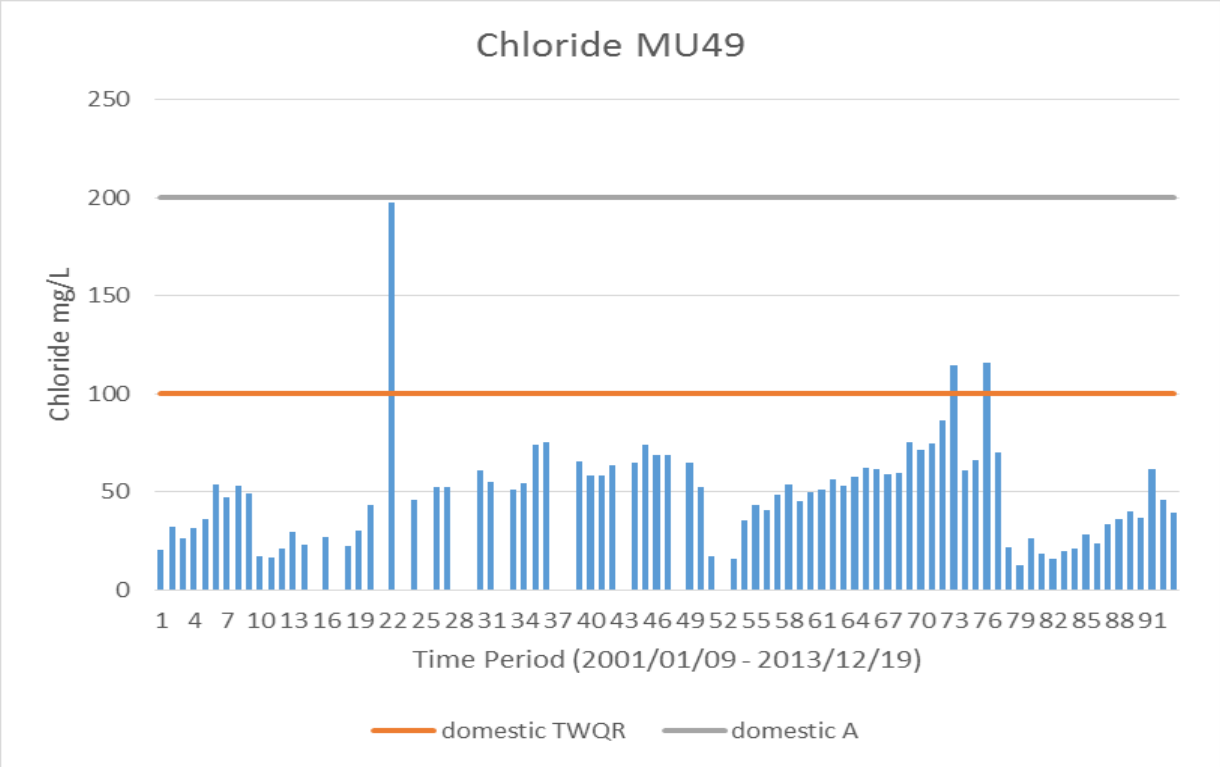
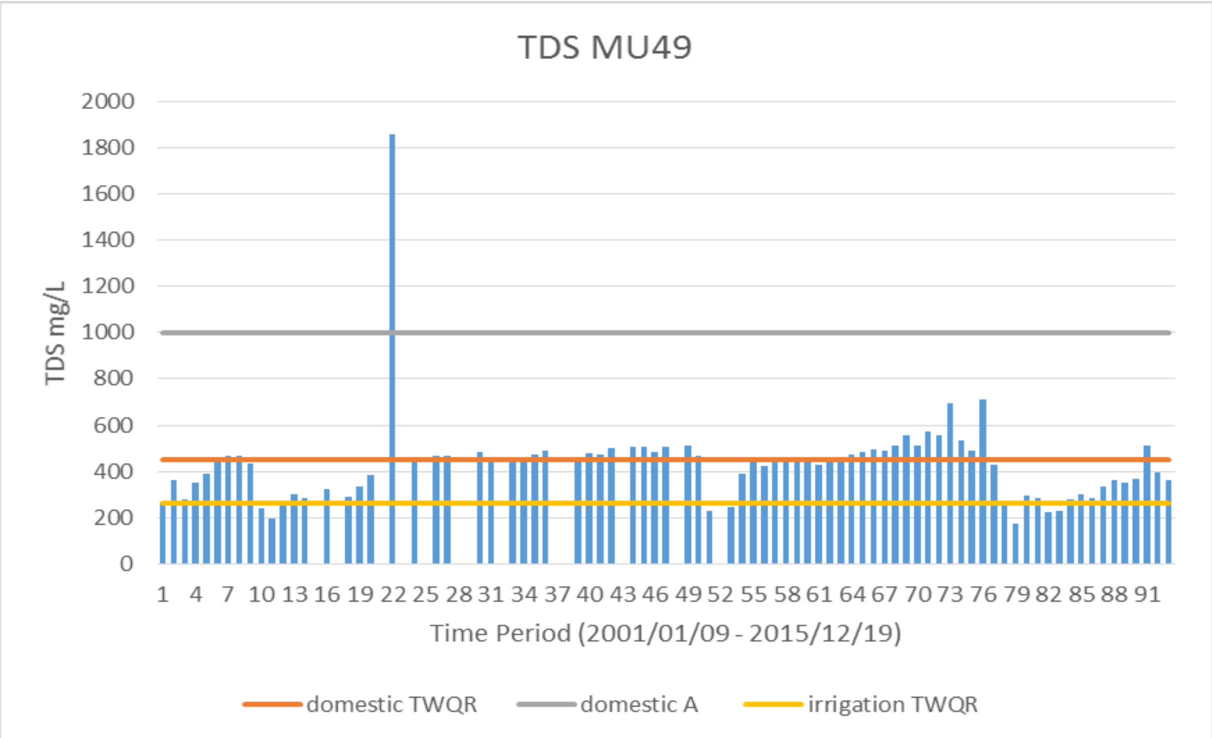
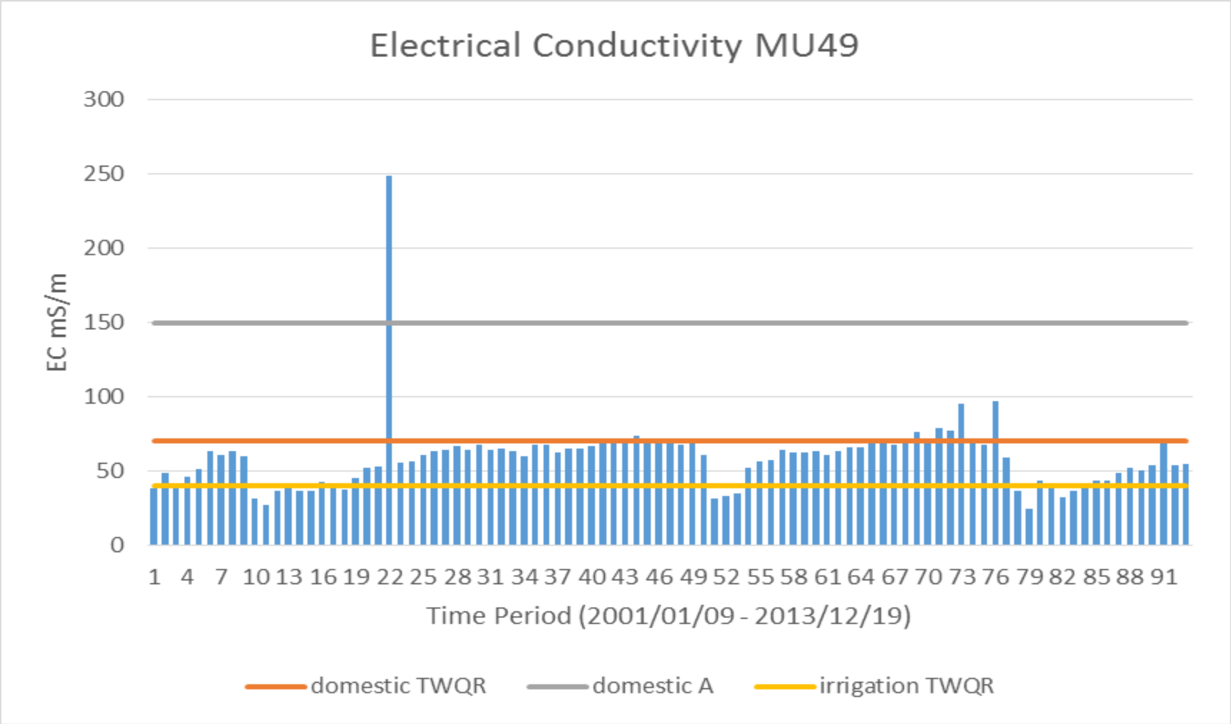
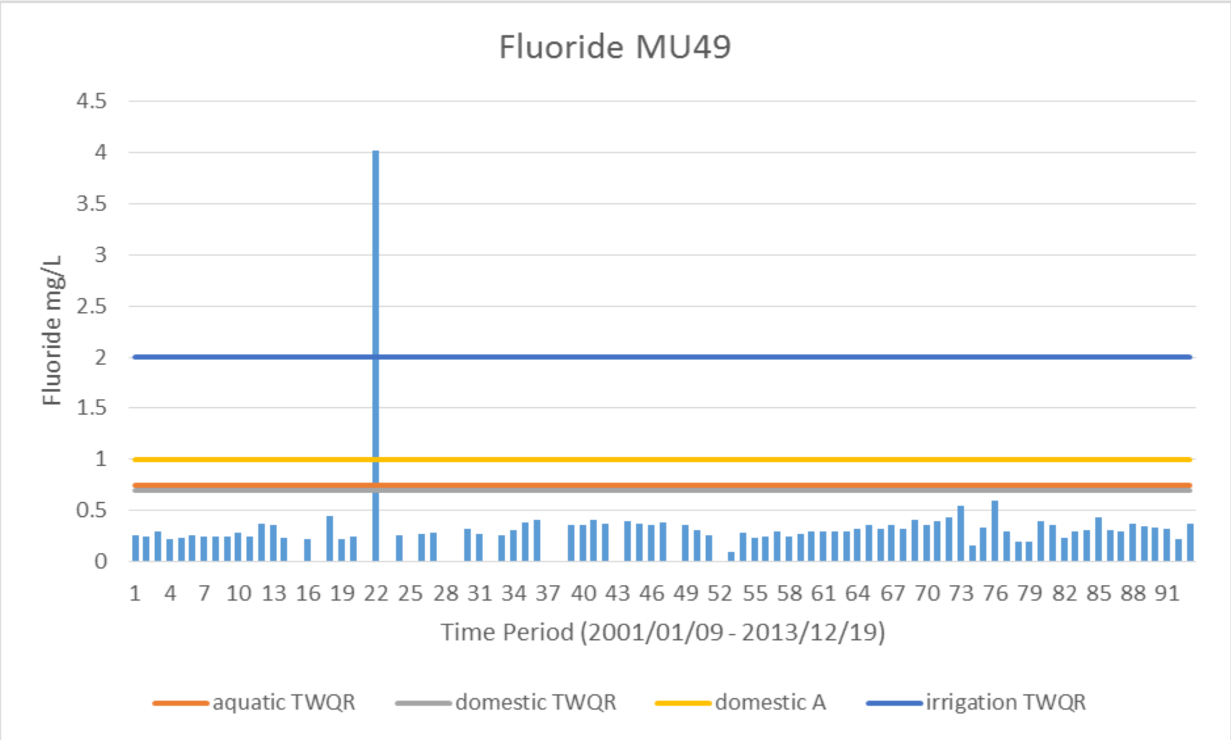
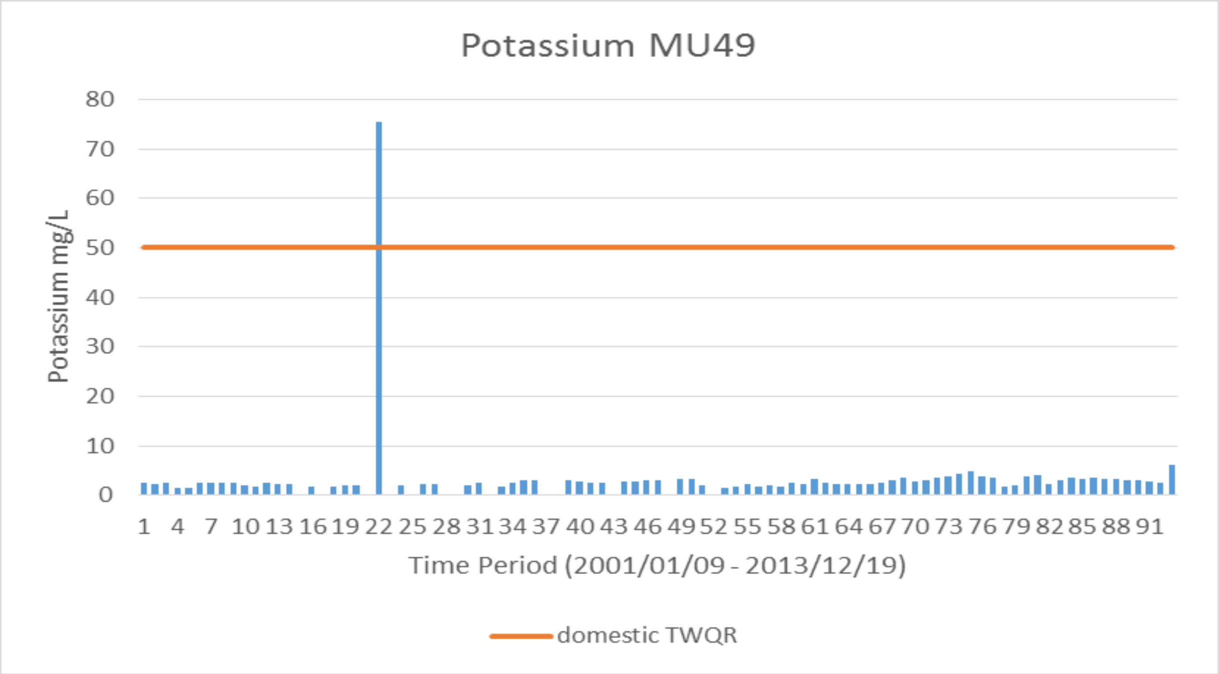


