# AN ECOLOGICAL ASSESSMENT OF THE HOLSLOOT RIVER, WESTERN CAPE, SOUTH AFRICA

BY

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**“Water is the most critical resource issue of our lifetime and our children’s lifetime. The health of our waters is the principal measure of how we live on the land.”     Luna B. Leopold**

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## Abbreviations

| | |
|---|---|
| AgroMet | Agrometeorological programme |
| ARC | Agricultural Research Council |
| ISCW | Institute for Soil, Climate and Water |
| ASPT | Average Score Per Taxon |
| CPOM | Coarse Particulate Organic Material |
| CSIR | Council for Scientific and Industrial Research |
| DO | Dissolved Oxygen |
| DWA | Department of Water Affairs |
| EC | Electrical Conductivity |
| FPOM | Fine Particulate Organic Material |
| HIB | Holsloot Irrigation Board |
| IHAS | Invertebrate Habitat Assessment System Index |
| IHI | Index of Habitat Integrity |
| MAR | Mean annual runoff |
| MIRAI | Macro Invertebrate Response Assessment Index |
| Mℓ | Mega litres |
| µS | Micro Siemens |
| PES | Present Ecological State |
| ppm | Parts per million |
| RCC | River Continuum Concept |
| REC | Recommended Ecological Category |
| RHP | River Health Programme |
| SASS | South African Scoring System |
| TDS | Total Dissolved Solids |
| VEGRAI | Riparian Vegetation Response Assessment Index |

# Preface

This thesis concerns a study of the Holsloot River in the south-western Cape, South Africa.

Chapter One is a general introduction to river ecology and an overview of the upper Breede River catchment area, as well as the River Health Programme. The objectives of this study are also stated in this chapter. Chapter Two describes the location and characteristics of the study area. Chapter Three describes the methodologies, where Chapters Four and Five give the results as well as a discussion of the results as found at five sample sites in the upper, middle and lower zones of the river. Chapter Six is a summary of the findings and includes recommendations for future management.

# Abstract

Human related activities have influenced the rivers of the southern Western Cape since as early as the 1700's. As there is no detailed information available on ecological status of the Holsloot River, a tributary of the Breede River, this study aimed to gain insight into the effect of impacts associated with human activities on the habitat integrity of this river. The study intended to understand how seasonal changes, catchment characteristics and events are reflected in the ecological status of habitats along the river by applying bio-monitoring and river health measurements at selected sites in the upper, middle and lower reaches of the Holsloot River and compare the results to that of an undisturbed reference site. Results obtained in this study are compared with data gathered in 2008/2009 to determine if the ecological status of the river had changed in the period between the two sampling times. The study included assessment of the ecological status of the river based on standard bio-monitoring protocol (SASS5, IHI, IHAS and VEGRAI) as well as in situ water quality analysis (pH, dissolved oxygen, electrical conductivity and total dissolved solids).

The construction of the instream Stettynskloof Dam changed the configuration of the riparian zone and river channel in the upper catchment area. Agricultural- and other human related activities, with consequent water abstraction, non-point-source pollution, loss of riparian vegetation, as well as dense stands of alien invader plants influence flow patterns and affects river ecology, especially in the dry summer months. Providing sufficient stream flow and adequate water levels, human related activities can create a larger variety of habitat types available that can support larger biodiversity and higher productivity. The level of inundation and stream flow, influenced by water abstraction as well as irrigation return-flow from extensive drainage systems especially in the dry months, contribute to the loss of biodiversity in the middle and lower reaches of the river. Where the upper reaches of the river are largely natural with few modifications, the habitat integrity deteriorates in the middle reaches so much so that ecosystem functioning are collectively impaired in lower reaches due to human related impacts. Sensitive macro-invertebrates found at lower seriously impacted parts of the river however, were in all probability washed down from lower impacted upstream habitats and may expectedly be able to again occupy habitats downstream if water quality and habitat availability improves.

## Key terms

Holsloot River, ecological status, habitat integrity, catchment characteristics, bio-monitoring, water quality, agriculture, water abstraction, pollution, alien plant invasion, loss of riparian vegetation

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# Chapter 1: The Upper Breede River Catchment Area

## 1.1 Introduction

Miller (2005) defines surface water as "precipitation that does not sink into the ground or evaporate". When it flows into streams, surface water becomes runoff. Mountainous areas collect and release water that falls to the earth's surface in the form of rain or melting snow. The area that delivers runoff, sediment and dissolved compounds to a stream is called a watershed or drainage basin where small streams join to form rivers that flow downhill and eventually empty their water in the oceans (Davies & Day 1998; Miller 2005). Rivers, or the downward flow of surface and groundwater from mountains to the sea, are characterised by different aquatic zones with different environmental conditions: The *source zone* (mountain stream) the *transition zone* (foothill stony run and foothill soft bottom), and the *floodplain zone* (Lubke & de Moor 1998; Miller 2005). Miller (2005) describes the *source zone* as the first, narrow "headwaters or mountain highland streams of cold clear water that rush over waterfalls or rapids." These turbulent flows dissolve large amounts of oxygen as it tumbles downward. Although the water is shallow and light can penetrate to the bottom, headwater streams are not very productive due to lack of nutrients as most nutrients come from organic matter in the form of plant material and the bodies of dead invertebrates or other animals that fall into the stream (Miller 2005; Van As, du Preez, Brown & Smit 2012). Animals that live in fast flowing headwater streams are adapted to cold water and usually have compact flattened bodies that allow them to live under stones (Miller 2005). Headwater streams (1st order streams) come together to form wider, deeper streams (2nd order streams) that flow down gentler slopes in the *transition zone*. Warmer water together with other conditions in this zone support more primary producers and other organisms with slightly lower oxygen requirements (Miller 2005). Where streams join to form wider and deeper rivers (3rd and 4th order streams) that meander across broad and flat valleys, the *floodplain zone* is reached which is usually characterised by slow moving water, warmer water temperatures and less dissolved oxygen. Erosion and runoff over large areas carry mud and high concentrations of silt to this zone. The floodplain zone usually support large populations of primary producers such as algae, cyanobacteria and rooted aquatic plants as well as other biota (Miller 2005; Van As *et al.* 2012).

Due to friction of moving waters, mountains are levelled and gorges are cut over millions of years as water erodes rocks and soil and deposit them as sediment in lowlying areas. These makes streams powerful shapers of the land as they move downhill (Miller 2005). The *River Continuum Concept* (RCC) explains ecological processes in pristine river ecosystems, where the structure and function of biological communities in streams are influenced by variations of allochthonous matter (derived from outside the system, such as fallen leaves) and autochthonous matter (generated within the system, such as plant growth) (Lubke & de Moor 1998; Van As *et al.* 2012). Lubke & de Moor (1998) regard a river as a continuum rather than a series of distinct zones from the headwaters to the estuary before flowing into the ocean.

Davies & Day (1998) state that engineers and farmers frequently portray rivers as wasted resources: “all that unused water running uselessly to the sea”, but in flowing to the sea, rivers carry out vital environmental functions:

- deposition of sediments as a result of erosion of mountains makes fertile floodplains and sediments deposited in oceans become mountains eons later;
- food and habitat are provided for aquatic and terrestrial organisms;
- nutrients vital for the continuance of estuaries and the coastal zone are supplied;
- self-cleansing and self-regulating usable water is provided for terrestrial animals, including humans (Davies & Day 1998).

By world standards, almost the entire southern Africa is categorised as a dryland with major water deficits. Rainfall is seasonal in southern Africa and climate ranges from semi-arid to hyper-arid where only a few relatively humid parts of the region receive more than 500 mm of rainfall per year. For a large part of southern Africa, any rain that reaches the ground soon evaporates and re-enters the atmospheric phase of the water cycle. Rainfall exceeds evaporation only at a few mountaintops in the Drakensberg and in the south-western Cape (Davies & Day 1998). The southern African continent is drained by six major river systems, the Congo River, Zambezi River, Kunene River, Okavango River, Limpopo River and Orange-Vaal River (Van As *et al.* 2012). Many rivers in the western part of South Africa are ephemeral and episodic systems with no water flowing for certain periods. According to Davies & Day (1998), more than half of the unregulated mean annual runoff (MAR) that South Africa receives is channelled into the Indian Ocean, where rivers in the southern and western coastal regions (such as the Olifants, Berg, Palmiet and Breede) deliver 13% of the MAR to the Atlantic Ocean.

In the first assessment of river ecosystems in South Africa, Nel, Roux, Maree, Kleynhans, Moolman, Reyers, Rouget & Cowling (2007), found that the main river ecosystems are in a critical state, far worse than terrestrial ecosystems. The study found that 84% of these ecosystems are threatened, a disturbing 54% critically endangered, 18% endangered, and 12% vulnerable. The authors however, state that ecosystem status is likely to differ with the inclusion of tributaries. Since tributaries are generally less regulated than main rivers, options may exist for conserving critically endangered ecosystems in intact tributaries. Despite the need for managing main rivers, the authors highlight the importance of healthy tributaries for achieving river conservation targets (Nel *et al.* 2007).

## 1.2 The ecological status of a river

Iverson (as quoted by Kleynhans & Louw 2004) defines the ecological status of a river as the "totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna."

Geology, climate, morphology, land uses as well as vegetation of a catchment are all interconnected drivers on catchment processes such as sediment supply, the hydrologic regime, organic material inputs, nutrient- and chemical inputs as well as light- or heat inputs. In various combinations, catchment drivers and -processes have direct effects on the physical habitat characteristics, water quality, and primary productivity that in unison influence the biological fitness and survival of riverine biota (Davies & Day 1998; Lubke & de Moor 1998; Kleynhans & Louw 2004; Van As *et al.* 2012).

Components of drivers thus interact to determine the physical habitat pattern for biological groups such as macro-invertebrates and riparian vegetation. The habitat integrity for each of these biological groups is determined based on the condition of the physical drivers (Kleynhans & Louw 2004; Kleynhans, Louw, Thirion, Rossouw, & Rowntree 2005; Dallas 2012).

Of all the drivers, processes and effects, only geology, climate and major morphology of the catchment are not affected by land use. Land use can be linked to habitat change, which in turn, is linked to biological responses. Using a biological indicator to assess the biological response identifies where ecosystem functions have been impaired and will possibly disclose causes of impairment (Beechie, Steel, Roni & Quimby 2003; Kleynhans & Louw, 2004). Biological and habitat information permit the categorization of the ecological status of river ecosystems. These are based on the degree of modification relative to the natural reference conditions in the absence of human impacts (Roux, Kleynhans, Thirion, Engelbrecht, Deacon & Kemper 1999).

Kleynhans & Louw (2004) state that a river will have a natural or close to natural eco-status if the following geomorphologic, hydrologic, water quality and biological requirements are met:

**a. Geomorphology and hydrology:**

- "The quantity and dynamics of flow reflect almost undisturbed conditions.
- The continuity of the river allows undisturbed migration of aquatic organisms and sediment transport.
- Channel patterns, width and depth variations, flow velocities, substrate conditions and both the structure and condition of the riparian zones almost correspond to undisturbed conditions."

**b. Water quality:**

- "The values of the physico-chemical elements almost correspond to undisturbed conditions.
- Nutrient concentrations remain within the range normally associated with undisturbed conditions.
- Levels of salinity, pH, oxygen balance, acid neutralizing capacity and temperature remain within the range normally associated with almost undisturbed conditions.
- Synthetic and non-synthetic pollutants is close to zero."

**c. Biology:**

- "The taxonomic composition and abundance of the riparian vegetation, phytoplankton, macrophytes, invertebrates and fish correspond nearly totally to the undisturbed conditions."

## 1.3 The River Health Programme

Monitoring aquatic ecosystem health is a requirement in terms of the National Water Act (Act 36 of 1998). The official custodian of the nation's freshwater resources is the Department of Water Affairs (DWA) (Impson, Herdien & Belcher 2007). Rivers in the Western Cape are under severe pressure from an increasing human population and growing agricultural production. Global climate change is expected to place further pressure on rivers, as predictions show that the region will become hotter and drier. Without active and effective management and sufficient resources, the condition of our rivers will continue to deteriorate (Impson *et al.* 2007).

A national biomonitoring programme, the River Health Programme (RHP) has been implemented in the Western Cape since 2001 through a partnership between CapeNature, the Department of Water Affairs and the Council for Scientific and Industrial Research (CSIR). The RHP assesses the biological and habitat integrity of rivers by focusing on selected indicator groups. The indices used are the South African Scoring System (SASS5) that focuses on aquatic macro-invertebrates, Freshwater Fish Index, Riparian Vegetation Index, Geomorphological Index and an Index of Habitat Integrity (Dallas 2000; Impson *et al.* 2007).

In 2007, the RHP already had more than 200 monitoring sites on rivers throughout the province covering all four Water Management Areas (Berg, Breede, Gourits, and Olifants-Doring). Most of the rivers in the Western Cape have been largely modified and only a few are un-impacted. A combination of RHP results provides an overall picture for the rivers assessed: 7% are still in a natural condition, 26% in a good condition, 51% in a fair condition and 16% are in a poor condition. The RHP has been an excellent tool for measuring the ecological health of the province's rivers and for increasing awareness of river issues through its regular State of River reports, which serve as a useful baseline against which to measure future change. These reports also highlight management interventions (e.g. alien plant eradication) that are required to improve the ecological condition of rivers (Impson *et al.* 2007).

## 1.4 An overview of the Upper Breede River Catchment Area.

The Breede River originates near Ceres where it's catchment is drained by four main tributaries, the Dwars, Koekedouw, Titus and Witels Rivers which form its headwaters.

The river then extends in a south-easterly direction to the foot of the Limietberg Mountains where it is joined by the Witte, Slanghoek, Molenaars/Smalblaar, Holsloot, Wabooms and Jan du Toit's Rivers respectively. These tributaries drain various mountain ranges in this portion of the catchment (Witteberg Mountains, Klein Drakenstein Mountains, Du Toit's Mountains, Slanghoek Mountains, Stettyns Mountains and Waaihoek Mountains). Most of the mentioned tributaries were once a braided system of perennial streams, but due to agricultural practises, they now join the Breede River as single seasonal streams (RHP 2011).

The Breede River Valley is very old (approximately 170 million years) and is characterised by a system of deep faults that stretches from Tulbagh to Mossel Bay. Although the ground had continuously been levelled by erosion as the Worcester-fault deepened, signs of the 6 000m drop on the southern side of the fault are still evident in some areas. Occasional movement of the upper portion of the fault causes earthquakes such as the one that hit the Tulbagh/Wolseley/Worcester area in 1969 with a magnitude of 6.3 on the Richter Scale (Norman & Whitfield 2006; RHP 2011). The upper Breede catchment area lies within the western- and southern Folded Mountain Eco-regions that receive relatively high rainfall and have a higher relief topography. A summary of the character of these Eco-regions is given in Table 1 (RHP 2011).

**Table 1:** A summary of the Eco-region characteristics of the Upper Breede River Catchment Area (RHP 2011).

| | **Western Folded Mountains** | **Southern Folded Mountains** |
|---|---|---|
| **Landscape** | Moderate/high mountains & hills | Moderate/high mountains & hills |
| **Vegetation** | Sandstone Fynbos | Sandstone Fynbos, Succulent Karoo |
| **Mean Altitude (m)** | 300 - 1700 | 300 - 1900 |
| **Rainfall pattern** | Winter | Very late summer to winter, to all year |
| **Mean Annual Precipitation (mm)** | 600 - 1800 | 200 - 1500 |
| **Mean Annual Runoff (mm)** | 5 to more than 250 | less than 5 to more than 250 |
| **Average Daily Temperature (°C)** | 0 - 32 | 10 - 32 |

Flügel (1989) describes the Breede River catchment as one of the most important agricultural production areas in the semi-arid Western Cape Province. Apart from dry land cultivation in the southern Overberg areas, land-use consists of irrigated crops such as fruit orchards, vineyards for wine and table grapes, citrus, as well as some cash crops and lucerne (alfalfa). These developments entail intensive irrigation in the catchment area of the Breede River (RHP 2011).

Although the economy of the region is mainly agriculture-based, the area is a popular tourist destination because of its pristine mountains, wine, trout fishing and water sport. Livestock farming is practised throughout the region (RHP 2011).

Early records of human life in the Breede catchment area indicate that it was first inhabited by Stone Age people, ancestral San, who lived mainly along the coast. The Khoekhoe (originally from the Zambezi Valley) migrated to the area approximately 2 000 years ago. They were nomadic pastoralists and introduced the first cattle and sheep to the area. After 1707, the Dutch in the Cape began to expand agriculture to the Breede and Overberg areas (RHP 2011).

From the 1890's, alien fish species were introduced into the rivers and dams of the Breede River catchment area for angling purposes and to provide food. Twelve of these species have become invasive with severe predatory and competitive impacts on indigenous fish species (Skelton 2001; RHP 2011).

Invasive alien plants such as the Australian *Acacia mearnsii* (black wattle) and *A. saligna* (Port Jackson willow) were introduced into the area approximately 150 years ago (RHP 2011).

According to the findings of the River Health Programme (2011), the tributaries of the Upper Breede River are generally in a good state and only degraded to a fair state in and around the towns. The River Health Programme (2011) also found the very upper reaches (below Ceres) of the Breede River to be in a fair state, with the main impacts being invasive alien *Acacia mearnsii* (black wattle) trees and alien fish species such as *Clarias gariepinus* (sharptooth catfish) and *Micropterus dolomieu* (smallmouth bass).

Characteristics of the sub-catchment areas and tributaries that supply the upper Breede River with water are given in Table 2. A number of large instream and off-channel storage dams, as well as farm dams have been constructed in the upper Breede River catchment area. Habitat modification as a result of instream structures such as dams and low water bridges, bulldozing, encroaching agricultural activities and mining have impacted on the riparian and instream habitat of most of the tributaries as well as the upper Breede River. Flow modification as result of impoundments such as the Koekedouw and Stettynskloof Dams in the Koekedouw and Holsloot Rivers respectively as well as water abstraction have critically impacted the instream habitat and water quality of the lower reaches of these rivers, particularly during the summer months (RHP 2011).

**Table 2**: A Summary of the characteristics of the upper Breede River sub-catchment (RHP 2011).

| | |
|---|---|
| **Rivers/main tributaries** | Breede, Dwars, Witte, Molenaars, Jan du Toit's, Hex, Holsloot |
| **Catchment size (km$^2$)** | 2 879 |
| **Geology** | Mountain sandstone, Witteberg, Bokkeveld and Malmesbury shales, Enon conglomerate |
| **Vegetation** | Mountain Fynbos and Central Mountain Renosterveld |
| **Mean Annual Precipitation (mm)** | 761 |
| **Mean Annual Evaporation (mm)** | 1 633 |
| **Mean Annual Runoff (million cubic metres)** | 960 |

## 1.5 Hypothesis and objectives

Water is a limited resource in South Africa. The arid nature of the country, with its comparatively high temperatures, seasonal or unpredictable rainfall and scarcity of permanent standing water bodies, has resulted in rivers becoming the focus for exploitation of surface water (Dallas, 2000).

Abundant water supplies and sufficient alluvial soils are some of the characteristics that make ancient floodplains and river valleys suitable for agriculture. Farming in the Goudini Valley is known from as early as 1709 when European settlers first occupied land in the area (DWAF 1995).

Aerial photographs from 1942 (obtained from the Chief Directorate: National Geo-spatial Information) portray the Holsloot River as a braided system of rivulets, streams and wetlands (Figure 1). To facilitate the establishment of grapevines on the floodplain over the years, the river was increasingly canalised and the wetlands drained.

The Holsloot– and Smalblaar Rivers (tributaries of the Breede River) originate in the mountains to the south of Worcester. The lower reaches of these rivers historically flowed over the same floodplain in a northerly direction to the Breede River. The development of agriculture in later years caused the flow of these rivers to be transformed to such an extent that most of the runoff carried by the Holsloot was channelled into the first water storage facility in this area, Lake Marais. Lake Marais (now known as the Brandvlei Dam), was constructed in 1922 to meet the increased demand for irrigation water in the dry summer months (Figure 1; DWAF 1995).

**Figure 1:** The western perimeter of Lake Marais (now the Brandvlei Dam) in 1942, with a braided system of streams flowing into the dam from the southwest (Department of Rural Development and Land Reform 1942).

The storage capacity of the Brandvlei Dam was first increased in 1950, and again in 1972 to what is today known as the Greater Brandvlei Dam (DWAF 1995). During winter months, runoff from both the Holsloot - and the Smalblaar Rivers is channelled into a cement canal feeding the Brandvlei Dam, a storing facility for irrigation schemes in the Robertson district.

From the previous discussions, it is clear that various human induced activities have influenced the rivers of the area. There is no detailed information available on the effect of these activities on the Holsloot River or its ecological status. This study focuses on the impacts associated with the Holsloot River.

**This study is aimed at:**

- how bio-monitoring protocols and river health measurements applied at selected sites in the upper, middle and lower reaches of the Holsloot River compare to an undisturbed reference site;
- how seasonal changes, catchment characteristics and events are reflected in the ecological status of habitats in upper, middle and lower reaches of the river;
- how data gathered in 2011/2012 compare with data gathered in 2008/2009 in an attempt to determine if the ecological status of the river had changed in the period between the two sampling times.

The study includes an assessment of the ecological status (aquatic macro-invertebrates, habitat integrity and riparian vegetation) of the river based on standard bio-monitoring protocol (SASS5, IHI, IHAS and VEGRAI) as well as *in situ* water quality analysis (pH, dissolved oxygen, electrical conductivity and total dissolved solids). The extent of human impacts on the river is considered and where necessary, recommendations are suggested for mitigation or prevention of impairment of the system.

Hypothesis ($H_1$): The Holsloot River maintained the same ecological status in the period between two sampling times (2008/2009 to 2011/2012).
Nul Hypothesis ($H_0$): The Holsloot River did not maintain its ecological status in the period between two sampling times (2008/2009 to 2011/2012).

## 1.6 References

Beechie, R.J, Steel, E. A, Roni, P. & Quimby, E. (eds.). 2003. *Ecosystem recovery planning for listed salmon: an integrated assessment approach for salmon habitat.* Technical Memorandum National Marine Fisheries Service-NWFSC-59. National Oceanic and Atmospheric Administration, US Dept Commerce.

Dallas, H.F. 2000. *Ecological reference conditions for riverine macroinvertebrates and the River Health Programme, South Africa*. 1st WARFSA/WaterNet Symposium: Sustainable Use of Water Resources. Available on the internet at: http://www.bvsde.paho.org/bvsacd/cd46/dallas.pdf (Accessed 1 November 2012).

Dallas. H.F. 2012. Ecological status assessment in mediterranean rivers: complexities and challenges in developing tools for assessing ecological status and defining reference conditions. *Hydrobiologia*, DOI 10.1007/s10750-012-1305-8. Available on the internet at: http://download.springer.com/static/pdf/321/art%253A10.1007%252Fs10750-012-1305-8.pdf?auth66=1352146117_7fb884e053eea97f18b3347e75c50e19&ext=.pdf (Accessed 1 November 2012).

