CITY OF CAPE TOWN
ISIXEKO SASEKAPA
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Water Quality Improvement Programme

Date: 23 April 2020

<u>Analysis of City of Cape Town water quality in the Upper Diep (N) Catchment</u>

Contents

1. Water Quality Monitoring

The pre Directive issued to the City of Cape Town by DEA&DP Law Enforcement requested an investigation of water quality in the Diep River in the portion of the catchment which lies above the N7 and within the city's boundaries. The City has a monthly sampling programme which includes a number of sample locations in the greater Diep Catchment area, and those which lie within the requested zone are indicated in Table 1 below.

Table 1: Water quality sampling sites in the upper Diep Catchment Area

CODE	DESCRIPTION	RIVER NAME	STATUS OF DATA
MOS04	Mosselbank u/s Diep confluence	Mosselbank River	Current
MOS05	Diep u/s Mosselbank confluence	Diep River	Current
RTV06	Diep River downstream of N7 bridge	Diep River	Current

Samples collected from monitoring points are analysed at the City's accredited Scientific Services laboratories with a range of microbiolgial and physico-chemical analytical tests being undertaken.

Key data that can be used to inform and assess general water quality were extracted and have been graphically presented and discussed in Sction 2.

2. Water Quality Analysis and Discussion

Times series graphs for the following constituents are presented: *E.coli*, nutrients (inorganic nitrogen and inorganic phosphorus), un-ionised ammonia, total suspended solids and dissolved oxygen.

2.1 E.coli

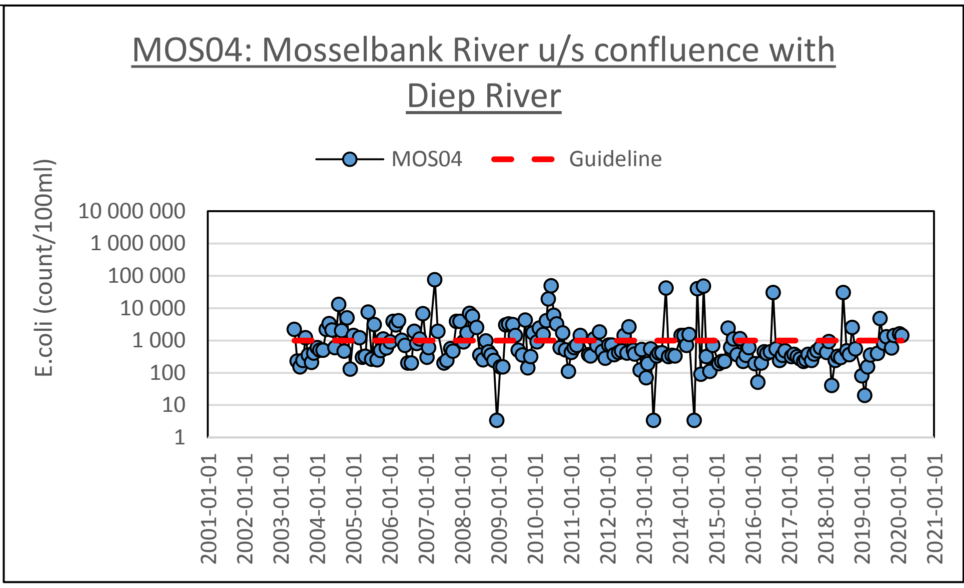
Faecal coliforms, and more specifically *Escherichia coli* (*E.coli*), can be used as a bacterial indicator of faecal pollution by warm-blooded animals (often interpreted as human faecal pollution, but also includes livestock, birds and domestic animals). *E. coli* is used to evaluate the quality of wastewater effluents, river water, sea water at bathing beaches, raw water for drinking water supply, treated drinking water, water used for irrigation and aquaculture and recreational waters. The presence of faecal pollution by warm-blooded animals may indicate the presence of pathogens responsible for infectious diseases such as gastroenteritis, salmonellosis, dysentery, cholera and typhoid fever.

Results are assessed in terms of the Department of Water and Sanitation (DWS) "Intermediate Contact Recreation Guidelines" which makes use of faecal coliforms as indicator organisms. "Intermediate" levels of contact include recreational activities such as sailing, canoeing, fishing, water skiing etc. Full body immersion for extended periods during swimming and diving are regarded as "Full Contact". These activities are not recommended in urban water bodies due to water quality challenges and due to the fact that "life-saving" facilities are not available on such systems.

The DWAF South African Water Quality Guideline series for Recreational Use provides guidance on public health risks associated with different levels of contact with recreational waters. The "Intermediate Contact" Guideline (which relates to activities such as sailing, canoeing, paddling but exclude full body immersion in swimming and diving) summarised in the text box below provides an indication of increasing public health risk associated with progressively high levels of faecal contamination. The guideline makes use of 'faecal coliform counts' which is however no longer routinely measured in many laboratories. *E.coli* is increasingly regarded as the preferred indicator as it provides a better indication of faecal pollution originating from warm-blooded organisms. *E.coli* may comprise up to 97 % of faecal coliform bacteria in human faeces.

< 1000 Target No/Very Low Risk	1 001 - 4 000 Slight Risk It may be expected that limited contact with water of this quality is associated with a risk of gastrointestinal illness	> 4 000 Intermediate recreational contact with water can be expected to carry an increasing risk of gastrointestinal illness as faecal coliform levels increase

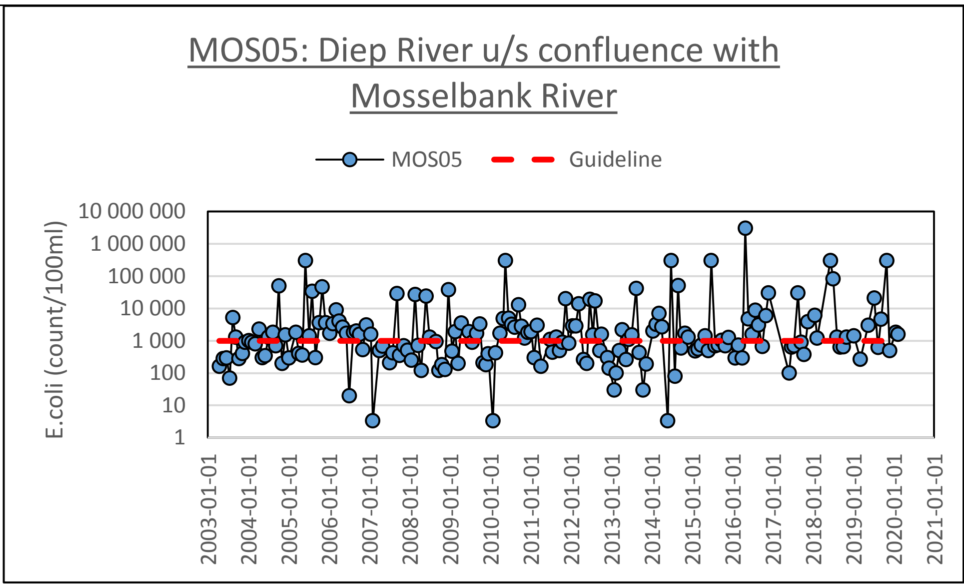
A 1000 *E.coli* count/100ml level is used to evaluate the data with the understanding that trends and sustained test results below this level would indicate that there is no / very low risk to recreational users. It should be noted that the river reaches included in this discussion are not used for formal human recreation and any contact is likely to be temporary during for example the wlaking in or through the river.



The Mosselbank River flows in a 'natural' earth channel through largely agricultural land where cattle feedlots / dairy farms, chicken farms and wheat are the main farming types. A few small urban settlements (Kraaifontein, Fisantkraal, Klipheuwel) are also located in the Mosselbank sub-catchment.

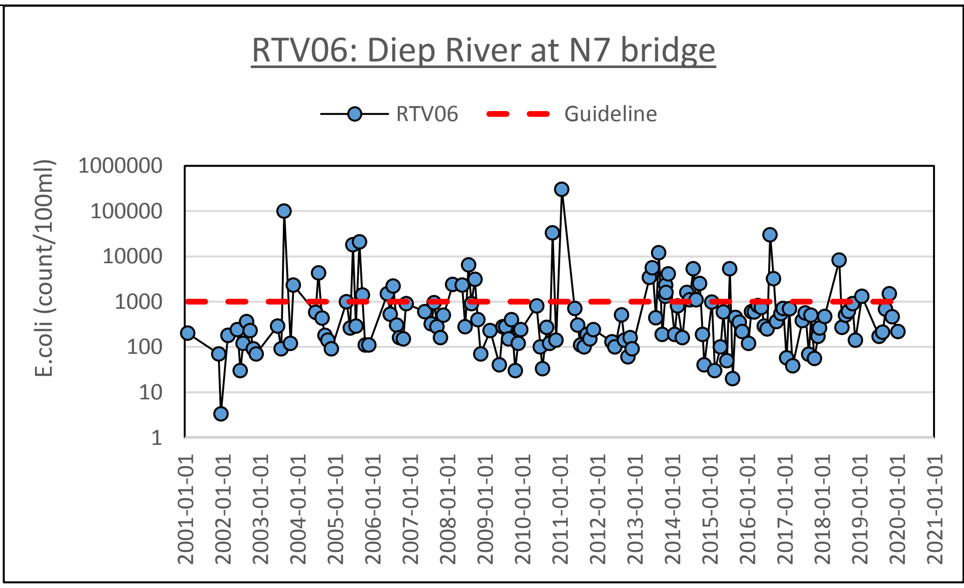
The Mosselbank and Diep River have their confluence at the R312 Philadelphia Road bridge. A livestock farm is located immediately downstream of the confluence of the Diep and Mosselbank Rivers with runoff from this likely affecting the Diep River.

Water quality (*E.coli* levels) in the Mosselbank River is relatively good and tends to fluctuate seasonally with occasional isolated peaks. Faecal contamination of the river in this localised reach is likely a result of runoff from farms.



The Diep River which originates in the Malmesbury area to the north of Cape Town flows in a 'natural' earth channel through agricultural land similar in character to that of the Mosselbank River previously discussed.

Water quality in the Diep River at this sample site which is approximately 7km from the City boundary and just upstream of the confluence of these two rivers fluctuates seasonally and the *E.coli* levels suggest that the Diep River is more impacted by faecal contamination than the Mosselbank River. Faecal contamination of the river in this localised reach is likely a result of runoff from farms.



The next sample point on the Diep River is located at the N7 bridge. Here too the Diep River flows in 'natural' earth vegetated channel, and the typical upstream land use is agricultural.

Water quality (*E.coli* levels) in this reach is relatively good and fluctuates seasonally.

2.2 Nutrients

Phosphorus and nitrogen from various sources can contribute to nutrient enrichment / eutrophication of receiving watercourses. Anthropogenic sources include fertilisers, livestock and domestic animal waste run-off, sewage from urbanised areas and industrial effluents.

The South African Water Quality Guideline series for Aquatic Ecosystems (DWAF[1] 1996) considers inorganic nitrogen (comprising ammonia, nitrite and nitrate) and inorganic phosphorus as important constituents which drive nutrient enrichment in aquatic ecosystems. Consequences of an abundance of nutrients in the aquatic environment include blooms of algae (mainly in closed waterbodies) and prolific growth of aquatic macrophytes such as reeds and water hyacinth.

The table below from the 1996 Guideline indicates the level of "eutrophication"and associated ecological effects that is characterised by different levels of inorganic N and P.

Average summer inorganic N (mg/l)	**Average summer inorganic P (mg/l)**	**Trophic state**	**Effects**
< 0.5	< 0.005	Oligotrophic	Usually moderate levels of species diversity; usually low productivity systems with rapid nutrient cycling; no nuisance growth of aquatic plants or the presence of blue-green algal blooms
0.5 – 2.5	0.005 – 0.025	Mesotrophic	Usually high levels of species diversity; usually productive systems; nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms seldom toxic
2.5 – 10	0.025 – 0.25	Eutrophic	Usually low levels of species diversity; usually highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms may include species that are toxic to man, livestock and wildlife
> 10	> 0.25	Hypertrophic	Usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms may include species that are toxic to man, livestock and wildlife

While 'oligotrophic" might be viewed as the ultimate desired state of a system, it is important to recognise that some eccosystems are naturally low in nutrients. Within a particular river different zones may also naturally exhibit different levels of nutrients e.g. mountain streams will have lower levels than rivers flowing through floodplains. It is therefore not strictly correct to expect an un-impacted river to be 'oligotrophic" and to use that level unilaterally as the "guideline".

- The guideline in fact states that inorganic nitrogen and phosphorus concentrations should <u>not be changed by more than 15 % from that of the water body under local un-impacted conditions</u> at any time of the year; and
- The <u>trophic status</u> of the water body should <u>not increase above its present level</u>; and
- The <u>amplitude and frequency of natural cycles</u> in inorganic phosphorus should not be changed.