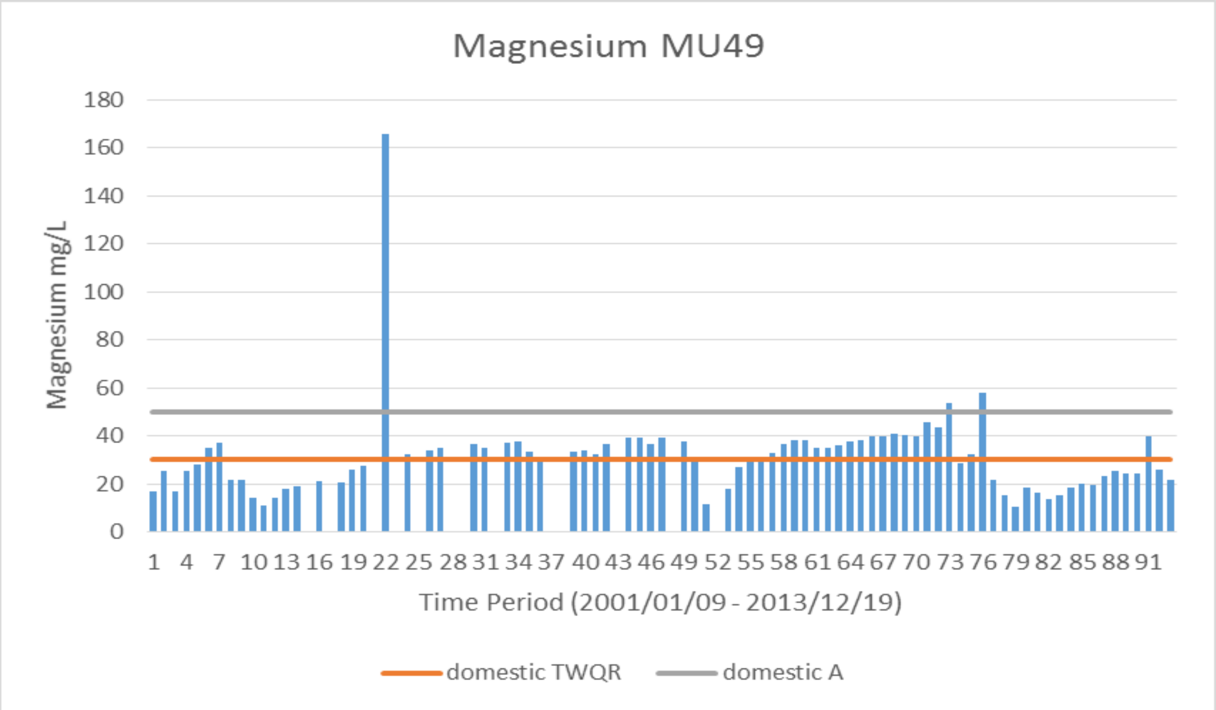

Chloride MU49
250
200
150
100
50
0
Chloride mg/L
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91
Time Period (2001/01/09 - 2013/12/19)
domestic TWQR
domestic A

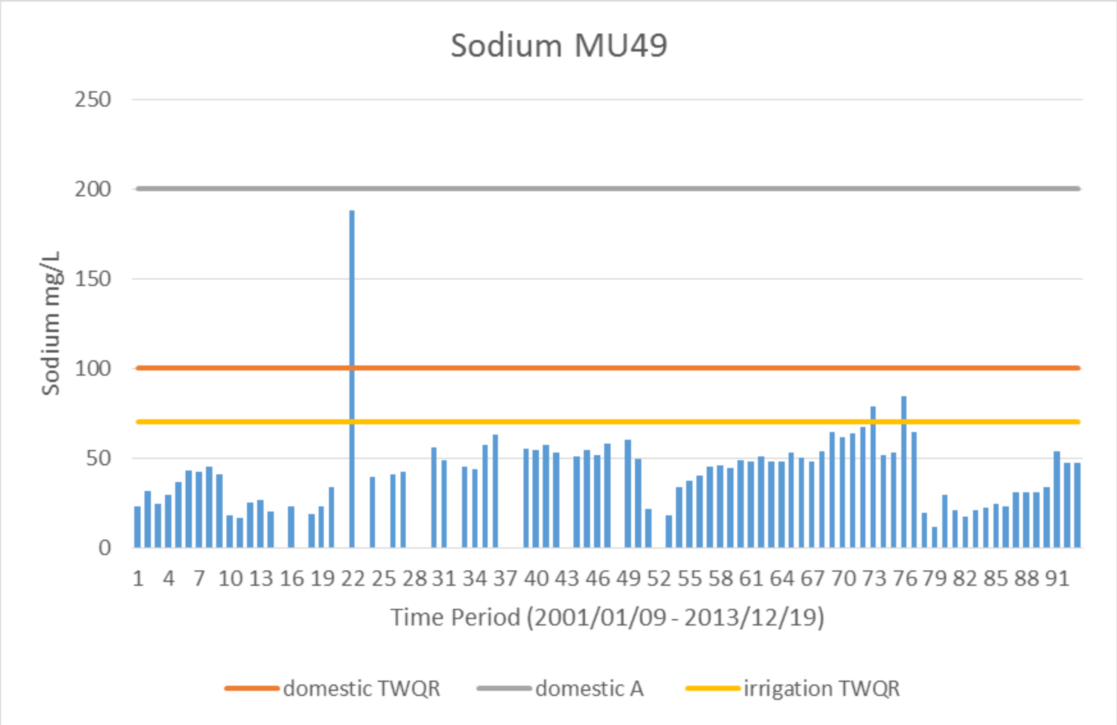

TDS MU49
2000
1800
1600
1400
1200
1000
800
600
400
200
0
TDS mg/L
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91
Time Period (2001/01/09 - 2015/12/19)
domestic TWQR
domestic A
irrigation TWQR

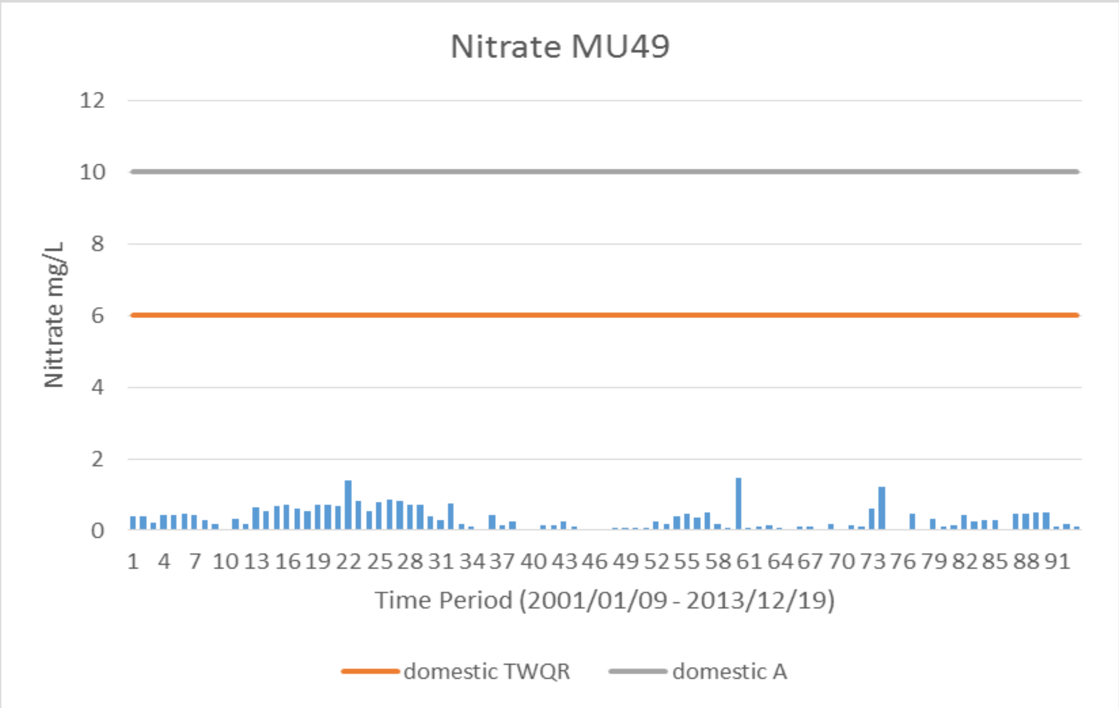

Electrical Conductivity MU49
EC mS/m
300
250
200
150
100
50
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91
Time Period (2001/01/09 - 2013/12/19)
domestic TWQR
domestic A
irrigation TWQR

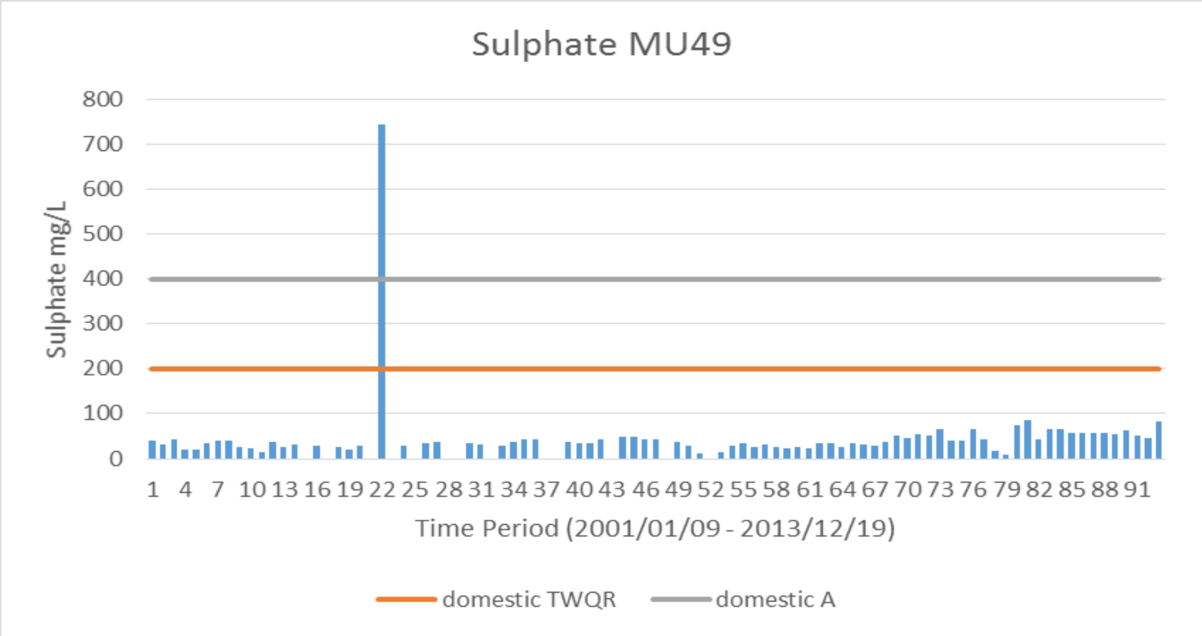

Fluoride MU49
Fluoride mg/L
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91
Time Period (2001/01/09 - 2013/12/19)
aquatic TWQR
domestic TWQR
domestic A
irrigation TWQR


Potassium MU49
Potassium mg/L
80
70
60
50
40
30
20
10
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91
Time Period (2001/01/09 - 2013/12/19)
domestic TWQR

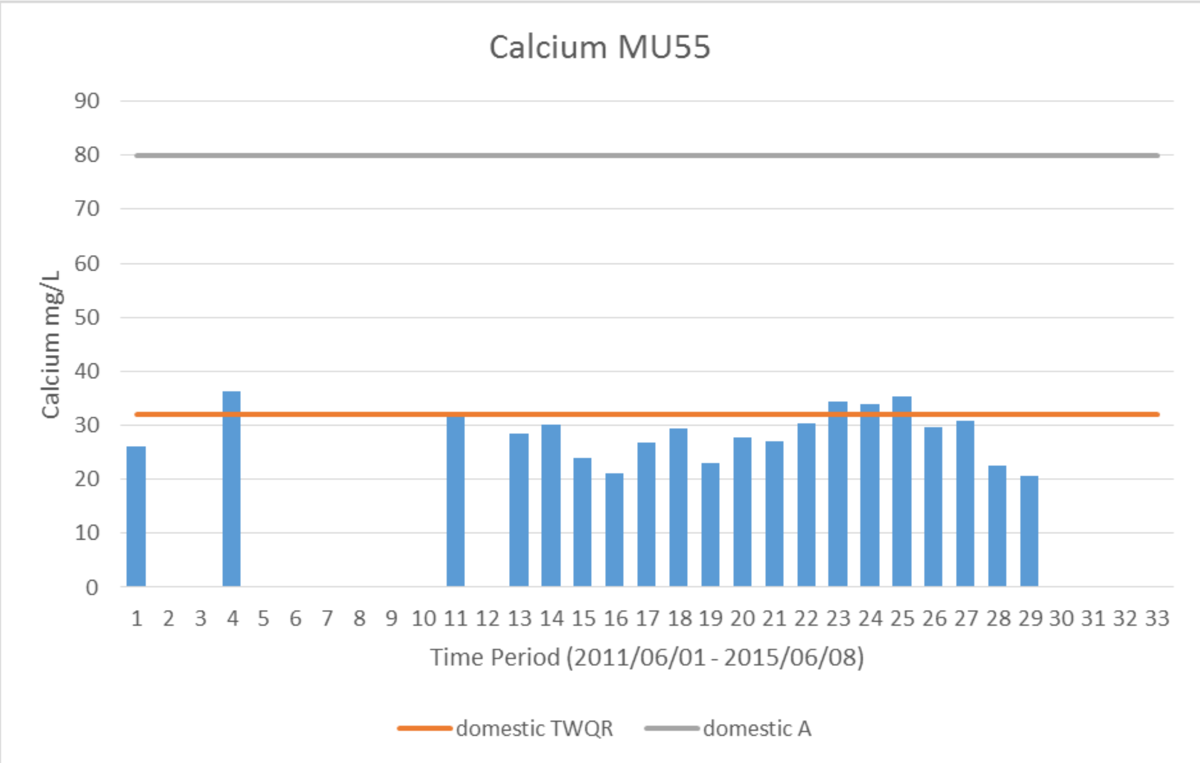

Magnesium MU49
Magnesium mg/L
180
160
140
120
100
80
60
40
20
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91
Time Period (2001/01/09 - 2013/12/19)
domestic TWQR
domestic A

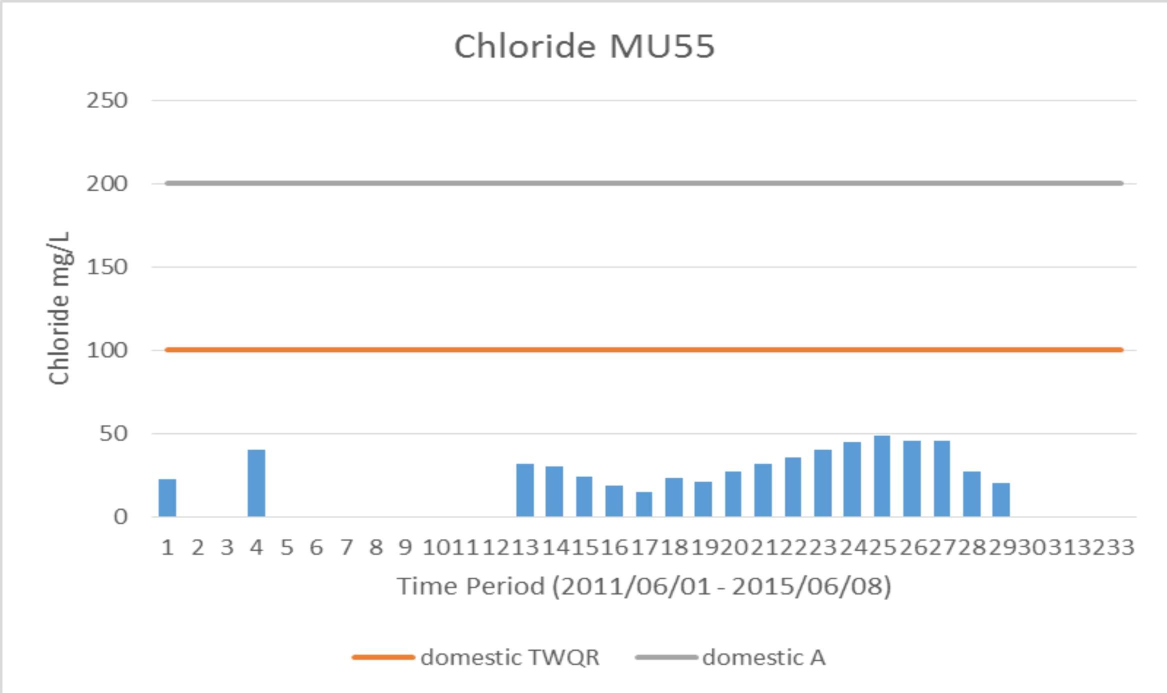

Sodium MU49
250
200
150
100
50
0
Sodium mg/L
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91
Time Period (2001/01/09 - 2013/12/19)
domestic TWQR
domestic A
irrigation TWQR

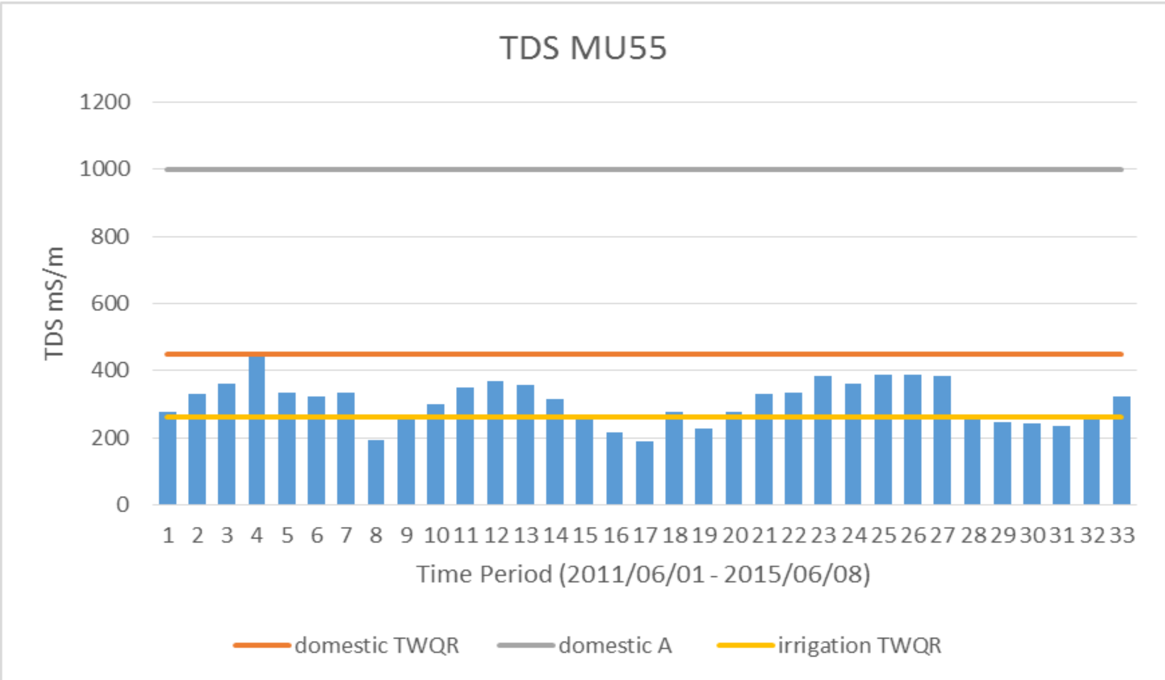

Nitrate MU49
12
10
8
6
4
2
0
Nittrate mg/L
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91
Time Period (2001/01/09 - 2013/12/19)
domestic TWQR
domestic A

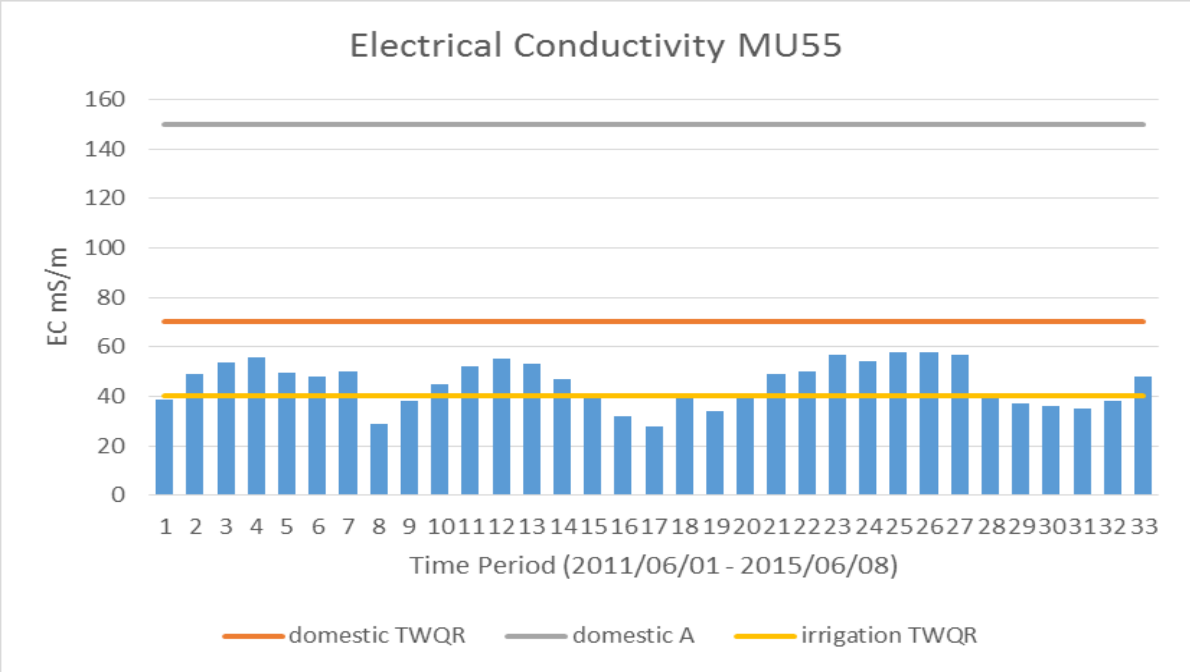


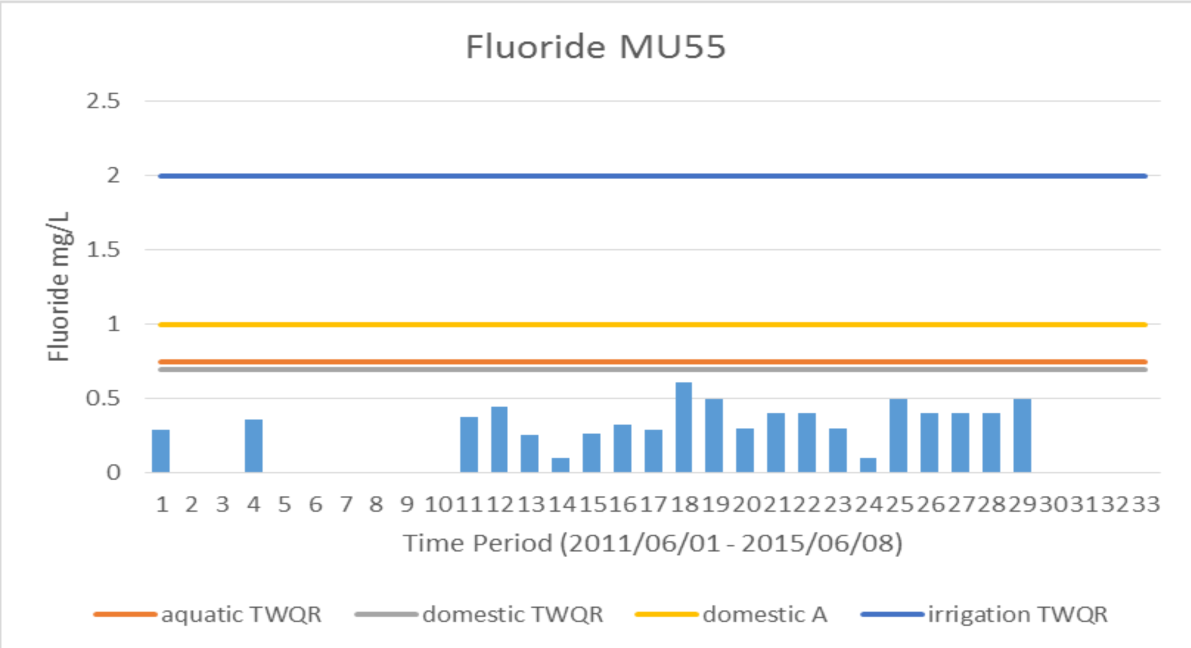
Management Unit 55

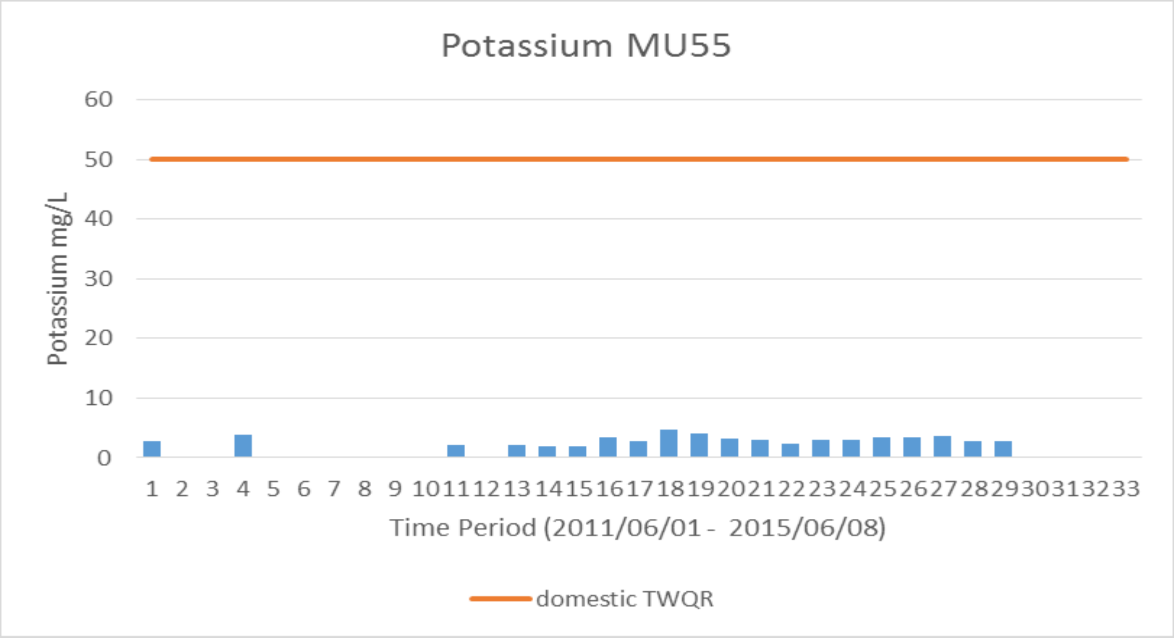


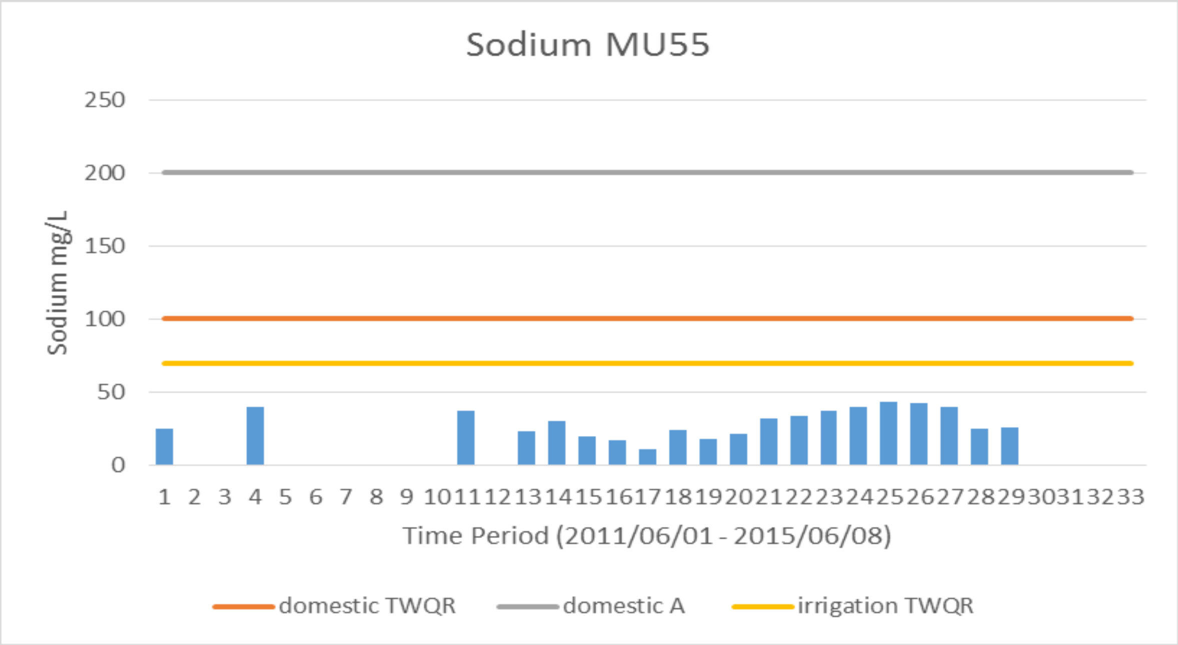

Chloride MU55
Chloride mg/L
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Time Period (2011/06/01 - 2015/06/08)
domestic TWQR
domestic A

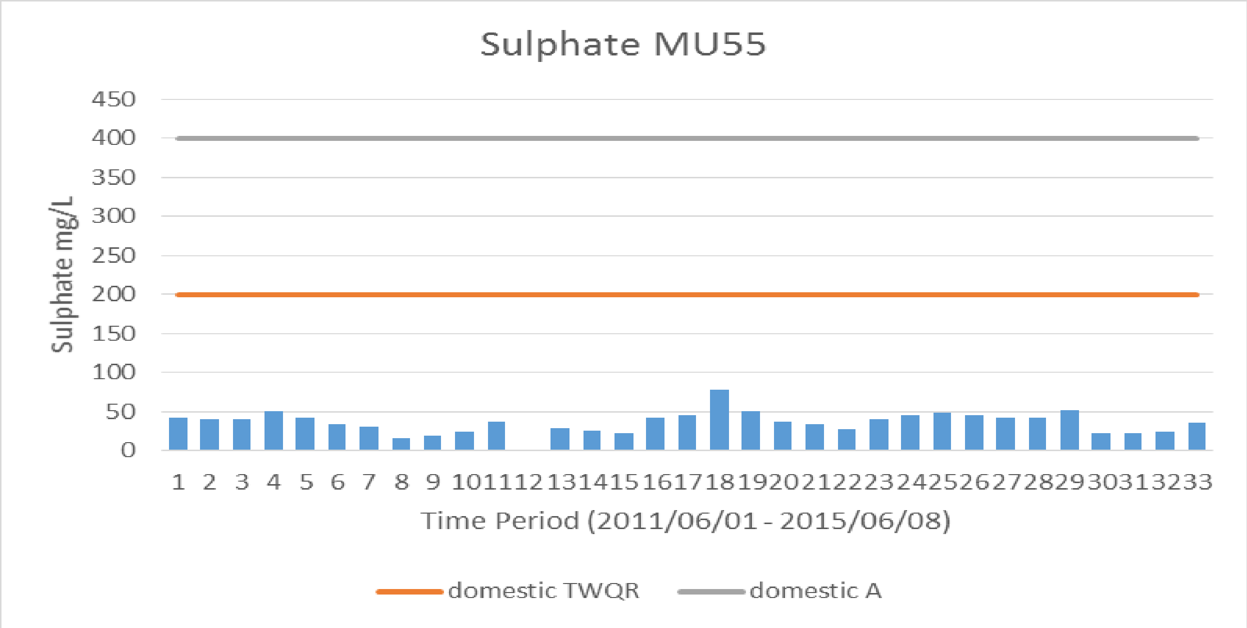

TDS MU55
TDS mS/m
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Time Period (2011/06/01 - 2015/06/08)
domestic TWQR
domestic A
irrigation TWQR


Electrical Conductivity MU55
EC mS/m
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Time Period (2011/06/01 - 2015/06/08)
domestic TWQR
domestic A
irrigation TWQR

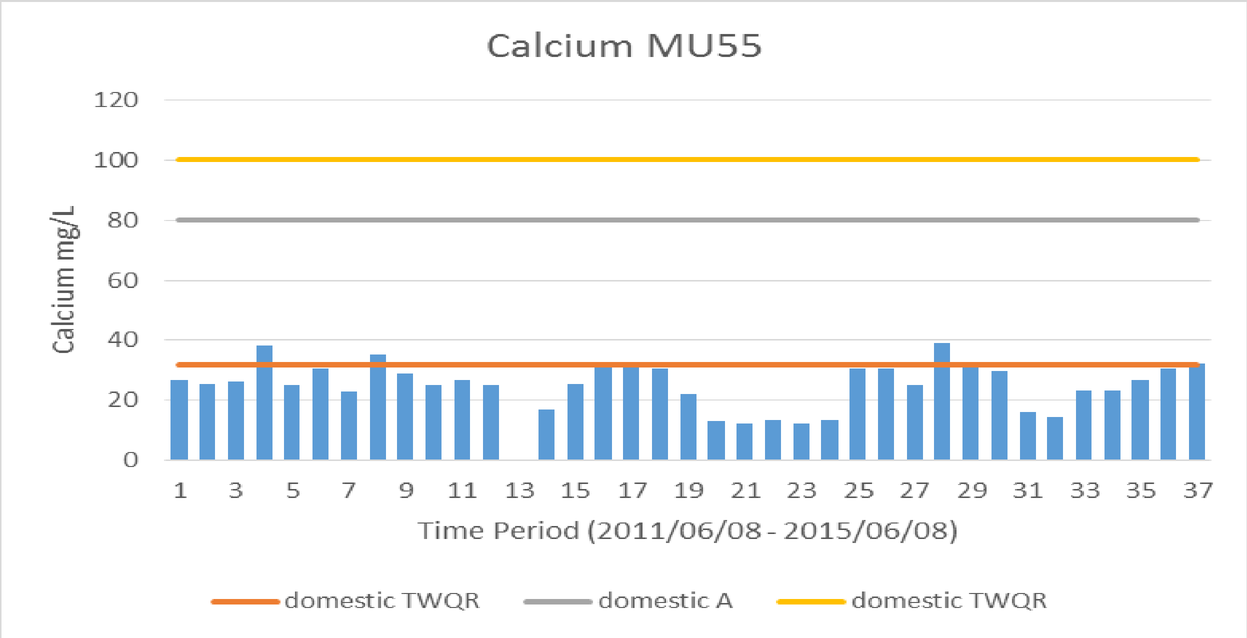

Fluoride MU55
Fluoride mg/L
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Time Period (2011/06/01 - 2015/06/08)
aquatic TWQR
domestic TWQR
domestic A
irrigation TWQR

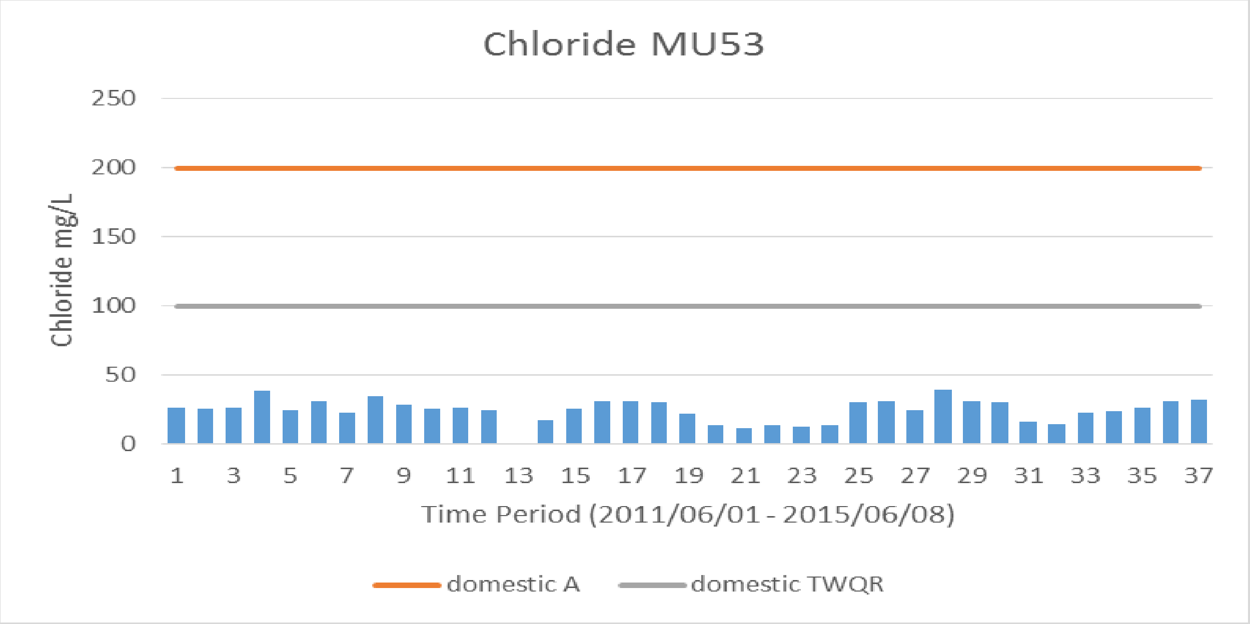

Potassium MU55
Potassium mg/L
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Time Period (2011/06/01 - 2015/06/08)
domestic TWQR

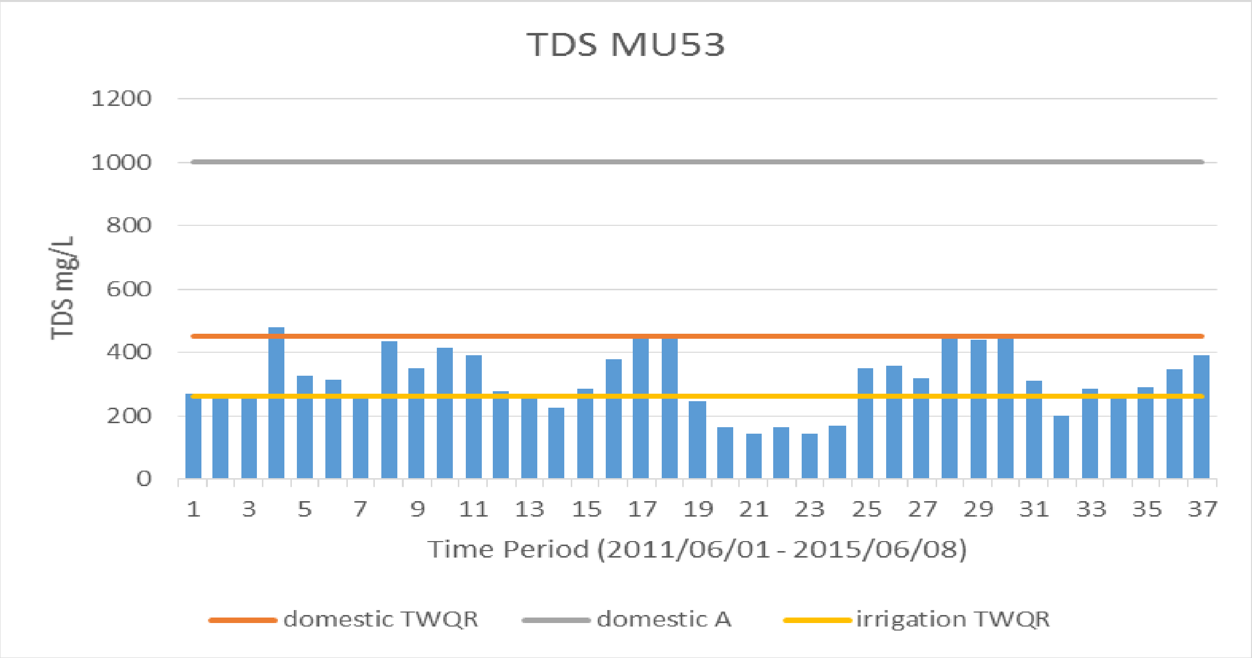

Sodium MU55
Sodium mg/L
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Time Period (2011/06/01 - 2015/06/08)
domestic TWQR
domestic A
irrigation TWQR

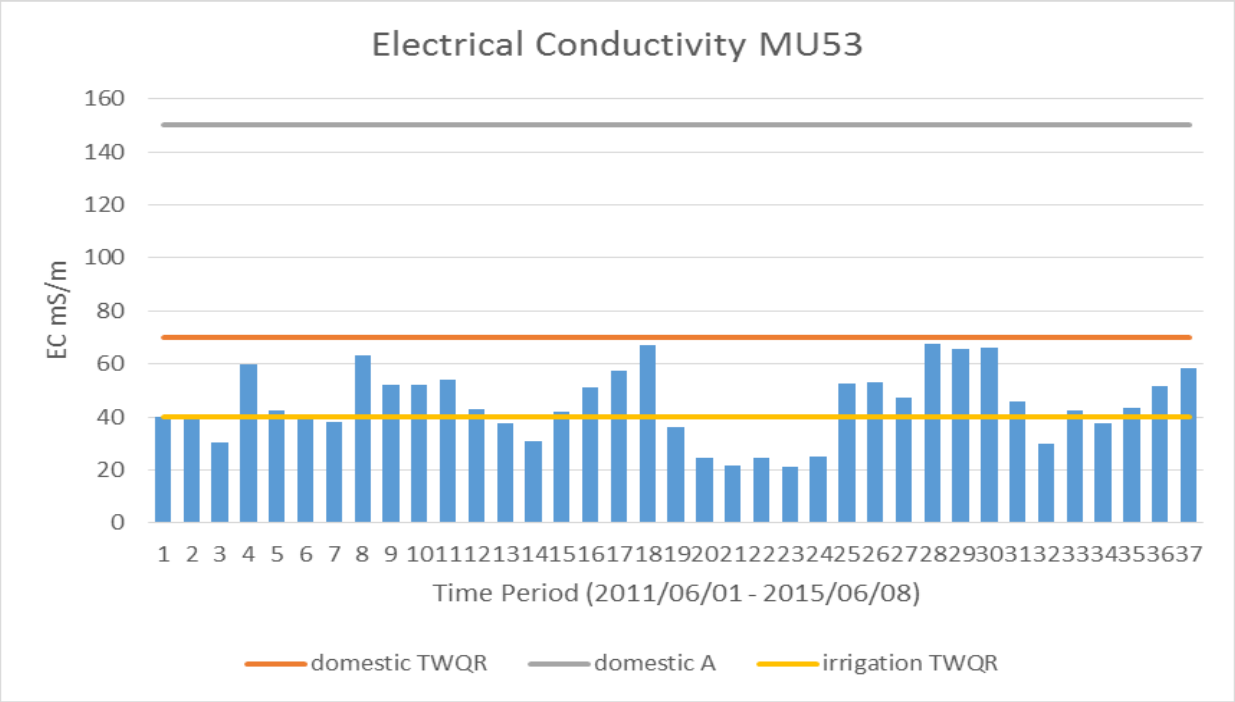


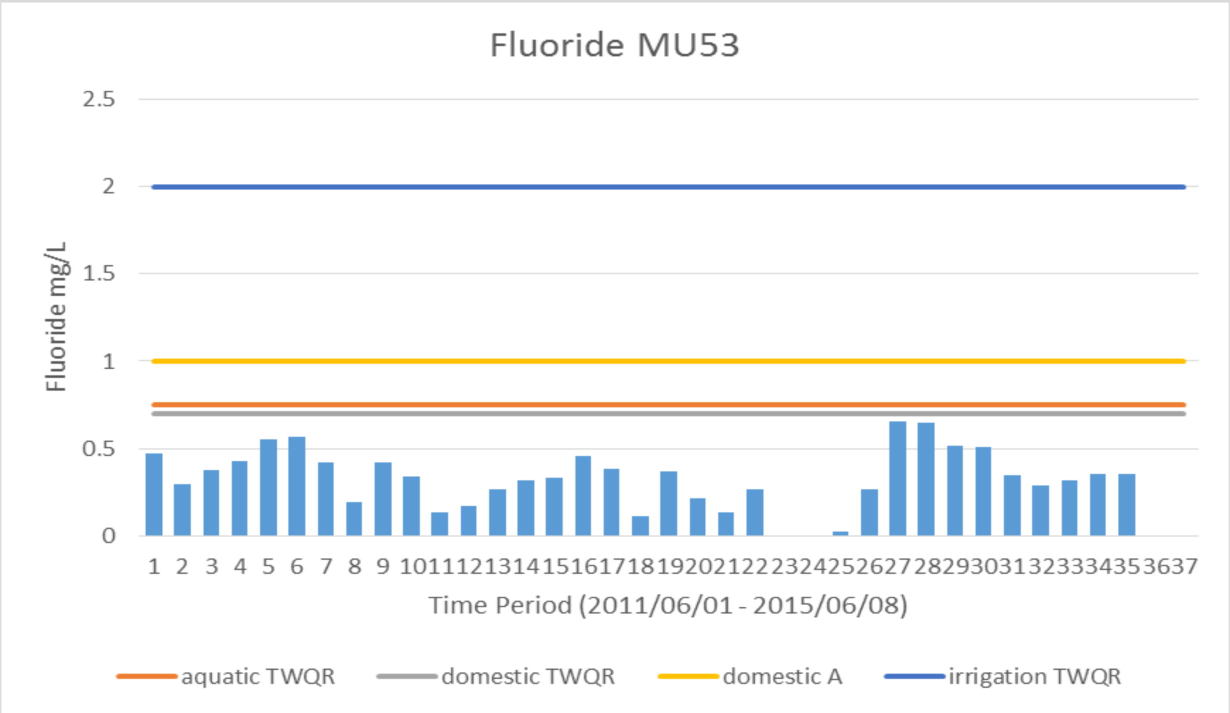
Management Unit 53

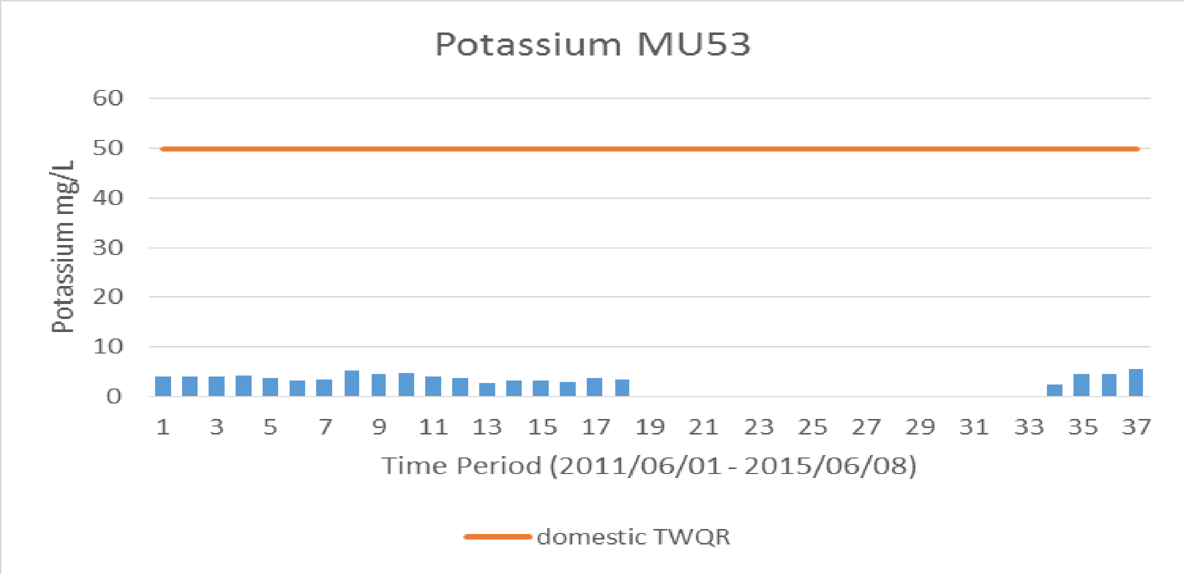


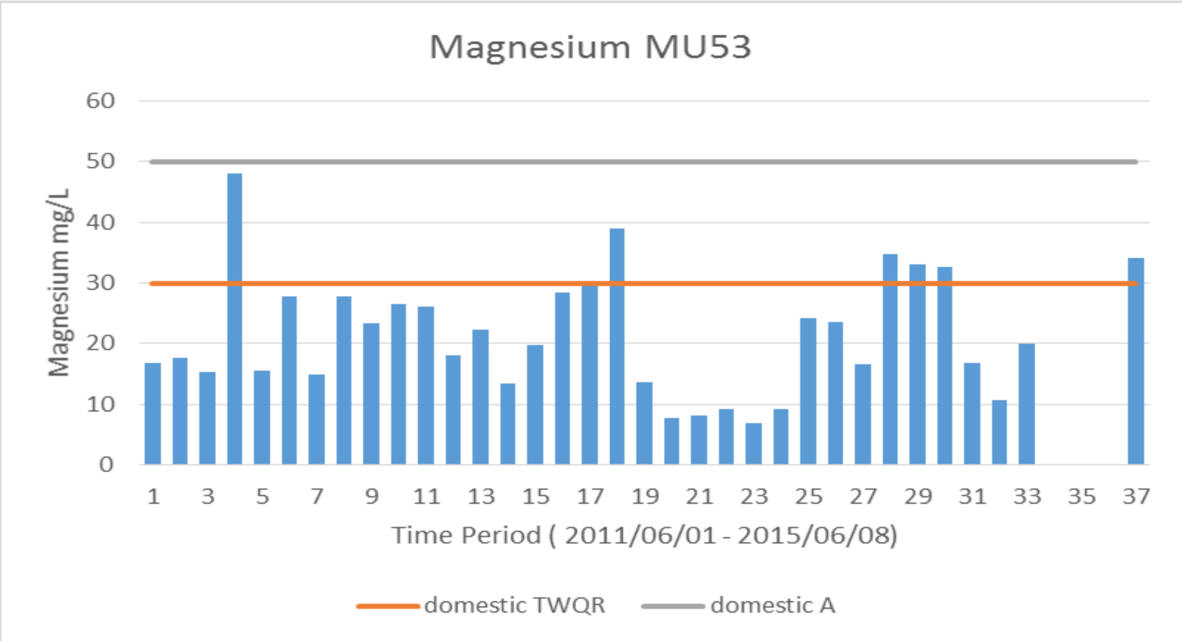

Chloride MU53
Chloride mg/L
250
200
150
100
50
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37
Time Period (2011/06/01 - 2015/06/08)
domestic A
domestic TWQR

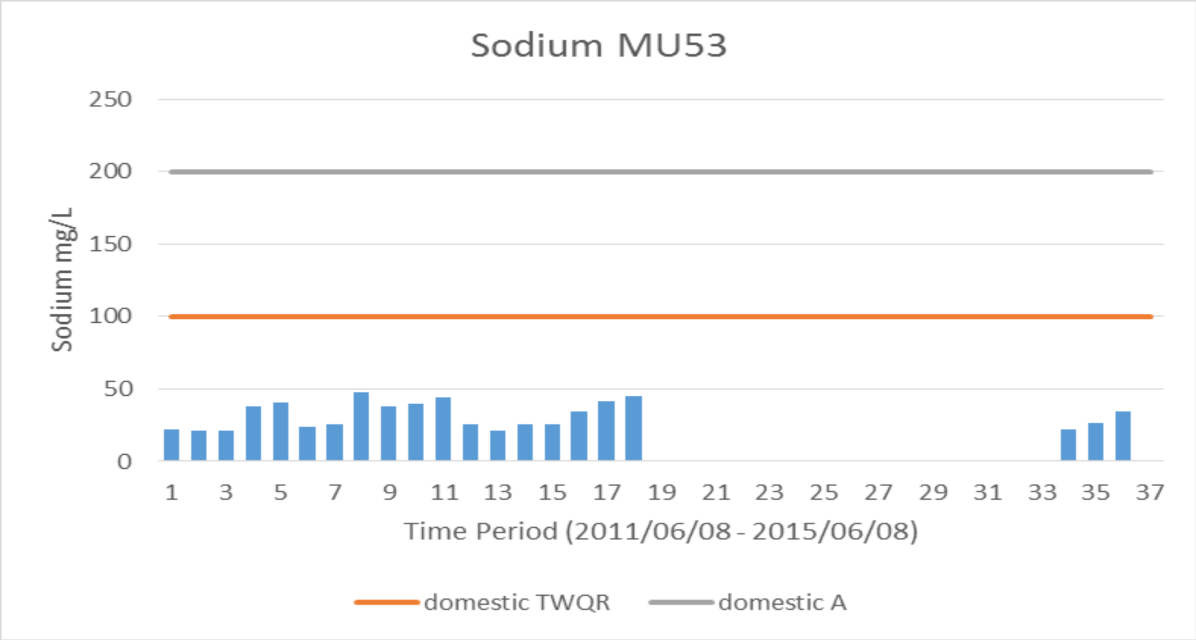

TDS MU53
TDS mg/L
1200
1000
800
600
400
200
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37
Time Period (2011/06/01 - 2015/06/08)
domestic TWQR
domestic A
irrigation TWQR

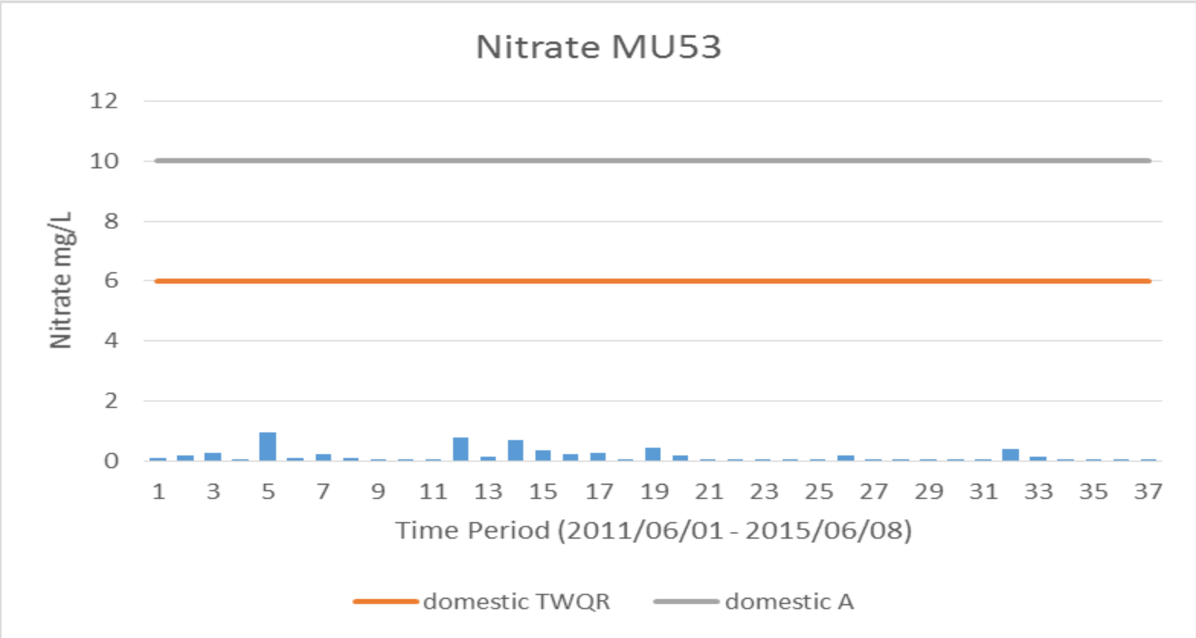

Electrical Conductivity MU53
EC mS/m
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10111213141516171819202122232425262728293031323334353637
Time Period (2011/06/01 - 2015/06/08)
domestic TWQR
domestic A
irrigation TWQR

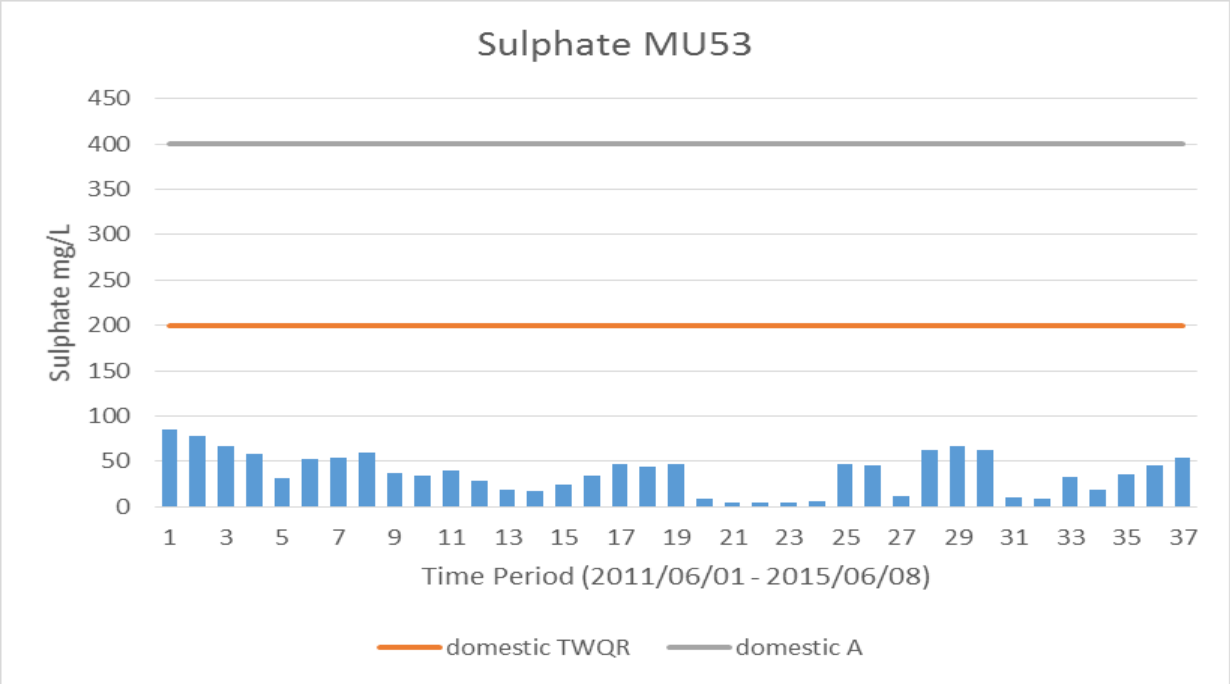

Fluoride MU53
Fluoride mg/L
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10111213141516171819202122232425262728293031323334353637
Time Period (2011/06/01 - 2015/06/08)
aquatic TWQR
domestic TWQR
domestic A
irrigation TWQR


Potassium MU53
Potassium mg/L
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37
Time Period (2011/06/01 - 2015/06/08)
domestic TWQR


Magnesium MU53
Magnesium mg/L
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37
Time Period (2011/06/01 - 2015/06/08)
domestic TWQR
domestic A


Sodium MU53
Sodium mg/L
250
200
150
100
50
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37
Time Period (2011/06/08 - 2015/06/08)
domestic TWQR
domestic A


Nitrate MU53
Nitrate mg/L
12
10
8
6
4
2
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37
Time Period (2011/06/01 - 2015/06/08)
domestic TWQR
domestic A


Sulphate MU53
Sulphate mg/L
450
400
350
300
250
200
150
100
50
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37
Time Period (2011/06/01 - 2015/06/08)
domestic TWQR
domestic A

APPENDIX D

PROJECT STEERING COMMITTEE MEMBERS

Title	Surname	First Name	Organisation
Mr	Atwaru	Yakeen	Department of Water and Sanitation
Mr	Bierman	Bertus	Joint Water Forum/ Lebalelo WUA
Dr	Burgess	Jo	Water Research Commission
Dr	Cogho	Vic	Glencore
Mr	Dabrowski	James	Private Consultant
Mr	De Witt	Pieter	Dept. of Agriculture, Forestry and Fisheries
Dr	Driver	Mandy	SANBI
Ms	Fakude	Barbara	DWS
Mr	Gouws	Marthinus NJ	Depart. Of Agriculture, Rural Development and Land Administration
Mr	Govender	Bashan	Dept. of Water and Sanitation
Mr	Govender	Nandha	Strategic Water Partnership Network
Mr	Grobler	Geert	Dept. of Water and Sanitation
Dr	Gyedu-Ababio	Thomas	IUCMA
Mr	Harris	James	Olifants River Forum
Mr	Hugo	Retief	AWARD
Mr	Jezewski	Witek	Dept. of Water and Sanitation
Mr	Keet	Marius	Dept. of Water and Sanitation: Gauteng
Mrs	Kobe	Lucy	Dept. of Water and Sanitation
Mr	Kruger	Dirko	Agri-SA
Ms	Kubashni	Mari	Shanduka Coal
Mr	Le Roux	Roelf	Magalies Water
Mr	Leballo	Labane	Lepelle Water
Mr	Lee	Clinton	South 32
Mr	Linstrom	Charles	Exxaro
Mr	Liphadzi	Stanley	Water Research Commission
Mr	Llanley	Simpson	DST
Mr	Mabada	Hangwani	Dept. of Water and Sanitation: Limpopo
Mr	Mabalane	Reginald	Chamber of Mines
Mr	Mabogo	Rudzani	Dept. of Mineral Resources
Mrs	Mabuda	Mpho	Dept. of Water and Sanitation
Mr	Mabuda	Livhuwani	Dept. of Water and Sanitation
Mr	Macevele	Stanford	Dept. of Water and Sanitation: Mpumalanga
Mr	Machete	Norman	Limpopo Provincial Administration
Mr	Madubane	Max	Dept. of Mineral Resources
Mr	Maduka	Mashudu	Dept. of Mineral Resources
Mr	Malinga	Neo	Dept. of Water and Sanitation
Mr	Mannya	KCM	Dept. of Agriculture, Forestry and Fisheries
Mr	Masenya	Reuben	Dept. of Mineral Resources
Ms	Maswuma	Z	Dept. of Water and Sanitation
Mr	Mathebe	Rodney	Dept. of Water and Sanitation
Ms	Mathekga	Jacqueline	Dept. of Mineral Resources
Ms	Mathey	Shirley	Dept. of Mineral Resources
Ms	Matlala	Lebogang	Dept. of Water and Sanitation
Mr	Matodzi	Bethuel	Dept. of Mineral Resources
Mr	Mboweni	Manias Bukuta	Department of Agriculture, Rural Development and Land Administration
Mr	Meintjies	Louis	National Water Forum TAU SA
Mr	Mntambo	Fanyana	Dept. of Water and Sanitation: Mpumalanga
Mr	Modipane	B J	House of Traditional Leadership
	Modjadji	N	Lepelle Water

Dr	Molwantwa	Jennifer	IUCMA
Mr	Mongwe	Victor	Dept. of Economic Development, Environment and Tourism
Mr	Moraka	William	SALGA – National
Mr	Morokane	Molefe	Dept. of Mineral Resources
Mr	Mortimer	M	Dept. of Agriculture, Fisheries and Forestry
Mr	Mosefowa	Kganetsi W	Dept. of Water and Sanitation
Ms	Mosoa	Moleboheng	Dept. of Water and Sanitation
Mr	Mphaka	Matlhodi	SANBI
Mr	Mthembu	Dumisani	Dept. of Environmental Affairs
Ms	Mudau	S	Chamber of Mines
Ms	Muhlbauer	Ritva	Anglo
Ms	Muir	Anet	Dept. of Water and Sanitation
Mr	Mulaudzi	M	Dept. of Water and Sanitation
Mr	Musekene	Lucky	Dept. of Water and Sanitation
Dr	Mwaka	Beason	Dept. of Water and Sanitation
Mr	Nditwani	Tendani	Dept. of Water and Sanitation
Ms	Nefale	Avhashoni	Dept. of Water and Sanitation
Mr	Nethononda	B	Dept. of Environmental Affairs
Mr	Nethwadzi	Phumudzo	Dept. Mineral Resources
Mr	Nico	Dooge	Glencore
Mr	Nokeri	Norman	Lepelle Water
Mr	Oberholzer	Michael	Dept. of Mineral Resources
Ms	Olivier	Dorothy	Dept. of Mineral Resources
Mr	Opperman	Nic	Agri-SA
Mr	Parrott	Brenton JS	Delmas WUA: Representing irrigators in the Upper Olifants Area
Mr	Phalandwa	Musa	Eskom
Mr	Po	Jan	Dept. of Agriculture, Fisheries and Forestry
Mr	Potgieter	Jan	National Dept. of Agriculture
Ms	Ralekoa	Wendy	DWS
Mr	Ramatsekia	Rudzani	Dept. Mineral Resources
Ms	Rammalo	Albertina	MDW
Mr	Ramovha	Matshilele	Dept. Mineral Resources
Mr	Ramphisa	Philip	Platreef Mine
Mr	Raphalalani	Israel	Dept. of Water and Sanitation
Mr	Riddel	Eddie	SANPARKS – KNP
Mr	Roman	Henry	DST
Mr	Rossouw	Ossie	Lebalelo WUA
Mr	Schmahl	Carel	Lepelle Water
Mr	Selepe	Marcus	IUCMA
Mrs	Shai	Caroline	Dept. of Water and Sanitation
Dr	Sharon	Pollard	Award
Ms	Shaw	Vicki	Mine Water Coordinating Body (MWCB)
Ms	Sigwaza	Thoko	Dept. of Water and Sanitation
Ms	Sinthumule	Ethel	Dept. of Mineral Resources
Ms	Sithole	Nelisiwe	Mpumalanga Provincial Department of Agriculture
Ms	Skosana	M	Dept. of Water and Sanitation
Mr	Stephinah	Mudau	Chamber of Mines
Mr	Surendra	Anesh	Eskom
Mr	Surmon	Mark	Palabora Mining Company
Mr	Tloubatla	L	Dept. of Water and Sanitation

Mr	Tshivhandekano	Aubrey	Dept. of Mineral Resources
Mr	Tshukudu	Rabeng	Mpumalanga Provincial Government
Ms	Ugwu	Phindile	DMR
Mr	Van Aswegen	Johann	Dept. of Water and Sanitation
Mr	Van Den Berg	Ockie	Dept. of Water and Sanitation
Mr	Van der Merwe	Alwyn	Eskom
Mr	Van Niekerk	Peter	Dept. of Water and Sanitation
Mr	Van Rooyen	Marius	Mpumalanga Provincial Department of Agriculture
Mr	Van Stryp	Johan	Loskop Irrigation Board: representing irrigators in the Middle Olifants Area
Mr	Van Vuuren	Jurie	Lower Blyde WUA: representing irrigators in the Lower Olifants Area
Mr	Venter	Jacques	SANPARKS – KNP
Mr	Viljoen	Pieter	Dept. of Water and Sanitation
Ms	Willard	Candice	DST
Ms	Zokufa	T	Dept. of Water and Sanitation

APPENDIX E

SUB- CATCHMENT STAKEHOLDERS WHO HAVE CONTRIBUTED TO THE PLAN

Name	Organisation
Adivhaho Rambuda	DWS, Bronkhorstpruit
Adolph Maredi	DWS
Alistair Collier	Olifants Joint Water Forum
Alta van Dyk	Lonmin Akanani
André Venter	Letaba Water User Association
Aneshia Sohan	Sasol
Angelika Möhr	SRK
Anna-Manth	OFF (MCCI)
Ansia de Jager	JWF
Avhafuni Ratombo	DWS, Bronkhorstspruit
Avril Owens	SRK
Ayanda Mtatwa	DWS: MWM
Betty Marhaneleh	LDARD: Mopani
Betty Nguni	DWS
Bongani Mtzweni	Samancor
Brenda Lundie	Sasol Satellite Operations
Cara	Kungwini Wise
Carina Koelman	DARDLEA
Caroline Shai	DWS, Compliance
Cecilia Mkhatshwa	City of Tshwane
Celiwe Ntuli	DWS
Charles Linström	Exxaro
Charlotte Khoza	Lepelle Northern Water
Christo Louw	DWS
Craig Zinn	Mpumamanzi Group
Danny Talhami	Clover Hill Club Share block
David Paila	Glencore Lion
Dayton Tangwi	DWS
Decia Matumba	SALGA
Derrick Netshitungulu	Nkwe Platinum
Dr James Meyer	Topigs SA
Eben Ferreira	Keaton Energy Mining Vanggatfontein Colliery Delmas
Eddie Ridell	KNP
Edwin Mamega	DAFF
Elmien Webb	Glencore
Emile Corradie	Bosveld Phosphate
Faith Mugivhi	ASA Metals/ Dilokong Chrome Mine
Farah Adams	Golder Associates Africa
Gavin Tennant	Agri-Letaba
Geert Grobler	DWS
Gloria Moloto	DWS, Bronkhorstspruit
Gloria Sambo	Agriculture

Heather Booysen	Samancor
Hugo Retief	AWARD
Imani Munyai	Wescoal Mining
Jakes Louw	Joint Water Forum
James Ndou	Modikwa Platinum Mine
Jan de Klerk	Sasol
Jaques Venter	SANparks
Jerry Penyene	AFASA
Johan van Stryp	Loskop Water Forum
Johanes Mathungene	LEPELLE/ farmer
Johannes Senyane	Two Rivers Platinum Mine
John Gearg	Wescoal/JKC
Joseph Phasha	DWS, Compliance
Kamo Meso	DWS
Karabo Motene	Glencore Mototolo Platinum Mine
Kerry Beamish	Rand Carbide
Kgaowelo Moshokwa	Anglo American Coal- Goedehoop Colliery
L.D Mutshaine	DWS: MWM
Leah Muoetha	Lepelle Northern Water
Lebo Mosoa	DWS
Lebohang Sebola	Lepelle Northern Water
Lee Boyd	Golder Associates Africa
Lee-Ann Ryan-Beeming	Glencore Eastern Chrome Mines
Lerato Maesela	LEDET
Linda Desmet	Palabora Mining Company
Love Shabane	DAFF
Lucas Masango	Private
Lulu Moya	Greater Giyani Municipality
M.S Makuwa	LEDET
Mahlakoane Foletji	DAFF: LUSM
Marcia Mofokeng	DWS: Letaba CMF
Marie Helm	DA Councillor, Mopani District Municipality
Martha Mokonyane	Mbuyelo Group (Pty)Ltd (Vlakvarkfontein and Rirhandzu Collieries)
Mashweu Matsiela	Industrial Development Corporation
Mathabo Kgosana	DWS, Planning and technical support
Michelle Proenca	GS Schoonbee Estates
Mologadi Mpahlele	Mbuyelo Group (Pty)Ltd (Vlakvarkfontein and Rirhandzu Collieries)
Moses Sithole	SBBC
Movwape Ntchabeleng	DAFF
Mpho Makgatha	Steve Tshwete Local Municipality
Musa Lubambo	DWS, Bronkhorstspruit
Ndwamato Ramabulama	DAFF
Nico Dooge	Glencore

Nnzumbeni Tshikalange	DWS
Nomathemba Mazwi	Resource Protection and Waste
Nonceba Noqayi	DWS, Mbombela
Nonki Lodi	AFASA
P.K Dzambuken	DWS: Tzaneen
Palo Kgasago	DAFF
Percy Ratombo	DWS
Phillemon Mphahlele	Municipal Health Services
Phuti Mabotha	LEDET
Pieter Pretorius	Loskop Irrigation Board
Pieter Viljoen	DWS
Portia Munyai	DWS
Pumale Nkuna	DWS:Mpumda
Raisibe Morudu	Thembisile Hani LM
Ramasenya Meso	DWS
Reginah Kganyago	DWS
Resenga Shibambo	DWS, Enforcement
Reynie Reyneke	EXXARO
Robert Davel	Mpumalanga Agriculture (provincial affiliate Agri SA)
Sabelo Mamba	Small Enterprise Finance Agency
Sakhi Mamashole	FOSKOR
Sakhile Mndaweni	DWS, National Office
Salome Sathekge	Polokwane Municipality
Siboniso Mkhaliphi	DWS
Simon Moewg	NEPRO
Solomon Tshikovhele	DWS: HO
Stanford Macevele	DWS: MP
Stephan Kitching	Wescoal Processing
Steven Friswell	Clover Hill Club Share block
Tanya Botha	Evraz Highveld
Tendani Nditwani	DWS: NWRP
Thabiso Mpahlele	Lepelle Northern Water
Thia Oberholzer	Evraz Highveld
Thomas Napo	LDARD
Timothy Marobane	Steelpoort Business Bridge Chamber
Tintswalo Ndleve	DEA (NRM)
Tony Bowers	Mpumamanzi Group cc
Tshepo Magongwoto	LEDET
Tshidi Mamotja	Department Environmental Affairs
Vinesh Dilsook	Anglo American Platinum
Wilna Wepener	Lonmin Akanani
Zama Ramokgadi	Tubatse Chrome
Zonke Miya	Mpumamanzi Group cc