Davies, B. & Day, J. 1998. *Vanishing Waters.* University of Cape Town Press, Cape Town.

Department of Water Affairs and Forestry (DWAF). 1995. *Brandvlei/Kwaggaskloof Struktuurplan*. Unpublished Internal Report, Department of Water Affairs, Worcester.

Flügel, W. 1989. *Groundwater dynamics influenced by irrigation and associated problems of river salination; Breede River, Western Cape Province*, R.S.A. Groundwater Contamination (Proceedings of the Symposium held during the Third IAHS Scientific Assembly, Baltimore, MD, May 1989), IAHS Publ. no. 185. Available on the internet at: http://iahs.info/redbooks/a185/iahs_185_0137.pdf (Accessed 23 October 2012).

Impson, N.D., Herdien, E. & Belcher, A. 2007. *Status of River Health in Western Cape Province State of Biodiversity 2007*, CapeNature Scientific Services Report.

Kleynhans, C.J & Louw, D. 2004. *The Ecostatus Project: A framework for Assessing Ecological Conditions for River Health and Ecological Reserve Determinations and Monitoring*. Available on the internet at: http://www.fetwater.co.za (Accessed 10 March 2010).

Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N.J. & Rowntree, K. 2005. *River EcoClassification: Manual for EcoStatus determination (Version 1).* Joint Water

Research Commission and Department of Water Affairs and Forestry report. WRC Report No. KV 168/05

Lubke, R.A. & de Moor, I. (eds.) 1998. *Field Guide to the Eastern & Southern Cape Coasts*. University of Cape Town Press.

Miller G.T.(Jr.) 2005. *Living in the Environment. Principles, Connections and Solutions. Fourteenth Edition.* Brooks/Cole Thomson Learning.

Nel, J.L., Roux, D.J., Maree, G., Kleynhans, C.J., Moolman, J., Reyers, B., Rouget, M. & Cowling, R.M. 2007. Rivers in peril inside and outside protected areas: a systematic approach to conservation assessment of river ecosystems. *Diversity and Distributions*, 13:341–352.

Norman, N. & Whitfield, G. 2006. *Geological journeys. A Traveller's guide to South Africa's rocks and landforms.* Struik, Cape Town.

River Health Programme 2011. *State of Rivers Report: Rivers of the Breede Water Management Area.* Department of Water Affairs, Western Cape, Republic of South Africa. Available on the internet at: http://www.dwaf.gov.za (Accessed 15 September 2012).

Roux, D.J., Kleynhans, C.J., Thirion, C., Engelbrecht, J.S., Deacon, A.R. & Kemper, N.P. 1999. Adaptive Assessment and Management of Riverine Ecosystems: The Crocodile/Elands River Case Study. *Water SA* 25:(4). Available on the internet at: http://www.dwaf.gov.za (Accessed 15 March 2010).

Skelton, P. 2001. *A Complete guide to the Freshwater Fishes of Southern Africa.* Struik, Cape Town.

Department of Rural Development and Land Reform. 1942. South Africa, Chief Directorate: National Geo-spatial Information (CD: NGI), Aerial photographs.

Van As, J., du Preez, J., Brown, L. & Smit, N. 2012. *The Story of Life & the Environment, an African perspective*. Struik (Pty) Ltd, Cape Town.

# Chapter 2: The Study Area

## 2.1 Location

The Holsloot River, a tributary of the Breede River, drains areas of the Du Toit's Mountains, Wemmershoek Mountains, Stettyns Mountains, Kweekkraal Mountains, Wabooms Mountains and Brandvlei Mountain (Figure 2). Together with other mountains drained by the upper Breede River (Witteberg Mountains, Klein Drakenstein Mountains Limietberg Mountains and Slanghoek Mountains), these mountains are part of what is known as the Cape Syntaxis, where the western and the southern branches of the Cape Fold Mountain Belt meet (Gresse & Theron 1992). This part of the upper Breede River catchment-area lies in the Western Folded Mountains Eco-region, southwest of the town of Worcester in the Western Cape Province of South Africa (Figures 2 & 3; Table 1).

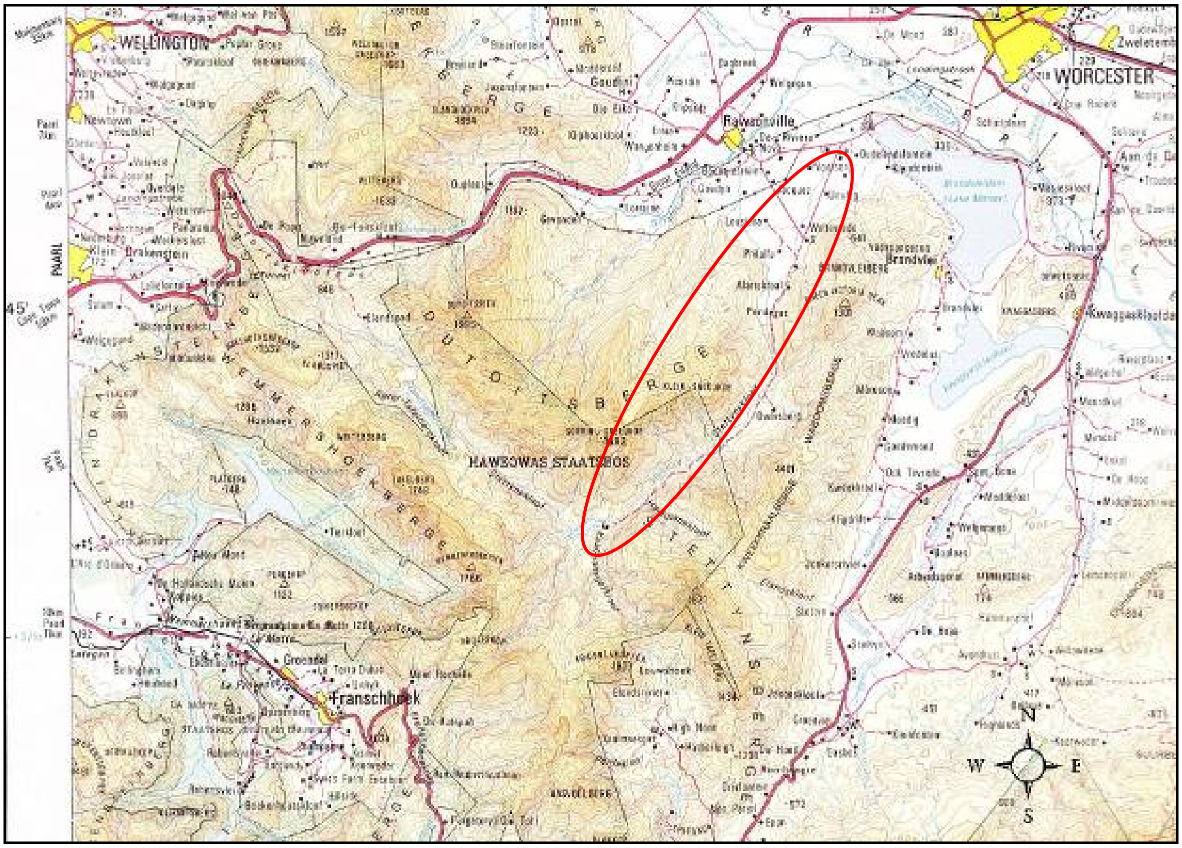

**Figure 2:** The location of the study area south of Worcester in the Western Cape (adapted from 1:250 000 Topographical sheet 3319 Worcester).

**Figure 3:** The lower reaches of the Holsloot River; after heavy rains and snow in August 2008.

## 2.2 Climate

The climate of the area is predominantly Mediterranean, receiving rainfall (usually associated with frontal systems) and snow mainly in the winter months (May, June & July) (Table 2). Mucina & Rutherford (2006) summarise the climate parameters for the predominant vegetation type in the area, Hawequas Sandstone Fynbos, as follows:

Mean annual precipitation: 1 197 mm
Mean annual temperature: 13.8 °C
Mean number of frost days: 11
Mean annual potential evaporation: 1 165 mm
Mean annual moisture stress: 55%

Long term weather data (January 1978 – September 2012) for the Holsloot catchment area, measured at the High Noon Weather Station about 10km southeast of the Stettynskloof Dam, was obtained from ARC-Institute for Soil, Climate and Water - AgroMet (ISCW) (Figure 4). The dry season generally stretches from the middle of

November to the middle of March (driest in February), where May, June, July and August usually are the wettest months (Figure 4).

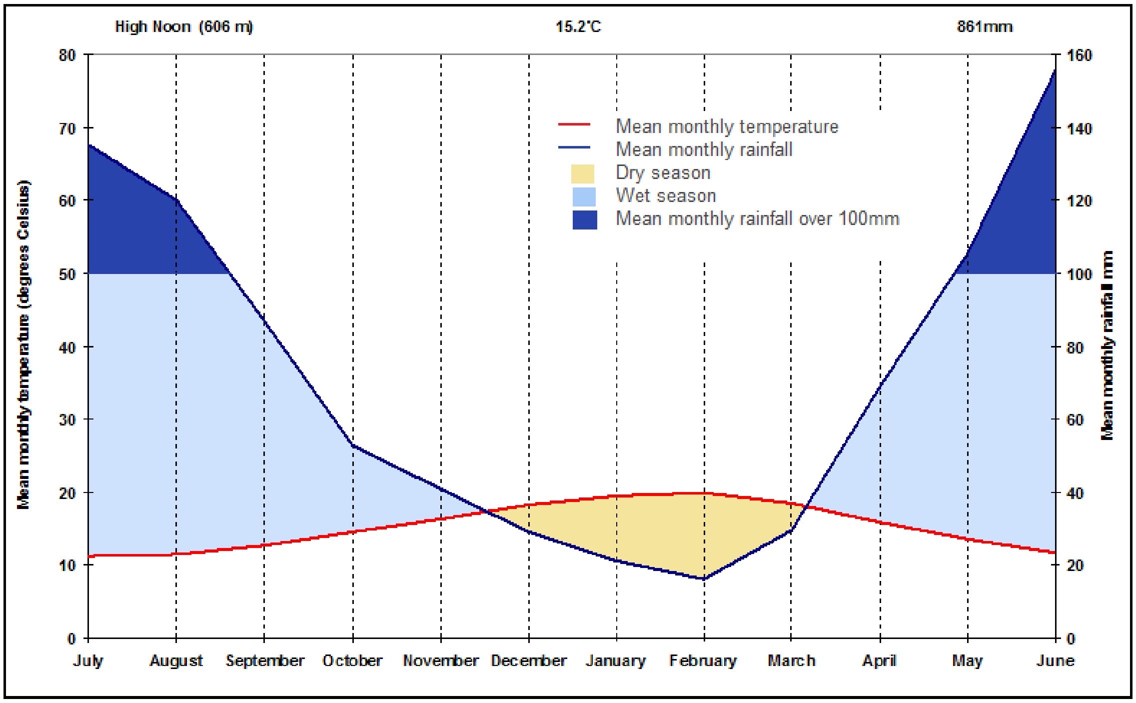

**Figure 4:** A climate diagram for the region (January 1978 – September 2012).

The average minimum- and maximum temperatures for the study area, as measured at the High Noon Weather Station is given in Figure 5.

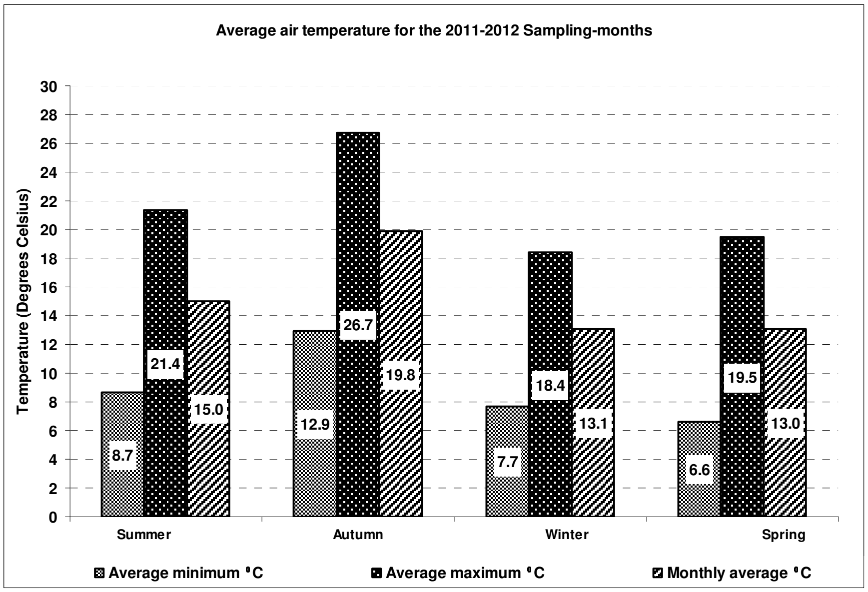

**Figure 5:** Average minimum- and maximum, as well as average air temperature for October 2011 (summer), February 2012 (autumn), May 2012 (winter) and September 2012 (spring). Data obtained from AgroMet-ISCW.

## 2.3 Geology

The Holsloot River follows a fault-line through the mountains where the larger part of the river runs through Table Mountain Sandstone sediments of the Cape Supergroup geological series (Figure 6). In the vicinity of the Stettynskloof Dam metasediments of the Malmesbury Group (Franschoek formation) is found on both sides of the dam (Figure 6; Table 2). Plutonic intrusion of the Cape Granite Suite is found on the eastern side of the river near the farm Dwarsberg (Figure 6; Gresse & Theron 1992). The riverbed is covered in alluvium deposits of various sizes (boulders, cobbles and sand).

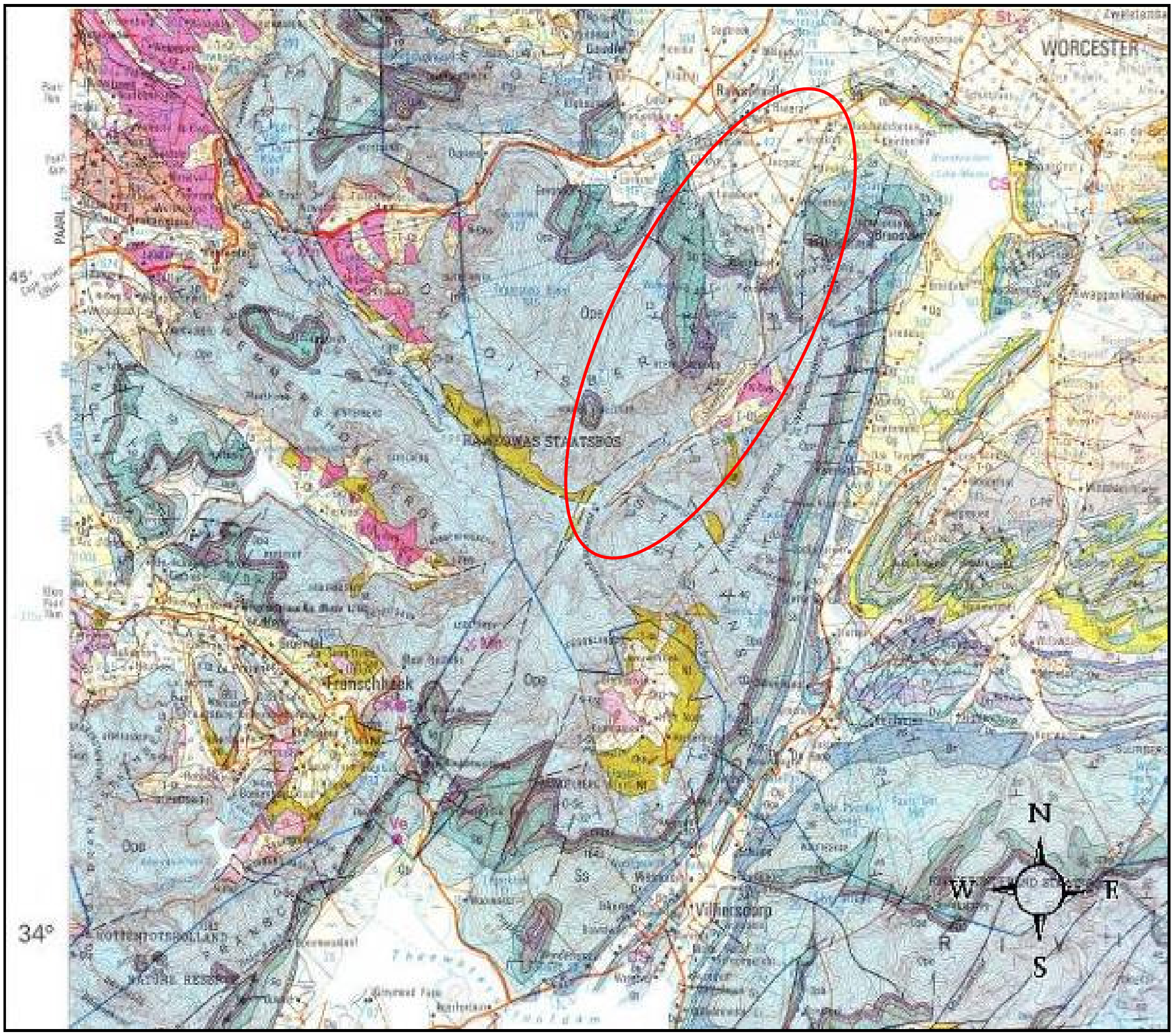

**Figure 6:** Geology of the study area. (Adapted from 1:250 000 GEOLOGICAL SERIES 3319 WORCESTER, Council For Geosciences, 1997)

Legend:

Ope - Skiereiland Peninsula (Table Mountain Group)

Nf - Franschhoek formation (Malmesbury Group)

N-Ewp - Wellington pluton (Cape Granite Suite)

Alluvial sediments - light yellow

## 2.4 Flora

The vegetation of the mountains in the study area comprises mostly of Hawequas Sandstone Fynbos, characterised by a high level of specific endemism (Mucina & Rutherford 2006). Small trees such as *Protea nitida* (tree protea/waboom) as well as the succulent tree, *Aloe plicatilis* (fan aloe) are found in Hawequa Sandstone Fynbos. Sheltered kloofs support an environment for larger trees like *Cunonia capensis* (butter-spoon tree/red alder) and *Podocarpus latifolius* (broad-leaved yellowwood/true yellowwood). *Brabejum stellatifolium* (wild almond), *Metrosideros angustifolia* (lance-leaved myrtle/smalblaar), *Morella integra* (western lance-leaved waxberry), *Brachylaena neriifolia* (waterwitels), *Diospyros glabra* (blueberry bush)*, Maytenus acuminata* (silky-bark)*, Searsia angustifolia* (willow karee)*, Elegia capensis* (horsetail restio)*, Seriphium plumosum* (slangbos)*, Cliffortia ruscifolia* (climber's friend)*, Pelargonium crispum* (malva)*, Salvia africana-caerulea* (wild sage/bloublomsalie)*, Lobostemon laevigatus* (agtdaegeneesbos)*, Restio sieberi* (besemriet)*, Pentaschistis airoides, Ehrharta calycina* (rooisaadgras), and *Asparagus rubicundus* are characteristically found in riparian areas of streams in mountainous as well as in alluvial areas.

Apart from localised slides during exceptionally heavy rainstorms, fynbos vegetation covering the mountain slopes ensure that erosion in the natural areas is of low impact. Alien plant invasions by *Pinus pinaster* (pine) and specifically *Hakea sericea* (hakea) are of concern (Mucina & Rutherford 2006). Stands of invasive Australian acacia species, such as *Acacia mearnsii* (black wattle) and *A. saligna* (Port Jackson willow), were observed in areas, growing on low slopes as well as in riparian areas.

Boland Granite Fynbos (Mucina & Rutherford 2006) is found in the area of the mentioned plutonic intrusions and is considered endangered vegetation. A critically endangered vegetation type, Elgin Shale Fynbos is found on the shale band of Malmesbury Group metasediments (Mucina & Rutherford 2006).

According to Mucina & Rutherford (2006) the dominant vegetation-type on the floor of the river valley is Breede Alluvium Fynbos. In the study area, vast areas of this vegetation type have been transformed due to the cultivation of vines. This practice, as well as extensive invasion of alien plant species such as *Acacia saligna*, *A. mearnsii*, *Hakea sericea* and *Sesbania punicea* causes this vegetation type to be classified as endangered.

## 2.5 Fauna

Several rare and endangered fish species are found in the Breede River and adjacent systems (DWAF 1995). Examples of endemic fish species are the endangered Breede River Redfin/Tradou Redfin (*Pseudobarbus burchelli*), and the vulnerable Berg-Breede River Whitefish (*Barbus andrewi*). Water abstraction and introduction of alien predatory fish such as Smallmouth Bass (*Micropterus dolomieu*), and two (2) trout species, Rainbow Trout (*Oncorhynchus mykiss*) as well as Brown Trout (*Salmo trutta*) are major threats to indigenous fish populations (Skelton 2001).

The vegetation and streams of the study area sustain indigenous mammal, reptile, amphibian, bird and insect species, of which several are endemic to the area. Examples of indigenous species are leopard (*Panthera pardus*), Cape clawless otter (*Aonyx capensis*), black eagle (*Aquila verreauxii*), booted eagle (*Aquila pennatus*) and Cape eagle owl (*Bubo capensis*). Although most amphibian species are tied to temporary and permanent pools and wetlands, some inhabits mountain Fynbos where they are found in or along streams and rivers. The Cape Ghost Frog (*Heleophryne purcelli*) is endemic to the Western Cape where it occurs in clear, swift flowing perennial mountain streams. The Banded Stream Frog (*Strongylopu*s *bonaespei*) prefers flatter, more open situations near streams in mountain Fynbos. Rose's Mountain Toad (*Capensibufo rosei*) is endemic to the winter rainfall region of the Western cape where the species is restricted to mountains where it occurs in undisturbed Mountain Fynbos – the conservation status of this species is "vulnerable" (De Villiers & Boycott 2004; Boycott 2004; Theron & Minter 2004; Turner & de Villiers 2007; Mokhatla, Measey, Chimimba & Van Rensburg 2012).

Dense *Prionium serratum* (palmiet) stands characterise the river and provide a habitat for numerous bird species associated with a riverine environment. The valley provides breeding areas for several species of migrant or partly migrant birds such as African reed warblers (*Arctocephalus baeticatus*), lesser swamp warblers (*Arctocephalus gracilirostris*), black crake (*Amaurornis flavirostra*), African snipe (*Gallinago nigripennis*), African rail (*Rallus caerulescens*), African purple swamphen (*Porphyrio madagascariensis*), African black duck (*Anas sparsa*) and the generally uncommon little bittern (*Ixobrychus minutus*) (K. Shaw personal communication, February 2009; Chittenden 2007).

## 2.6 Topography & hydrology

The Table Mountain Group sandstones contain vast quantities of groundwater, which makes up an important natural long term reservoir of water, as rainwater, which had not evaporated back into the atmosphere or ran off the surface into the river, soaks into the soil and percolates down into underlying rocks of the catchment area. (Table 2; Davies & Day 1998; Compton 2006).

From the upper reaches of the river to the lower areas where the valley opens up, the land drops approximately 200 m. Fast flowing water with plenty of rapids and riffles are characteristics of the upper reaches. Where the river broadens in the middle reaches, surface flow is relatively slower.

Water flow is influenced by releases from the dam as well as runoff carried to the mainstream by various mountain streams and drainage. Stream flow is measured at a gauging weir under the high-water bridge over the river downstream of the Stettynskloof Dam. Figure 7 shows the relationship between flow, rainfall and compensation water (for irrigation purposes) releases from the dam (at an average of 40 mega litres per day). Apart from this compensation water, the river is able to maintain an average flow of 120 Mℓ per day as surface flows, as well as groundwater from numerous mountains streams drain into the mainstream (Figure 7).

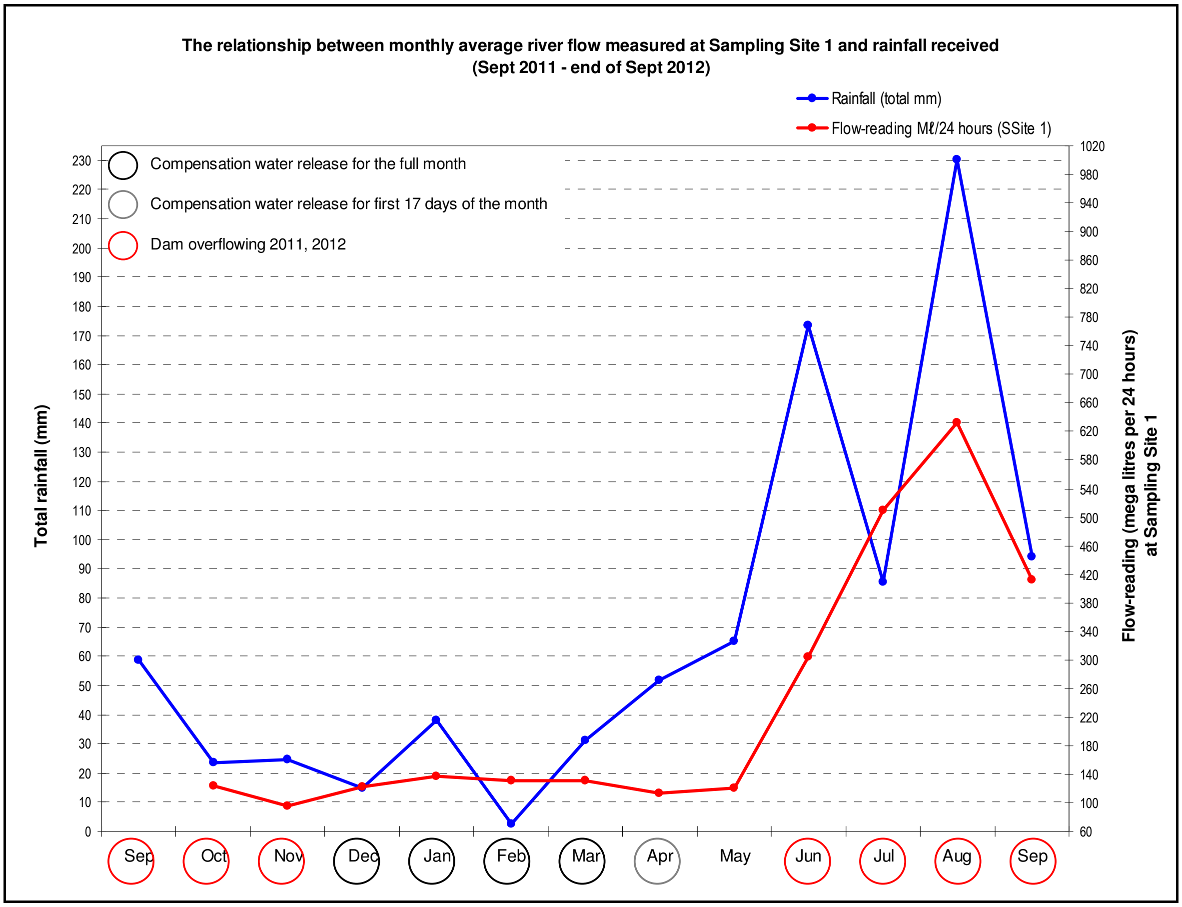

**Figure 7:** The association between monthly average stream flow and the total rainfall received during the period between September 2011 and the end of September 2012 (Sampling Site 1).

Rainfall is measured at the dam. Because river flow is measured at the gauging weir close to the dam, stream flow values are a reflection of rainfall at the dam. Discharges from mountain streams may however not always be reflected in the flow and rainfall data measured at the dam as the amount of precipitation that any small sub-catchment within the larger area receives is influenced by the movement and strength of frontal systems as well as by the mountainous terrain. Irregular rainfall will thus influence the amount of water available to specific areas along the reach of the river, as well as downstream thereof.

Kirchner, Moolman, du Plessis & Reynders (1997) state that most of the precipitation that falls in the mountains of the Breede River catchment either recharges aquifer systems or produces runoff, and a large percentage of the recharged water is released through springs and flows into the Breede River and its tributaries. During the dry summer months, surface flow often disappear in the vicinity of the farm Malkopklip in the middle reaches of the river, but again reappear downstream, indicating subsurface flow and/or groundwater discharges throughout the dry season (A le Roux personal observation).

The Holsloot River sharply reacts to the occurrence of rainfall with almost immediate increased flow during and after rain. The decrease of water flow after rainfall can be gradually or abrupt, depending on the season, the amount of rainfall as well as where it fell in the catchment (Figures 8 - 11).

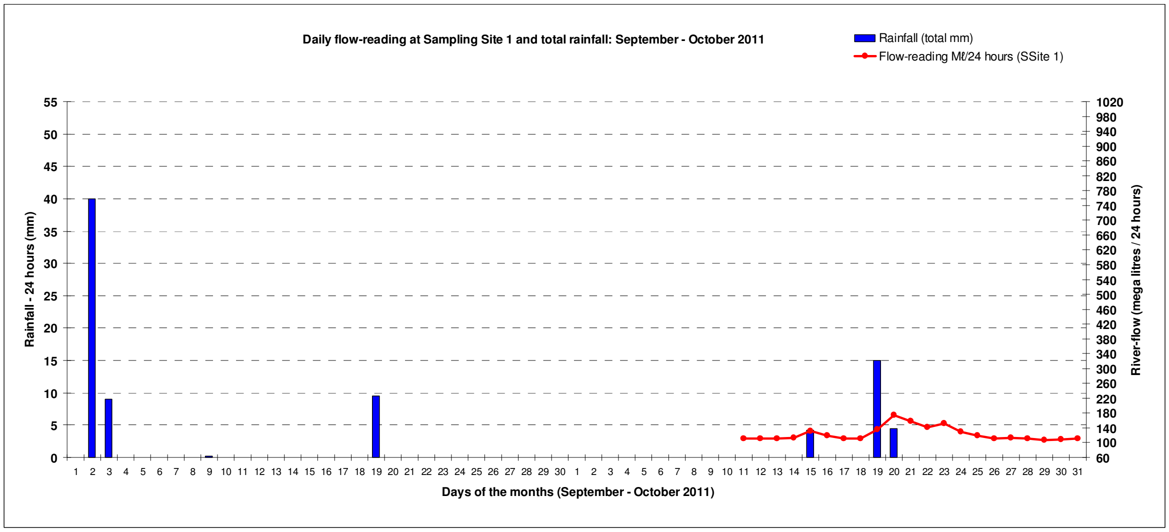

**Figure 8:** Stream flow-reading and total rainfall in summer, September – October 2011.

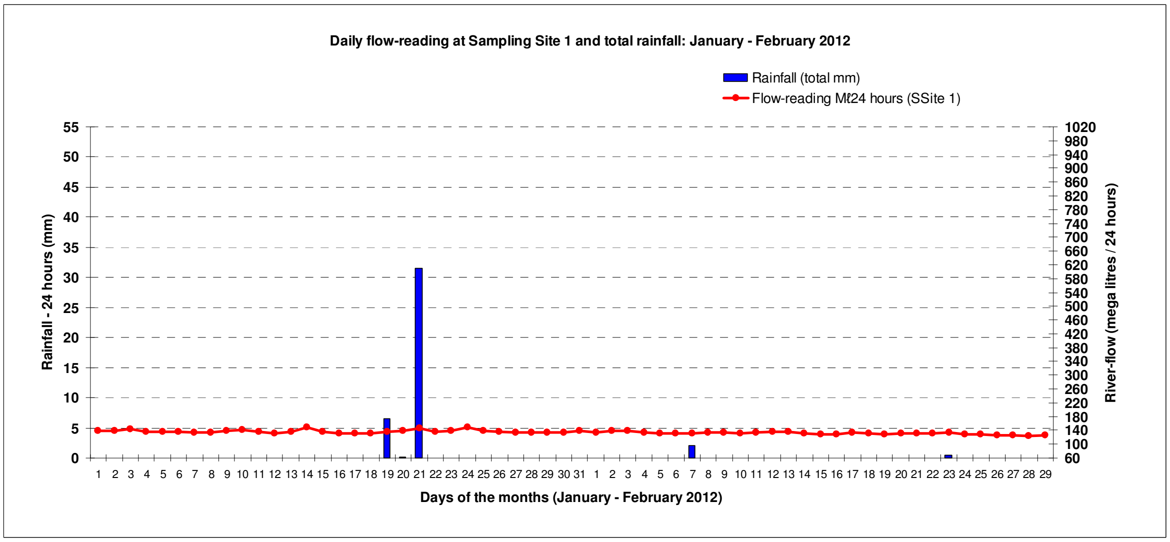

**Figure 9:** Stream flow-reading and total rainfall in autumn, January – February 2012.

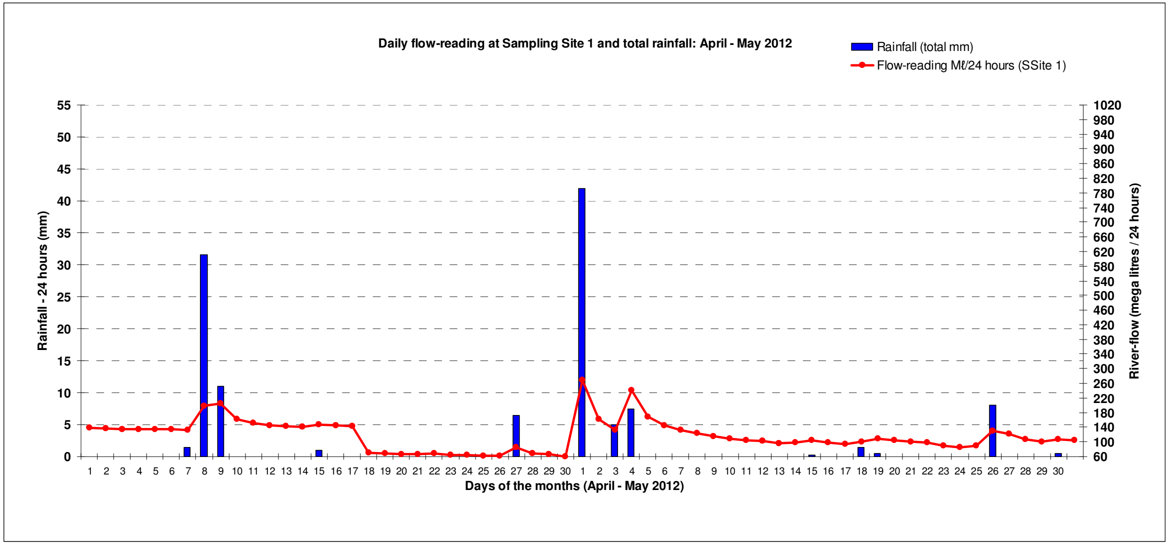

**Figure 10:** Stream flow-reading and total rainfall in winter, April – May 2012.

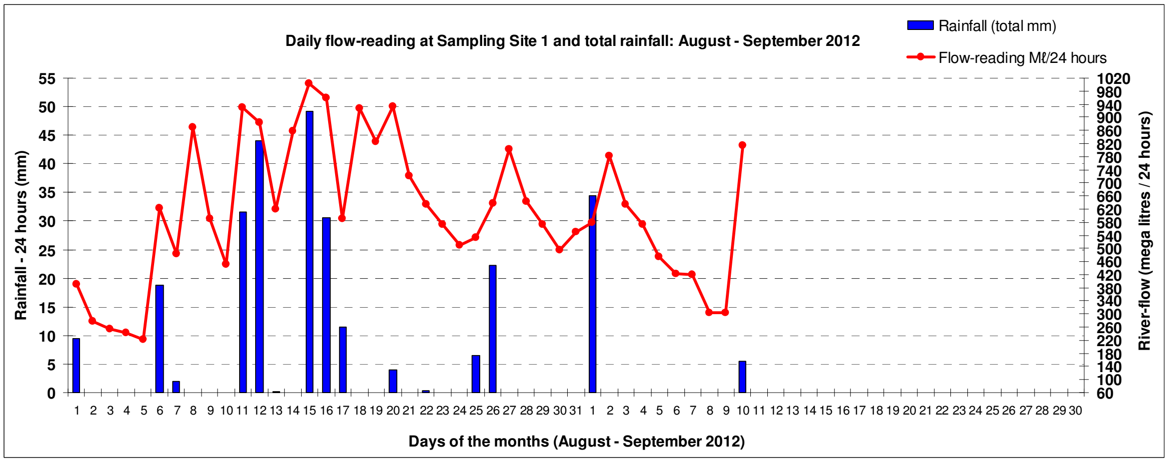

**Figure 11:** Stream flow-reading and total rainfall in spring, August – September 2012.

## 2.7 Land and water use

Figures 12 – 18 provide a bird's eye view of the present, as well as historic state and land use of the study area.

The presence of a large reservoir, the Stettynskloof Dam, has an important impact on the Holsloot River (Figure 12). This reservoir which is located about 30 km south-west of Worcester, was completed in 1954 (DWAF 1984) in the upper catchment-area of the river where three main drainage lines meet (Figure 13). At full capacity, the Stettynskloof Dam covers 100.35 ha (with shoreline of 10.14 km) receiving runoff from approximately 55 km$^2$ and storing 15 000 000 m$^3$ water (DWAF 1984). Apart from inundation of a vast area, a comparison of aerial photographs from 1942 with present Google satellite images shows how the construction of the dam had also changed the character of river downstream of the dam wall - from a fairly open braided system of meandering streams in 1942 to a densely vegetated single channel in 2012 (Figures 12 – 14).

The dam is owned by the Breede River Municipality and supplies the town of Worcester of water through a pipeline with a maximum capacity of 110 000 $m^3$ water per day (DWAF 1984).  The Breede River Municipality may annually store runoff during the period 16 November to 15 March. Following a good rainy reason, mountain streams may, for a period into spring and even into summer, still fill the dam to full capacity and cause overflow into the river (H. Groenewald personal communication, February 2009).

It is estimated that the average tempo of sedimentation in the Stettynskloof Dam is 0.02% per annum (DWAF 1984).

Through an agreement with the Breede Valley Municipality, farmers of the Holsloot Irrigation Board are also supplied with irrigation water from the dam (DWAF 1984). The annual volume supplied to the irrigators and the assurance of that supply is dependent on the storage in Stettynskloof Dam (H. Groenewald, personal communication, February 2009). When the water level drops and there is no overflow, an average of 40 mega litres/day of compensation water is hypo-limnetically discharged from the dam (Figure 12) at the request of the chairperson of the Holsloot Irrigation Board (H. Groenewald personal communication, February 2009). Water from the mainstream is measured and diverted by in-stream structures from where it flows in open ditches to supply registered users on farms in the Louwshoek and Voorsorg areas.  Downstream of the farm Skukuza, surplus water from the Holsloot River joins that from the Smalblaar River and is diverted into the Brandvlei Dam by means of a concrete canal (DWAF 1984).

Apart from water outlet from the dam, numerous mountain streams feed the Holsloot River with runoff from plateau's and steep slopes characteristic of the rocky mountainous environment (Figures 12 & 15).

Water is not managed downstream from the farm Malkopklip (P.D. le Roux personal communication, December 2011). From this point all the way downstream to where the river is diverted into the Brandvlei Dam, the river supplies bordering farms with household- and irrigation water. As surface flow often disappears just downstream of the farm Malkopklip (A. le Roux personal observation), winter runoff or drainage is often stored in farm-dams to be used during the dry months. Subsurface water supplies are pumped from wells in the riverbed or from boreholes (P.D. le Roux personal communication, February 2012).

Cooper, Lake, Sabater, Melack & Sabo (2012) state that land use changes have had a large effect on aquatic environments in Mediterranean climate regions such as south-western South Africa: “Historical land use changes denuded landscapes of native vegetation and promoted erosion, flooding, and downstream sedimentation, often producing the altered environments evident today”. In the middle and lower reaches of the river, water from the Holsloot River thus supports extensive agricultural development. A comparison of historical aerial photographs with present Google satellite images shows how agricultural development had expanded in the middle and lower reaches of the river since 1942 (Figures 15 – 19). These developments consist mainly of cultivation of grapes for the wine industry, but also include deciduous fruits, olives as well as lucerne and hay to a lesser extent. The Goudini Wine Cellar extracts water from the Holsloot River for industrial use on the farm Skukuza. Effluent from the cellar is treated according to Van Schoor (2005) and not discharged into the Holsloot River, but into the Smalblaar River (P.D. le Roux personal communication, February 2012).

## 2.8 Tourism

The Breede River Valley is a popular tourist destination due to its spectacular scenery and wine. The study area is a popular ecotourism and trout fishing location. Apart from the popular Dwarsberg Trout Haven Resort, which offers trout fishing, ecotourism (a hiking trail as well as mountain bike track), a conference and celebration venue, chalets and camping sites on the banks of the river, numerous other privately owned camping sites have over the last few years been developed along the banks of the river.

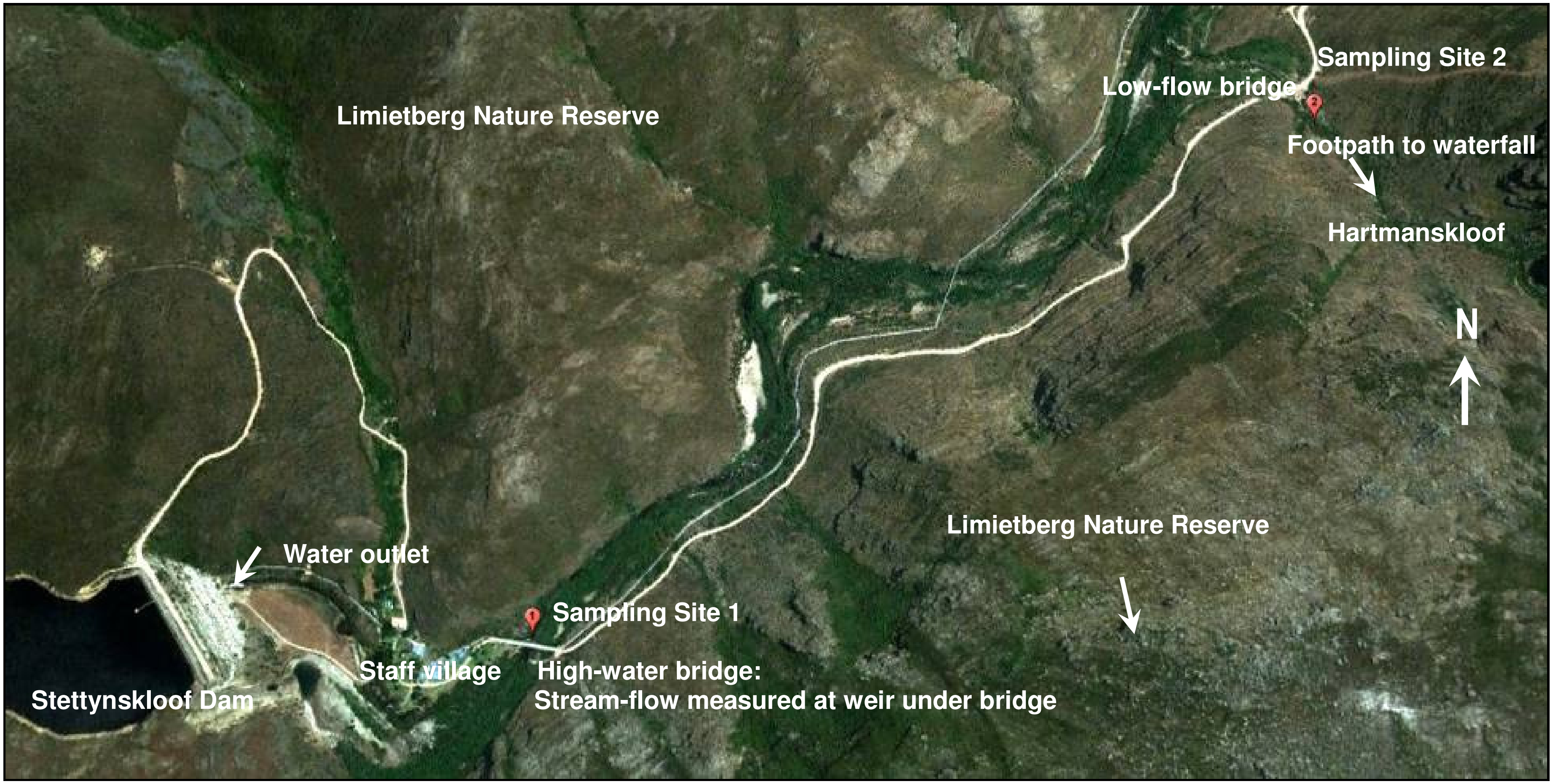

**Figure 12:** Apart from infrastructure and housing development at the dam, the natural area northeast of the Stettynskloof Dam is part of the Limietberg Nature Reserve (from the Google Earth Satellite Image 2012).

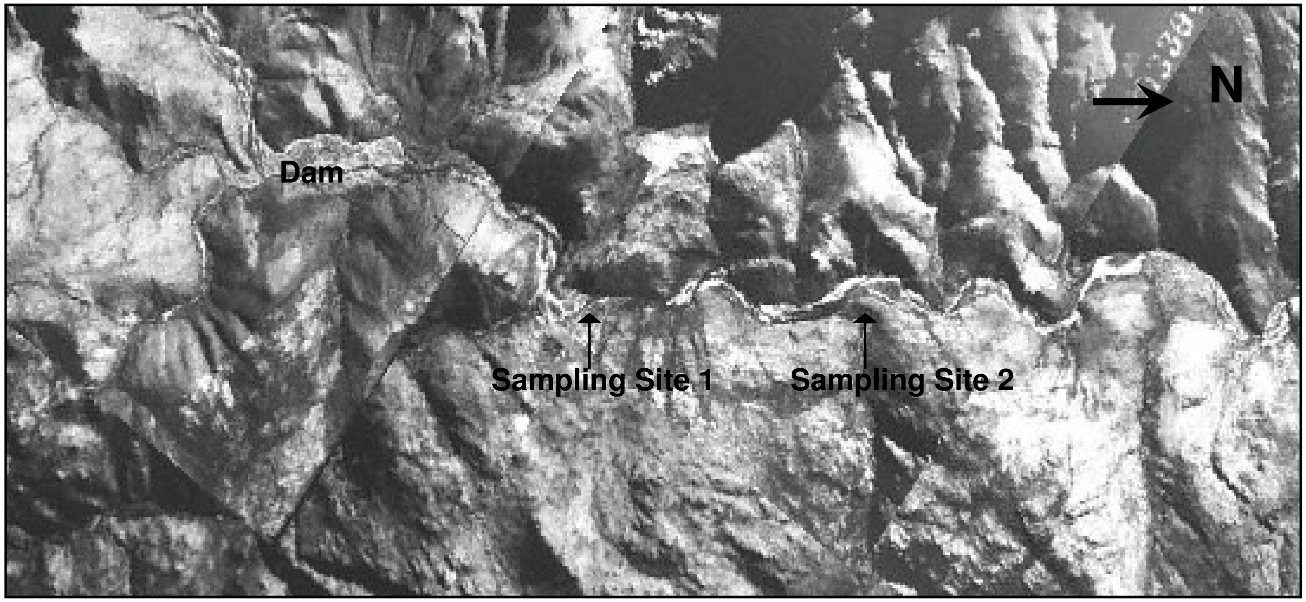

**Figure 13:** An assemblage of aerial photographs from 1942 of the upper catchment area of the Holsloot River, indicating the divided stream character of the river before the Stettynskloof Dam was built (Department of Rural Development and Land Reform 1942).

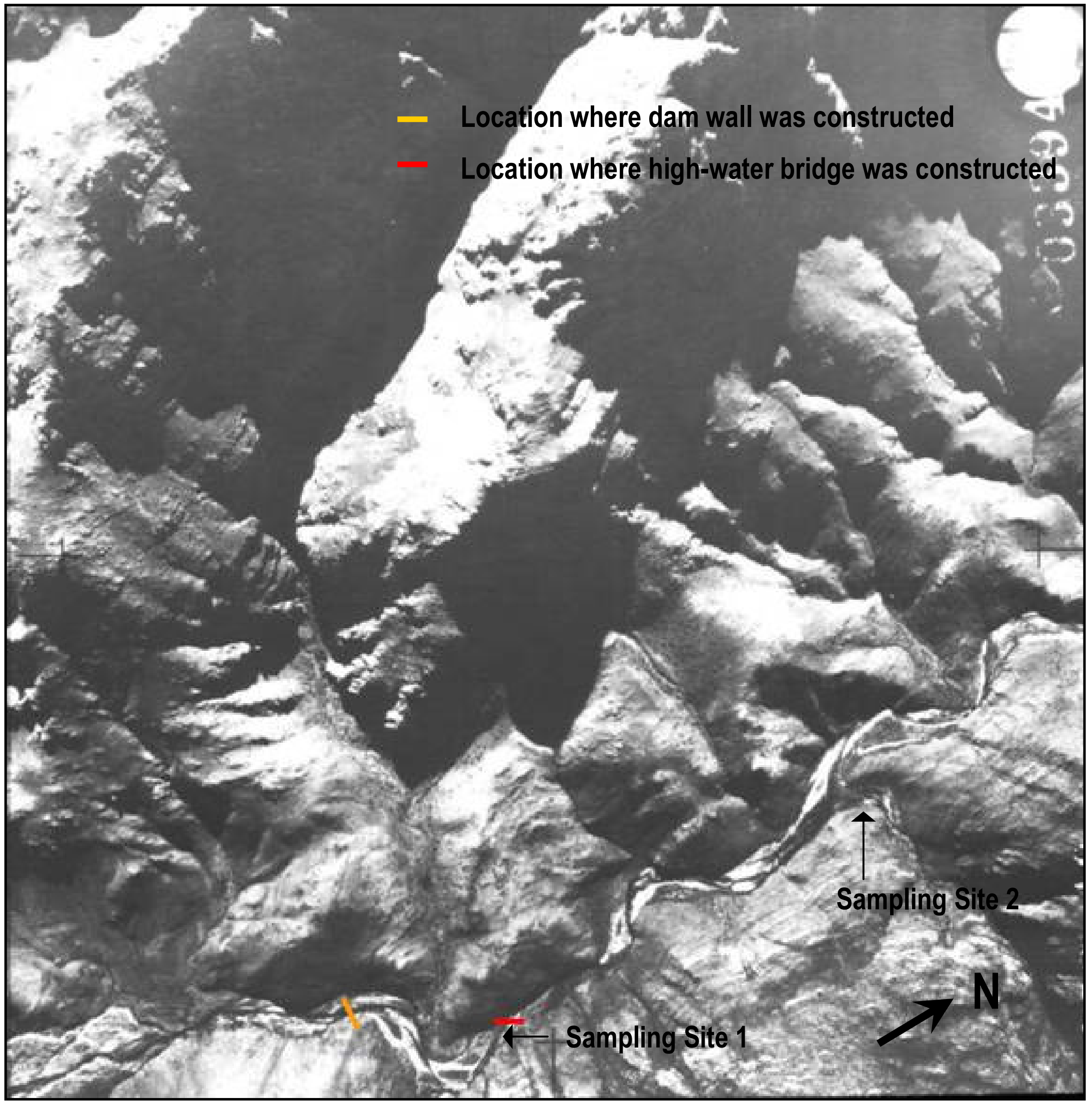

**Figure 14:** An aerial photograph from 1942 indicates the braided stream system in the locality where the Stettynskloof Dam was built as well as the character of the stream at Sampling Site 1 (Department of Rural Development and Land Reform 1942).

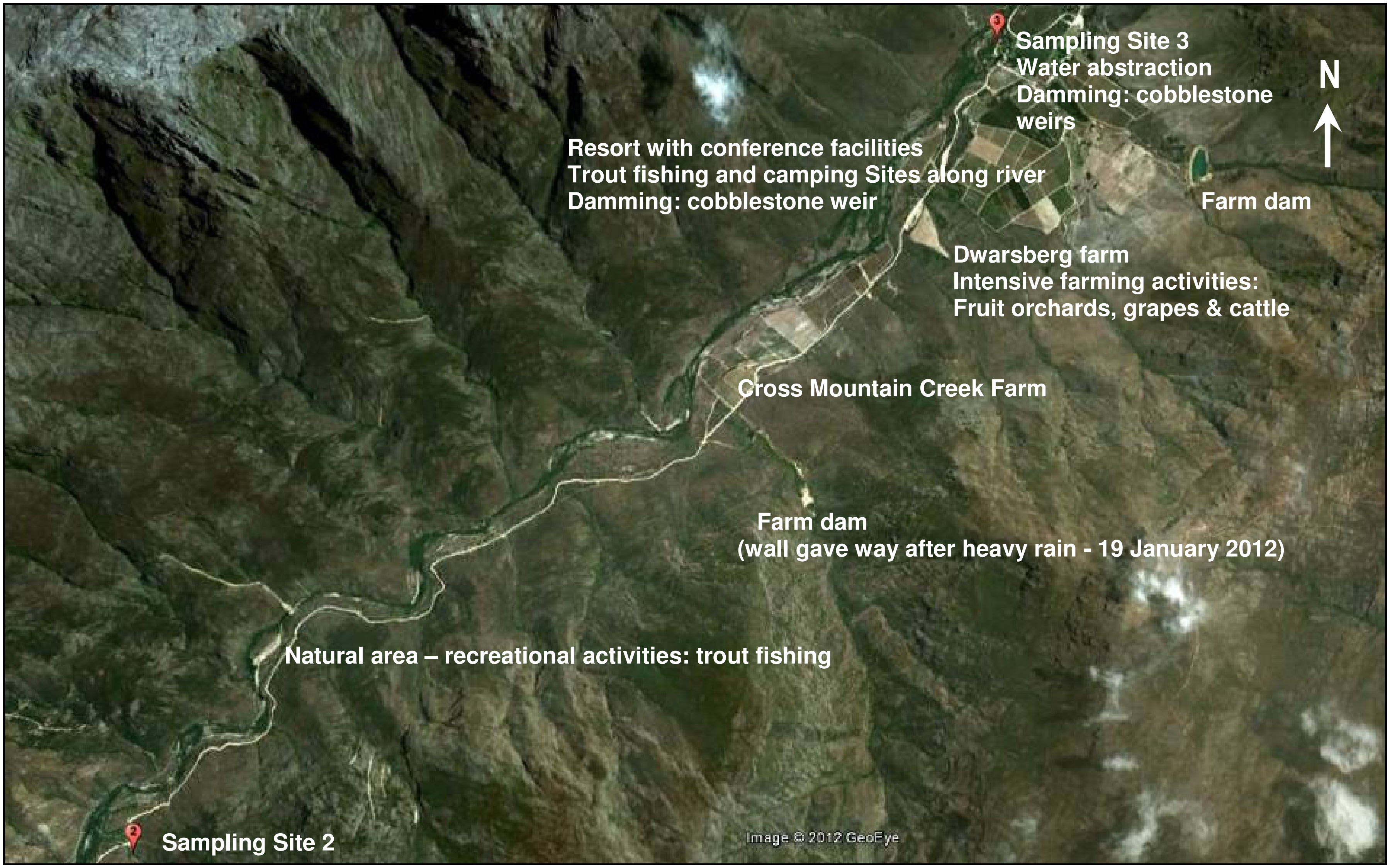

**Figure 15:** Land-use between the Hartmanskloof and the Dwarsberg farm: Intensive farming activities as well as recreational use of the river occur upstream and at the Dwarsberg farm (from the Google Earth Satellite Image 2012).

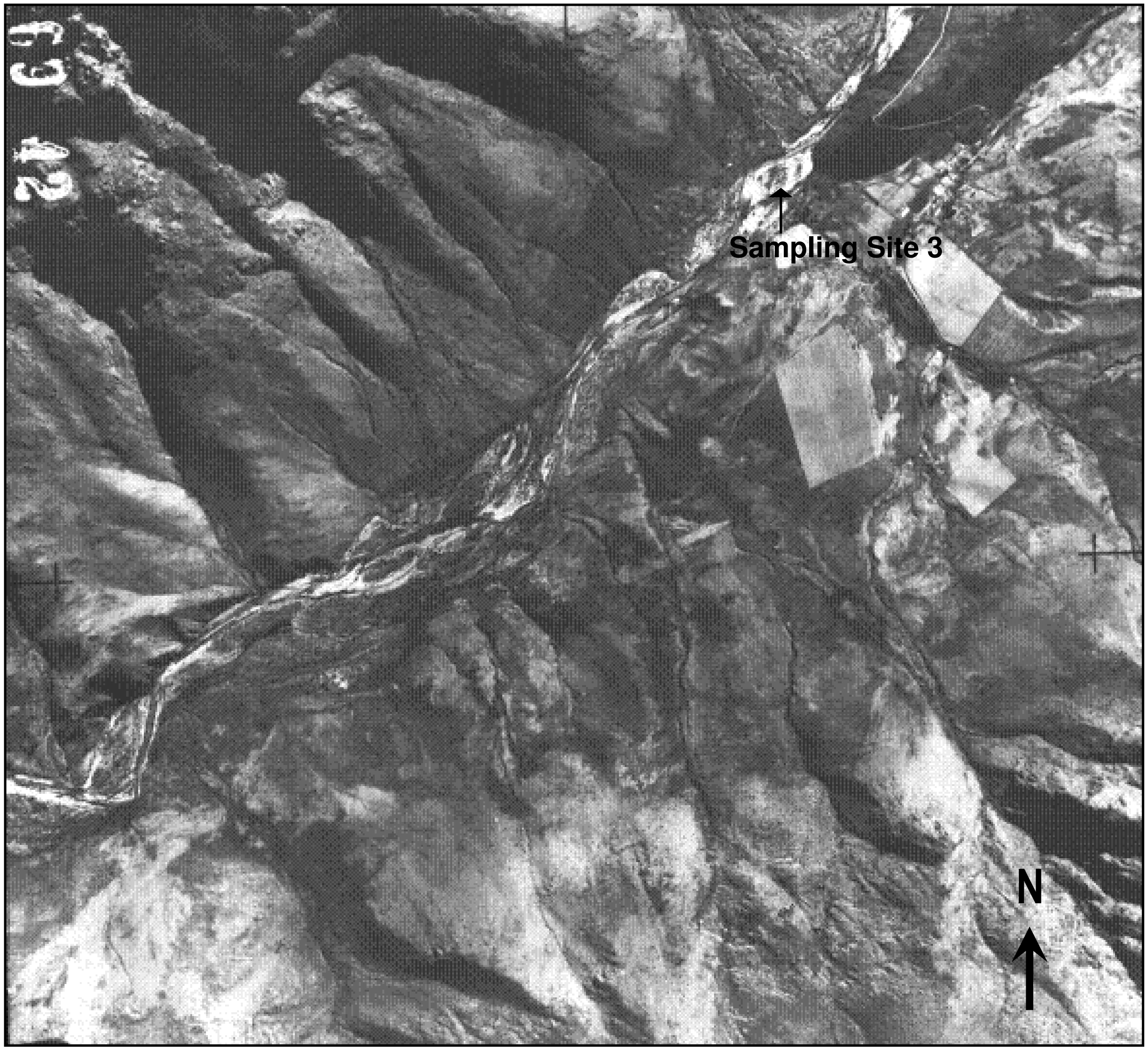

**Figure 16:** An aerial photograph from 1942 indicates the character of the river, as well as agricultural development downstream and at Sampling Site 3 (Department of Rural Development and Land Reform 1942).

**Figure 17:** Apart from the natural area just downstream from the farm Dwarsberg, land-use between the Dwarsberg and Malkopklip farms involves intensive farming activities as well as recreational use of the river (from the Google Earth Satellite Image 2012).

**Figure 18:** Land-use between the farms Malkopklip and Skukuza comprises of intensive farming activities as well as recreational use of the river (from the Google Earth Satellite Image 2012).

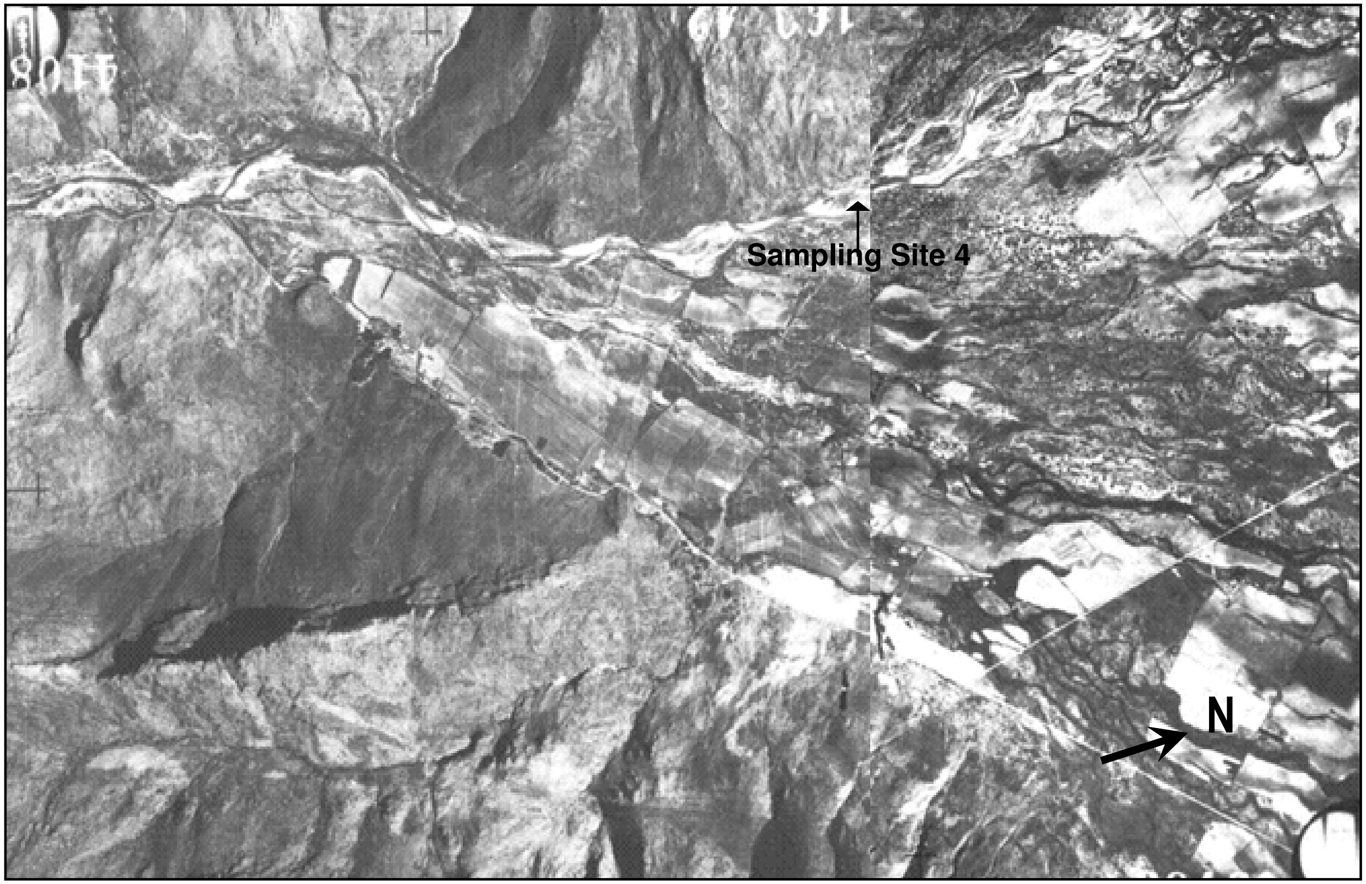

**Figure 19:** An assemblage of aerial photographs from 1942 indicates the braided stream character of the river in the middle reaches, as well as the extent of agricultural development upstream and downstream of Sampling Site 4 (Department of Rural Development and Land Reform 1942).

## 2.9 References

Boycott, R.C. 2004. *Heleophryne purcelli* Sclater, 1898, in Minter, L.R., Burger, M., Harrison, J.A., Braack, H.H., Bishop, P.J., Knoepfer, D. (eds.) *Atlas and Red Data Book of the Frogs of South Africa,Lesotho & Swaziland. SI/MAB Series #9* (pp 104-105). Smithsonial Instutution, Washington DC.

Chittenden, H. 2007. *Roberts Bird Guide*. Trustees of the John Voelcker Bird Book Fund, Cape Town.

Compton, J.S. 2006 *The Rocks and Mountains of Cape Town*. Double Storey Books, Cape Town.

Cooper, S.D., Lake, P.S., Sabater, S., Melack J.M. & Sabo, J.L. 2012. The effects of land use changes on streams and rivers in mediterranean climates. *Hydrobiologia,* DOI 10.1007/s10750-012-1333-4.

Davies, B. & Day, J. 1998. *Vanishing Waters.* University of Cape Town Press, Cape Town.

De Villiers, A.L. & Boycott, R.C. 2004. *Strongylopu*s *bonaespei* Dubois, 1980. in: Minter, L.R., Burger, M., Harrison, J.A., Braack, H.H., Bishop, P.J., Knoepfer, D. (eds.) *Atlas and Red Data Book of the Frogs of South Africa,Lesotho & Swaziland.* SI/MAB *Series #9*. (pp 308-309). Smithsonial Instutution, Washington DC.

Department of Rural Development and Land Reform. 1942. South Africa, Chief Directorate: National Geo-spatial Information (CD: NGI), Aerial photographs.

Department of Water Affairs and Forestry (DWAF). 1984. *Stettynskloofdam – Kapasiteitsbepaling.* Unpublished internal Report, Department of Water Affairs, Worcester.

Department of Water Affairs and Forestry (DWAF). (1995) *Brandvlei/Kwaggaskloof Struktuurplan.* Unpublished internal Report, Department of Water Affairs, Worcester.

Gresse, P.G. & Theron, J.N. 1992. *The geology of the Worcester area.* Government Printer, Pretoria.

Kirchner, J., Moolman, J.H., du Plessis, H.M. & Reynders, A.G. 1997. Causes and management of Salinity in the Breede River Valley, South Africa. *Hydrogeology Journal,* 5(1):98-108.

Mokhatla, M.M., Measey, G.J., Chimimba. C.T. & Van Rensburg, B.J. 2012. A biogeographical assessment of anthropogenic threats to areas where different frog breeding groups occur in South Africa: implications for anuran conservation. *Diversity and Distributions,* 18:470–480.

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

Skelton, P. 2001. *A Complete guide to the Freshwater Fishes of Southern Africa.* Struik, Cape Town.

South Africa 1:250 000 Topographical Sheet 3319 Worcester, Third edition, Director General of Surveys, 1980.

South Africa 1:250 000 Geological Series 3319 Worcester, Council for Geosciences, 1997.

Theron, J. & Minter, L.R. 2004. *Capensibufo rosei* (Hewitt, 1926). in Minter, L.R., Burger, M., Harrison, J.A., Braack, H.H., Bishop, P.J., Knoepfer, D. (eds.) *Atlas and Red Data Book of the Frogs of South Africa,Lesotho & Swaziland. SI/MAB Series #9* (pp 87-90). Smithsonial Instutution, Washington, DC.

Turner, A.A. & de Villiers, A.L. 2007. Amphibians. *In Western Cape Province State of Biodiversity. CapeNature Scientific Services*, Cape Town.

Van Schoor, L.H. 2005. *Guidelines for the management of Wastewater and Solid Waste at Existing Wineries.* Enviroscientific & Winetech report. Available on the internet at: http://awsassets.wwf.org.za (Accessed 15 March 2010).

Weather data January 1978 - October 2012: AgroMet - Institute for Soil, Climate and Water (ISCW).

Daily rainfall figures and flow measurements, January 2011 – October 2012: Breede District Municipality.

# Chapter 3: Methods

## 3.1 Literature review and desktop survey

A literature study was carried out using information from various reference works as listed in the reference section of the various chapters of this dissertation. The study was discussed with key people at the Department of Water Affairs (DWA), the Breede Municipality and the Holsloot Irrigation Board who supplied additional data and reference works. The various property owners granted permission to access the Sampling Sites.

Weather data, measured at the High Noon weather station, approximately 10km southeast of the Stettynskloof dam, was obtained from AgroMet - Institute for Soil, Climate and Water (ISCW), Stellenbosch. Rainfall and stream flow data, measured at the Stettynskloof dam, were obtained from the Breede River District Municipality.

## 3.2 Sample Sites

Maps, aerial photographs as well as *Google Earth* satellite images were used to identify possible sample sites. Various site visits were then undertaken during July and August 2008 to assess potential impacts and identify suitable sampling sites. Five sample sites were selected (Figure 20) and are indicated in Figures 21-30.

General information per sampling site is presented in Table 3, channel morphology in Table 4 and cross-sectional features present at each sampling site (direction – downstream) in Table 5.

**Figure 20:** Land-use from the Stettynskloof dam to where the Holsloot River joins the Breede River northeast of Sampling Site 5 (from the Google Earth Satellite Image 2012).

### 2.7.1 Sampling Site 1: Site code: RHP H1 / HOLS – STETT (Figures 21 & 22)

**Figure 21:** Up-stream view,
Spring 2011.

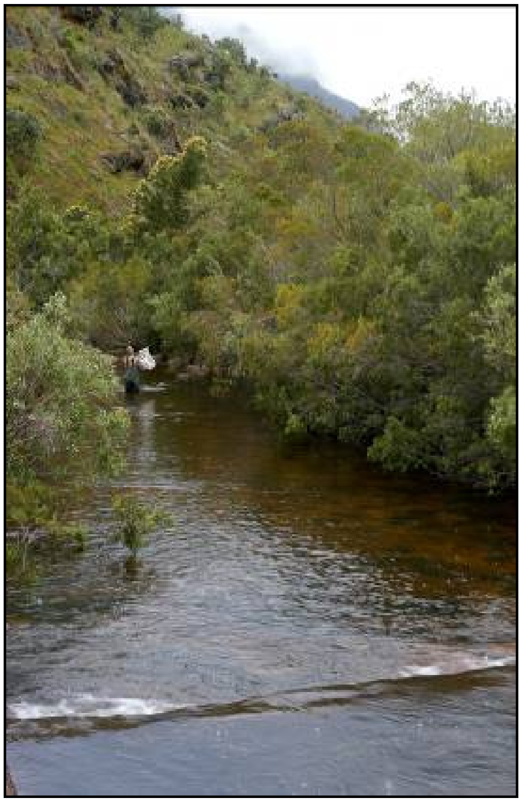

**Figure 22:** Down-stream view,
Spring 2011.

### 2.7.2 Sampling Site 2: Reference site, code: H 1 TRIB / HOLSL (Figures 23 & 24)

**Figure 23:** Up-stream view,
Winter 2009.

**Figure 24:** Down-stream view,
Winter 2009.

### 2.7.3 Sampling Site 3: Site code: H1 / HOLS – DWARS (Figures 25 & 26)

**Figure 25:** Up-stream view, Summer 2011**.**

**Figure 26:** Down-stream view, Summer 2011**.**

### 2.7.4 Sampling Site 4: Site code: H 1 / HOLS – MALKO (Figures 27 & 28)

**Figure 27:** Up-stream view, Winter 2012.

**Figure 28:** Down-stream view, Winter 2012.

### 2.7.5 Sampling Site 5: Site code: RHP H 1 / HOLS – RAWSO (Figures 29 & 30)

**Figure 29:** Upstream view, Summer 2011.

**Figure 30:** Down-stream view, Summer 2011.

**Table 3:** General information per sampling site (AMSL = Above Mean Sea Level; IC = in current; OoC = out of current; u/s = upstream).

| | **SAMPLING SITE 1** | **SAMPLING SITE 2** | **SAMPLING SITE 3** | **SAMPLING SITE 4** | **SAMPLING SITE 5** |
|---|---|---|---|---|---|
| **Site code** | RHP H1 / HOLS - STETT | H 1 TRIB / HOLSL | H1 / HOLS - DWARS | H 1 / HOLS - MALKO | RHP H 1 / HOLS - RAWSO |
| **Locality** | Downstream of Stettynskloof Dam, under the high-water bridge over the Holsloot River, municipal land. | Tributary of the Holsloot River, up-stream of low flow causeway, municipal land. | On the farm Dwarsberg, in locality of Trout Hideaway resort recreational area, opposite to the reception/conference venue | On the farm Malkopklip, just downstream of a steel-bridge river crossing, close to the border with the farm Louwshoek | On the farm Skukuza, upstream of the road-bridge over the Holsloot, east of Rawsonville |
| **Latitude** | S 33° 50' 13.4" | S 33° 49' 45.0" | S 33° 47' 11.1" | S 33° 43' 46.4" | S 33° 41' 35.5" |
| **Longitude** | E 019° 15' 27.4" | E 019° 16' 18.3" | E 019° 19' 38.6" | E 019° 19' 32.0" | E 019° 19' 32.7" |
| **Altitude (AMSL)** | 429 m | 415 m | 317 m | 253 m | 217m |
| **Length (m)** | 10 | 10 | 10 | 10 | 10 |
| **Description** | Natural- & present day perennial mountain stream | Pristine, natural- & present day perennial mountain stream, tributary of the Holsloot River | Transitional, natural- & present day perennial river | Upper foothill, natural - perennial, present day - seasonal river | Lower foothill, natural- & present day perennial river with associated wetland |
| **Stream dimensions** | Macro channel width: 10 - 20m Active channel width: 5 - 10m Water surface width: 5 - 10m | Macro channel width: 10 - 20m Active channel width: 2 - 5m Water surface width: 2 - 5m | Macro channel width: 10 - 20m Active channel width: 5 -10 m Water surface width: 5 - 10m | Macro channel width: 20 - 50m Active channel width: 5 - 10m Water surface width: 5 - 10m | Macro channel width: 10 - 20m Active channel width: 10 - 20m Water surface width: 2 - 5m |
| **Average water depth** | Deep water: 1.3m, run Shallow water: riffles upstream | Shallow water: 0.4 - 1m, run/riffles, relative shallow pools | Deep water: 0.3 - 0.5m, run/pool u/s Shallow water: 0.2 - 0.4m, run/riffles | Deep water: 2m, pool upstream Shallow water: 40cm, run/riffles | Shallow water: 20cm, run |
| **Biotopes** | Pool, run & riffle upstream & downstream (3 mix) | Pool, riffle/rapid & run (3 mix) | Pool, riffle/rapid & run (3 mix) | Riffle/rapid & run (2 mix) | Riffle & run (2 mix) |
| **Canopy cover** | Open, Partially open downstream, Coarse woody debris limited, source = local | Closed to partially open – open due to recent fire. Coarse woody debris present - no impact on site, source = upstream | Partially open, Coarse woody debris limited, source = local | Open | Open |
| **Marginal & aquatic vegetation** | IC: sedges rare<br>OoC: grasses & shrubs common.<br>Algae on stones in water (not filamentous) | IC: grasses & sedges rare<br>OoC :grasses sparse, shrubs common<br>Sedges & Moss common in water | IC: grasses & reeds sparse, shrubs common.<br>OoC: grasses sparse, reeds & shrubs common.<br>Filamentous algae common in water | IC: grasses sparse<br>OoC: grasses & shrubs common | IC: grasses sparse<br>OoC: *P. serratum* sparse<br>Algae common in water |
| **Vegetation** | Hawequas Sand Fynbos | Hawequas Sand Fynbos | Hawequas Sand Fynbos, Boland Granite Fynbos, Breede Alluvium Fynbos | Hawequas Sand Fynbos, Breede Alluvium Fynbos | Breede Alluvium Fynbos |

**Table 4:** Channel morphology per sampling site. Adapted from RHP: Site Characterisation Field-data Sheets, Version 1 - 03/2005.

| Sampling Site | Channel type | | | | |
|---|---|---|---|---|---|
| 1 | [✓ Mixed bedrock and alluvial - dominant type(s)] | sand | gravel | [✓ cobble] | [✓ boulder] |
| | Alluvial with dominant type(s) | sand | gravel | cobble | boulder |
| 2 | [✓ Mixed bedrock and alluvial - dominant type(s)] | sand | gravel | [✓ cobble] | [✓ boulder] |
| | Alluvial with dominant type(s) | sand | gravel | cobble | boulder |
| 3 | Mixed bedrock and alluvial - dominant type(s) | sand | gravel | cobble | boulder |
| | [✓ Alluvial with dominant type(s)] | [✓ sand] | [✓ gravel] | [✓ cobble] | [✓ boulder] |
| 4 | Mixed bedrock and alluvial - dominant type(s) | sand | gravel | cobble | boulder |
| | [✓ Alluvial with dominant type(s)] | [✓ sand] | gravel | [✓ cobble] | [✓ boulder] |
| 5 | Mixed bedrock and alluvial - dominant type(s) | sand | gravel | cobble | boulder |
| | [✓ Alluvial with dominant type(s)] | sand | gravel | [✓ cobble] | boulder |

**Table 5:** Cross-sectional features present at each sampling site (direction – downstream). Adapted from RHP: Site Characterisation Field-data Sheets, Version 1 - 03/2005.

| | SAMPLING SITE 1 | | SAMPLING SITE 2 | | SAMPLING SITE 3 | | SAMPLING SITE 4 | | SAMPLING SITE 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cross Sectional feature** | **LB** | **RB** | **LB** | **RB** | **LB** | **RB** | **LB** | **RB** | **LB** | **RB** |
| High terrace (rarely inundated) | ✓ | ✓ | | | | | | | | |
| Terrace (infrequently inundated) | ✓ | ✓ | | | | | | | ✓ | ✓ |
| Flood bench (inundated by annual flood) | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | |
| Side bar | | | | | | | | | ✓ | |
| Mid channel bar (no vegetation) | | | | | | | | | | |
| Island (vegetation) | | | | | | ✓ | | ✓ | | |
| Secondary / lateral channel | | | | | | | ✓ | ✓ | | |
| Flood plain (inundated by annual flood) | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| Hill slope abutting onto river channel | 5 m from bank | | | | | | | | | |

LB = Left Bank; RB = Right Bank

## 3.3 Measurements and indices used to determine River Health

Standard bio-monitoring protocols and river health measurements were undertaken in field surveys from September 2008 to May 2009 and again from October 2011 to September 2012. During both sampling periods, four seasonal samples were taken at each site:

| | |
|---|---|
| Spring | August 2008 and September 2012 |
| Summer | November 2008 and at the end of October 2011 |
| Autumn | February 2009 and February 2012 |
| Winter | May 2009 and May 2012 |

The results of data gathered during the 2011 – 2012 sampling period are presented in the Results section of this dissertation. These will be compared with results from the previous sampling period (2008 – 2009).

### 3.3.1 Physico-chemical water quality analysis

Water quality analysis involves the physical properties of water that determine its fitness for use or necessary for protecting the health of aquatic ecosystems. Amongst other, water quality is reflected in concentrations of substances (either dissolved or suspended) and in physico-chemical attributes such as temperature, dissolved oxygen, pH and electrical conductivity (DWAF 2008).

*In situ* physico-chemical water quality analysis (water temperature, dissolved oxygen, pH, electrical conductivity and total dissolved solids) was undertaken in the field using water quality meters:

- *YSI* EcoSense DO 200 - dissolved oxygen,
- *YSI* Environmental EC 300 - water temperature
- *HANNA* HI 991300 pH/EC/TDS - pH and electrical conductivity.
- *CHEMetrics* I-1100 Total Dissolved Solids Meter - Total Dissolved Solids

### 3.3.2 Habitat- and biological indices

#### 3.3.2.a South African Scoring System (SASS5)

The SASS5 (Dickens & Graham 2002) method was used to monitor aquatic macro-invertebrates. The first group of samples (2008 - 2009) was collected in collaboration with the River Health Programme (CapeNature and DWAF). Results of this first study (2008 – 2009) were presented at a conference of the International Water History association (IWHA) in July 2011 (Appendix 4). The second group of samples (2011 – 2012) was collected in collaboration with the Department of Environmental Sciences, UNISA. Data was noted on standard field-data sheets (Dallas 2005) (Appendix 3). Data interpretation is based on two (2) calculated values, namely SASS Score, which is the sum of the sensitivity weightings for taxa present at a site, and Average Score Per Taxon (ASPT), which is the SASS Score divided by the number of SASS taxa recorded at the site (DWAF 2008).

#### 3.3.2.b Index of Habitat Integrity (IHI) and Invertebrate Habitat Assessment System Index (IHAS)

DWAF (2008) state that the habitat integrity of a river refers to the maintenance of a balanced composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region. Habitat integrity was assessed by considering the current condition of instream and riparian zones (DWAF 2008; Kleynhans 1996; Kleynhans Mackenzie & Louw 2007).

During both sampling periods, site characterisation and Index of Habitat Integrity (IHI) (Kleynhans 1999) were done on the first sample date, using standard field-data sheets (Dallas 2005). IHI data was used in the IHI model *Microsoft Excel* spreadsheets provided by Dr C. J. Kleynhans (personal communication, February 2012) (Kleynhans, Louw & Graham 2008). Changes observed on later sampling dates were noted as such. Invertebrate Habitat Assessment System Index (IHAS) (McMillan 1998), which indicates the extent to which the habitat available at the sampling time was suitable to support a diverse macro-invertebrate community, was done with the taking of every sample.
Although most aquatic scientists do not regard the IHAS model useful (Dr C. J. Kleynhans personal communication, February 2012), it is used in this study as indication of the changeability of available habitat in the Holsloot River in different seasons.

#### 3.3.2.c Riparian Vegetation Response Index (VEGRAI)

The Riparian Vegetation Response Assessment Index (VEGRAI) (Kleynhans *et al.* 2007) aims to provide a practical and rapid approach to assess changes in riparian vegetation condition (DWAF 2008).
DWAF (2008) provides the general features of VEGRAI:

- "VEGRAI considers the condition of the different vegetation zones separately but allows for the integration of zone scores to provide an overall index value for the riparian vegetation zone as a unit.
- It is based on the interpretation of the influence of riparian vegetation structure and function on instream habitat.
- Vegetation is assessed based on woody and non-woody components in the respective zones and according to the different vegetation characteristics.
- It provides an indication of the causes of riparian vegetation degradation.
- It is impact based, i.e. the condition of the riparian vegetation is assessed relative to a reference condition.
- The reference condition is broadly defined and based on the natural condition in the absence of anthropogenic impacts. Where possible reference conditions are derived based on reference sites or river reaches.
- Although biodiversity characteristics are used in assessing the riparian vegetation condition, it is not a biodiversity assessment index *per se*."

Data regarding the Riparian Vegetation Response Index (Kleynhans *et al.* 2007) was gathered only in the second sampling period (2011 – 2012). Kleynhans *et al.* (2007) describe that VEGRAI has a spreadsheet model composed of a series of metrics and metric groups, which compare differences between the current- and reference states as a measure of vegetation response to various impacts (Kleynhans *et al.* 2007). The mentioned metrics and metric groups were rated in the field with the guidance of data collection sheets (Kleynhans *et al.* 2007).

The Level 3 version of the VEGRAI was used where marginal-, and non-marginal (combination of the lower- and upper zones) riparian vegetation were used as the metric groups.

The national conservation status of rare and endangered plant species was studied from SANBI (2013).

### 3.3.3 Interpretation

Results of the Index of Habitat Integrity were interpreted by the method of Kleynhans (1999) which classifies habitat integrity into one of six ecological classes, ranging from unmodified (Category A), to critically modified (Category F), for both in-stream and riparian habitats (Kleynhans 1999) (Table 6).

Results from the VEGRAI metrics, determined an Ecological Category (Table 6) for the present state of the riparian vegetation of the various sampling points.

**Table 6:** Habitat Integrity Classes (Kleynhans 1999).

| Class | Description | Integrity Score (%) |
|---|---|---|
| A | **Natural**, unmodified | 90 – 100 |
| B | **Largely Natural** with few modifications. A small change in natural habitats and biota may be evident but the assumption is that ecosystem functioning is essentially unchanged | 80 – 89 |
| C | **Moderately Modified**: A loss or change in natural habitat and biota has occurred, but basic ecosystem functioning appears to be predominantly unchanged. | 60 – 79 |
| D | **Largely Modified:** A loss of natural habitat and biota and a reduction in basic ecosystem functioning is assumed. | 40 – 59 |
| E | **Seriously Modified:** The loss of natural habitat, biota and ecosystem functioning is extensive | 20 – 39 |
| F | **Critically Modified**: An almost complete loss of natural habitat and biota due to a critical level of modifications is evident. Basic ecosystem functioning in the worst cases destroyed. | <20 |

Habitat results for the IHAS index were interpreted according to the guidelines of McMillan (1998) (Table 7).

**Table 7:** Scores for IHAS, interpreted according to the guidelines of McMillan (1998).

| Score (%) | Description |
|---|---|
| <65 | Inadequate for supporting a diverse aquatic macro-invertebrate community |
| 65%-75 | Adequate for supporting a diverse aquatic macro-invertebrate community |
| >75 | Highly suited for supporting a diverse aquatic macro-invertebrate community |

Results of bio-monitoring are interpreted by plotting both SASS5 scores and ASPT values relative to Biological Band/Ecological categories as suggested in Dallas (2007) (Figures 31 & 32; Table 8).

**Table 8:** Biological Bands / Ecological categories for interpreting SASS data (Dallas 2007).

| Biological Band Ecological Category | Ecological Category Name | Description |
|---|---|---|
| A | Natural | Natural Unmodified |
| B | Good | Largely natural with few modifications |
| C | Fair | Moderately modified |
| D | Poor | Largely modified |
| E | Seriously modified | Seriously modified |
| F | Critically modified | Critically or extremely modified |

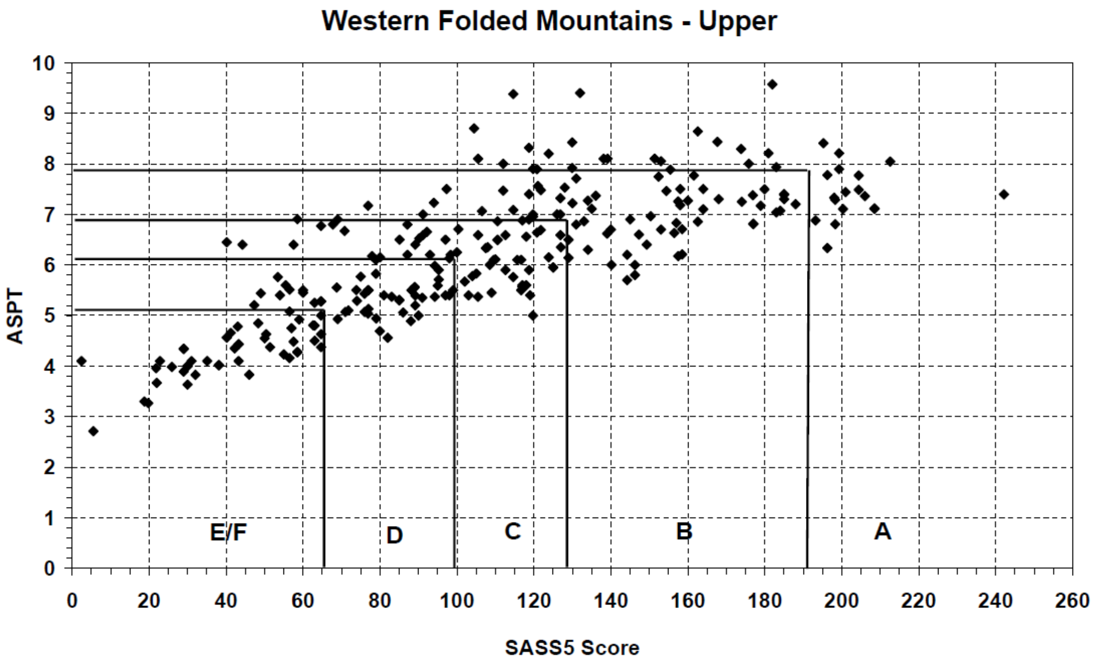

**Figure 31:** Biological Bands for the Western Folded Mountains – Upper zone, calculated using percentiles (Dallas 2007).

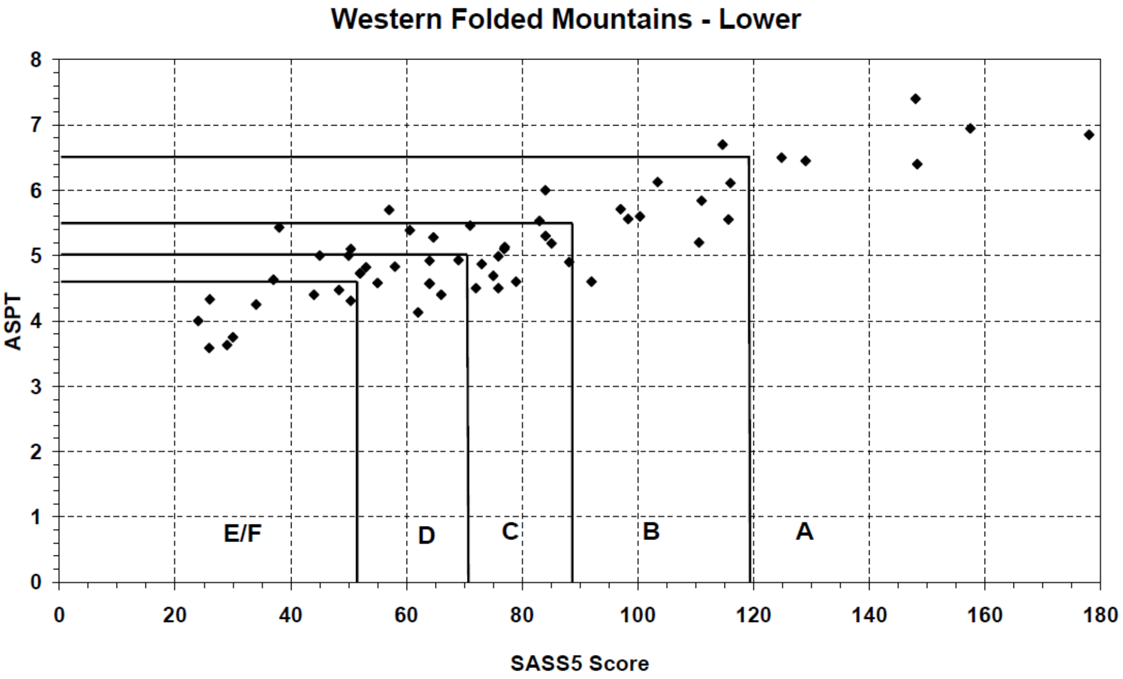

**Figure 32:** Biological Bands for the Western Folded Mountains – Lower zone, calculated using percentiles (Dallas 2007).

## 3.4 References

Dallas, H.F. 2005. *River Health Programme: Site Characterisation Field-Manual and Field-Data Sheets*. Resource Quality Services, DWAF.

Dallas, H.F. 2007. R*iver Health Programme: South African Scoring System (SASS) Data Interpretation Guidelines*. Department of Water Affairs and Forestry.

Dickens, C.W.S & Graham, P.M. 2002. The South African Scoring System (SASS) Version 5 Rapid Bioassessment Method for rivers. *Journal of Aquatic Science*, 27:1-10.

Department of Water Affairs and Forestry (DWAF). 2008. National Aquatic Ecosystem Health Monitoring Programme (NAEHMP): *River Health Programme (RHP) Implementation Manual. Version 2.* Department of Water Affairs and Forestry, Pretoria, South Africa.

Kleynhans, C.J. 1996. A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo system, South Africa). *Journal of Aquatic Ecosystem Health*, 5: 41-54.

Kleynhans, C.J. 1999. *Comprehensive Habitat Integrity Assessment*. Institute for Water Quality studies, Department of Water Affairs and Forestry.

Kleynhans, C.J., Mackenzie, J. & Louw, M.D. 2007. *Module F: Riparian Vegetation Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2).* Joint Water Research Commission and Department of Water Affairs and Forestry report.

Kleynhans, C.J., Louw, M.D. & Graham, M. 2008. *Module G1: Index of Habitat Integrity, Section 1: Model Manual*. In: River EcoClassification manual for EcoStatus Determination (Version 2).

McMillan, P.H. 1998. *An integrated habitat assessment system (IHAS v2) for the rapid biological assessment of rivers and streams.* A CSIR research project. Number ENVP-1 98132 for the water resources management programme. CSIR.

SANBI. 2013. Red List of South African plants version 2013.1. Available on the internet at: http://redlist.sanbi.org/ (Accessed January 2013).

# Chapter 4: Results & Discussion: Physico-chemical water quality analysis

## 4.1 Seasonal variation in water temperature

The significance of water temperature is underlined by Bogan, Mohseni & Stefan (2003): “Most physical properties of water and most chemical and biological processes in water are a function of temperature.” As temperature increases, viscosity, surface tension, compressibility, specific heat, the ionization constant and the latent heat of vaporization decrease, while thermal conductivity and vapour pressure increase. With increasing temperature, hydrogen (H), nitrogen (N), carbon dioxide $CO_2$ and oxygen ($O_2$) gasses are less soluble (DWAF 1996a; Bogan *et al*. 2003).

Water temperature is a complex, but significant physicochemical habitat variable, which is influenced by the characteristics of the catchment as well as climate (DWAF 1996a). The temperature of a river can be influenced by the following (DWAF 1996a):

- climatic factors (e.g. air temperature, cloud cover, wind speed, vapour pressure and precipitation events)
- hydrological factors (e.g. source of water, the relative contribution of ground water and the rate of flow or discharge into the stream).

Structural characteristics of the river and catchment area, including topographic features, vegetation cover, channel form, water volume, depth and turbidity are also factors that could influence water temperature (DWAF 1996a).

According to Mohseni & Stefan (1999) flow rate is an important factor that affects the stream's response to equilibrium temperature. The greater the flow rates, the further downstream the influence of upstream temperatures will be present. Mohseni & Stefan (1999) describe the equilibrium temperature as “a hypothetical temperature that water reaches under constant atmospheric heating/cooling where no more heat is transferred at the air/water interface.” According to the authors, water temperature along the reaches of a river varies between the equilibrium temperature and the upstream water temperature, with the actual temperature depending on the travel time. Where the upstream temperature depends upon geology, climate, human-made reservoirs and discharges, the equilibrium temperature is a function of weather conditions but also of stream shading and wind sheltering (Mohseni & Stefan 1999; Bogan *et al.* 2003;

O’Driscoll & DeWalle 2006). Bogan *et al.* (2003) gives equilibrium temperature as a better indicator of the surface heat exchange processes than air temperature because it accounts for solar radiation, forced convection and evaporative heat fluctuation.

Water temperature readings for the study area were expected to be a reflection of the climate of the region (Figure 4). A gradual increase in water temperature was expected to be found from the coldest months (June, July) to the warmest months (January, February).

Water temperature readings found at the various sampling sites along the river (Figure 33) were compared with monthly average air temperatures for the sampling months (Figure 5). Though it was expected that the stream temperature would reflect that of the seasonal air temperatures (Figures 4 & 5) with the lowest temperatures in winter and gradually increasing to the highest in autumn, the spring samples rendered the lowest water temperatures. Furthermore, the water temperature readings obtained in winter were higher than that obtained in summer (Figure 33).

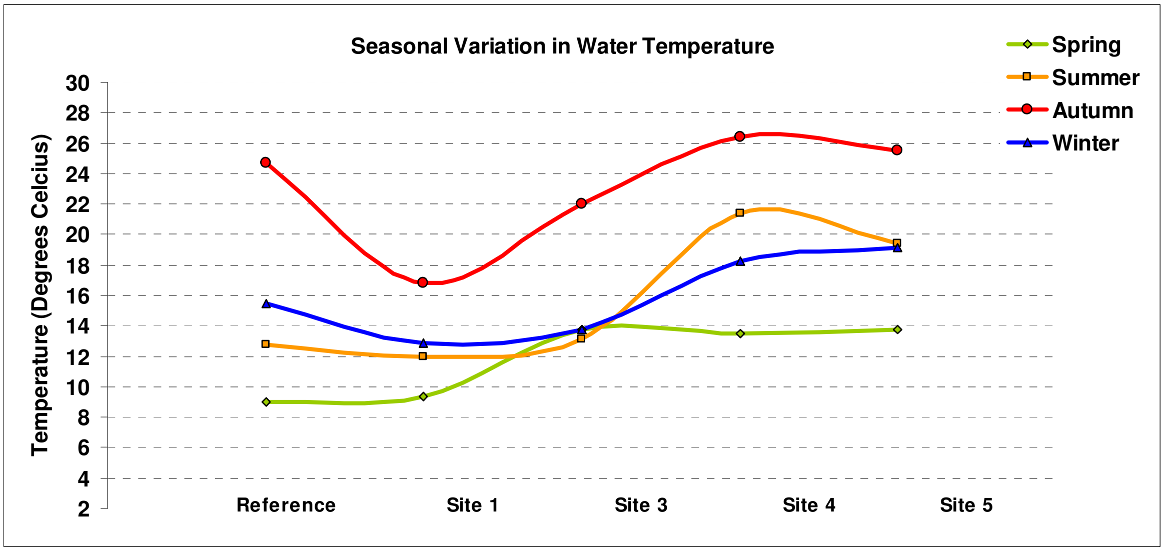

**Figure 33:** Seasonal variation in water temperature (2011 – 2012).

### 4.1.1 Sampling Site 2 (hereafter referred to as the Reference Site)

As reflected in the average air temperatures for the sampling periods (Figure 5), the lowest water temperature at the Reference Site was measured in spring, followed by that of summer. Contrary to what would be expected (compared to air temperatures), water at the Reference Site was warmer in winter than in both spring and summer.

It is known that surface water temperatures can vary daily (Holmes 2000), and that weather conditions such as air temperature influence stream temperature (Mohseni & Stefan 1999; Bogan *et al.* 2003; O'Driscoll & DeWalle 2006). In an earlier study concerning stream temperatures in an alpine area, Johnson (1971) found a good association between water- and air temperatures. The author concluded however, that "stream water temperatures are not only affected by and dependent on air temperatures but also depend to a large degree on the topographical characteristics of the catchment." Surface water temperatures often vary daily and seasonally, while ground water temperatures are relatively constant at about the mean annual air temperature. Groundwater inflow will therefore lower stream temperatures in summer and increase them in winter (Holmes 2000).

Apart from groundwater inflows, stream temperature is also influenced by factors such as heat exchanges with the atmosphere by short- and longwave radiation, convection and evaporation through the water surface (Bogan *et al.* 2003). Although Sinokrot & Stefan (1993) give heat exchange across the air-water interface as the most important factor, the heat exchange between the water column and the riverbed and banks can also influence water temperature in shallow streams (Sinokrot & Stefan 1993; Webb, Hannah, Moore, Brown & Nobilis 2008). Moore, Sutherland, Gomi & Dhakal (2005) state that heat conduction from the bed of an open pool can be as much as approximately 10% of the net radiation under sunny conditions. Flow rate also affects the water temperature of streams - the greater the flow rates the further downstream the influence of upstream temperatures will be present (Mohseni & Stefan 1999).

Because of good rains received prior to the spring sample, stream level was high and flow was very strong (Figure 7; Figure 11). This strong, fast stream-flow most probably caused cold runoff to be carried downstream to the lower reaches of the river causing lower stream temperatures at most of the sampling sites in spring. Water at the Reference Site was found to be warmer in winter than in summer. Apart from high water level and flow rate causing lower water temperatures in summer, other factors that could have influenced the unexpectedly higher water temperatures in winter could be heat exchange across the air-water interface as well as heat exchange between the streambed and the water (Sinokrot & Stefan 1993).

Due to the relatively high average air temperature during autumn (Figure 5) as well as relative low stream flow (Figure 7 & 9), the highest water temperature (25 ℃) was measured in autumn - not only for the Reference Site, but also for the other sampling sites.

### 4.1.2 Sampling Site 1

Except for spring when the river flow was fast and water levels high due to good rains (Figure 11), temperature readings at Sampling Site 1 are lower than that of the Reference site (Figure 33).

Compared to the Reference Site, the temperature of the water at Sampling Site 1 was similar in spring, only slightly lower in summer and in winter, but considerably colder in autumn.

Stream flow is measured at a weir in the river at Sampling Site 1 (Figure 22) causing water to dam and form a fairly deep pool/run at the site (Tables 3 & 5). Lower water temperatures at Sampling Site 1 could in all probability be ascribed to the deep pool character of Sampling Site 1 (Figures 21 & 22), partial day shade due to the steep mountain slopes that surround the area (Table 3) as well as hypo-limnetic releases from the Stettynskloof Dam when the dam is not overflowing (Bogan *et al.* 2003).

The dam stopped overflowing in November 2011, where compensation water releases started at the beginning of December 2011 and ended on the 17th of April 2012 (Figure 7). While the dam overflowed with the spring and summer samples, water temperature at Sampling Site 1 is comparable to that of the Reference Site. When the dam however, had stopped overflowing and compensation was released in autumn, the water temperature at Sampling Site 1 was found to be considerably lower than that of the Reference Site due to hypo-limnetic releases (from the cold bottom layer of water) from the dam that contributes to river flow in the dry season. The releases from the dam affect stream flow. During the period where compensation water was released from the dam before onset of the rainy season, an average flow of between 122 Mℓ/day to 137 Mℓ/day (December 2011 – March 2012) was maintained at Sampling Site 1 (Figure 7).

As a result of compensation releases, a higher flow was measured in February 2012 (average flow 131 Mℓ/day) which is known to be the hottest and driest month (Figure 4), than what was measured in October 2011 (123.34 Mℓ/day) when no compensation water was released but when the dam was still overflowing (Figure 7).

While the dam was not yet overflowing at the time of the winter sample, and no compensation water was released from the dam, only runoff from mountain streams and groundwater could have contributed to the flow of the river at that time. This is in all probability the reason for the smaller difference in water temperature at Sampling Site 1, which was only about 2 °C lower than that of the Reference Site (Figures 7 & 33) in winter.

### 4.1.3 Sampling Site 3

Except for the noticeably high value in autumn, as reflected in the high average temperature (Figure 5), together with low stream flow (Figure 9), water temperature at this sampling site did not vary more than 1 °C for spring, summer and winter. Where water temperature for the winter sample was the same as that for the spring sample (13.8 °C), the summer sample was only 0.7 °C lower (13.1 °C) (Figure 33). The water temperature for the winter and spring samples corresponds with the average air temperature for the sampling month, but the summer stream temperature is lower than the average air temperature for the sampling month (Figure 5). The lower water temperature in summer probably relates to the relatively low average air temperature experienced in summer (Figure 5).

Water temperature at Sampling Site 3 was found to be slightly warmer than that of the Reference Site in spring. Compared to the rather narrow, fast flowing mountain stream of the Reference Site (Figures 23 & 24), Sampling Site 3 is a transitional, fairly broad, divided perennial stream with numerous large pools, runs and riffles (Figures 25 & 26; Tables 3 & 5). Cold-water released from the dam seemingly does not influence water temperature at Sampling Site 3 due to the longer distance between the dam and this sampling site (Figure 20). That together with the larger water surface, as well as bed surface area exposed to solar radiation with consequent increased heat exchange with the atmosphere by short- and longwave radiation, is the reason that the water temperature is higher than that of the Reference Site (Sinokrot & Stefan 1993; Mohseni & Stefan 1999; Moore *et al.* 2005). In spring, the water temperature at Sampling Site 3 was higher compared to that of the Reference Site. Although high water levels and strong stream flow were evident in spring (Figure 11), the difference in water temperatures likely relate to the different characters of the two sampling sites (Figures 23 & 25; Table 3). Factors such as distance from the source, heat exchange across the air-water interface as well as between the streambed and the water could cause higher water temperatures at Sampling Site 3 where the stream is divided and running over a wide area (Figure 26; Table 5).

### 4.1.4 Sampling Site 4

Removal of riparian vegetation cover increases the amount of solar radiation reaching the water (DWAF 1996a). Because of its broad stream and shallow cobblestone bed character (Tables 3 & 4), water temperature at Sampling Site 4 is expected to be higher (due to increased heat exchange across the air-water interface as well as between the streambed and the water) than at the Reference Site. Sampling Site 4 is too far from the dam to be directly influenced by cold-water releases, as well as a relative distance from mountain streams draining into this part of the river (Figure 20). Because upstream temperatures have a greater influence on downstream sites during times of greater flow rates (Mohseni & Stefan 1999), the low water temperature measured at Sampling Site 4 in spring likely relates to the high water level and strong flow (Figure 11).

Where the summer water temperature of the upstream sampling sites was lower than that measured at the winter sample, at Sampling Site 4 it was higher (3.2 ℃) than that of the winter sample and had the highest value of all the sampling sites in summer (Figure 33). For all the sampling sites in summer, the shallowest water and slowest flow was found at Sampling Site 4 where the smallest amount of cobblestones were submerged for that particular sample (Figures 29 & 30, 34-37). Low water level together with slow flow provide favourable conditions for heat exchange across the air-water interface as well as heat exchange between the streambed and the water and have likely caused high water temperature here compared to the other sampling sites in summer.

The highest water temperature measured during the study was at Sampling Site 4 in autumn when the site was reduced to a murky pool (dammed for water abstraction) (Figure 38) from which only limited surface flow was observed just downstream thereof (Figure 39).

**Figure 34:** Water level, summer Sampling Site 1.

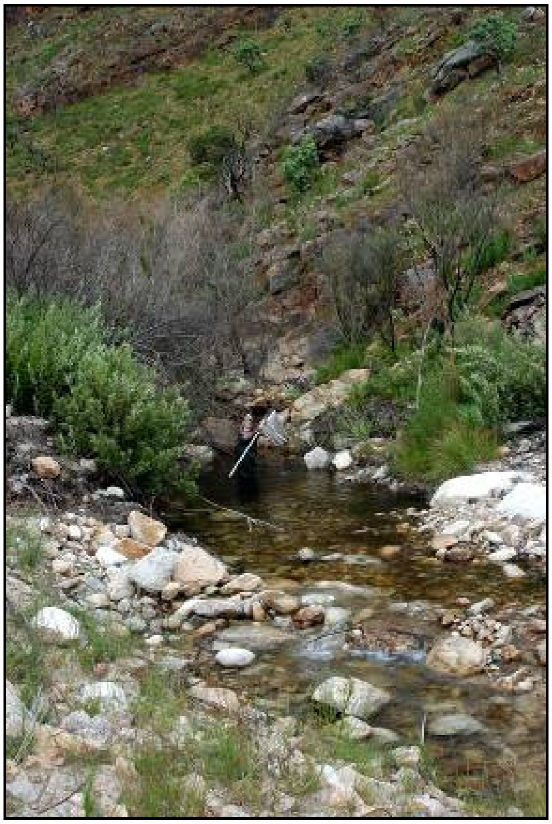

**Figure 35:** Water level, summer Sampling Site 2.

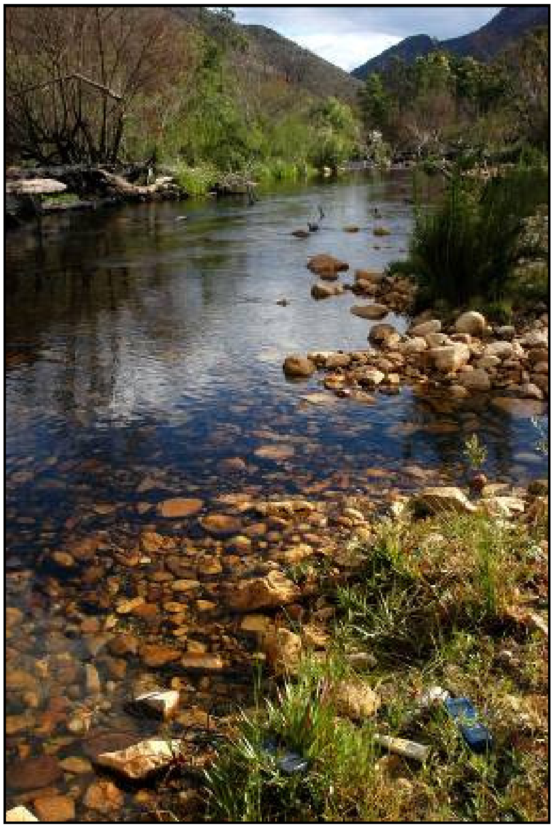

**Figure 36:** The water level - Sampling Site 3 in summer – most cobblestones are submerged.

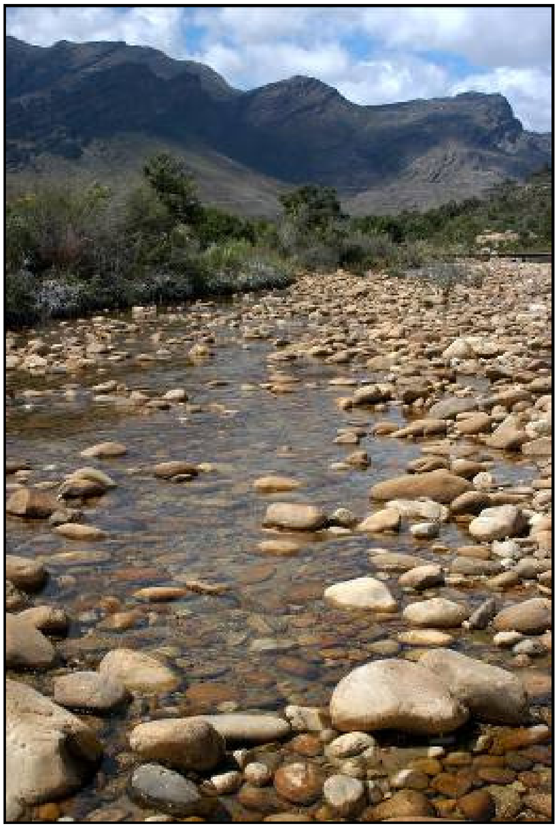

**Figure 37:** A lower water level - Sampling Site 4 in summer: many cobblestones are not submerged.

**Figure 38:** Water dammed during low flow conditions at an abstraction point at Sampling Site 4 in autumn.

**Figure 39:** Low flow conditions at Sampling Site 4 in autumn – surface water is known to disappear at this point during the dry season.

### 4.1.5 Sampling Site 5

Because Sampling Site 5 is lower downstream and has a more open and disturbed character compared to Sampling Site 4, it was hypothesised that, especially in the warmer months, its water temperature would be warmer.

Water temperatures measured at Sampling Site 5 in spring, winter and autumn correspond to that found at Sampling Site 4, but the value for summer shows lower water temperature, which is similar to that measured in the winter (Figure 33). While the higher temperature at Sampling Site 4 in summer could be a result of lower water volume, equivalent flow conditions were evident at Sampling Site 5 and the lower temperature measured there in summer could therefore not be as result of difference in water flow.

Compton (2006) notes that groundwater “can occur in rocks to great depths below the surface in places.” Table Mountain Group sandstones are known to contain vast quantities of groundwater that is an important natural long-term water reservoir (Compton 2006). It is also known that just downstream of Sampling Site 4, surface flow can disappear in the dry summer months while surface flow reappears upstream from Sampling Site 5 (A le Roux personal observation; P.D. le Roux personal communication, February 2009; B. du Plessis personal communication, October 2011; Figure 39).

Shallow water tables are usually found within floodplains. As a result of the permeability of alluvium floodplain sediments, rainfall easily infiltrates and drains freely to recharge the groundwater table. In lowland gaining streams groundwater flowing from the catchment moves through the floodplain and it is known that exchanges between the groundwater and the surface water have a seasonal impact on the river discharge (Doble, Simmons, Jolly & Walker 2006; Krause, Bronstert & Zehe 2007). Holmes (2000) states that as groundwater contributions increase, temperature variations in the surface stream tend to be moderated. The decrease in water temperature from Sampling Site 4 to Sampling Site 5 in summer could therefore be a result of cooler groundwater contributions between these two sampling sites.

Comparable to the other sampling sites, the highest water temperature (though lower than that of Sampling Site 4) was found with the autumn sample when the water level was low at Sampling Site 5 and flow was very slow (Figures 40 & 41).

**Figure 40:** Damming for water abstraction at Sampling Site 5, autumn 2012.

**Figure 41:** Low water level and flow at Sampling Site 5 in autumn 2012.

### 4.2 Seasonal variation in water pH

The hydrogen ion activity in water (pH) is controlled by interrelated chemical and biological reactions that produce or consume hydrogen ions (Kroening 2004). An increase in the concentration of hydrogen ions ($H^+$), decreases pH and the solution becomes more acidic whereas a decrease in ($H^+$), increases pH and the solution becomes more alkaline (DWAF 1996a).

McCauley, Jones & Jacobsen (2009) state that soil pH is influenced by both acid and alkaline-forming ions in the soil. Common acid-forming cations (positively charged dissolved ions) are hydrogen ($H^+$), aluminium ($Al^{3+}$), and iron ($Fe^{2+}$ or $Fe^{3+}$), whereas common alkaline-forming cations include calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), potassium ($K^+$) and sodium ($Na^+$). An increase in precipitation, as occurs during the rainy season, causes increased leaching of base cations and the soil pH is lowered (McCauley *et al.* 2009).

Acidic conditions occur in soil having parent material high in elements such as silica (i.e. Table Mountain Sandstone), high levels of sand with low buffering capacities (ability to resist pH change), and in regions with high amounts of precipitation (McCauley *et al.* 2009). As noted by Compton (2006), water flowing off the Table Mountain Sandstone series of rocks is acidic “with pH values less than 4 because it collects $CO_2$ from the organic rich fynbos soils through which it seeps." Sedimentary rocks of the Table Mountain Group lack feldspar or carbonate minerals that can react with and neutralize the acidic waters (Compton 2006). Compton (2006) furthermore notes that "these waters leach soluble organic compounds from the Fynbos soil to give mountain streams a distinct yellow to brown colour similar to that of rooibos tea". The pH of water drained from Fynbos catchments south-western Cape may drop as low as 3.9 due to the influence of organic acids (humic and fulvic acids) (DWAF 1996a).

A geohydrological investigation of the Breede River Valley between Wolseley and the Brandvlei Dam included samples of surface- and groundwater in the upper reaches of the Holsloot River and found that water from the Table Mountain Sandstone ranged between pH 4 and 5 (Rosewarne 1981).

The pH of the water was found to vary along the length of the river during this study, but was generally found to be higher than expected. The water was mainly acidic at all the sampling sites in the dry season (summer and autumn), but contrary to what was expected, mainly alkaline during the wetter periods (winter and spring) (Figure 42). The winter sample showed alkaline water at all the sampling sites with the highest pH measured at Sampling Sites 1 and 4.

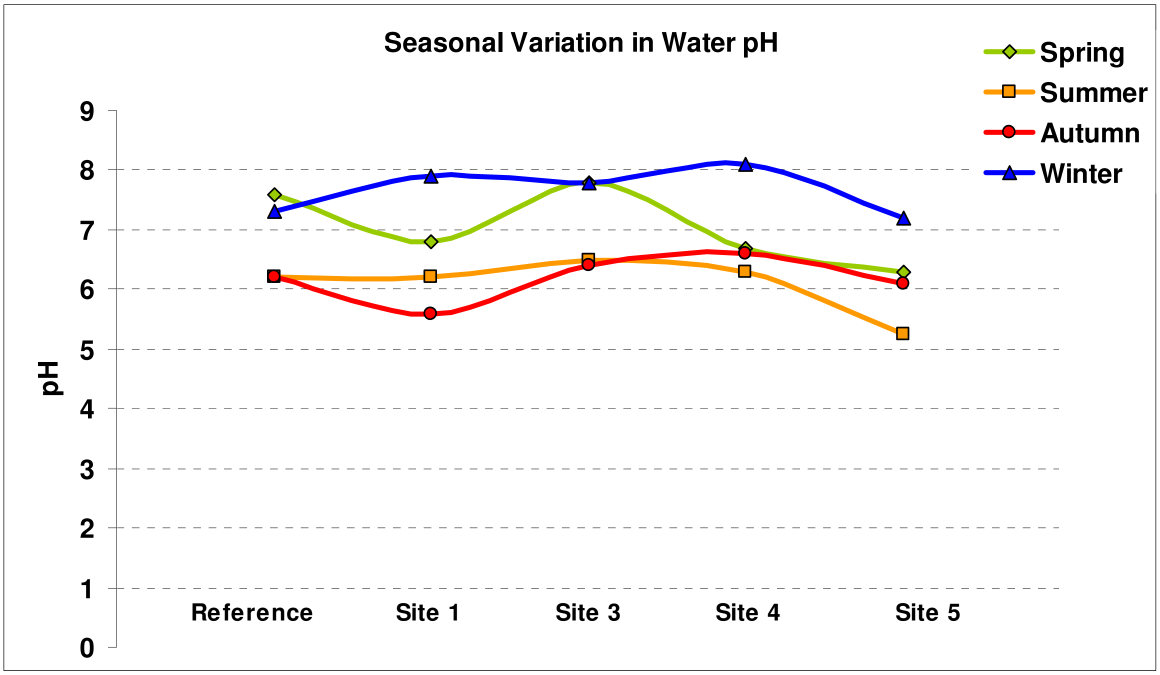

**Figure 42**: Seasonal variation in water pH (2011 – 2012).

Seasonal pH variability is largely related to the hydrological cycle, particularly in rivers draining catchments with vegetation such as fynbos, where the concentration of organic acids is consistently lower during the rainy season (DWAF 1996a). The Cape Granite Suite as well as Malmesbury Group shales usually form loamy soils and heavy clays (Muhl 2008). The coarse loamy soils derived from the Cape Granite Suite in some parts of the study area are known to be acidic (Dr J. Viljoen personal communication, October 2012). However, clay soils from the Franschoek formation of the Malmesbury Group which is exposed in areas of the catchment (Figure 6), may influence runoff and cause an increase in pH (Kirchner *et al.* 1997).

The use of dolomitic ($Mg_2CO_3$) and calcitic ($Ca_2CO_3$) lime in agriculture is known to neutralize soil acidity (Dr J. Viljoen personal communication, October 2012). Dolomite occurs in soil derived from Malmesbury metasediments (Agnello 2005). Mitchell (2002) states that the Langvlei dolomite quarry north-west of Robertson in the Breede River Valley (east of the study area) occurs within the Malmesbury Group phyllite. Gresse & Theron (1992) agree that phyllite occurs in the Franschoek formation of the Malmesbury Group found in the study area (Figure 6), but the influence thereof on runoff pH in the study area is uncertain (Dr J. Viljoen personal communication, October 2012). The Franschoek formation of the Malmesbury Group has been associated with saline groundwater due to high concentrations of mineral elements such as sodium, calcium and magnesium. When studying the origin of groundwater salinity in the Berg River basin, Demlie, Jovanovic & Naicker (2011) found high pH values for groundwater in Malmesbury phyllites. In a study near Durbanville in the Western Cape, Conrad (2011) tested the pH of groundwater in the Franschoek formation of the Malmesbury Group and alkaline water (pH 7.09; pH 7.28) was found in two (2) protected boreholes in this geological formation. The mineral composition of the Franschoek formation in the study area, is however uncertain.

Factors such as temperature, the concentrations of inorganic and organic ions, and biological activity, affect water pH (DWAF 1996a). The concentration of $CO_2$ in aquatic ecosystems, not only reflects internal carbon dynamics, but also external biogeochemical processes in the terrestrial ecosystem (Cole, Caraco, Kling & Kratz 1994; Jones & Mulholland 1998). $CO_2$ is typically supersaturated in stream and river ecosystems because the in-stream rate of organic matter decomposition regularly exceeds the photosynthetic uptake and because ground water flowing to the channel is often $CO_2$-rich (Kling, Kipphut & Miller 1991; Jones, Stanley & Mulholland 2003).

The acid neutralizing capacity of surface waters is explained by Holmes (2000), where groundwater can influence stream ecosystems through processes associated with dissolved inorganic carbon. Precipitation is in equilibrium with atmospheric $CO_2$, but as precipitation percolates through the soil, it becomes super saturated with $CO_2$ due to soil and root respiration (Holmes 2000). With respect to the atmosphere, streams are generally supersaturated with $CO_2$ as a result of these groundwater discharges (Jones & Mulholland 1998). In order to reach equilibrium with atmospheric $CO_2$, dissolved $CO_2$ in stream-water degasses into the atmosphere, a process that is enhanced at turbulent locations in the stream (Herman & Lorah 1987). Degassing of $CO_2$ in the surface water leads to consumption of hydrogen ($H^+$) and consequently increases pH (Holmes 2000).

Elevated pH values can be caused by increased biological activity. Water pH values may vary over a 24-hour period because of changing rates of photosynthesis and respiration (DWAF 1996a). In a study regarding the acidity in Finnish rivers, the importance of organic acids in controlling the pH levels in the major Finnish rivers was underlined as Mattsson, Kortelainen, Lepistö & Räike (2007) found that a high total organic carbon concentrations decreased pH values in the river water. In addition, Michaud (1991) notes that the process of photosynthesis uses dissolved carbon dioxide which acts like carbonic acid ($H_2CO_3$) in water. The removal of $CO_2$ reduces the acidity of the water and causes increases in pH. Respiration of aquatic and riparian organisms on the other hand, produces $CO_2$ which dissolves in water as carbonic acid, thereby lowering the stream pH. Tank, Lesack & McQueen (2009) describe high pH levels (higher than pH 10) in streams often as the result of rapid photosynthesis sequentially depleting $CO_2$ in the water column. Water pH may therefore be higher during daylight hours and during the growing season, when photosynthesis is at a maximum (Tank *et al.* 2009).

An important aspect regarding the unexpectedly high water pH in a predominantly sandstone catchment can be associated with the effects of a fierce fire in which most of the Stettynskloof from downstream of Sampling Site 4 up to the dam burnt down in January 2011 (Figure 43).

**Figure 43:** An uncontrolled fire raging through the Stettynskloof in January 2011.

Fire-induced increases in soil pH are widely reported and can significantly enhance site fertility (as nutrient availability is related to soil acidity) when it increases the pH of acidic sites. Fire releases nutrients bound in organic material. Certain cations remain onsite after burning and are subsequently washed into the soil where they exchange with $H^+$ ions – the resulting increase in $H^+$ ions in solution increases the pH (Tisdale & Nelson 1975; Chandler, Cheney, Thomas, Trabaud & Williams 1983; Tester 1989; Wright & Bailey 1982; Clark 2001; Edwards, Giles & Tindal 2003).

Knicker (2007) describes that the fertilizing effect of the nutrient-rich ash that remains after fire, has been known since the beginning of agriculture, and that the so-called liming effect (increase in pH), has a positive impact on the biological recovery of soils after fire (Baath & Arnebrant 1994; Chambers & Attiwill 1994; Pyne 2001).

Where controlled fires are commonly initiated at moderate soil moisture levels, wildfires, that occur uncontrolled in the presence of an abundant and dry fuel load, can be very severe. In acid top soils, increases of up to three pH units were observed immediately after burning (pH increases occur only at high temperatures) (Kutiel & Inbar 1993; Ulery

1993; Knicker 2007). This increase in pH can be ascribed to the accumulation of potassium-, sodium-, magnesium- and calcium carbonates, but also to destruction of acid groups in the organic matter (Kutiel & Inbar 1993; Knicker 2007).

Similar to conditions in the study area, most cases of increased pH after fire occurred on forest soils where the initial pH was acidic and a large amount of organic material burned (Clark 2001). In a study concerning the effect of fire on the availability of nutrients in Mediterranean soils, Kutiel & Shaviv (1989) found that the pH changed from 7.6 in unburned soil to 8.3 in the soil burned at 250 ℃, and to 11.7 in the soil burned at 600 ℃.

### 4.2.1 Reference Site

Water pH was slightly acidic in summer and autumn (pH 6.2), but slightly alkaline in winter (pH 7.3) and even more so in spring (pH 7.6).

The mountain stream of the Reference Site is fed by a large sub-catchment area to the east (Figure 13 & 20). Geologically, this area largely consists of oligotrophic soils and rocks derived from sandstone of the Skiereiland Peninsula formation (Table Mountain Group). Smaller areas of more mineral rich shales derived from the Franschoek formation (Malmesbury Group) are exposed on the southern, northern and north-western shores of the Stettynskloof Dam (Figure 6). These shales are exposed on the northern slopes of the Stettynskloof through which the Elandspad River that feeds the dam flows (Figure 6).

The increase in pH in winter and spring is not what would be expected from a stream that originates in Table Mountain Sandstone, but could be as a result of one or both of the following factors:

- runoff influenced by the Malmesbury shales in the sub-catchment (especially after rainfall),
- the degassing of dissolved $CO_2$ from stream-water into the atmosphere, a process that is enhanced at the Reference Site due to fast, turbulent stream flow (Herman & Lorah 1987; Holmes 2000) less than a week after rainfall (Figures 8 & 11), and/or
- the liming effect of the fire

In addition, the primary production (through the process of photosynthesis which utilizes $CO_2$) of the plants and algae in the pools of the Reference Site during the growing season could also have contributed to the higher pH in winter and spring.

Since the effect of fire to maintain a moderately alkaline soil pH can persist even three years after burning (Knicker 2007), the most important cause for the increase in water pH relates to the effects of the fire, that burnt down vast areas of the catchment in 2011 (Figure 43).

### 4.2.2 Sampling Site 1

Corresponding with the Reference Site, water pH at Sampling Site 1 was found to be acidic in summer (pH 6.2) and more so in autumn (pH 5.6). The water was nearly neutral in spring (pH 6.8) and more alkaline in summer (pH 7.9). Except for the winter sample, which was considerably more alkaline than the water of the Reference Site, pH here was mostly lower than that of the Reference Site (Figure 42).

The dam was not overflowing, and compensation water not released at the time of the winter sample. Only runoff from mountain streams and probably also groundwater had contributed to the flow of the river at that time. The liming effect of the fire most likely caused runoff to be more alkaline with consequent higher water pH in the river. In the warmer months (summer and autumn), when water levels and flow rate were lower (due to less runoff entering the stream), the organic debris in the pool at Sampling Site 1 (Figure 21) as well as the degassing of $CO_2$ saturated groundwater discharges most likely contributed to the lower pH (Kling *et al.* 1991; DWAF 1996a; Jones *et al.* 2003; Compton 2006).

Primary production in the pool at the weir in Sampling Site 1, runoff influenced by the effects of the fire as well as the Malmesbury shale around the dam, could have contributed to the higher pH during winter and spring (Kutiel & Inbar 1993; Ulery 1993; Kirchner *et al.* 1997; Knicker 2007; Tank *et al.* 2009).

### 4.2.3 Sampling Site 3

Water pH was found to be equally slightly acidic in summer and autumn (pH 6.5; pH 6.4), and equally alkaline in winter (pH 7.8). Although slightly higher, the pattern of seasonal variation in pH at Sampling Site 3 compares with that of the Reference Site.

The slightly higher pH compared to that of the Reference Site in spring could be a result of the liming effect of the fire, or possibly due to primary production in the larger, open pools at Sampling Site 3 (Figures 25 & 26; Tables 3 & 5). Agricultural runoff could also have played a role in the increased pH in spring, as Sampling Site 3 is situated on a producing farm (Figures 15 & 17) where lime (approximately 4 tons per hectare) is used to neutralize acidic soils in preparation of soil for vineyards and fruit orchards (E. Stofberg personal communication, October 2012).

### 4.2.4 Sampling Site 4

Water pH at Sampling Site 4 was slightly acidic in spring and autumn (pH 6.7; pH 6.6), but more acidic in summer (pH 6.29). Only the winter sample rendered water with pH value of 8.1, which was the most alkaline sample recorded throughout the study.

Apart from the liming effect of the fire, because of the character of Sampling Site 4 (an open stream with pools, runs and riffles over a cobblestone bed) (Figures 27 & 28; Tables 3 & 4), $CO_2$ degassing could likely have contributed to the high pH of the water at the winter sample. Primary production could also have played a role, as a fair amount of aquatic vegetation is present at this sampling site (Figures 27 & 38) (DWAF 1996a; Jones & Mulholland 1998; Holmes 2000; Mattsson *et al.* 2007; Tank *et al.* 2009).

The low pH measured in summer (at a time of lower water levels and slower flow) could be as result of decomposition of organic debris in the deeper pools as well as respiration of aquatic biota (DWAF 1996a; Mattsson *et al*. 2007; Tank *et al.* 2009).

### 4.2.5 Sampling Site 5

Water pH was slightly acidic in spring and autumn (pH 6.3; pH 6.1), but more acidic in summer (pH 5.24) which was the most acidic sample recorded throughout the study. Comparable to the other sampling sites, the winter sample was close to neutral (pH 7.2) which is almost similar to that at the Reference Site.

The pH at Sampling Site 5 could in all probability be affected by fertilizer-enriched agricultural runoff draining into the river due to extensive farming activities at the site as well as upstream thereof. The almost neutral pH in winter could furthermore be a result of one or more factors such as the degassing of $CO_2$ enhanced in the riffles or due to the $CO_2$ removal from the water by aquatic plants during the process of photosynthesis (DWAF 1996a; Holmes 2000; Tank *et al.* 2009).

Respiration of aquatic biota as well as decomposition of organic debris in pools at Sampling Site 5 could have caused that the most acidic water throughout the study (was found at this Sampling Site in summer (Michaud 1991). Kelting (1954) showed that the urea of grazers could affect the soil by decreasing the pH. Although a small number of cattle was observed grazing in the riverbed at Sampling Site 5, the effects of animal manure on the water pH is considered small. Though geology as well as biological and chemical conditions within the water most probably contribute to the low pH, potential upstream sewage spill-over into the river, could possibly lead to a decrease in water pH at this site. (Kelting 1954; Del Rosario, Betts & Resh 2002).

It is known that organic enrichment is reflected in high values of pH (Hamada, McCreadie & Adler 2002; Couceiro, Hamada, Luz, Forsberg & Pimentel 2007). Eutrophication caused by fertilizer enriched agricultural runoff as well as possible sewage drainage into the river can cause enhanced aquatic vegetation and algae production in the growing season which can cause diurnal fluctuations in stream pH as a result of photosynthesis (increases pH) and respiration (lowers pH). When these die off, the effects of decomposition can cause a decrease in the pH of the stream (DWAF 1996a; Kroening 2004; Michaud 1991; Daniel, Montebelo, Bernardes, Ometto, De Camargo, Krusche, Ballester, Victoria & Martinelli 2002; Tank *et al.* 2009).

### 4.3 Seasonal variation in dissolved oxygen (DO)

Gaseous oxygen ($O_2$) from the atmosphere dissolves in water and is also generated during photosynthesis by aquatic plants and phytoplankton (DWAF 1996a).The amount of oxygen that can dissolve in water depends on the rate of aeration from the atmosphere, temperature, air pressure and salinity (Davies & Day 1998). The rate of increase of dissolution of oxygen can be accelerated if turbulence of the water increases (DWAF 1996a).

Higher temperatures reduce the solubility of dissolved oxygen in water, decreasing its concentration and consequent availability to aquatic organisms (DWAF 1996a). DO levels are dependent on the relative rates of photosynthesis and respiration and fluctuates diurnally, usually lowest at dawn, peaking in the afternoon and decreasing at night depending on the relative rates of respiration by organism and of photosynthesis of plants (DWAF 1996a; Davies & Day 1998). DO concentrations in unpolluted surface waters are usually close to saturation, but seasonal variations arise from changes in temperature and biological productivity (DWAF 1996a).

Reduction in the concentration of DO can be caused by several factors: Re-suspension of anoxic sediments as a result of river floods or dredging activities; the presence of oxidizable organic matter, either of natural origin (detritus) or originating, and also the amount of suspended material in the water (DWAF 1996a). According to DWAF (1996a), DO concentrations of less that 100% saturation indicate oxygen depletion, whilst results in excess of saturation usually indicate eutrophication of a waterbody. Dawson (2003) give expected (natural) DO percentage saturation for electrical conductivity readings for south-western Cape rivers between 80 - 120% for mountain stream zone, the upper foothill zone as well as the lowland river zone.

Throughout the study period, the percentage saturation of DO in the river mostly fluctuated between 91% and 113% for the autumn, spring and winter samples. DO graphs for spring and winter were almost similar while that of autumn is different especially at Sampling Sites 4 and 5 (Figure 44).

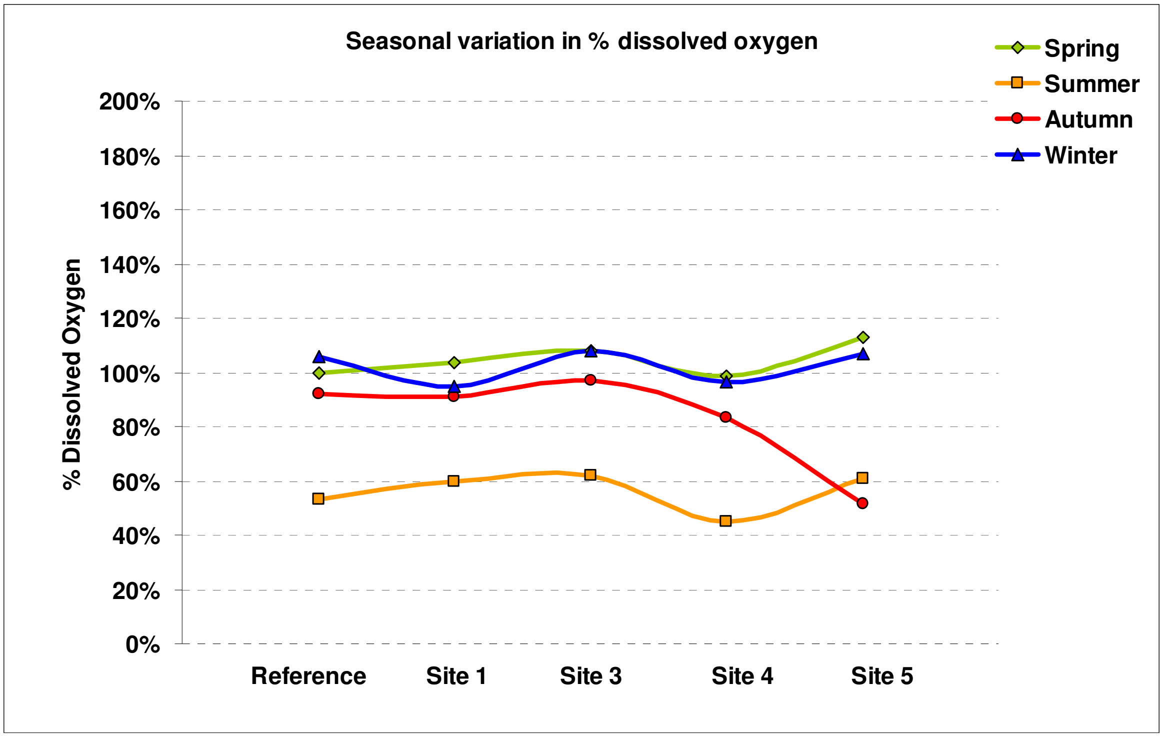

**Figure 44:** Seasonal variation in dissolved oxygen (2011 – 2012).

Although the DO graph for summer shows a similar pattern to that of winter and spring, DO concentrations were noticeably lower at all the sampling sites in summer. Given the weather conditions, water level (with the dam still overflowing) and stream flow at the time (Figure 8), higher oxygen levels than the measured values were expected in summer. The low levels of oxygen measured at all the Sampling Sites could possibly be due to a faulty measuring instrument.

### 4.3.1 Reference Site

Due to the fast flowing nature of the Reference Site, DO is expected to be high. Levels of 92.2%, 100% and 105% respectively found for the autumn, spring and winter samples. (Figure 44), agree with the expected (natural) DO percentage saturation for electrical conductivity readings for south-western Cape rivers (Dawson 2003).

### 4.3.2 Sampling Site 1

DO at Sampling Site 1 generally compares with that measured at the Reference Site, but was found to be 10% lower at Sampling Site 1 in winter. As indicated in Table 3 and in Figures 22 & 34, the dense riparian vegetation on the banks at Sampling Site 1 supply the river (especially at times of high levels of inundation) with allochthonous coarse particulate organic material (CPOM) such as leaves, petals, twigs and stems of various sizes which can be utilized by aquatic herbivores and decomposers. As stated by Davies & Day (1998), the warmer the water, the less oxygen is available, and where organic matter accumulates, oxygen levels are naturally low because of the consumption of oxygen by decomposer microorganisms (Davies & Day 1998). As good rains only started to fall from May 2012 (Figure 7), low flow conditions were still apparent at the time the winter sample was collected (Figure 10). Low flow conditions during winter, as well as decomposition of organic matter in the dark pool at Sampling Site 1 could provide an explanation for the low percentage of DO.

The water temperature was not high at Sampling Site 1 in summer, and the dam was still overflowing during the summer data collection period (Figure 7). Therefore, the higher amount of DO measured was expected at this Sampling Site because of the specific conditions that occurred in summer (as a result of churning: a high rate of air-water exchange as a result of water cascading to the ground from the dam-overflow at the time).

### 4.3.3 Sampling Site 3

Conditions at Sampling Site 3 were found to be similar to that at the Reference Site as well as Sampling Site 1, except for a higher amount of DO in the stream in winter. Stream flow at Sampling Site 3 was moderately fast in winter and the water well aerated due to numerous riffles moving fast over the cobblestone bed. The rather low temperatures of the water at that time, together with churning are favourable for oxygen to dissolve in water (DWAF 1996a; Davies & Day 1998).

It is known that organic pollution from domestic sewage causes eutrophication as especially phosphorus and nitrogen concentrations, which are essential for autotrophic production, are increased (Thorne & Williams 1997; Couceiro *et al.* 2007). Irrigation return-flow, nutrient enriched runoff from lime as well as manure/fertilizer, possible sewage spills and domestic effluent are potential influences on the river at Sampling Site 3 that could cause eutrophication as illustrated by dense stands of reeds at the site. Larger quantities of nutrients facilitate higher primary production (Thorne & Williams 1997; Couceiro *et al.* 2007) in a system where water is naturally principally oligotrophic as result of a predominant sandstone catchment. Filamentous algae are often visible in the shallow water at Sampling Site 3 (A le Roux personal observation). Higher DO concentrations at Sampling Site 3 compared to that of the Reference Site in autumn may have been the product of photosynthesis by prolific growth of macrophytes at the site, especially at the time of sampling in the early afternoon when levels of DO can be high (DWAF 1996a; Davies & Day 1998).

### 4.3.4 Sampling Site 4

Conditions at Sampling Site 4 were found to be similar to that of the Reference Site, except for lower DO in autumn and a considerably lower percentage of DO found in summer (Figure 44).

Dissolved oxygen levels are expected to be lower at Sampling Site 4 due to the open broad and shallow cobblestone bed character of the stream where water is usually warmer compared to the narrow, partially covered and fast flowing Reference Site (Figures 24 & 28; Tables 3-5) (Allan 1995). Water is furthermore dammed for water abstraction at the site. Dark-coloured organic matter in the water absorbs light and the amount of organic matter present may potentially control the depth of the photic zone (Kroening 2004), therefore probably causing a lower production of oxygen by algae through photosynthesis. Warmer water temperatures in autumn and high oxygen demand of stream organisms due to higher productivity in the warm months, as well as decomposition of organic matter (Davies & Day 1998; DWAF 1996a) in the dark pool (Figure 38) can possibly be another factor contributing to the lower amount of DO in autumn (Figure 44).

### 4.3.5 Sampling Site 5

Dissolved oxygen levels at Sampling Site 5 are similar to that of the Reference Site during seasons with high water levels and strong flow (winter and spring). The DO level for autumn follows a different pattern and is considerably lower than any of the other Sample Sites (Figure 44).

Wilcock (1986) state that a marked lower percentage of DO below saturation indicates that the stream may be receiving untreated waste water or an excessive amount of nutrients from non-point-source pollution. If the organic load into a water body is high, oxygen depletion accelerates microbial activity, which takes place at higher water temperatures (DWAF 1996a). During autumn, when almost no flow was found at

Sampling Site 5, and water temperature was high, the lowest level of DO during the study (51%) was measured here (Figures 40, 41 & 44). The cause for this low percentage of DO likely relates to the low flow conditions, high water temperature (attributable to reduced flow and lack of shade due to the absence of riparian vegetation), possible non-point-source pollution and decomposition of organic substances. Together with the low DO, the lower water pH at Sampling Site 5 during low-flow conditions likely relate to the possibility of increased dissolved organic carbon concentrations in the river as well as high concentration of dissolved salts as shown by the marked high electrical conductivity and total dissolved solids values for Sampling Site 5 in autumn.

### 4.4 Seasonal variation in electrical conductivity (EC) and Total Dissolved Solids (TDS)

The total dissolved solids (TDSolids) concentration of water is a measure of the quantity of all compounds dissolved in water. Total dissolved salts (TDSalts) concentration is a measure of all dissolved compounds in water that carry an electrical charge. Given that most dissolved substances in water carry an electrical charge, TDSalts concentration is usually used as an estimate of the concentration of TDSolids in water and TDSalts concentration is generally used as a measure of the TDSolids (DWAF 1996a).

TDS concentrations of natural waters are in part dependent on the characteristics of the geological formations which the water has been in contact with, but also depends on physical processes such as evaporation and rainfall. Because of the dissolution of minerals in rocks, soils and decomposing plant material, the TDS quantities of natural waters can vary (DWAF 1996a).

Electrical conductivity (EC) is a measure of the ability of water to conduct an electrical current and provides an indication of the concentration of total dissolved salts such as carbonate, bicarbonate, sulphate, chloride, sodium, potassium, magnesium and calcium ions that can carry an electrical charge. While TDSalts is directly relative to EC, TDSolids also includes organic compounds that do not dissociate into ions and, therefore, do not carry an electrical charge. TDSolids is therefore often positively correlated with EC, but the relationship between TDSolids and EC will not reflect changes in the concentration of nutrients such as phosphates and nitrates (DWAF

1996a; Tharme, Ratcliffe & Day 1997; Dallas 1998; Day 1990; Dawson 2003; Kroening 2004).

EC and TDSolids vary regionally as it is dependent on the geological formations which the water is in contact with (Tharme *et al.* 1997; Dallas 1998; Dawson 2003).The sandstone rocks, characteristic of the largest mountainous part of the study area weather to sandy surface soil with high infiltration ability. According to Compton (2006) the salt content of water running off Table Mountain sandstone remains low because the rocks are mainly made up of quarts, which is only slightly soluble in water. Wooldridge (2005) states that rocks from the Malmesbury Group are rich in carbonates such as limestone and dolomite, commonly used in agriculture to neutralize soil acidity. Representative values of total dissolved solids in groundwater from various geological units are given by Kirchner *et al.* (1997), which state TDS for groundwater from the Table Mountain Geological Group is relative low at 100 ppm, where groundwater TDS from the Malmesbury Group gives values as high as 700 ppm. As the Malmesbury Geological Group is represented in the study area, runoff and groundwater discharges from this group could contribute to TDS values of the river water.

Fire causes a significant increase in the soil's electrical conductivity (Kutiel & Shaviv 1989; Goberna, García, Insam, Hernández & Verdú 2012). EC significantly increased after the burning of Mediterranean soils due to the large amounts of soluble inorganic ions in the soil solution as result of the combustion (Kutiel & Shaviv 1989; Kutiel & Inbar 1993).

Expected electrical conductivity (EC) readings for south-western Cape Rivers as provided by Dawson (2003) are given in Table 9. Electrical conductivity (EC) and Total Dissolved Solids (TDS) readings as found in the study are given in Figures 45 and 46 respectively.

**Table 9:** Expected electrical conductivity (EC) readings for south-western Cape Rivers (Dawson 2003)

| **River zone** | **Median** | **Minimum** | **Maximum** |
|---|---|---|---|
| Mountain stream | 3 µS/m | 0.9 µS/m | 21.5 µS/m |
| Upper foothill | 3.10 µS/m | 1.5 µS/m | 11.2 µS/m |
| Lowland River | 21 µS/m | 4.5 µS/m | 107 µS/m |

No results for EC are available for summer due to malfunctioning measuring equipment.

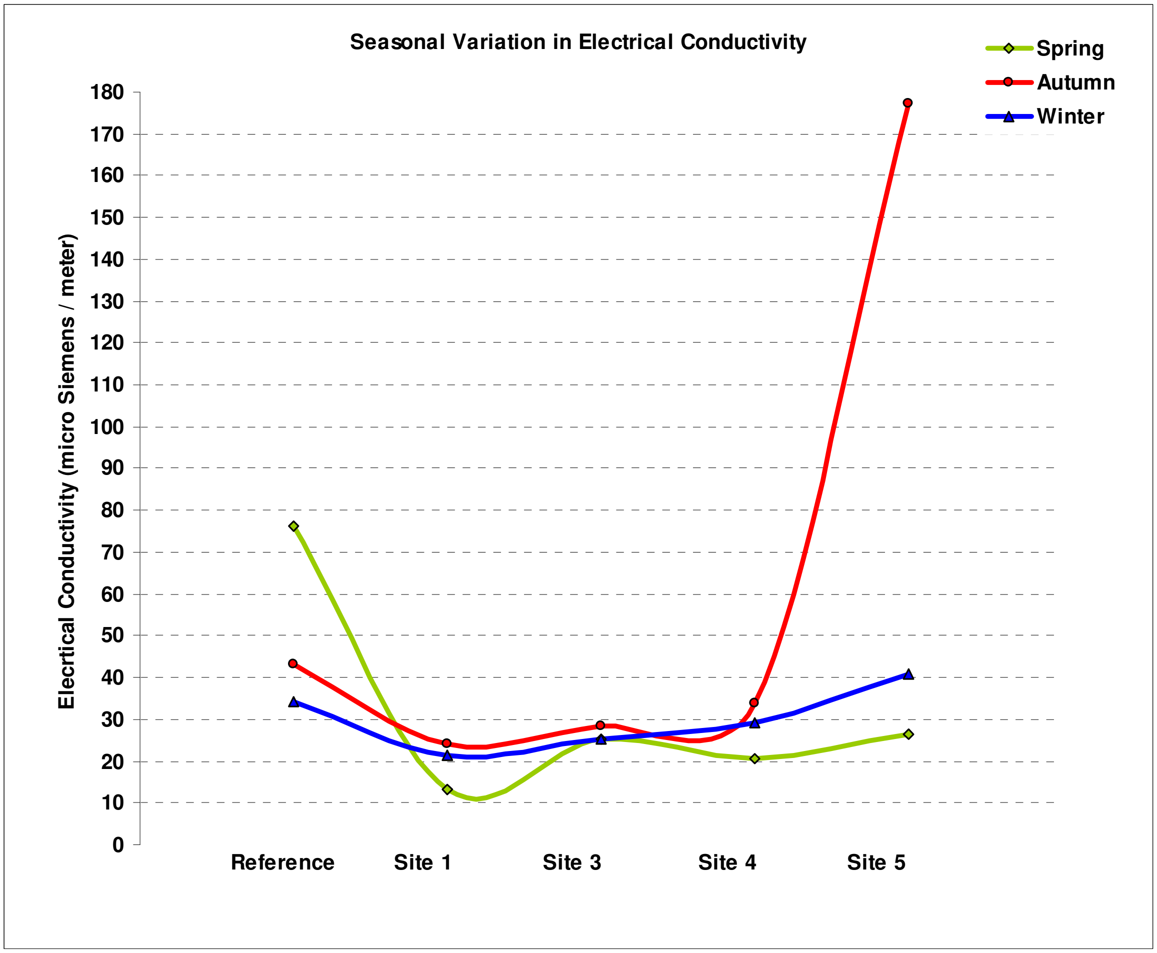

**Figure 45:** Seasonal variation in electrical conductivity (EC) (2011 – 2012).

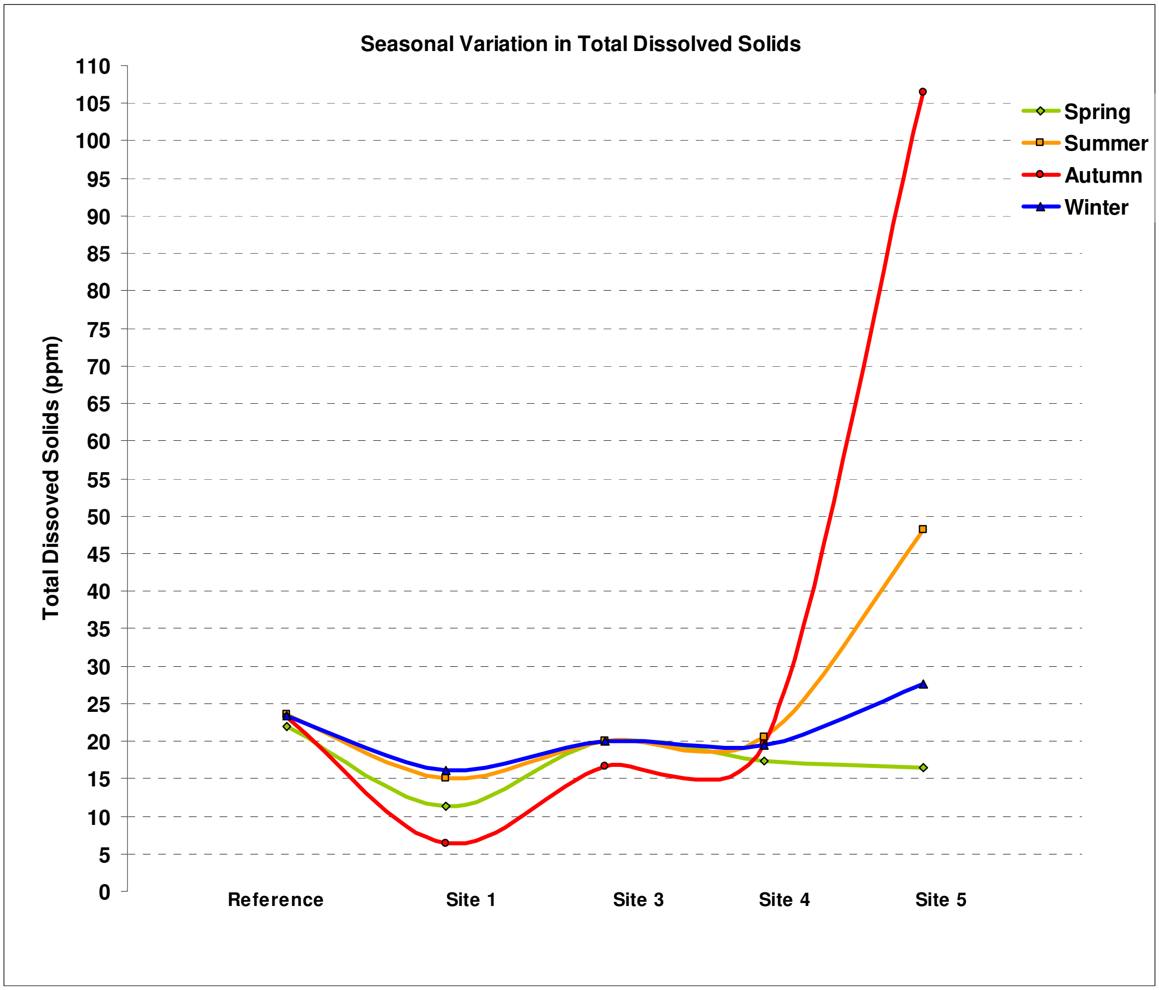

**Figure 46:** Seasonal variation in Total Dissolved Solids (TDS) (2011 – 2012).

### 4.4.1 Reference Site

The electrical conductivity at the Reference Site varied from 34.4 µS/m in winter, to 43 µS/m in autumn and 76.1 µS/m in spring (Figure 41). EC readings for all seasons exceed the norm for south-western Cape mountain streams (Table 9). Because fire can drastically increase the EC of soils, it is believed that the effects of the fire mainly caused the high mineral concentration found in the water. Kutiel & Shaviv (1989) found an 11-fold increase in EC of a burned pine forest area in comparison to an unburned one. Runoff from clay or dolomitic soils of the Malmesbury Group in the area could also contribute to the salt concentration of the water. The highest EC reading found in spring, after good rains prior to sampling together with resultant high stream flow (Figure 11), reinforces the likelihood that soluble inorganic ions released by the effects of fire (most of the surroundings at the Reference Site burnt down) still leached from the slopes into the streams and consequently into the river. Another factor that could have influenced the high EC in spring is illustrated by Flügel (1989), who states that due to saline return-flow from the artificial drainage systems, salts collect and are temporarily stored in the unsaturated soil during the irrigation season (dry season). The winter rainfall later flushes out such collected salts (Flügel 1989).

Although the EC varied at the Reference Site (Figure 45), the total concentration of all dissolved compounds (TDS) was stable throughout the study (Figure 46). The stable concentration of dissolved solids at the Reference Site provides the sum of the concentration of electrically charged ions and the concentration of minor ions and nutrients such as phosphates and nitrates. The finding of a higher EC, but similar TDS compared to that of the other seasons in spring, can possibly be due to a higher concentration of ions and possibly a smaller concentration of minor ions and other nutrients in spring, or a higher concentration of minor ions and nutrients during the other seasons but not in spring.

### 4.4.2 Sampling Site 1

Compared to that of the Reference Site, EC of the stream was lower at Sampling Site 1.

The EC measured in winter and in spring fall within the expected range of readings provided by Dawson (2003). Although within the expected range, the salt concentration of the water at Sampling Site 1 was found to be close to the highest value in the range. Mountain Sandstone water has a low salt concentration, but runoff and groundwater from the other geological units in the study area, such as the Malmesbury shale surrounding the dam could be more saline (Kirchner *et al.* 1997) and could contribute to the dissolved salts concentration at this Sampling Site.

The autumn sample showed slightly more dissolved salts in the stream, but this could be due to concentration of dissolved salts as result of evaporation during the warm dry season under relatively low flow conditions (Figures 9 & 45). The low amount of dissolved salts in spring (EC 13.3 µS/m – lowest during the study) relate to increased runoff as well as overflow of the dam due to good rains received prior to sample collection.

Comparable to the EC, the concentration of TDS is lower at Sampling Site 1 compared to that of the Reference Site. The only difference is that the lowest figure for TDS at this Sampling Site was measured in autumn (Figure 46), while the highest figure for EC was measured in autumn (Figure 45). The autumn sample could possibly give an indication of the ratio of dissolved compounds. In autumn, a higher concentration of electrically charged ions had probably contributed more to the ratio of dissolved compounds than the concentration of minor ions and other nutrients such as phosphates and nitrates.

### 4.4.3 Sampling Site 3

Because of the farming activities upstream as well as at Sampling Site 3, EC was expected to be higher than that of the Reference Site due to the possibility of irrigation return-flow (Kirchner *et al.* 1997). The 2011 fire affected areas around Sampling Site 3, but EC in all the different seasons was found to be lower at this Sampling Site than at the Reference Site (Figure 45).

The spring EC graph shows a higher salt concentration at Sampling Site 3 compared to the reading at Sampling Site 1 and Sampling Site 4. This could possibly relate to fertilizer enriched irrigation return-flow or the mobilization of salts that became available for dissolution during land preparation (Kirchner *et al.* 1997).

Because salts are continuously being added through natural and human-related sources whilst very little is removed by precipitation or natural processes, salts accumulate as water moves downstream (DWAF 1996a). This explains why the EC graphs show more dissolved salts at Sampling Site 3 than that measured at Sampling Site 1.

Similar to what was found in autumn at the Reference Site and at Sampling Site 1, a higher concentration of electrically charged ions had probably contributed more to the ratio of dissolved compounds than the concentration of minor ions and other nutrients such as phosphate and nitrates.

### 4.4.4 Sampling Site 4

Where rainwater (with low TDSalts) dilutes the salt concentration in streams, EC is expected to be higher during the dry season at low flow conditions as a result of the concentration of dissolved salts through evaporation (DWAF 1996a).

Because of the farming activities upstream as well as at Sampling Site 4 (Figure 17), EC was expected to be higher than that of the Reference Site. The dissolved salt concentration at Sampling Site 4 was however found to be lower than that of the

Reference Site. The EC measures at Sampling Site 4 show a similar pattern to what was found at Sampling Site 1 throughout the study where the lowest salt concentration was measured in spring (after the rain, during high water levels and strong flow) and the highest concentration in autumn (during low flow conditions and warm temperature, favourable for evaporation) (Figure 45).

The winter and autumn samples show more dissolved salts downstream at Sampling Site 4 compared to Sampling Site 3, but possibly due to dilution of dissolved compounds as a result of rainfall, EC was lower in spring.

### 4.4.5 Sampling Site 5

Compared to the Reference Site, EC at Sampling Site 5 was only lower in spring, and probably due to diluted conditions (Figures 11 & 45). The autumn sample (EC 177.3 µS/m) showed a very high increase and the highest concentration of dissolved salts found throughout the study (Figure 45). TDS concentrations can be high because of evapo-concentration (DWAF 1996a).

TDS are likely to accumulate in water as it moves downstream because salts are continuously being added through natural and manmade processes whilst very little is removed by precipitation or natural processes (DWAF 1996b). Kirchner *et al*. (1997) report that a large percentage of water used by irrigation is not used by plants and returns to rivers via various pathways. Irrigation return-flow is probably the main cause of downstream salinisation in the Breede River Valley (Kirchner *et al.* 1997). Extensive farming activities in and beyond the riparian zone (Figure 18), water abstraction and probable nutrient enriched irrigation return-flow draining into the riverbed between Sampling Site 4 and Sampling Site 5, most likely contribute to an increase in the concentration and facilitate the accumulation of minerals downstream. These factors in particular can influence water quality in conditions of lower flow and can be reasons for the increase in electrical conductivity at Sampling Site 5 in autumn.

As ablution facilities at various recreational sites are often situated on the banks of the river and uncertainty of treatment of organic waste disposal methods prevails, the presence of camping, and picnic sites between Sampling Site 4 and Sampling Site 5, and recreational use of the river at such sites may possibly add organic pollution to the scenario. This high concentration of dissolved salts is likely due to a combination of natural downstream accumulation of salts, low water levels, and very low flow, high temperatures with consequent evaporation as well as irrigation return-flow and human-related pollution. The positive relationship that is evident between the TDS measures and EC measures at Sampling Site 5 confirm that dissolved compounds are continuously being added through natural and human-related sources and accumulate as water moves downstream.

## 4.5 References

Allan, J.D. 1995. *Stream Ecology: Structure and Function of Running Waters.* Chapman & Hall, London.

Agnello, V.N. 2005. *Dolomite and Limestone in South Africa: Supply and Demand.* Department of Minerals and Energy. Republic of South Africa. Report R49/2005.

Baath, E. & Arnebrant, K. 1994. Growth rate and response of bacterial communities to pH in limed and ash treated forest soils. *Soil Biology and Biochemistry*, 26:995–1001.

Bogan, T., Mohseni, O., & Stefan, H.G. 2003. Stream temperature–equilibrium temperature relationship. *Water Resources Research,* 39(9):1245–1256.

Chandler, C., Cheney, P., Thomas, P., Trabaud, L. & Williams, D. 1983. *Fire in forestry, Volume I: Forest fire behavior and effects.* John Wiley & Sons, New York.

Chambers, D.P. & Attiwill, P.M. 1994. The ash-bed effect in *Eucalyptus regnans* forest: chemical, physical and microbiological changes in soil after heating or partial sterilization. *Australian Journal of Botany*, 42:739–749.

Clark, B. 2001. *Fire Effects Guide.* National Wildfire Coordinating Group Fire Use Working Team. NFES 394 National Interagency Fire Centre. Available on the internet at: www.nwcg.gov/pms/RxFire/FEG.pdf (Accessed 29 October 2012).

Cole, J.J., Caraco, N.F., