Client

Envirosure

ASSESSMENT OF THE GROOT RIVER, MEIRINGSPOORT FOLLOWING DIESEL CONTAMINATION

FINAL REPORT

Prepared by

Justine Ewart-Smith

November 2017

FreshwaterConsulting cc

Freshwater Consulting cc
Unit F6, Prime Park
Mocke Road
Diep River, 7800
Email: Justine@freshwaterconsulting.co.za
Phone: 082 3738380

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Background

On the 15th August 2017, 41 000 litres of diesel was accidentally spilled from an overturned tanker into a roadside stormwater drain which discharges runoff directly in the Groot River as it flows through the Meiringspoort Pass. The bulk of the diesel flowed down the drain and discharged into the sandy river bank, entering the Groot River immediately downstream of the bridge crossing the river. Efforts to contain the spillage through the deployment of emergency measures were implemented immediately through the placement of lime as an absorbent within the stormwater drain, building of sand berms and the construction of retention ponds within the river bank, as well as placement of absorbent booms about 600 m downstream from the point of entry into the Groot River (HilLand Environmental 2017). Nevertheless, the Spill Tech emergency clean up team, who arrived the same day, reported that the effect of the diesel spill could be seen as far downstream as 1 km, immediately upstream of the Derde Tol bridge crossing the Groot River. The emergency team therefore took immediate action to contain the fuel and prevent any further spread downstream.

Envirosure Underwriting Managers (Pty) Ltd who insure the Kelrn Vervoer vehicle responsible for the spillage, contacted Freshwater Consulting cc and requested an initial assessment of the extent of ecological damage caused by the spillage and to make provisional recommendations for clean-up operations and the need for rehabilitation and monitoring. During the site visit on the 18th August 2017, Freshwater Consulting cc confirmed that refined diesel contamination was restricted to the active channel of the river and was visible as a floating film across the wetted perimeter for approximately 1 km downstream of the point of entry. Where diesel had made contact with either sediments or vegetation along the wetted margins of the channel, residues of diesel were evident and would likely leach into the sediments and remain within the system well beyond the period when diesel is visible. Also, significant numbers of the threatened redfin minnow (*Pseudobarbus spp.*) were struggling for oxygen and many were dying at the time of the site visit. Besides recommendations to ensure ecologically sensitive clean-up operations, it was strongly recommended that a fish rescue operation be implemented with immediate effect and that the system be monitored from an ecological perspective to evaluate the extent and rate of recovery following clean-up.

In response to a directive issued by the Breede Gouritz Catchment Management Agency (BGCMA) Envirosure Underwriting Managers (Pty) commissioned Riaan van der Walt of Advanced Environmental Corporation Pty (Ltd) to undertake a fish rescue operation. Freshwater Consulting cc was commissioned to compile a Rehabilitation and Monitoring Plan for the Meirings River.

1.2 Terms of Reference

Accordingly, the Freshwater Consulting Group was commissioned to:

1. Undertake a baseline assessment of the Groot River to understand its condition and integrity prior to the spill and to establish a baseline for evaluating the potential impacts of surfactants, if necessary, on the biota associated with clean-up operations.
2. Undertake a site visit to guide the removal of sediments and vegetation (if necessary)
3. Establish the extent and need for rehabilitation through collaboration with the clean-up team to understand the proposed Action Plan and the timeframe for implementation of the Action Plan.
4. Following on from the baseline assessment, compile a monitoring plan for fish and macroinvertebrates.
5. Monitor key biological (fish and invertebrates), physical (habitat) and chemical indicators for a minimum period of one year at key sites within the catchment. Monitoring will be undertaken every 3 months and the need for longer term monitoring will need to be addressed after this period.
6. Compile a report that specifically details the proposed Monitoring and Rehabilitation Plan. This report will include information on how the channel margins will be revegetated.
7. Compile quarterly reports that provide details of the recovery of the aquatic ecosystem based on data collected in the field with recommendations for ongoing monitoring or the need to adapt the monitoring approach.

This report specifically addresses point 1 above. It constitutes the Baseline Assessment of the Meirings River which provides a basis for evaluation of the ecological state of the system for monitoring recovery over time.

Following the approval of these Terms of Reference, it was decided that clean-up operations would include the use of surfactants in addition to the initial efforts that were based purely on mechanical removal of the contaminant (see section 2 for details). In addition to the Baseline Assessment, water samples were collected for assessment of the potential effects of surfactants on water chemistry following application of the surfactant, Biosolve®. These data are included in this report.

1.3 Limitations

The assessment of ecosystem health for any river is dependent on an understanding of the reference state or condition of the system, prior to any anthropogenic impacts. There is no primary data set that provides an indication of the reference condition of the Groot/Meirings River. Interpretation of the biophysical data in this study is therefore limited to comparison with control sites upstream and downstream of the impacted reaches. Also, there is no reliable flow data for the Groot/Meirings River. Water quality and biological integrity is somewhat dependant on flow characteristics of river ecosystems and therefore interpretation of the data is further limited by a lack of reliable flow data for this catchment.

1.4 Use of this Report

This report reflects the professional judgement of its author. It is Freshwater Consulting's policy that the full and unedited contents thereof should be presented to the client and included in any application to relevant authorities. Any summary of the findings should only be produced with the approval of the author.

2 CLEAN-UP OPERATIONS UNDERTAKEN TO DATE

Initial clean-up operations focused specifically on containment of the diesel spill to minimise the spatial extent of the impact. Thus, an absorbent boom was placed about 600 m downstream from the point of entry of the diesel from the stormwater drain, together with the creation of a temporary retention pond within the drain to minimise the volume of diesel reaching the river itself (HilLand Environmental 2017). Within hours thereafter, a Spill Tech emergency response team arrived to prioritise actions to minimise the impact and begin clean-up operations. Spill Tech identified the river reach between the spill entry point as far as the Derde Tol Drif bridge crossing, approximately 1 km downstream, as the "impact zone". Therefore containment and clean-up measures focused on this length of river with the deployment of several containment berms, the use of sorbants to soak up the diesel for later removal, product skimming and the creation of several "over and under structures" to allow uncontaminated river water to flow downstream.

A site assessment by Geomeasure identified the continual leaching of diesel from the stormwater drain into the Meirings River via the highly porous sandy river bank as the primary concern requiring further intervention. They proposed the application of a surfactant (i.e. 4.5% solution of BioSolve®) to the sandy river bank receiving diesel from the drain as well as sections of river bank where flow is slow or stagnant. BioSolve® promotes the emulsification of diesel and thus aids in the biodegradation of the contaminant. Furthermore, Geomeasure recommended the use of BioShock®, a liquid bioremediation agent, to treat contaminated sediments and vegetation along the active channel of river within the impact zone. Like Biosolve®, BioShock®, promotes the degradation of diesel through the addition of nutrients that intensify microbial breakdown of organic fuels. Further recommendations included the agitation of contaminated sediments within the active channel to promote release of trapped diesel.

BOX 1:
Surfactants (e.g. Biosolve®)
Surfactants are compounds that break up oil into smaller droplets so that they mix more readily in the water column. Thus, surfactants act to promote the degradation of diesel by microorganisms. While surfactants enhance biodegradation of fuels, they also increase the amount of fuel in the water column thus increasing the concentration of dissolved Polycyclic aromatic hydrocarbons (PAHs) and significantly increasing the risk of toxicity to aquatic biota, particularly fish (Schein *et al.* 2008). Essentially, surfactants enhance diesel toxicity with both acute and chronic effects to aquatic fauna (Ramachandran *et al.* 2004).

Bioremediation agents (e.g. BioShock®)
Bioremediation agents can include either fertilizers or microorganisms that increase the rate at which natural biodegradation occurs. BioShock® is a fertiliser and, thus poses the risk of a shift in trophic status and the knock-on ecological effects associated with nutrient

BioSolve® and BioShock® are associated with significant risks to natural aquatic ecosystems, particularly toxicity to aquatic fauna and change in trophic status associated with nutrient enrichment (See Box 1) and thus it was recommended by Freshwater Consulting cc that clean-up operations preclude the use of these products, in favour of physical measures that do not further threaten the integrity of an ecosystem of high ecological importance. Thus, it was decided that a 1% solution of BioSolve® would be applied only to the contaminated river bank as the source of ongoing contamination. BioSolve® was applied on the 14th September 2017, following the fish rescue operation (van der Walt 2017) and the collection of baseline data for this report. While it was recommended that water quality be monitored immediately following the application of BioSolve®, water quality data were only collected on the 17 October 2017 to establish any adverse effects associated with the application of Biosolve®. These data are included in this report.

Considering the ecological importance of the Meirings River as a fish sanctuary for two threatened species of the indigenous redfin minnow, as well as the die-off of redfins within the impact zone immediately following the spill incident, a fish rescue operation was commissioned by both Cape Nature and Advanced Environmental Corporation Pty Ltd (AEC), prior to the application of Biosolve®.

3 DESCRIPTION OF THE AFFECTED RIVER ECOSYSTEM

3.1 The Groot River Catchment

The Groot River Catchment covers three quaternary catchments, with its source in J33C, where its main tributaries, including the Aaps and Sand Rivers drain the north facing slopes of Swartberg Mountains (Figure 2.1). In its upper reaches, the main channel of the Groot River is surrounded by farming activities which encroach into the floodplain in some areas. Near the town of Klaarstroom the Groot River enters the Meiringspoort Gorge within J33D. The river is now known as the Meirings River as it flows southwards through the poort. Although some farming activities take place at the northern end of the poort the surrounding catchment is largely natural as the channel is confined within the steep-sided gorge which falls within the Grootswartberg Nature Reserve. Close to the town of De Rust, the Meirings River flows exits the gorge and flows through farmlands within J33E before it confluences with the Olifants River. The Olifants River is one of the main tributaries of the Gouritz River and thus the study area is part of the larger Breede-Gouritz Water Management Area.

3.2 A description of the Meirings River within the study area

Upstream of Klaarstroom, the Groot River flows as an upper foothill river through a colluvium –filled valley through succulent Karoo vegetation. Within this reach, the river is characterised by shale cobbles and gravels with *Acacia karoo* as the dominant riparian species. During the driest times of the year, flow may be reduced to a slow trickle or a series of non-flowing shallow pools. Within this reach, the river is impacted by surrounding farmlands which contribute to enrichment and sediment impacts thus affecting water quality of the system. Also, the riparian fringe is impacted in areas by grazing and trampling with abstraction for irrigation also affecting the ecological integrity of this system.

The Groot River becomes known as the Meirings River as it enters the Meiringspoort Gorge. Here the vegetation changes from succulent Karoo to Swartberg Shale Renosterveld. It is within this reach that the diesel spill pertinent to this assessment took place. Within this reach, the active channel is still dominated by small cobbles and gravels with bedrock outcrops derived from shales. The instream habitat forms a series of shallow runs and riffles separated by deeper pools with bedrock and gravel substrata. The channel tends to braid with flow through thick stands of the sedge *Pseudoschoenus cf inanis*. Besides *Acacia karoo* which dominates the dry bank of the riparian fringe, other vegetation typical on the wetter banks includes shrubs such as *Conyza scabrida* and the Cape Willow (*Salix mucronata*). About 1.5 km downstream from the site of the diesel spill, the character of the Meirings River changes considerably. The change in character coincides largely with a change in vegetation from Swartberg Shale Renosterveld to South Swartberg Sandstone Fynbos associated with a change in soils from clays derived from shale to acidic soils derived from sandstone. The channel becomes confined within the gorge and the substrata shifts to large sandstone boulders and bedrock with cascades separating deep pools. There are fewer *Acacia karoo* specimens within this reach and Cape Willow (*Salix mucronata*) becomes the dominant riparian vegetation type.

3.3 The Conservation Importance of the Meirings River

The entire length of the Groot / Meirings River system falls within catchments classified as a fish sanctuary within the NFEPA database (Figure 2.2). Fish sanctuaries are “rivers that are essential for protective threatened and near-threatened freshwater fish that are indigenous to South Africa” (Nel *et al.* 2011). One of the goals of NFEPA is to prevent threatened species from going extinct. In order to achieve this goal, the NPEFA guidelines indicate that no further deterioration in river condition in fish sanctuaries should be permitted (Nel *et al.* 2011). Also, the entire length of the Groot / Meirings River is classified as an Aquatic core Biodiversity Area (CBA1). According to the land use guidelines described in the Western Cape Biodiversity Spatial Plan (WCBSP) handbook (Pool-Stanvliet *et al.* 2017), the desired management objective for CBA1 aquatic and terrestrial habitats is to maintain them “in a natural or near-nature state with no further loss of natural habitat. Degraded areas should be rehabilitated”(Pool-Standvliet *et al.* 2017).

The Groot catchment is recognised as an area that supports at least one population of critically endangered or endangered fish species. Indeed, the Groot /Meirings River supports two threatened native freshwater fish species, namely smallscale redfin *Pseudobarbus asper* and the slender redfin *Pseudobarbus tenuis*. *P. asper* is listed as endangered and only occurs in the Gouritz and Gamtoos catchments, while *P. tenuis* is listed as near threatened and is endemic to the Gouritz catchment (van der Walt 2017). Thus the Groot/Meirings River is an ecosystem of very high conservation importance and a listed priority for the conservation and protection of aquatic ecosystems.

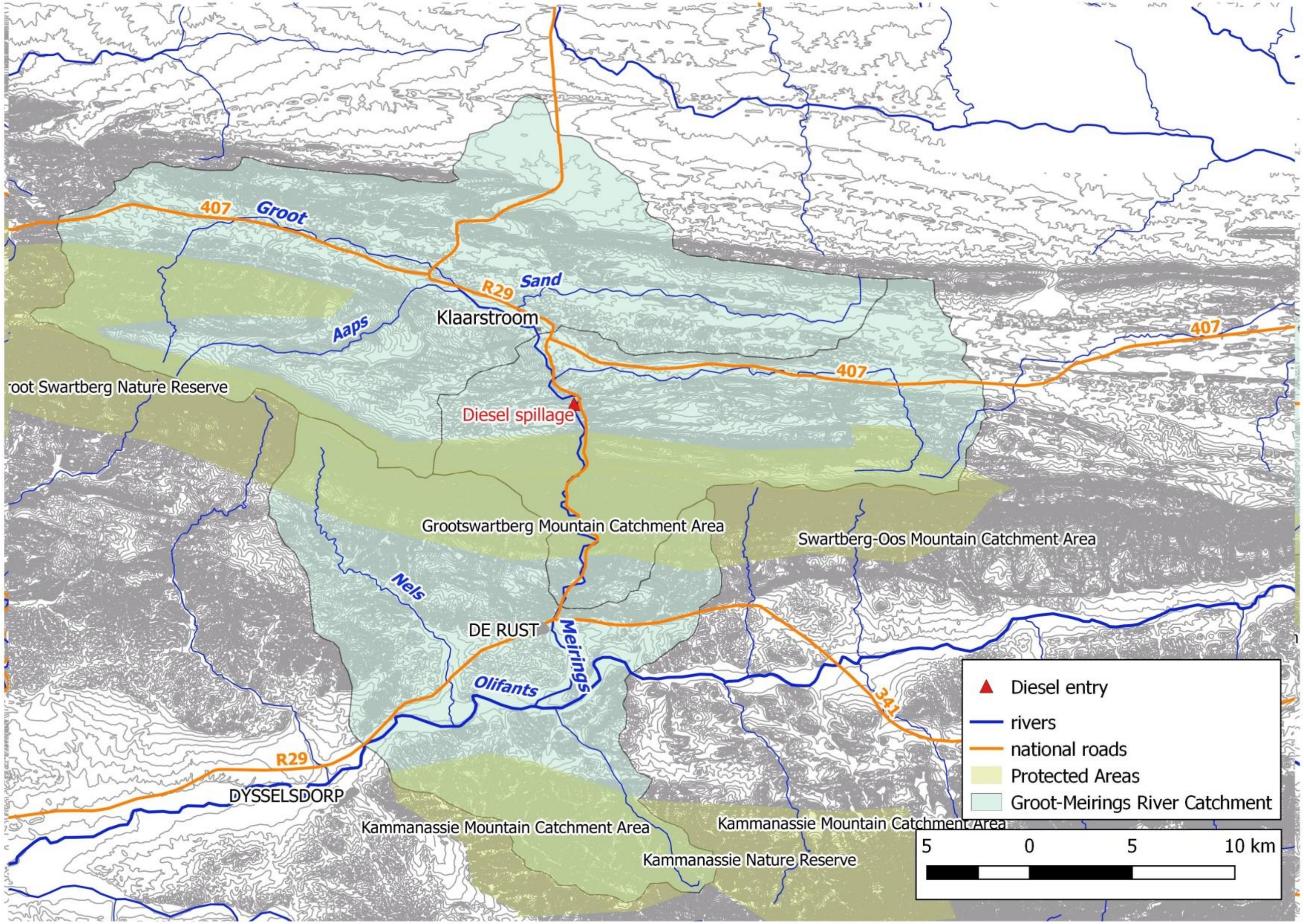

Figure 2.1 The Groot-Meirings River Catchment showing the site of the diesel spill on the Meirings River within the Meiringspoort upstream of the protected area (the Grootswartberg Mountain Catchment Areas which forms part of the Swartberg Nature Reserve)

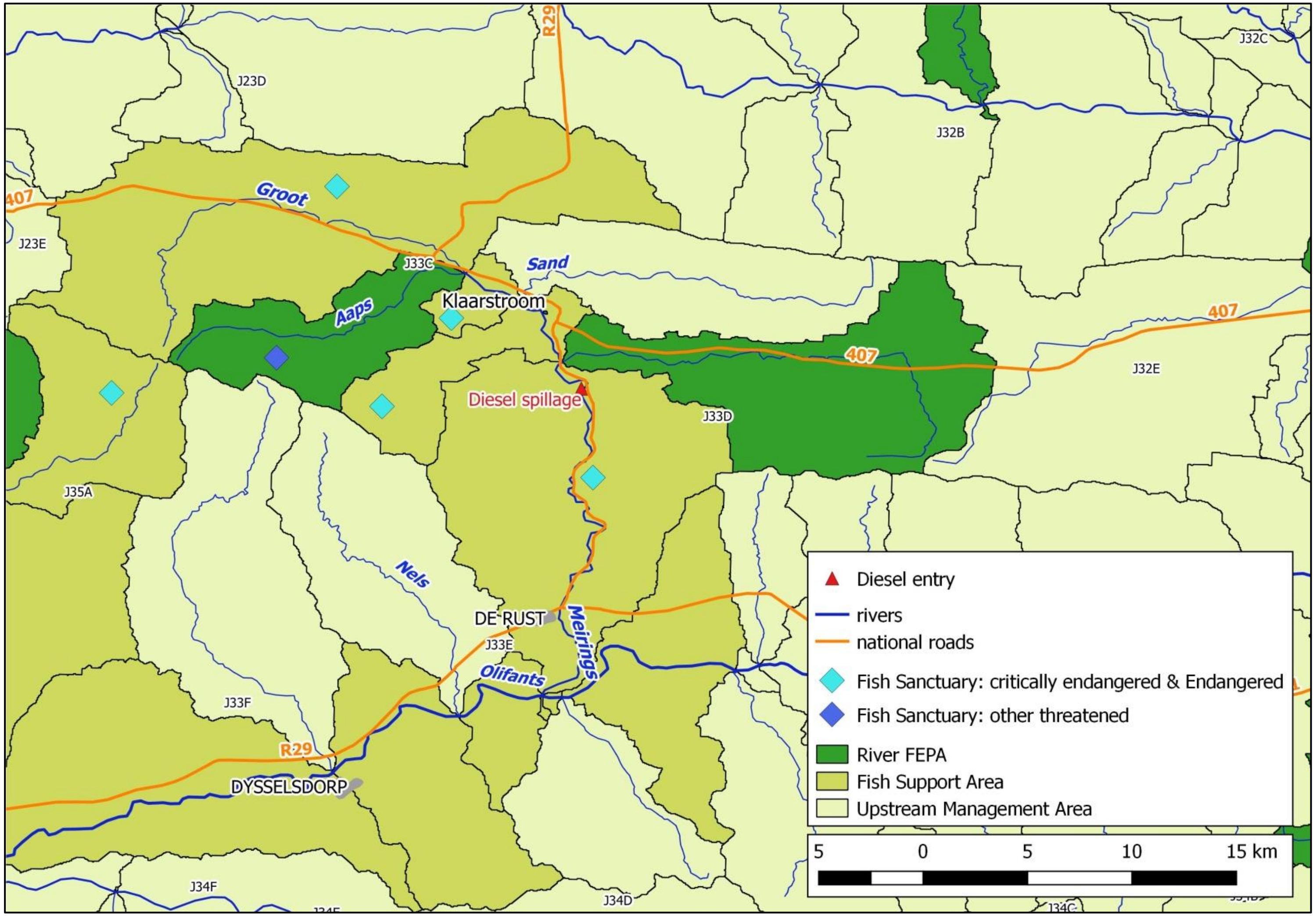

Figure 2.2 National Freshwater Ecosystem Priority Area of the Groot-Meirings River Catchment indicating that the site of the diesel spill is within a Fish Sanctuary for critically endangered and Endangered species.

4 ASSESSMENT APPROACH AND METHODOLOGY

Considering the lack of quantitative background information on the water chemistry and biota of the Groot/Meirings River, the basic approach to this study was to select sites upstream and downstream of the impact zone as controls against which to monitor recovery over time within the impacted zone. Also, sites were selected both within the impact zone and with distance downstream to establish whether the biological effects extended beyond what was visibly evident as the impacted zone.

4.1 Sampling dates

Collection of data specific to the Baseline Assessment for this study was undertaken on the 12th September 2017. However, water chemistry data were collected during the initial site visit following the spill on the 18th August 2017 as a basis for understanding the initial intensity of the impact associated with diesel contamination. Water chemistry data were collected again on the 17th October 2017 after application of Biosolve to determine any changes in water chemistry associated with the use of surfactants within the Meirings River. Samples were collected for different purposes on all three occasions and thus the number of sampling sites and the location of these sites differed somewhat.

Table 4.1 Summary of site visits and data collected from various sites during each visit

Date	Data collected	Number of sampling sites
18 August 2017	I*n situ* physico-chemistry, water and substrate samples for the analysis of water chemistry and hydrocarbon concentrations.	3 sampling sites
12 September 2017	I*n situ* physico-chemistry; macroinvertebrates.	5 sampling sites
17 October 2017	I*n situ* physico-chemistry and samples for the analysis of water chemistry	6 sampling sites

4.2 Sampling sites

During an initial site visit on the 18th August 2017, data were collected from three sites (Sites A, B and C) (Figure 4.1). **Site A**, upstream of the impact zone was selected as an initial control for comparison with samples collected within the impact zone (**Site B** and **Site C**).

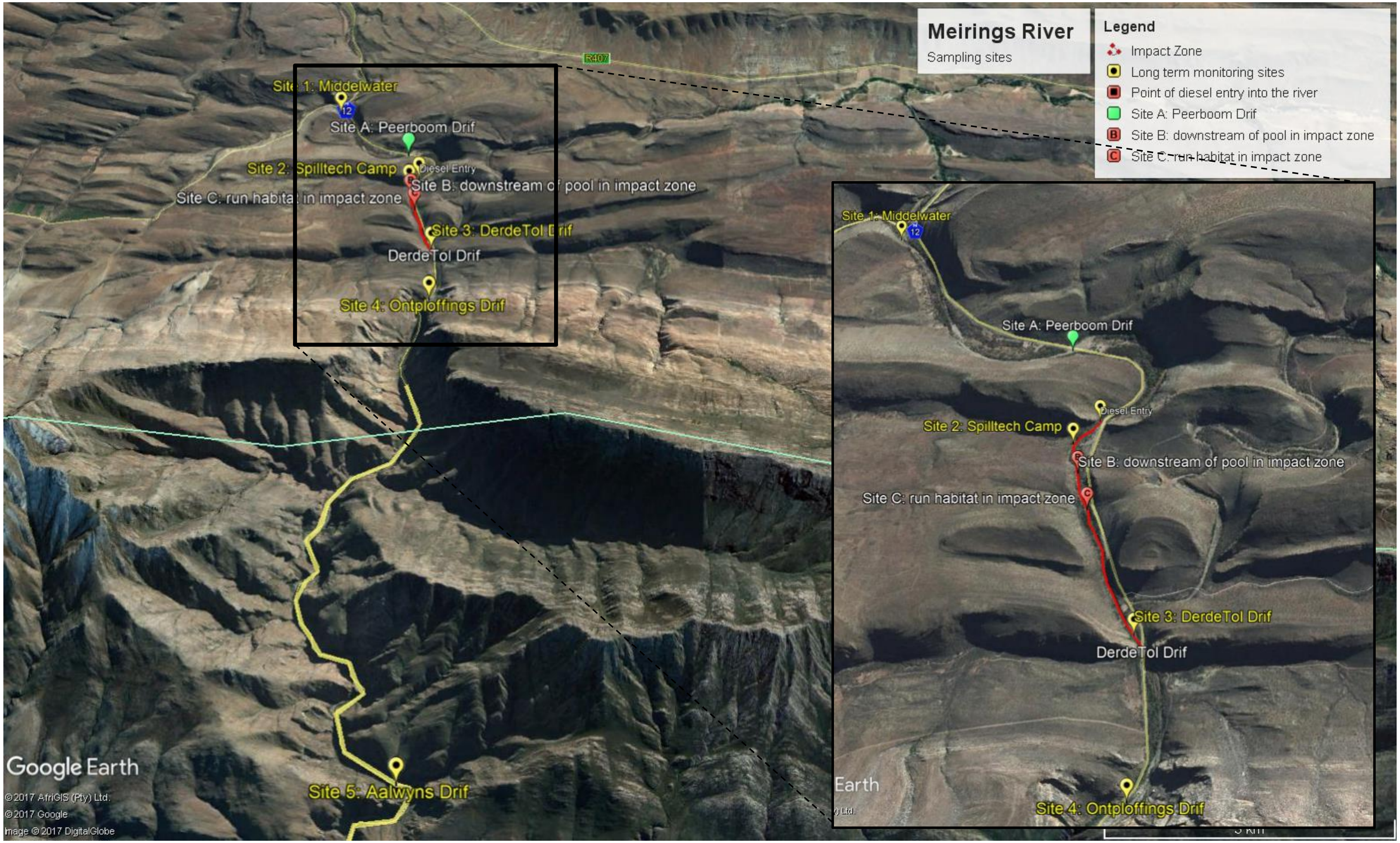

Figure 4.1 Location of the sites sampled on three different occasions between August and October 2017 following the diesel spill.

Five sites (Figure 4.1) were selected for ongoing monitoring during September 2017. Site selection took into consideration available habitat for macroinvertebrates and fish as follows:

Site 1 (control): is upstream of the impact zone immediately downstream of the low flow crossing at Middelwater (Site 1). Habitats for sampling include Stones-in-current (SIC) mostly shallow riffles and runs over gravel and small cobble, marginal vegetation (mostly sedges) both in current and out of current (pool margin) and stones-out-of-current (SOOC) within a large pool. *Reason for selection:* upstream control for impacted river reach to account for impacts unrelated to the diesel spill.

Site 2 (impact): is within the impact zone, approximately 100 m from the diesel entry point adjacent to the Spiltech Camp. Available habitats include both SIC (runs and riffles over boulders and cobbles), SOC (in pool), marginal vegetation (mostly sedges) in current and out of current with some gravel in the pool. *Reason for selection:* to monitor recovery over time within the impacted zone close to the point of impact.

Site 3 (impact): is within the impact zone but near the downstream extent, approximately 50 m upstream of Derde Tol Drif. The site is characterised by runs and riffles over cobble with gravel in the pool at the upstream end of the site. Marginal vegetation includes sedges both in current and out of current. *Reason for selection:* to monitor recovery over time within the impacted zone close to its downstream extent.

Site 4 (not specified): is upstream of Ontploffings Drif, approximately 800 m downstream of the impact zone (i.e. downstream of Derde Tol Drif). This site is dominated by boulders and bedrock with riffles and runs separating large pools with stony substrata. Some gravel and sand is present in slackwaters but the channel is dominated by large material. Marginal vegetation is sparse with isolated patches of sedge along pools. This site is transitional between the upper "Karoo-like" reaches of the Meirings River and the downstream "Fynbos-like" reaches. *Reason for selection:* to determine whether ecological impacts extend downstream beyond the so-called impact.

Site 5 (control): is approximately 8.5km downstream of the impact zone (i.e. downstream of Derde Tol Drif). The site is immediately downstream of Alwyns Drif and is characterised by cobbles runs and riffles with limited marginal vegetation including both sedges and juvenile willows (*Salix mucronata*). This site is typically a fynbos river system with sandstone substrata and acidic waters. *Reason for selection:* to monitor natural variability in biota and water chemistry well beyond the effects of the diesel spill.

During October 2017, water quality data was collected from all 5 of these sites , as well as from the point of enter of the Diesel spill because BioSolve® was applied to the river bank at this point and thus it was necessary to determine if there were any effects on water chemistry immediately downstream of the point of application. This site is referred to as **Site 2(i):** Diesel Entry. These sites are illustrated in Figure 4.2.

Figure 4.2 a) Site 1 at Middelwater looking upstream from the pool showing predominantly shale bedrock with small gravel and cobble runs and riffles b) Site 2 (i) the pool immediately downstream of the diesel entry point. c) Site 2 at the Spiltech camp looking upstream showing the active channel dominated by boulders and large cobble with the wet bank dominated by the sedge (*Pseudoschoenus* sp.). d) Site 3 looking downstream towards Derde Tol Drif showing the active channel dominated with large cobble runs and riffles and densely vegetated wet banks.

Figure 4.2 continued e) Site 4 immediately upstream of Ontploffings Drif showing the active channel dominated by large sandstone derived boulders and bedrock. High turbidity is associated with bridge maintenance activities at the time of the site visit in October 2017. F) Site 5 at Alwyns Drif showing the active channel dominated by sandstone derived cobbles and boulders with a riparian fringe dominated by *Salix mucronata*.

4.3 Water quality Assessment

4.3.1 Sample collection

In situ measurements of Electrical Conductivity (EC) (mS m^{-1}), pH, Dissolved Oxygen (DO) (mg/ℓ) and temperature (^{0}C) were carried out at the sites described above during the three site visits, using a calibrated hand-held Lovibond Sensodirect 150 multimeter.

Water samples collected for analysis of various water quality components were kept cool and sent to a laboratory for further analysis within 48 hours of collection.

4.3.2 Laboratory methods of analysis

All inorganic components were analysed by UIS analytical laboratory in Pretoria within 48 hours of collection. Concentrations of orthophosphates (PO_4^{3-}-P), nitrates (NO_3^--N), nitrites (NO_2^--N), and Ammonium (NH_4^+-N) ions were analysed by ion chromatography and reported as mg ℓ^{-1} using method UIS-EA-T008 for all components except ammonium which was determined by method UIS-EA-T009. Chemical oxygen demand (COD) was determined using method UIS-EA-T030 and reported as ppm of oxygen (O_2). Oils and greases were determined by method UIS-EA-T007 and reported as ppm.

The concentrations of Total Petroleum Hydrocarbons (TPH) in the range C10-C28, C28-C40 were analysed by the UIS organic laboratory following collection of both water column and substrate samples in August 2017. The results were reported as micrograms per litre (µg ℓ^{-1}).

4.4 SASS5 Bioassessment

The South African Scoring System version 5 (SASS5) is a widely used approach for the assessment of macroinvertebrate communities in South African rivers. This method provides an excellent index of species richness and water quality in perennial rivers with relatively natural habitats. Thus, SASS5 was only considered suitable for application to sites within the Meirings River.

The SASS5 protocol uses a kick-sampling technique that disturbs the streambed so that invertebrates are dislodged from the substratum and vegetation, and retained on a hand-held 950µm-mesh sieve (attached to a 300mm x 300mm frame). The sample was placed in a basin and each taxon recorded, at the level of invertebrate family. The abundance grouping of each family was recorded, where "1" is given to a single appearance of a taxon, "A" accorded where individuals number 1-10, "B" for 11-100 individuals, "C" for 101-1000 individuals, and "D" for > 1000 individuals.

The SASS5 protocol allocates a predetermined score for each taxon according to its sensitivity to water quality perturbation. Sensitive taxa are allocated high weightings (maximum of 15) while taxa more common to degraded/disturbed systems receive low weightings (Dickens and Graham 2002).

SASS5 sampling was done separately for each available biotope (defined by flow and substratum characteristics). The available habitat during March 2013 included 'stones-in-current', which included riffles and runs, 'stones-out-of-current', which include slackwater on the edge of the stream and pools. Very little marginal vegetation provided habitat, although some in channel sedges along the pool margins were sampled. Some sand and gravel were sampled as part of the 'Gravel-sand-mud' biotope but the predominant habitat within this biotope was silt/mud. Each biotope was sampled for a maximum of 5 minutes, while vegetation was sampled by sweeping the SASS-net through approximately 2m swathes of vegetation.

SASS5 scores, Average Scores Per Taxon (ASPTs)[1] – (calculated by dividing the SASS5 score by the number of taxa) and total number of taxa were calculated for each biotope.

Interpretation of SASS5 data made use of the Biological Bands developed by Dallas (2007), which allow SASS5 data to be interpreted relative to reference condition sites in similar river reaches, in the same ecoregions. The biological bands allow data to be categorised from Category A to F with Category A being natural or reference condition systems.

For this study, samples from each habitat were preserved in 98% ethanol for later identification to species level (or closest taxonomic level) if necessary.

5 RESULTS

5.1 Water Quality

Water quality variables sampled from three sites on the 18th August 2017, three days after the diesel spill into the Meirings River, are presented in Tables 5.1 to 5.3 as well as Figure 5.1. Those measured *in situ* at the five biomonitoring sites on the 12th September 2017 are presented in Table 5.4, while samples collected from the area following the application of the surfactant, BioSolve®, are presented in Figure 5.2 and Table 5.5.

Unsurprisingly, excessively high Total Petroleum Hydrocarbon (TPH) concentrations in the range C_{10}-C_{28}, which represent the diesel range organics, were recorded in the water column within the impact zone, decreasing within distance from the entry point (Table5.1.). A visual assessment of the site on the 18th August 2017 indicated that residues of diesel were present where diesel had made contact with either sediments or vegetation along the wetted margins of the active channel. Refined fuels such as diesel tend to spread on the surface of water into thin slicks or sheens and thus, as expected, substrata sampled within the pool and run habitats three days after the spill were evidently uncontaminated with no trace of hydrocarbons (Figure 5.2). These data suggest that the fuel had not sunken out and deposited on the substrata (Table 5.2). However, sediment samples taken from the sand bank and river base within the impact zone by Geomeasure about a week following the spill indicated significantly high concentrations of Diesel Range Organics (DRO's) in the range of C10-C20 and Gasoline Range Organics (GRO's) with high concentrations m,p,o Xylene isomers, 1,3,5-Trimethylbenzene and 1,2,4-Trimethylbenzene (Geomeasure 2017). These concentrations were many orders of magnitude higher compared to the water samples which suggest that while surface

[1] ASPTs are particularly useful as indicators of water quality of an aquatic system, as a low score will indicate that the community is dominated by species resistant to anthropogenic perturbations such as pollution, while high scores indicate the occurrence of more sensitive and, often rare, species, that would be expected to occur in undisturbed systems.

water clean-up operations were effective, the sediments along the river were contaminated at this time.

Dissolved Oxygen (DO) concentrations were significantly lower at Sites B and C within the impact zone compared with Site A upstream of the point of diesel entry into the river on the 18^{th} August 2017 (Figure 5.1). According to DWAF (2008), pristine rivers generally have DO concentrations of >8 mg/l with only slight changes in concentrations indicative of impacted systems that have adverse effects on aquatic biota. In particular, DO concentrations between 4-6 mg/l are considered impacted with a "large change" from natural conditions. Thus a drop in DO from 9.1 mg/l upstream of the spill to 7.2 mg/l and 5.0 mg/l within the impact zone, respectively suggests that the diesel spill had a significant impact on dissolved oxygen concentrations of the Meirings River. It is therefore not surprising that significant numbers of redfin minnow were struggling for oxygen at the surface and dying at the time of the site visit in August (see Section 1.1). Interestingly, the onset of fish mortality was coupled with an increase in ambient temperatures and a likely increase in water temperatures. Although the diesel spill occurred during particularly cold conditions, air temperatures increased on the 17^{th} August and by mid-day of the 18^{th} August fish began to surface and die. Evidently, higher water temperatures combined with low dissolved oxygen levels can compound stress effects on aquatic organisms as was evident in the Meirings River.

Chemical Oxygen Demand (COD) within the impact zone (Figure 5.1) was excessively high and is the likely cause of oxygen depletion as oxygen is used by micro-organisms (mostly bacteria and fungi) in the degradation of refined fuels such as diesel. Even though COD was considerably lower at Site C, relative to Site B, dissolved oxygen (DO) was even lower at this site (5.0 mg/l) and indicative of a system that would impose severe stress on aquatic fauna. Nevertheless, by 12^{th} September 2017, DO concentrations where above 8 mg/l for all sites (Figure 5.2) suggesting that the initial effects of biodegradation were no longer apparent less than a month following the spill event. A month after the application of BioSolve® to the river bank at the point of diesel entry into the Meirings River (see Section 2), DO concentrations were over 8 mg/l at all biomonitoring sites, with the exception of site 2(i) sampled at the point of entry. However, COD was high both within the impact zone (site 2(i), site 2, site 3) as well as downstream at Ontploffings Drif (site 4) (Figure 5.3), indicative of the presence of diesel contamination.

Total Oils and Grease (TOG) concentrations in August 2017 did not provide any insight into the effects of diesel contamination as concentrations were higher upstream of the diesel spill entry point, compared with that measured within the impact zone (Figure 5.1). By contrast TOG concentrations were considerably higher within the impact zone and as far downstream as Alwyns Drif in October 2017 (Figure 5.3). Although TOG is a measure of all oil and grease based contaminants, it is likely that the application of surfactants may have increased the concentration of TPH's, especially PAHs that are not as soluble compared to alkyl benzenes (BTEX compounds) of Benzene, Toluene, Ethyl Benzene and Xylene in the water column (Box 1). There are no clear guidelines for thresholds of toxicity associated with oils and grease in South Africa. However, the United Nations Environmental Programme (UNEP 1992) stipulate maximum permissible limits of 10 ppm (or mg/l) for oils. Table 5.5 indicates that the TOG concentrations ranged between 10-14 ppm within and downstream of the impact zone.

In terms of nutrients, phosphates at all sites in both August 2017 (Table 5.3) and October 2017 (Table 5.5) were indicative of moderate to high enrichment (meso-euthrophic), possibly due to irrigation return flows from nutrient rich cultivated crops adjacent to the river upstream of the Meiringspoort Gorge. By contrast, Total Inorganic Nitrogen (TIN) and ammonia both upstream and within the impact zone are indicative of unimpacted conditions (DWAF 2008) (Table 5.3 and Table 5.5). Essentially, these data indicate that there is no apparent effect of the diesel spill or use of surfactants on the trophic status of the Meirings River.

Table 5.1 Total Petroleum Hydrocarbon (TPH) C10-C40 Analysis for <u>water column</u> samples taken from the active channel of the Meirings River at 3 sites sampled on 18th August 2017

Site	Site Description	C10-C28 (µg/l)	C28-C40 (µg/l)	Total (µg/l l)
SITE A	Upstream of spill site @Peerboom Drif	<267	<267	<267
SITE B	Pool within impact zone	**54000**	<4966	54000
SITE C	Run near centre of impact zone	**770**	<267	770

Table 5.2 Total Petroleum Hydrocarbons (TPH) C10-C40 Analysis for <u>substrates</u> within the active channel of the Meirings River at 3 sites sampled on 18th August 2017

Site	Site Description	C10-C28 (µg/l)	C28-C40 (µg/l)	Total (µg/l)
SITE A	Upstream of spill site @Peerboom Drif	<38	<38	<38
SITE B	Pool within impact zone	<38	<38	<38
SITE C	Run near centre of impact zone	<38	<38	<38

Table 5.3 Water quality components measured in situ or from laboratory analysis in August 2017

Site	Site Description	pH	EC (mSm)	Temp (^{0}C)	Dissolved Oxygen (mg/l)	TDS (mg/l)	TSS (mg/l)	NO_3 - N (mg/l)	PO_4.P (mg/l)	NO_2 - N (mg/l)	COD (mg/l)	Tot. Oil & Grease (ppm)	$NH4^+$ + NH_3 [mg/l]	NH_3 - N [mg/l]	TIN (mg/l)
SITE A	Peerboom Drif	7.63	104	13.3	9.1	642	<20	<0.13	0.092	0.002	12	7	<0.001	0.000024	0.002
SITE B	Pool in impact zone	7.42	93.4	12.2	7.2	594	62	<0.13	0.027	<0.001	133	3	0.037	0.000546	0.037
SITE C	Run in impact zone	6.83	94.6	12.7	5.0	614	<20	<0.13	0.029	<0.001	17	4	0.003	0.000011	0.003

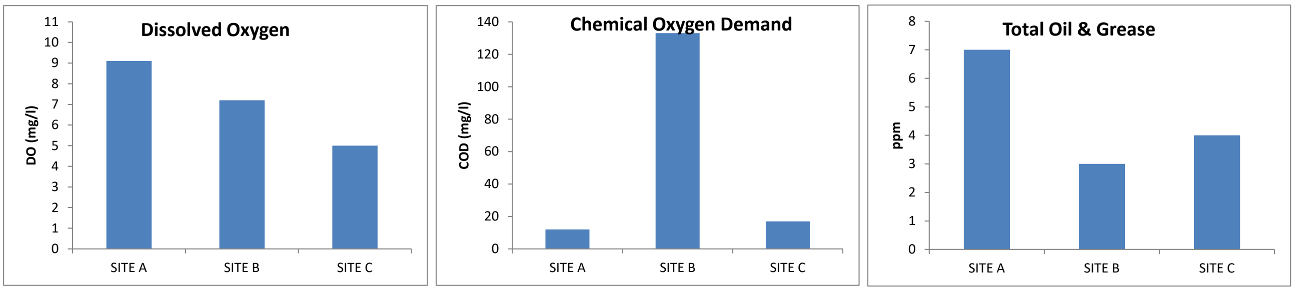

Figure 5.1 **Graphic representation of the concentrations of various water quality components analysed from water samples taken at three sites on the *15th August* 2017.**

Table 5.4 ***In situ* measurements of physico-chemistry from the 5 biomonitoring sites on *12th September 2017.***

Site	Site Description	pH	EC (mSm)	Temp (^{0}C)	Dissolved Oxygen (mg/l)
Site 1	Middelwater	8.07	92	19.0	9.1
Site 2	Spiltech	7.00	82	17.9	9.1
Site 3	Derde Tol Drif	6.85	72	21.8	9.6
Site 4	Ontploffings Drif	7.95	76	15.2	9.6
Site 5	Alwyns Drif	6.50	19	16.5	10.7

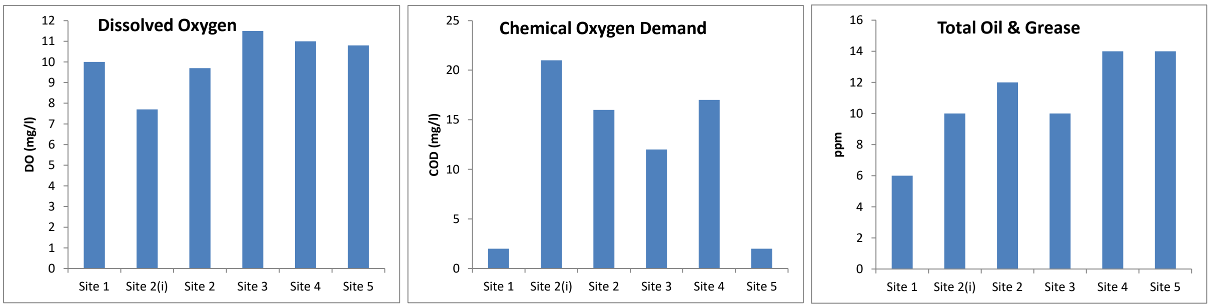

Figure 5.3 **Graphic representation of the concentrations of various water quality components analysed from water samples taken at three sites on the *17th October 2017*, following the application of Biosolve on the 14th September 2017.**

Table 5.5 **Water quality components measured *in situ* or from laboratory analysis in October 2017.**

Site	Site Description	pH	EC (mSm)	Temp (^{0}C	Dissolved Oxygen (mg/l)	NO_3 - N (mg/l)	NO_2 - N (mg/l)	PO_4 P (mg/l)	COD (mg/l)	Tot. Oil & Grease (ppm)	BOD (mg/l)	$NH4^+ + NH_3$ [mg/l]	NH_3 - N [mg/l]	TIN (mg/l)
Site 1	Middelwater	7.76	29.9	13.3	10.0	<0.13	0.002	0.045	<10	6	<10	0.028	0.000888	0.03
Site 2(i)	Diesel Entry	7.42	67.1	13.4	7.7	<0.13	0.002	0.04	21	10	<10	0.025	0.000369	0.027
Site 2	Spiltech	7.64	68.5	12.8	9.7	<0.13	0.002	0.045	16	12	<10	0.019	0.00046	0.021
Site 3	Derde Tol Drif	7.76	65.5	14.6	11.5	<0.13	0.002	0.045	12	10	<10	0.02	0.000634	0.022
Site 4	Ontploffings Drif	7.14	66	11.8	11.0	<0.13	0.003	0.045	17	14	<10	0.032	0.000249	0.035
Site 5	Alwyns Drif	6.54	13.9	13.0	10.8	<0.13	0.003	0.047	<10	14	<10	0.027	0.000053	0.03

5.2 Macroinvertebrate fauna

Upstream of the diesel spill (i.e. Site 1: Middelwater), the Meirings River is rated as a Class C (Table 5.6), based on the overall SASS and ASPT score in September 2017 (Figure 5.4), thus reflecting a system that is moderately modified with a loss of most pollution sensitive taxa (Table 5.7). Impairment at this site is largely a consequence of water quality impacts, probably due to farming activities upstream. The condition of the system deteriorates considerably however with a SASS and ASPT score near the spill entry site (i.e. Site 2: Spiltech) reflecting a Class E/F (Figure 5.4). Essentially, very few invertebrates were present at the time of the site visit, with those surviving taxa known to be hardy and pollution tolerant. Taxa included adult Dytiscid beetles which are air breathers and relatively mobile. It is likely that the few individuals present at the time of the site visit had colonised since the spill event. The only other invertebrates present were 2 tabanid (horsefly) larvae and 2 chironomid (midge) larvae (Table 5.8).

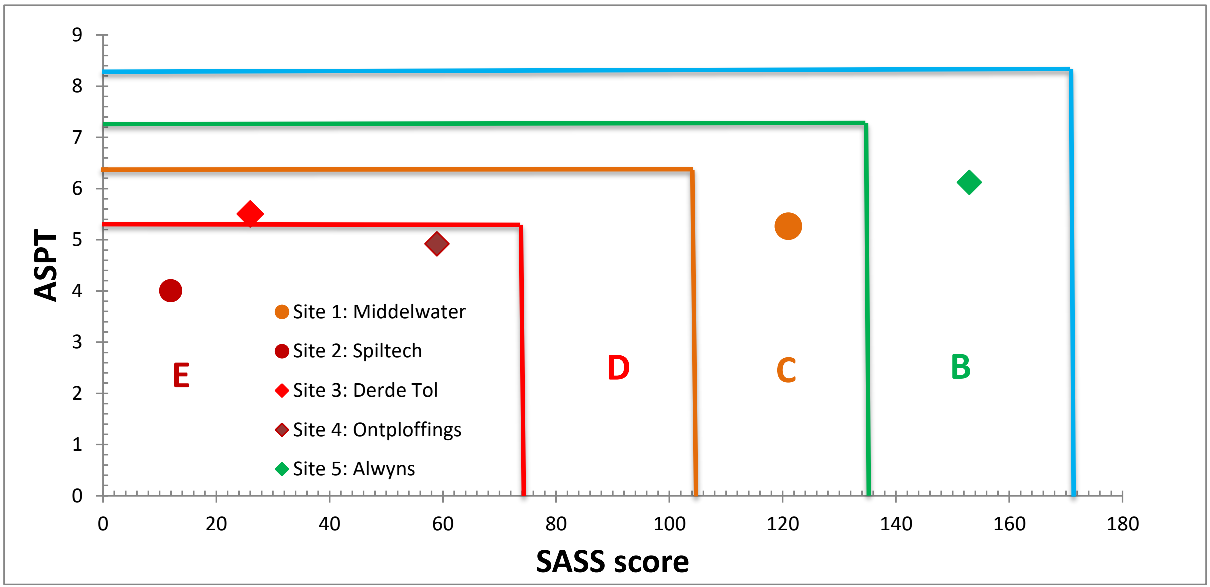

Figure 5.4 SASS scores and ASPT values at biomonitoring sites on the Meirings River. The biological bands depicting change in condition are taken from Dallas (2007).

Conditions at the downstream extent of the impact zone (i.e. Site 3: Derde Tol Drif) were slightly improved with a SASS and ASPT score reflecting a Class D condition in terms of the macroinvertebrate condition (Table 5.6). Nevertheless, the invertebrate community at this site was still severely impaired with a dominance of airbreathing taxa that are likely to have recolonised since the spill event. These include the hemiptera, corixidae and naucoridae as well as dyticid and gyrinid beetles, mostly within the marginal vegetation. Other taxa include hardy fly larvae such as chironomids, ceratopogonids and ephydrids. However, unlike the Spiltech site, other more sensitive taxa including 1 individual of the family Athericidae, as well as 2 elmid beetle larvae were present at this site (Table 5.9), suggesting that the impact was less severe with distance from the spill entry site.

Surprisingly, a further 800 m downstream of the impact zone at Site 4 (i.e. Ontploffings Drif), the macroinvertebrate community sampled in September 2017 was severely impacted with a SASS and ASPT score reflecting a Class E/F (Figure 5.4 and Table 5.6). While there was no visual evidence of contamination at this site, with in situ physico-chemistry indicative of unimpacted conditions (see Table 5.4), these data suggest that the impact of the diesel spill extended well below the so-called impact zone. Unfortunately, no water chemistry samples were collected at this site but the slightly elevated COD and TOG concentrations measured at this site in October 2017 further suggest that the impacts of the spill extended a considerable distance downstream of the entry point. Once again, the community was dominated by airbreathers within the order hemiptera (true bugs) and coleoptera (beetles) (Table 5.10).

The macroinvertebrate community a further 8.5 km downstream of the impact zone at Site 5 (Alwyns Drif) suggests that the diesel spill had no apparent impact on this reach of the river. The SASS and ASPT scores reflect a Class B condition (Figure 5.4), indicative of an ecosystem that is in good condition (Table 5.6). Indeed, sensitive taxa, including at least three species of mayfly larvae (baetidae) and leptophlebidae were present, together with trichoptera (Table 5.11). Other sensitive taxa included the riffle beetle larvae, Elmidae, the dragonfly larvae, aeshnidae and the sensitive true fly larvae, Dixidae (Table 5.11).

Table 5.6 A description of the ecological categories for interpreting SASS data as an indictor of ecosystem health.

Class	Description
A	SASS and ASPT scores are representative of reference conditions i.e. sites that are near natural with little or no impairment of habitat or water quality
B	SASS and ASPT scores are lower than expected; condition is good and the system is still largely natural i.e. there may be some impairment of water quality and/or habitat with a loss of some pollution-sensitive taxa
C	SASS and ASPT scores are much lower than expected, condition is fair and the system is moderately modified i.e. substantial impairment of water quality and/or habitat with a major loss of pollution-sensitive taxa
D	SASS and ASPT scores are considerably lower than expected, condition is poor and the system is largely modified i.e. substantial impairment of water quality and/or habitat with almost a total loss of pollution-sensitive taxa
E/F	Few of the expected taxa remain indicating severe impairment. The system is critically modified and the remaining taxa are hardy and pollution-tolerant

Table 5.7 Invertebrate taxa recorded in each SASS biotope at Site 1: Middelwater sampled in September 2017. 1 = 1 individual; A = 2-10 individuals; B = 11-100 individuals

Date: 12.09.2017		Sensitivity	Biotope						Sensitivity	Biotope			
Order	**Family/taxa**	**rating**	**Stones**	**Veg**	**GSM**	**Overall**	**Order**	**Family/taxa**	**rating**	**Stones**	**Veg**	**GSM**	**Overall**
PORIFERA		5					TRICHOPTERA	Dipseudopsidae	10				
COELENTERATA		1						Ecnomidae	8				
TURBELLARIA		3						Hydropsychidae 1 sp.	4				
ANNELIDA	Oligochaeta	1	1			1		Hydropsychidae 2 sp.	6				
	Leeches	3						Hydropsychidae >2 sp.	12				
CRUSTACEA	Amphipoda	13						Philopotamidae	10				
	Potamonautidae	3						Polycentropodidae	12				
	Atydiae	8						Psychomyiidae	8				
	Palaemonidae	10						Barbarochthonidae	13				
HYDRACARINA		8	A		A	A		Calamoceratidae	11				
PLECOPTERA	Notonemourdae	14						Glossosomatidae	11				
	Perlidae	12						Hydroptilidae	6				
EPHEMEROPTERA	Baetidae 1 sp.	4	A			A		Hydrosalpingidae	15				
	Baetidae 2 sp.	6	A	B		B		Lepidostomatidae	10				
	Baetidae > 2 sp.	12						Leptoceridae	6	1	1		1
	Caenidae	6	A			A		Petrothrinicidae	11				
	Ephemeridae	15						Pisuliidae	10				
	Heptageniidae	13						Sericostomatidae	13				
	Leptophlebiidae	9					COLEOPTERA	Dytiscid	5	A	B	A	B
	Oligneuridae	15						Elmidae	8		A		A
	Polymitarcyidae	10						Gyrinidae	5	A	1		A
	Prosopistomatidae	15						Haliplidae	5				
	Teloganodidae	12						Helodidae	12				
	Tricorythidae	9						Hydraenidae	8	A			A
ODONATA	Calopterygidae	10						Hydrophilidae	5		1	1	A
	chlorocyphidae	10						Limnichidae	10				
	Chlorolestidae	8						Psephenidae	10				
	Coenagrionidae	4					DIPTERA	Athericidae	10				
	Lestidae	8						Blepharoceridae	15				
	Platycnemidae	10						Ceratopogonidae	5	A			A
	Protoneuridae	8						Chironomidae	2	B	B	A	B
	aeshnidae	8		1		1		Culicidae	1		B		B
	Corduliidae	8						Dixidae	10		A		A
	Gomphidae	6						Empiddidae	6			1	1
	Libellulidae	4		1	1	1		Ephydridae	3		1		1
LEPIDOPTERA	Pyralidae	12						Muscidae	1				
HEMIPTERA	Belostomatidae	3						Psychodidae	1				
	Corixidae	3						Simulidae	5	B	A	1	B
	Gerridae	5		1	1			Syrphidae	1				
	Hydrometridae	6						Tabanidae	5				
	Naucoridae	7						Tipulidae	5	A	1		A
	Nepidae	3					GASTROPODA	Ancylidae	6				
	Notonectidiae	3						Bulininae	3				
	Pleidae	4		1		1		Hydrobiidae	3				
	Veliidae/Mesoveliidae	5		A		A		Lymnaeidae	3		1		1
MEGALOPTERA	Corydalidae	8						Physidae	3				
	Sialidae	6						Planorbidae	3				
								Thiaridae	3				
								Viviparidae	5				
							PELECPODA	Corbiculidae	5				
								Sphaeriidae	3				
								Unionidae	6				
									SASS	66	90	40	**124**
									Total number of families	13	18	8	**24**
									ASPT	5,1	5	5	**5,2**
									Water quality condition		**C**		

Table 5.8 Invertebrate taxa recorded in each SASS biotope at <u>Site 2: SillTech</u> sampled in September 2017. 1 = 1 individual; A = 2-10 individuals; B = 11-100 individuals

Date: 12.09.2017		Sensitivity	Biotope						Sensitivity	Biotope			
Order	**Family/taxa**	**rating**	**Stones**	**Veg**	**GSM**	**Overall**	**Order**	**Family/taxa**	**rating**	**Stones**	**Veg**	**GSM**	**Overall**
PORIFERA		5					TRICHOPTERA	Dipseudopsidae	10				
COELENTERATA		1						Ecnomidae	8				
TURBELLARIA		3						Hydropsychidae 1 sp.	4				
ANNELIDA	Oligochaeta	1						Hydropsychidae 2 sp.	6				
	Leeches	3						Hydropsychidae >2 sp.	12				
CRUSTACEA	Amphipoda	13						Philopotamidae	10				
	Potamonautidae	3						Polycentropodidae	12				
	Atydiae	8						Psychomyiidae	8				
	Palaemonidae	10						Barbarochthonidae	13				
HYDRACARINA		8						Calamoceratidae	11				
PLECOPTERA	Notonemourdae	14						Glossosomatidae	11				
	Perlidae	12						Hydroptilidae	6				
EPHEMEROPTERA	Baetidae 1 sp.	4						Hydrosalpingidae	15				
	Baetidae 2 sp.	6						Lepidostomatidae	10				
	Baetidae > 2 sp.	12						Leptoceridae	6				
	Caenidae	6						Petrothrinicidae	11				
	Ephemeridae	15						Pisuliidae	10				
	Heptageniidae	13						Sericostomatidae	13				
	Leptophlebiidae	9					COLEOPTERA	Dytiscid	5	A			A
	Oligneuridae	15						Elmidae	8				
	Polymitarcyidae	10						Gyrinidae	5				
	Prosopistomatidae	15						Haliplidae	5				
	Teloganodidae	12						Helodidae	12				
	Tricorythidae	9						Hydraenidae	8				
ODONATA	Calopterygidae	10						Hydrophilidae	5				
	chlorocyphidae	10						Limnichidae	10				
	Chlorolestidae	8						Psephenidae	10				
	Coenagrionidae	4					DIPTERA	Athericidae	10				
	Lestidae	8						Blepharoceridae	15				
	Platycnemidae	10						Ceratopogonidae	5		A		A
	Protoneuridae	8						Chironomidae	2	1			1
	aeshnidae	8						Culicidae	1				
	Corduliidae	8						Dixidae	10				
	Gomphidae	6						Empiddidae	6				
	Libellulidae	4						Ephydridae	3				
LEPIDOPTERA	Pyralidae	12						Muscidae	1				
HEMIPTERA	Belostomatidae	3						Psychodidae	1				
	Corixidae	3						Simulidae	5				
	Gerridae	5						Syrphidae	1				
	Hydrometridae	6						Tabanidae	5	1	1		A
	Naucoridae	7						Tipulidae	5				
	Nepidae	3					GASTROPODA	Ancylidae	6				
	Notonectidiae	3						Bulininae	3				
	Pleidae	4						Hydrobiidae	3				
	Veliidae/Mesoveliidae	5						Lymnaeidae	3				
MEGALOPTERA	Corydalidae	8						Physidae	3				
	Sialidae	6						Planorbidae	3				
								Thiaridae	3				
								Viviparidae	5				
							PELECPODA	Corbiculidae	5				
								Sphaeriidae	3				
								Unionidae	6				
									SASS	12	10	-	**17**
									Total number of families	3	2	-	**4**
									ASPT	4	5	-	**4,25**
									Water quality condition	**E/F**			

Table 5.9 Invertebrate taxa recorded in each SASS biotope at Site 3: Derde Tol Drif sampled in September 2017. 1 = 1 individual; A = 2-10 individuals; B = 11-100 individuals

Date: 12.09.2017		Sensitivity	Biotope						Sensitivity	Biotope			
Order	**Family/taxa**	**rating**	**Stones**	**Veg**	**GSM**	**Overall**	**Order**	**Family/taxa**	**rating**	**Stones**	**Veg**	**GSM**	**Overall**
PORIFERA		5					TRICHOPTERA	Dipseudopsidae	10				
COELENTERATA		1						Ecnomidae	8				
TURBELLARIA		3						Hydropsychidae 1 sp.	4				
ANNELIDA	Oligochaeta	1						Hydropsychidae 2 sp.	6				
	Leeches	3						Hydropsychidae >2 sp.	12				
CRUSTACEA	Amphipoda	13						Philopotamidae	10				
	Potamonautidae	3						Polycentropodidae	12				
	Atydiae	8						Psychomyiidae	8				
	Palaemonidae	10						Barbarochthonidae	13				
HYDRACARINA		8		1		1		Calamoceratidae	11				
PLECOPTERA	Notonemourdae	14						Glossosomatidae	11				
	Perlidae	12						Hydroptilidae	6				
EPHEMEROPTERA	Baetidae 1 sp.	4	A	1		A		Hydrosalpingidae	15				
	Baetidae 2 sp.	6						Lepidostomatidae	10				
	Baetidae > 2 sp.	12						Leptoceridae	6				
	Caenidae	6	A		1	A		Petrothrinicidae	11				
	Ephemeridae	15						Pisuliidae	10				
	Heptageniidae	13						Sericostomatidae	13				
	Leptophlebiidae	9					COLEOPTERA	Dytiscid	5	1	A	1	A
	Oligneuridae	15						Elmidae	8	A			A
	Polymitarcyidae	10						Gyrinidae	5		1		1
	Prosopistomatidae	15						Haliplidae	5				
	Teloganodidae	12						Helodidae	12				
	Tricorythidae	9						Hydraenidae	8				
ODONATA	Calopterygidae	10						Hydrophilidae	5				
	chlorocyphidae	10						Limnichidae	10				
	Chlorolestidae	8						Psephenidae	10				
	Coenagrionidae	4					DIPTERA	Athericidae	10			1	1
	Lestidae	8						Blepharoceridae	15				
	Platycnemidae	10						Ceratopogonidae	5		1		1
	Protoneuridae	8						Chironomidae	2	A	B	A	B
	aeshnidae	8						Culicidae	1				
	Corduliidae	8						Dixidae	10				
	Gomphidae	6						Empiddidae	6				
	Libellulidae	4						Ephydridae	3			1	1
LEPIDOPTERA	Pyralidae	12						Muscidae	1				
HEMIPTERA	Belostomatidae	3						Psychodidae	1				
	Corixidae	3	1	1		A		Simulidae	5				
	Gerridae	5						Syrphidae	1				
	Hydrometridae	6						Tabanidae	5				
	Naucoridae	7		A		A		Tipulidae	5				
	Nepidae	3					GASTROPODA	Ancylidae	6				
	Notonectidiae	3						Bulininae	3				
	Pleidae	4	1	1		A		Hydrobiidae	3				
	Veliidae/Mesoveliidae	5						Lymnaeidae	3				
MEGALOPTERA	Corydalidae	8						Physidae	3				
	Sialidae	6						Planorbidae	3				
								Thiaridae	3				
								Viviparidae	5				
							PELECPODA	Corbiculidae	5				
								Sphaeriidae	3				
								Unionidae	6				
									SASS	32	43	26	**70**
									Total number of families	7	9	5	**13**
									ASPT	4,6	4,8	5,2	**5,4**
									Water quality condition		**D**		

Table 5.10 Invertebrate taxa recorded in each SASS biotope at Site 4: Ontploffings Drif sampled in September 2017. 1 = 1 individual; A = 2-10 individuals; B = 11-100 individuals

Date: 13.09.2017		**Sensitivity**	**Biotope**			
Order	**Family/taxa**	**rating**	**Stones**	**Veg**	**GSM**	**Overall**
PORIFERA		5				
COELENTERATA		1				
TURBELLARIA		3				
ANNELIDA	Oligochaeta	1				
	Leeches	3				
CRUSTACEA	Amphipoda	13				
	Potamonautidae	3				
	Atydiae	8				
	Palaemonidae	10				
HYDRACARINA		8				
PLECOPTERA	Notonemourdae	14				
	Perlidae	12				
EPHEMEROPTERA	Baetidae 1 sp.	4		A	A	A
	Baetidae 2 sp.	6	A			A
	Baetidae > 2 sp.	12			B	B
	Caenidae	6	A		A	A
	Ephemeridae	15				
	Heptageniidae	13				
	Leptophlebiidae	9				
	Oligneuridae	15				
	Polymitarcyidae	10				
	Prosopistomatidae	15				
	Teloganodidae	12				
	Tricorythidae	9				
ODONATA	Calopterygidae	10				
	chlorocyphidae	10				
	Chlorolestidae	8				
	Coenagrionidae	4		A		A
	Lestidae	8				
	Platycnemidae	10				
	Protoneuridae	8				
	aeshnidae	8				
	Corduliidae	8				
	Gomphidae	6				
	Libellulidae	4				
LEPIDOPTERA	Pyralidae	12				
HEMIPTERA	Belostomatidae	3				
	Corixidae	3		A	A	A
	Gerridae	5				
	Hydrometridae	6				
	Naucoridae	7				
	Nepidae	3				
	Notonectidiae	3			1	1
	Pleidae	4				
	Veliidae/Mesoveliidae	5				
MEGALOPTERA	Corydalidae	8				
	Sialidae	6				

		Sensitivity	**Biotope**			
Order	**Family/taxa**	**rating**	**Stones**	**Veg**	**GSM**	**Overall**
TRICHOPTERA	Dipseudopsidae	10				
	Ecnomidae	8				
	Hydropsychidae 1 sp.	4				
	Hydropsychidae 2 sp.	6				
	Hydropsychidae >2 sp.	12				
	Philopotamidae	10				
	Polycentropodidae	12				
	Psychomyiidae	8				
	Barbarochthonidae	13				
	Calamoceratidae	11				
	Glossosomatidae	11				
	Hydroptilidae	6				
	Hydrosalpingidae	15				
	Lepidostomatidae	10				
	Leptoceridae	6				
	Petrothrinicidae	11				
	Pisuliidae	10				
	Sericostomatidae	13				
COLEOPTERA	Dytiscid	5	A	A	A	B
	Elmidae	8				
	Gyrinidae	5	A		A	B
	Haliplidae	5				
	Helodidae	12				
	Hydraenidae	8	1	1		1
	Hydrophilidae	5		1		1
	Limnichidae	10				
	Psephenidae	10				
DIPTERA	Athericidae	10				
	Blepharoceridae	15				
	Ceratopogonidae	5	1	1	A	A
	Chironomidae	2	A		A	A
	Culicidae	1		A		A
	Dixidae	10				
	Empiddidae	6				
	Ephydridae	3				
	Muscidae	1				
	Psychodidae	1				
	Simulidae	5				
	Syrphidae	1				
	Tabanidae	5				
	Tipulidae	5				
GASTROPODA	Ancylidae	6				
	Bulininae	3				
	Hydrobiidae	3				
	Lymnaeidae	3				
	Physidae	3				
	Planorbidae	3				
	Thiaridae	3				
	Viviparidae	5				
PELECPODA	Corbiculidae	5				
	Sphaeriidae	3				
	Unionidae	6				
		SASS	37	35	45	**59**
		Total number of families	7	8	9	**12**
		ASPT	5,3	4,4	5	**4,92**
		Water quality condition	**E/F**			

Table 5.11 Invertebrate taxa recorded in each SASS biotope at <u>Site 5: Aalwyns Drif</u> sampled in September 2017. 1 = 1 individual; A = 2-10 individuals; B = 11-100 individuals

Date: 12.09.2017		Sensitivity	Biotope			
Order	**Family/taxa**	**rating**	**Stones**	**Veg**	**GSM**	**Overall**
PORIFERA		5				
COELENTERATA		1				
TURBELLARIA		3				
ANNELIDA	Oligochaeta	1				
	Leeches	3				
CRUSTACEA	Amphipoda	13		1		1
	Potamonautidae	3				
	Atydiae	8				
	Palaemonidae	10				
HYDRACARINA		8	1			1
PLECOPTERA	Notonemourdae	14				
	Perlidae	12				
EPHEMEROPTERA	Baetidae 1 sp.	4				
	Baetidae 2 sp.	6	B	B	B	B
	Baetidae > 2 sp.	12	C	C		C
	Caenidae	6	B	A	A	B
	Ephemeridae	15				
	Heptageniidae	13				
	Leptophlebiidae	9	A			A
	Oligneuridae	15				
	Polymitarcyidae	10				
	Prosopistomatidae	15				
	Teloganodidae	12				
	Tricorythidae	9				
ODONATA	Calopterygidae	10				
	chlorocyphidae	10				
	Chlorolestidae	8				
	Coenagrionidae	4		1		1
	Lestidae	8				
	Platycnemidae	10				
	Protoneuridae	8				
	aeshnidae	8	1			1
	Corduliidae	8				
	Gomphidae	6				
	Libellulidae	4			1	1
LEPIDOPTERA	Pyralidae	12				
HEMIPTERA	Belostomatidae	3				
	Corixidae	3		A		A
	Gerridae	5				
	Hydrometridae	6				
	Naucoridae	7		A	A	A
	Nepidae	3				
	Notonectidiae	3				
	Pleidae	4		A		A
	Veliidae/Mesoveliidae	5				
MEGALOPTERA	Corydalidae	8				
	Sialidae	6				

		Sensitivity	Biotope			
Order	**Family/taxa**	**rating**	**Stones**	**Veg**	**GSM**	**Overall**
TRICHOPTERA	Dipseudopsidae	10				
	Ecnomidae	8				
	Hydropsychidae 1 sp.	4				
	Hydropsychidae 2 sp.	6	A			A
	Hydropsychidae >2 sp.	12				
	Philopotamidae	10				
	Polycentropodidae	12				
	Psychomyiidae	8				
	Barbarochthonidae	13				
	Calamoceratidae	11				
	Glossosomatidae	11				
	Hydroptilidae	6				
	Hydrosalpingidae	15				
	Lepidostomatidae	10				
	Leptoceridae	6		A		A
	Petrothrinicidae	11				
	Pisuliidae	10				
	Sericostomatidae	13				
COLEOPTERA	Dytiscid	5	1	B	A	B
	Elmidae	8	A			A
	Gyrinidae	5	A			A
	Haliplidae	5				
	Helodidae	12				
	Hydraenidae	8	A	A	A	A
	Hydrophilidae	5	1	A	A	A
	Limnichidae	10				
	Psephenidae	10				
DIPTERA	Athericidae	10				
	Blepharoceridae	15				
	Ceratopogonidae	5		A	A	A
	Chironomidae	2	A	A	B	B
	Culicidae	1		A		A
	Dixidae	10		A		A
	Empiddidae	6				
	Ephydridae	3				
	Muscidae	1				
	Psychodidae	1				
	Simulidae	5	A		A	B
	Syrphidae	1				
	Tabanidae	5				
	Tipulidae	5				
GASTROPODA	Ancylidae	6		A		A
	Bulininae	3				
	Hydrobiidae	3				
	Lymnaeidae	3		A		A
	Physidae	3				
	Planorbidae	3				
	Thiaridae	3				
	Viviparidae	5				
PELECPODA	Corbiculidae	5				
	Sphaeriidae	3				
	Unionidae	6				
		SASS	93	106	53	**153**
		Total number of families	14	18	10	**25**
		ASPT	6,6	5,9	5,3	**6,1**
		Water quality condition	**B**			

5.3 Fish communities

Fish communities in the Groot/Meirings River are described in two separate reports associated with the fish rescue operation undertaken by Cape Nature (Jordaan 2017) and AEC (van der Walt 2017) in September 2017. Although fish were moved downstream to Aalwyns Drif during the fish rescue operation, their findings provide a baseline understanding of fish communities within this system for monitoring recovery over time and can be summarized as follows:

- *Pseudobarbus asper* was found upstream, within and downstream of the impact zone, while *Pseudobarbus tenuis* was only present downstream in early September (Jordaan 2017)(Table 5.12).
- A further 79 *Pseudobarbus asper* were found in a different pool (and relocated) within the impact zone a week later (van der Walt 2017).
- Despite the presence of live *Pseudobarbus asper* within the impact zone, individuals were lethargic and clearly affected by contamination.
- *P. asper* favours the upper part of the Meirings River within the poort, with the best available habitat due to water quality associated with the shale geology of the upper Meiringspoort. Further upstream the river dries out while downstream the river is dominated with sandstones with slightly more acidic waters that are favourable for *P. tenuis*. Thus the presence of *P. tenuis* downstream is likely a consequence of favourable habitat and water quality for this species, rather than a response to diesel contamination.
- Essentially, the Meirings River, particularly within the impacted zone is a sanctuary for one of the largest populations of *P. asper* and recovery of this habitat is important to the long term survival of this species.

Table 5.12. Number of individual fish upstream (control), within (impact) and downstream (downstream) of the impact zone associated with the diesel spill into the Meirings River *(taken from Jordaan 2017).*

Zone	Site name	DDS	DDE	*P. asper* (n)	*P. tenuis*(n)
Control	C1	-32.527861	22.541667	4	0
Control	C2	-33.361806	22.541972	0	0
Control	C3	-33.362	22.542389	23	0
Impact	I1	-33.372306	22.554083	1	0
Impact	I2	-33.372639	22.553889	9	0
Impact	I3	-33.364194	22.558889	57	0
Downstream	D1	-33.409111	22.554361	30	22
Downstream	D2	-33.409056	22.555111	24	8
Downstream	D3	-33.409278	22.553583	59	17
Total				207	47

6 DISCUSSION

Given the large number of petroleum derived hydrocarbons and their wide range of toxicities, there are no guidelines for concentrations of these contaminants for protection of aquatic ecosystems. Regardless, the data presented in this report indicate a severe adverse effect of the diesel spill on the aquatic macroinvertebrate communities within and downstream of the impact zone. Also, contamination by diesel into the Meirings River resulted in the die-off of significant numbers of *P. asper* evident on the 18th August 2017. Despite the survival of a population within the impact zone, communities captured for relocation were lethargic and generally unhealthy a month after the spill incident (van der Walt 2017). The water chemistry data suggest that low dissolved oxygen levels and associated high Chemical Oxygen Demand in response to microbial degradation of diesel was responsible for the mortality of both aquatic macroinvertebrates and fish.

The poor condition of the aquatic macroinvertebrate community downstream of the impact zone was unexpected but suggests that the extent of *the impact on the aquatic biota of the Meirings River extends downstream of the impact zone.* Considering that river discharge has risen on a few occasions following the incident, particularly after the application of BioSolve® when diesel would have been emulsified and difficult to contain with absorbent booms, it is possible that diesel extended downstream of the point at which it was assumed to be contained.

Of particular concern was the slightly elevated TOG concentrations measured as far downstream as Aalwyns Drif, the so-called downstream control site, following the application of BioSolve®. TOG gives a broad indication of oil contamination not specific to diesel. However, considering that the system lies within a natural landscape and the lack of other potential point sources of contamination since the spill incident, it is likely that these slightly elevated concentrations are indicative of diesel contamination. There was a case in the United States where BioSolve® was used in a clean-up of diesel in a parking area which drained into a river system and resulted in total mortality of fish for nearly 5 km downstream (Dr. J. Michel, RPI, Columbia, US. Pers. Comm.). While there does not seem to be any evidence of adverse effects on the aquatic biota at this stage, data collection in December 2017, as scheduled within the monitoring programme, should provide some insight into whether or not this is of concern from an ecological perspective.

Aside from the indirect effects of the diesel spill on survival of the aquatic fauna of the Meirings River, hydrocarbons have direct acute and chronic toxic effects that persist in the long term. While hydrocarbons are generally insoluble in water, the soluble components contain Polycyclic Aromatic Hydrocarbons (PAH's), and monoaromatic hydrocarbons, known as BTEX (Benzene, Toluene, Ethyl Benzene and Xylene) which are toxic to aquatic fauna (Santos *et al.* 2013). It is well known that hydrocarbons, termed genotoxins, damage DNA (Zhang *et al.* 2004) and can cause damage to fish tissues (Adeyemi *et al*. 2009). Hydrocarbons usually have a high affinity for fatty tissues and are therefore stored and concentrated in animal tissues. There are a number of studies that have shown the long-term adverse effects of so-called bioaccumulation of these contaminants in aquatic ecosystems, particularly with regards to fish (Schein *et al.* 2008). Considering the conservation importance of the redfin populations within the Meirings River for the protection of these species and the limited distribution of the small scale redfin (*P. asper*), the long term effects on the diesel spill on this population is of particular concern.

7 CONCLUSIONS AND RECOMMENDATIONS

The purpose of the baseline assessment for the Meirings River was to establish an initial understanding of the physical and biological condition of the river that would inform recovery of the river ecosystem following the diesel spill in August 2017 and associated clean-up operations. Evaluation of water chemistry, macroinvertebates and fish within this system clearly show that the diesel spill has had a significant adverse impact on the ecological integrity of the Meirings River. Of particular concern is evidence to suggest that the impact has extended downstream of the impact zone, despite no visual evidence of diesel contamination beyond this river reach. While populations of small scale redfin (*P. asper*) were rescued from the site a month after the spill, the acute and chronic effects of exposure to soluble toxins could have long-term impacts on the survival of this species within this system. As a system of high conservation importance for the protection of endangered fish species, recovery of this system is imperative and any clean-up measures implemented should take cognisance of the ecological sensitivity and importance of this river.

It is recommended that:

- Monitoring of biological and physical components of the Meirings River continue according to the initial programme of quarterly sampling over an annual cycle, assuming that no further surfactants or remediation agents are used in the clean-up operation.
- Should any further application of surfactants or remediation agents be applied, it is strongly recommended that changes in water chemistry be closely monitored with the immediate collection of samples to inform any potential adverse effects to the ecological integrity of the Meirings River.
- Water quality sampling at all 5 sites should include analysis of hydrocarbons as far downstream as Aalwyns Drif. If any hydrocarbons are detected at this site, the sampling protocol should be updated to include a site further downstream.
- Sediment samples at all five sites should be collected for assessment of hydrocarbons to determine whether any hydrocarbons have settled on to the substrata downstream of the impact zone.

8 REFERENCES

Adeyemi, O., O. B. Oloyede, A. T. Oladiji & E. A. Adebayo. 2009. Effect of water contaminated with phthalate, benzene and cyclohexane on *Clarias gariepinus* cellular system. Food and Chemical Toxicology, 47: 194-944.

Dallas, H. 2007. River Health Programme: South African Scoring System (SASS) Data interpretation guidelines. Freshwater Consulting Group report prepared for the Institute of Natural Resources and DWA.

Department of Water Affairs and Forestry (DWAF), South Africa. 2008. Methods for determining the water quality component of the ecological reserve for rivers. Second Draft. Prepared by P-A Scherman of Scherman Consulting.

Dickens, C.W. and Graham, P.M., 2002. The South African Scoring System (SASS) version 5 rapid bioassessment method for rivers. *African Journal of Aquatic Science*, *27*(1), pp.1-10

Geomeasure 2017. Initial Environmental Site Assessment report for the Kelrn Vervoer diesel spill – De Rust- Western Cape. Ref. no: 2017/424.Report prepared for Envirosure Underwriting Mangers (Pty) Ltd.

HilLand Environmental 2017. Initial incident report: Diesel spill TR 33/4, Km 16, Meiringspoort. MUR16/819/05. Report prepared for the Department of Transport and Public works – Roads Infrastructure.

Jordaan, M. 2017. Preliminary fish monitoring report. Meiringspoort diesel spill incident. Internal Cape Nature Report (Scientific Services department).

Mucina, L. and Rutherford, M.C. (eds). 2006. The vegetation of South Africa, Lesotho and Swaziland. *Stelitzia* **19.** South African National Biodiversity Institute, Pretoria

Nel, J.L., Murray, K.M., Maherry, A.M., Petersen, C.P., Roux, D.J., Driver, A., Hill, L., Van Deventer, H., Funke, N., Swartz, E.R., Smith-Adao, L.B., Mbona, N., Downsborough, L. and Nienaber, S. (2011). Technical Report for the National Freshwater Ecosystem Priority Areas project. WRC Report No. K5/1801.

Pool-Stanvliet , R., Duffell-Canham, A., Pence, G. and Smart, R. (2017). The Western Cape Biodiversity Spatial Plan Handbook. Stellenbosch: Cape Nature.

Santos, C.A., Lenz, D., Brandão, G.P., Chippari-Gomes, A.R. and Gomes, L.C., 2013. Acute toxicity of the water-soluble fraction of diesel in Prochilodus vimboidesKner (Characiformes: Prochilodontidae). *Neotropical Ichthyology*, *11*(1), pp.193-198.

Schein, A., Scott, J.A., Mos, L. and Hodson, P.V., 2009. Oil dispersion increases the apparent bioavailability and toxicity of diesel to rainbow trout (Oncorhynchus mykiss). *Environmental Toxicology and Chemistry*, *28*(3), pp.595-602.

United Nations Environment Programme (UNEP). 1992. Determination of Petroleum Hydrocarbons in Sediments. Reference Methods for Marine Pollution Studies 20

van der Walt, R. 2017. Report on native fish rescue in the Groot River, Meigingspoort from 10 to 13 September 2017. Report prepared by Advanced Environmental Corporation (AEC) for Envirosure Underwriting Mangers (Pty) Ltd.

Zhang, J. F., X. R. Wang, H. Y. Guo, J. C. Wu & Y. Q. Xue. 2004. Effects of water-soluble fractions of diesel oil on the antioxidant defenses of the goldfish, *Carassius auratus*. Ecotoxicology and Environmental Safety, 58: 110-116