Understanding the natural background seasonal levels of nutirents that would have been present under in-impacted historic conditions is not possible in most systems since monitoring records do not extend far enough into the past. Failing that, a natural / least impacted background condition

[1] DWAF: Department of Water Affairs and Forestry (as it was known then), now Department of Water and Sanitation.

could be inferred by comparing similar river types or tributaries that may have lower levels of impact. One also should track the trophic state of a system over time and ensure that it does not increase above present level. In many cases this is what is required when tracking water quality (nutrient levels) in our urban waterways which have been irrevocably modified, and for which an 'unimpacted' state is not known.

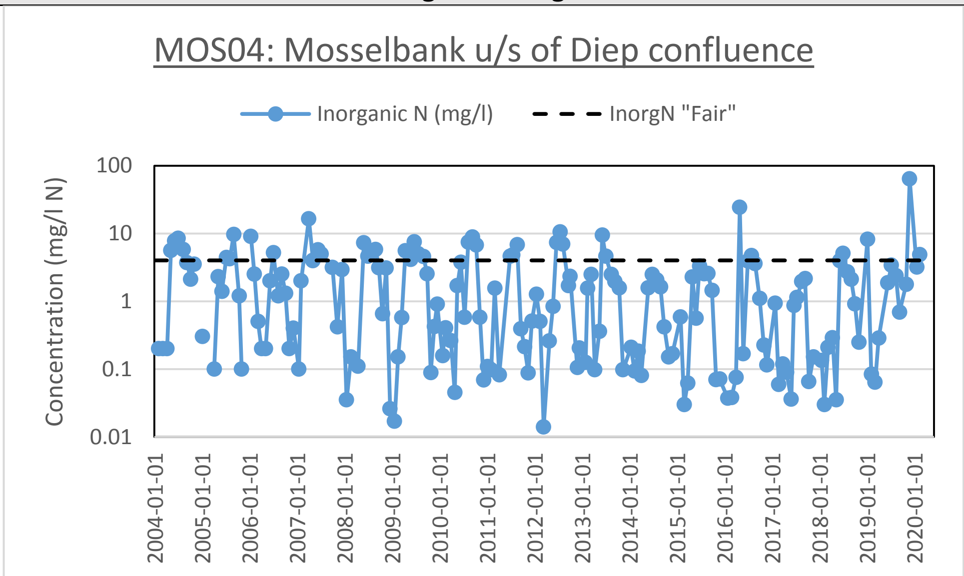
The above trophic state guidance has been updated to better align with the standard A - F classes used by DWAF (Ecological reserve water quality benchmarks 2005):

Variable	Units	Natural A	Good B	Fair C	Poor D	Unacceptable E/F
TIN (inorganic N)	mg/l	<0.25	0.25-1	**1-4**	4-10	>10
SRP (inorganic P)	mg/l	<0.005	0.005 - 0.025	**0.025 - 0.125**	0.125-0.250	>0.250

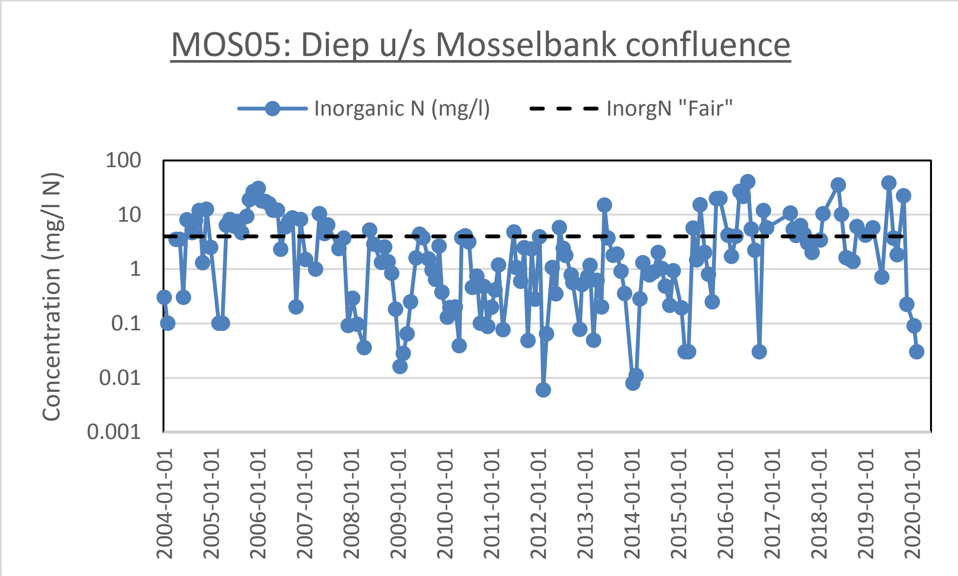
The upper limit of the **"FAIR" / "C" category** has been displayed as a breakpoint in the following series of graphs depicting ambient nutrient levels in the Diep and Mosselbank sample sites under discussion in this document.

It is noteworthy that nitrogen levels tend to be present at 'better' levels than phosphorus and that a single site will not necessarily exhibit the same category (A to F) for both inorganic N and inorganic P. Rivers flowing in 'natural' earth, vegetated channels have an inherent ability to break down and assimilate certain contaminants (more so than e.g. concrete canals) due to bio-geochemical processes of absorption, ingestion and metabolisation of organic loads by instream fauna, flora and microbial organisms. The fate of nitrogenous compounds differs from that of compounds containing phosphorus since the latter constituent is a 'conservative' element which does not break down as is done in the nitrogen cycle where the end point for the conversion (denitrification) of ammonia into nitrites and nitrates is nitrogen gas lost to the atmosphere through volatilization.

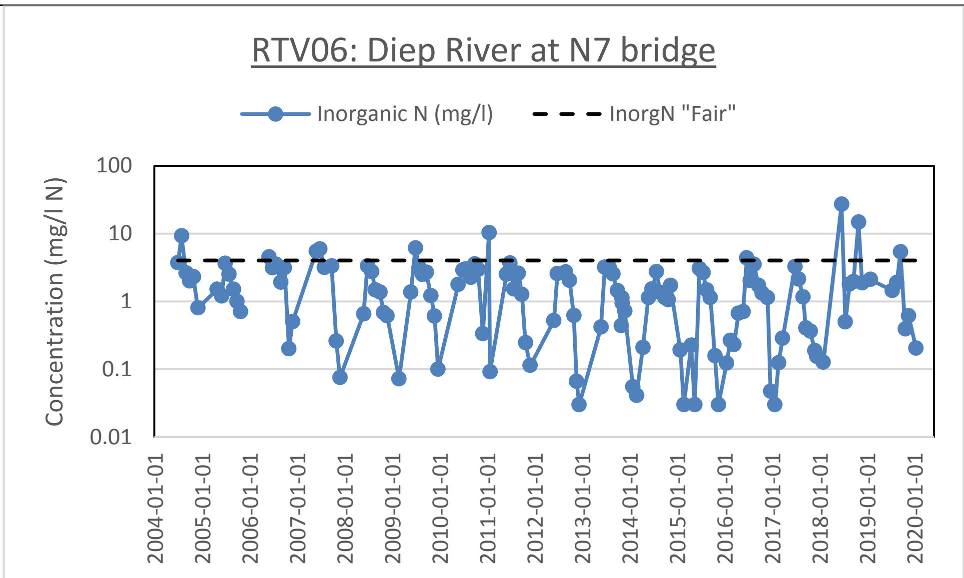
Inorganic nitrogen



Levels of inorganic nitrogen at this location in the Mosselbank River fluctuate seasonally and **generally lie well within the "Fair / C" band with many of the lowest results being "Natural / A"**.

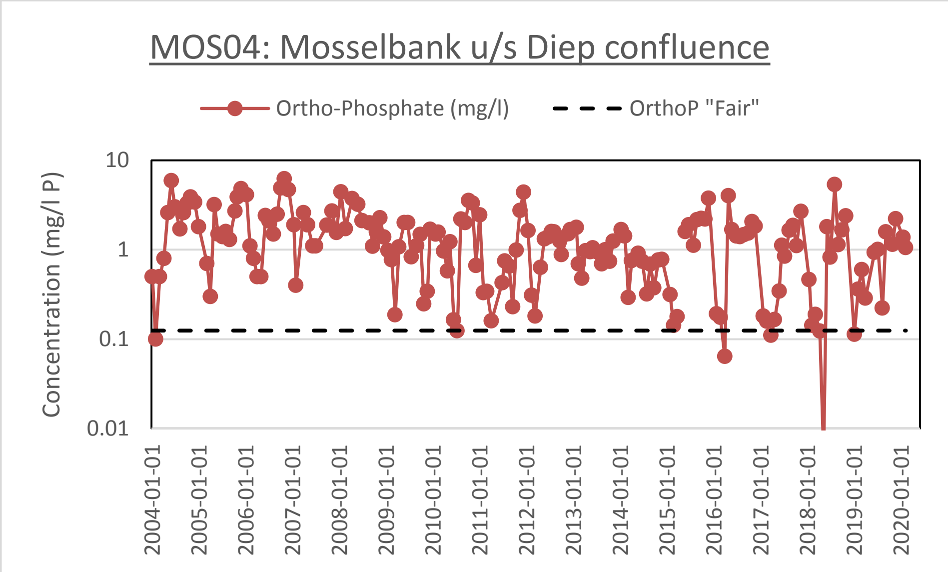


Levels of inorganic nitrogen at this location in the Diep River also fluctuate seasonally and appear for most of the time series record to be similar to that of the Mosselbank site i.e. **"Natural / A" to "Fair / C"**. **However the data indicates that there has been an increase in inorganic nitrogen level since about 2015 with most of the more recent results falling in the "Poor / D" to "Unacceptable / E-F" range**. Although the source of this is not known, the drought may have had some influence due to the concentration of contaminants that occurs due to reduce flow in the river.



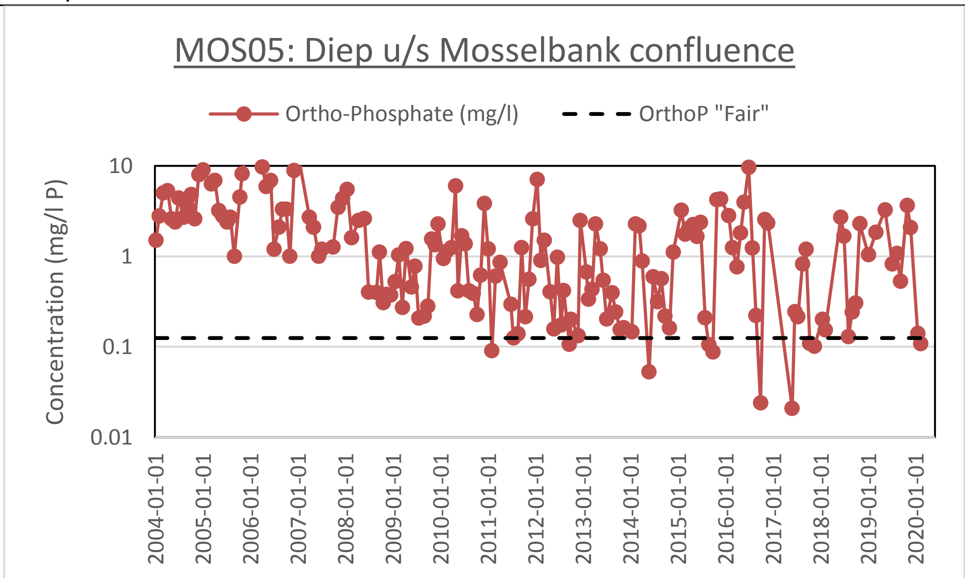
Inorganic nitrogen levels at this location on the Diep River have largely been stable and showed consistent seasonal fluctuations. **Almost all results lie well within the "Fair / C" range and even exhibiting "Natural / A" to "Good / B" levels of this consituent. A slight increase is evident in the last 18 months to 2 years** – although the reason for this is not known, the drought may have had some influence due to the concentration of contaminants that occurs due to reduce flow in the river. It should be noted that this sample site frequently has little to no flow due to abstraction taking place in the upstream catchment.

Inorganic phosphorus

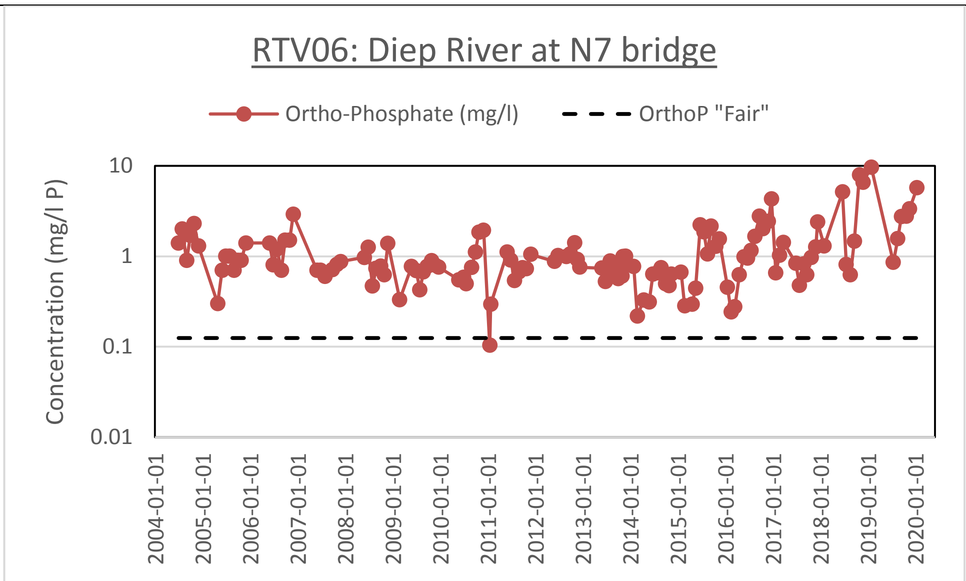


The inorganic phosphorus time series for the Mosselbank River upstream of the confluence with the Diep River illustrates that this constituent is **elevated well above the Fair (C) Category and lies largely at Poor to Unacceptable levels.** This is largely due to agricultural run-off which is the main land use for the immediate local and upstream catchment area. Seasonal fluctuations are evident indicating that increased runoff from these farmed areas takes place during wnter rainfall periods.

Although phytoplankton / algae blooms are not common in river environments, the consequences of this enrichment is manifested as prolific growth of reeds and other aquatic invasive and opportunistic plants.



Inorganic phosphorus in the Diep River upstream of the confluence with the Mosselbank River **fluctuates seasonally across the “Poor” to “Unacceptable” range**.



Inorganic phosphorus in the Diep River at the N7 bridge is **consistently elevated and at an "Unacceptable" level showing signs of increasing over the past 5 years**.

It should be noted that this sample site frequently has little to no flow due to abstraction taking place in the upstream catchment.

2.3 Ammonia

The DWAF 1996 South African Water Quality Guideline series for Aquatic ecosystems explain that 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. They exist either as dissolved ions, or can be adsorbed onto suspended organic and inorganic 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. The ammonium ion does, however, contribute to eutrophication.

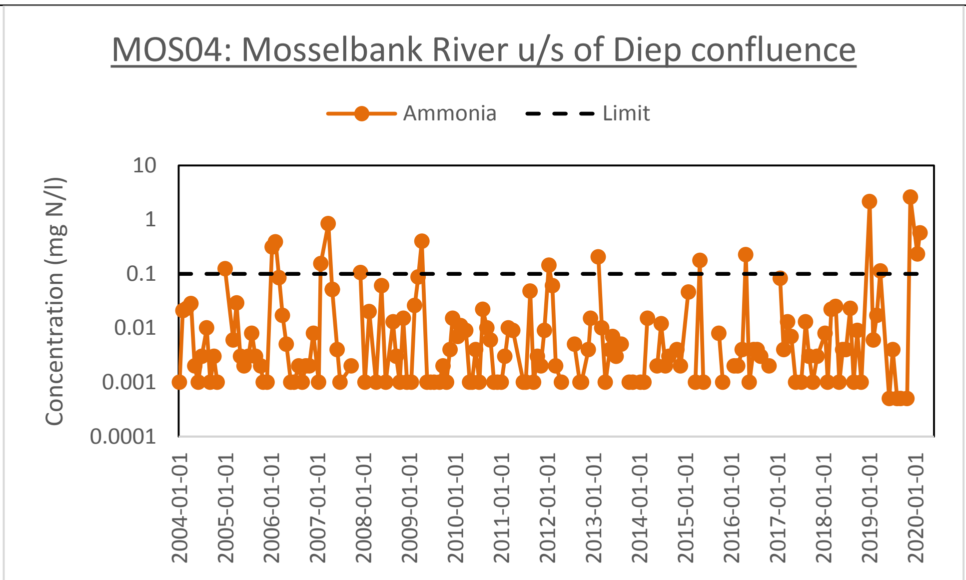
Ammonia is present in small amounts in air, soil and water, and in large amounts in decomposing organic matter. Natural sources of ammonia include gas exchange with the atmosphere; the chemical and biochemical transformation of nitrogenous organic and inorganic matter in the soil and water; the excretion of ammonia by living organisms; the nitrogen fixation processes whereby dissolved nitrogen gas enters the water and ground water. Ammonia, associated with clay minerals enters the aquatic environment through soil erosion. Bacteria in root nodules of legumes fix large amounts of nitrogen in the soil and this may be leached into surrounding waters.

Anthropogenic ources of ammonia include fertilisers, fish-farm effluent (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.

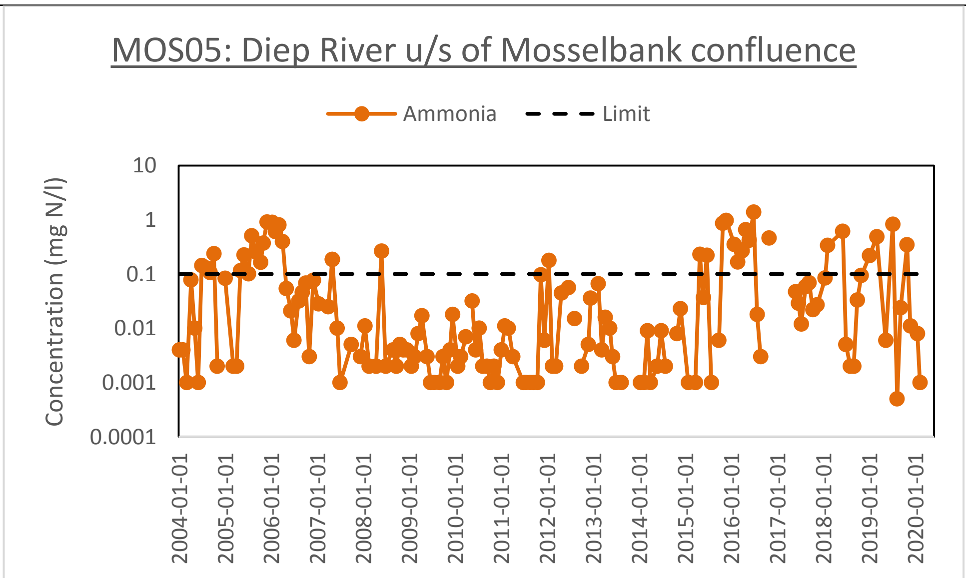
The above guidance has been aligned with the standard A - F classes used by DWAF (Ecological reserve water quality benchmarks 2005):

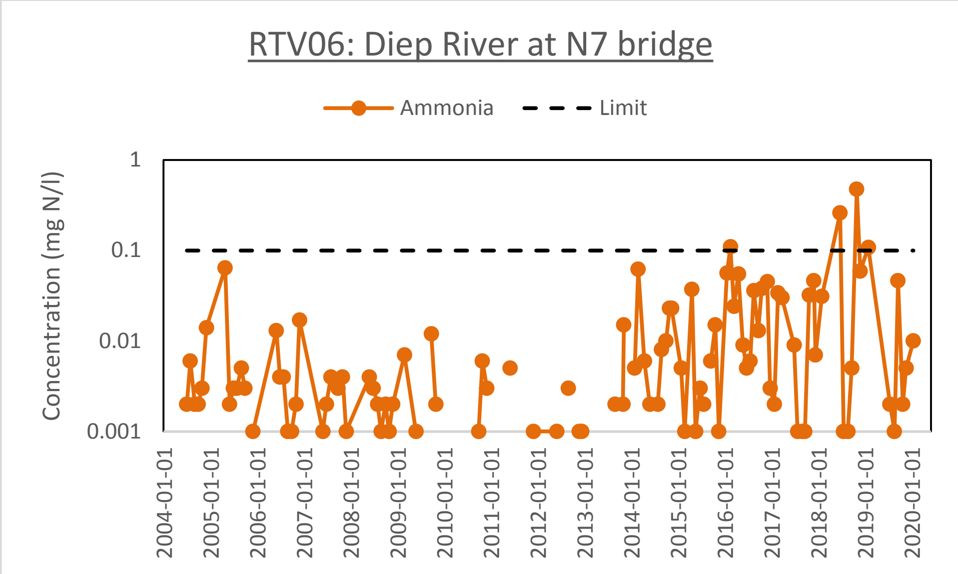
Variable	Units	Natural A	Good B	Fair C	Poor D	Unacceptable E/F
Ammonia (NH3-N)	mg/l	<0.015	0.015-0.058	**0.058-0.1**	0.1-0.2	>0.2

The **"FAIR" / "C" category** (un-ionised ammonia 0.1 mg/l) has been displayed as a breakpoint in the following series of graphs depicting ambient un-ionised ammonia levels in the Diep and Mosselbank sample sites under discussion in this document.



Un-ionised ammonia levels in the Mosselbank River at this location are generally in the "Natural / A" to "Fair / C" range with occasional peaks at "Unacceptable" levels. These peaks may not result in increased mortality of aquatic fauna if they are transient or short lived in nature. Since the monitoring programme is monthly it is not known to what extent the peaks may be sustained over longer periods.



Un-ionised ammonia levels in the Diep River at this location generally lie in the “Fair” range but exceedance of this level are more frequent and appear to be sustained in the “Unacceptable” range across multiple sample dates.
 Unionised ammonia levels at this location in the Diep River are very low, falling largely in the “Natural / A” and “Good / B” range.

2.4 Total suspended solids

“Total suspended solids” represents all particulate suspended matter in a sample that is retained when a sample is filtered (i.e. includes both inorganic and organic material such as silt, sand, leaves, algae etc). The DWAF (1996) South African Water Quality Guideline series for Aquatic Ecosystems provides the following background information:

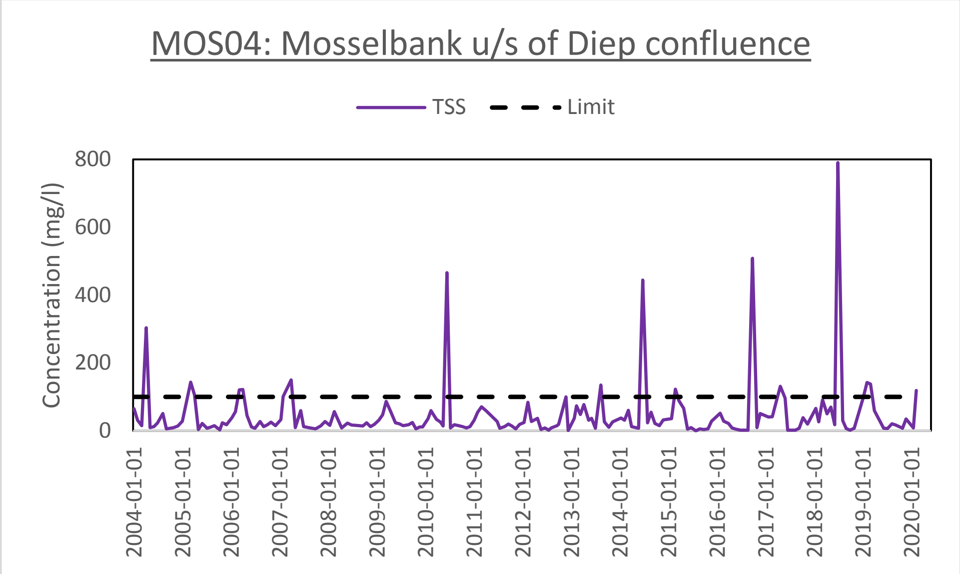
“Natural variations in rivers often result in changes in the TSS, the extent of which is governed by the hydrology and geomorphology of a particular region. In South Africa, all rivers, except some in the Natal foothills of the Drakensberg and in the south-western Cape, become highly turbid and laden with suspended solids during the rainy season. The major part of suspended material found in most natural waters is made up of soil particles derived from land surfaces. Erosion of land surfaces by wind and rain is a continuous and natural process. However, land use practices such as overgrazing, non-contour ploughing, removal of riparian vegetation and forestry operations accelerate erosion and result in increased loads of suspended solids in rivers”.

“Increases in total suspended solids may also result from anthropogenic sources, including:

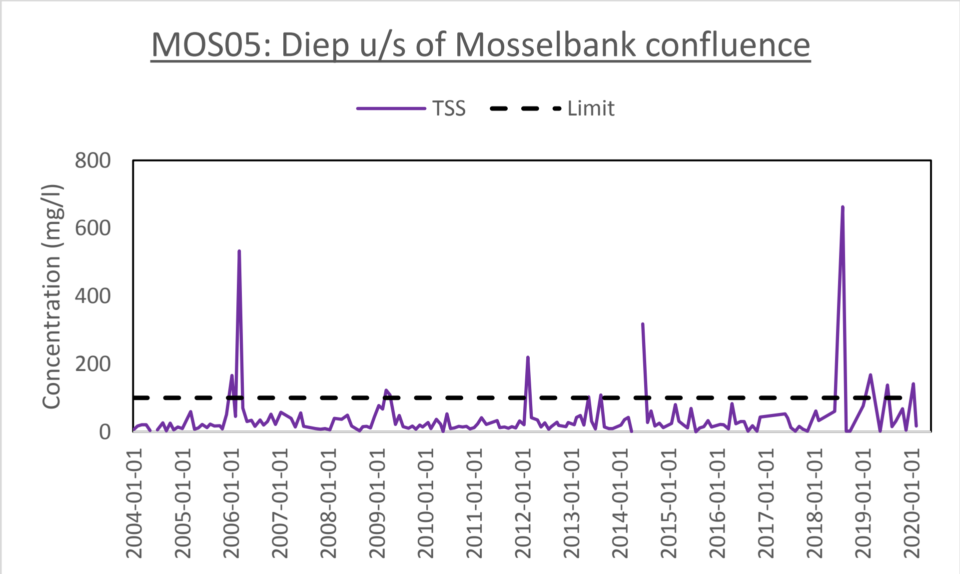
- discharge of domestic sewage,
- discharge of industrial effluents (such as the pulp/papermill, china-clay, and brick and pottery industries),
- discharge from mining operations,
- fish-farm effluents (mostly organic suspended solids) and
- physical perturbations from road, bridge and dam construction”.

The DWAF guideline states that the background level of TSS for all ecosystems should be < 100 mg/l and that any increase in TSS concentrations must be limited to < 10 % of the background TSS concentrations at a specific site and time.

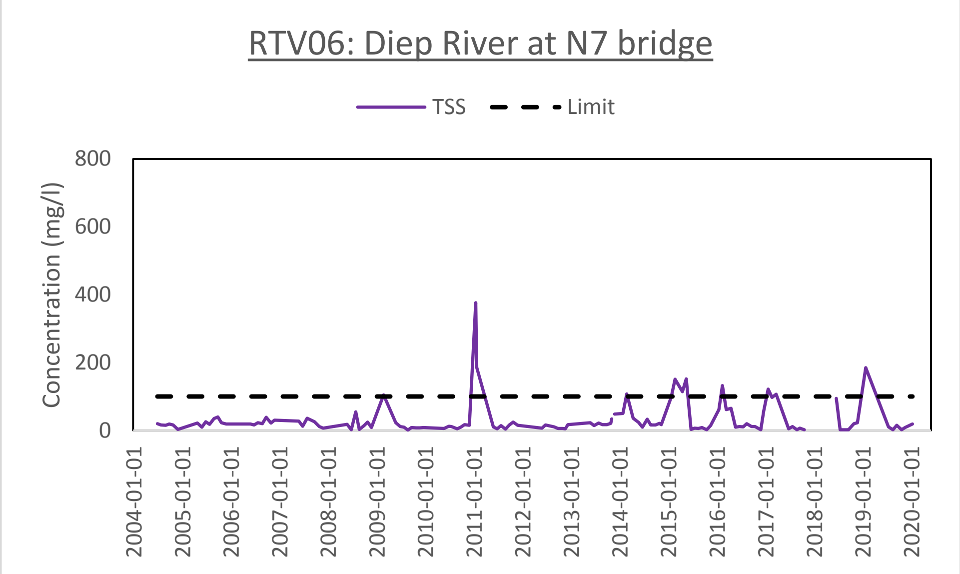
It is noteworthy that the greater Diep Catchment is underlain by Malmesbury shale which represents a fine grained sediment that imparts a degree of natural turbidity to the river. Increased loads during rainfall are expected but may also be artificially elevated due to extensive agricultural practises with large tracts of land adjacent to the river being ploughed and stripped of natural vegetation which would ordinarily assist with binding the soil and reducing loss of sediment to the river.



Total suspended solids levels in the Mosselbank River at this location are generally below 100mg/l with the exception of spikes which largely occurred in the winter rainfall period and are assumed to represent increased runoff from agricultural lands.
Minimum: < 1 mg/l
Maximum: 790 mg/l
Median: 22 mg/l



Total suspended solids levels in the Diep River at this location exhibit a similar pattern to that of

the Mosselbank River although spikes are slightly lower in magnitude. Minimum: < 1 mg/l Maximum: 663 mg/l Median: 21 mg/l
 Total suspended solids levels in the Diep River at the N7 bridge are much lower than that of the two previously discussed sample sites. The river at this location is bordered by extensive reedbeds which likely assist with filtering of suspended particles. Minimum: 1 mg/l Maximum: 376 mg/l Median: 16 mg/l

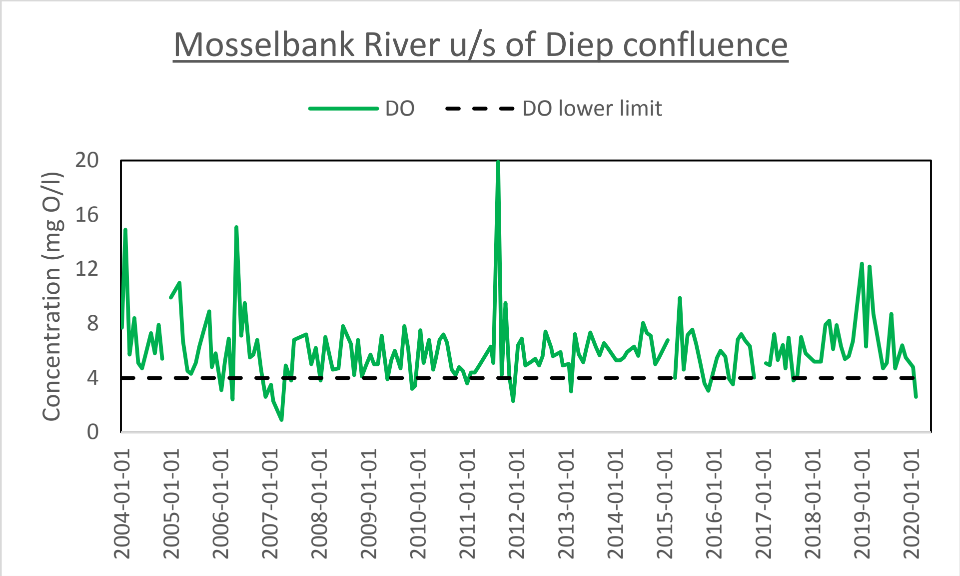
2.5 Dissolved oxygen

Dissolved oxygen is important for the survival of aquatic biota. Reductions in oxygen content can occur when organic matter / pollutants which create an oxygen demand are present in the water. Oxygen levels may also decline during periods of dry periods when this is little / no water movement and water begins to stagnate. Under sustained conditions of low dissolved oxygen, the aquatic biotic community may become dominated by hardy, pollution tolerant species.

The DWS Ecological Reserve water quality benchmarks (2005) provides the following guidance on measured dissolved oxygen levels in aquatic ecosystems:

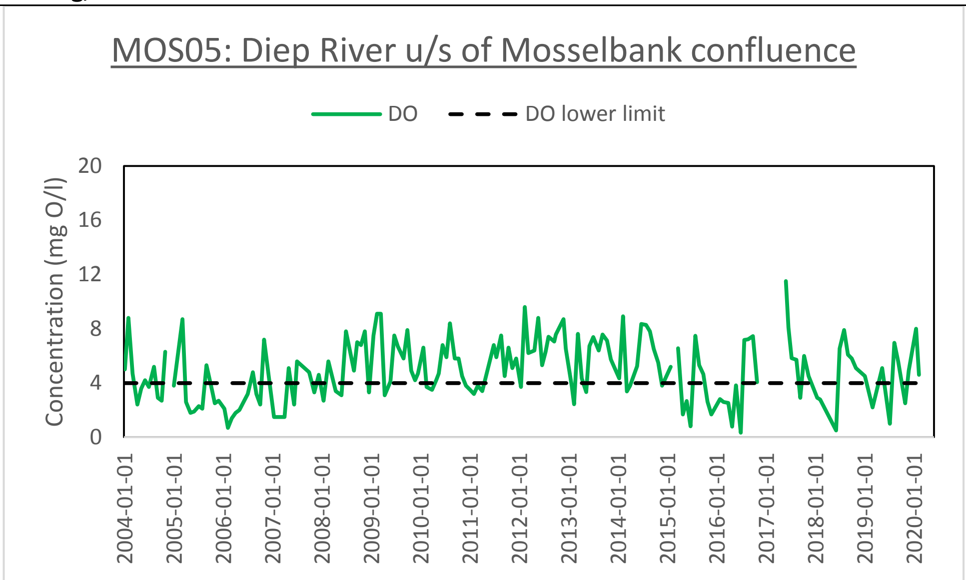
Variable	Units	Natural A	Good B	Fair C	Poor D	Unacceptable E/F
Dissolved Oxygen	mg/l	>8	8-6	**6-4**	4-2	<2

The lower limit for the "Fair / C" category is used on the following series of graphs. Dissolved oxygen levels *above* 4 mg/l are regarded to be acceptable ("Fair" or better).



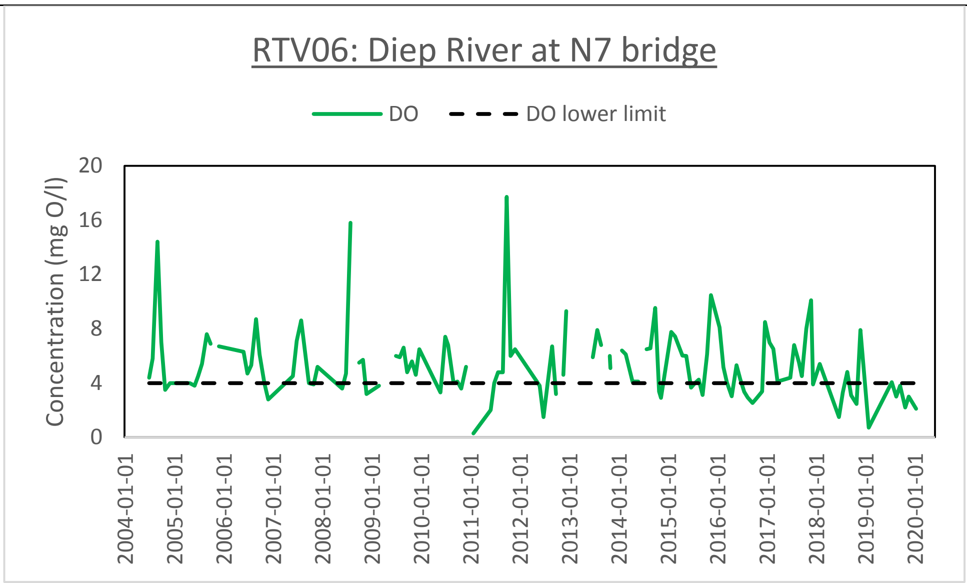
Dissolved oxygen levels at this location in the Mosselbank River are 'acceptable' with virtually all results > 4 mg/l.

Minimum: < 1 mg/l
Maximum: 19.9 mg/l
Median: 5.6 mg/l



Dissolved oxygen levels at this location in the Diep River are variable and somewhat worse than the Mosselbank River site with results below the "Fair" limit being frequently recorded, particularly since 2015. The reduced oxygen content is likely a result of organic pollutants in the river but may also be influenced by reduced flow since significant abstraction from the river takes place in the agricultural areas of the catchment.

Minimum: < 1 mg/l
Maximum: 11.5 mg/l
Median: 4.8 mg/l



Dissolved oxygen content at this location in the Diep River is variable but largely above the 4 mg/l lower limit of the "Fair / C" category. Reduced oxygen content at times is likely due to reduced flow / stagnant conditions that often are present at this location. The lower levels in the 2018 to current period may in part be due to drought experienced over that period.

Minimum: < 1 mg/l
Macimum: 17.7 mg/l
Median: 4.8 mg/l

3. Conclusion

In fulfilment of the pre Directive issued to the City by DEA&DP, the analysis compared sections of the Diep and Mosselbank Rivers flowing within the City's boundary and the N7 freeway. Both rivers flow through a landscape with similar land use characteristics, viz. agriculture (wheat and livestock). Both the Diep and Mosselbank Rivers have similar levels of instream and riparian modification i.e. the rivers flow in earth channels with typical bank vegetation comprising *Phragmites* reeds and narrow, often invaded remnants of natural fynbos or renosterveld vegetation.

Cumulative water quality impacts from the urbanised sections of the far upper reaches of the Diep (Malmesbury) cannot be determined with certainty at the MOS05 sample site as a degree of water quality improvement probably takes place as a result of the natural functioning of the river. **Water quality of both the Diep and Mosselbank Rivers at the sample locations described in this report, is likely driven by nutrient enriched run-off from the farmed local areas and immediate upstream reaches. Enrichment with phosphates is of concern.**

A detailed analysis of rainfall data along with the measured wet vs dry season water quality data was not undertaken. Nevertheless, seasonal fluctuations with elevated concentrations ('peaks') of constituents in the wet months due to run-off from adjacent fields, are apparent. Abstraction from the rivers for agricultural purposes reduces natural flow which results in concentration of some of the measured constituents particularly in drier periods. The influence of the recent extended drought is also apparent in some cases.

4. References

Department of Water Affairs and Forestry (1996). South African Water Quality Guidelines. Volume 2 Recreational Water Use.

Department of Water Affairs and Forestry (1996). South African Water Quality Guidelines. Volume 7 Aquatic Ecosystems.

Department of Water Affairs and Forestry (2005). Ecological Reserve water quality benchmarks.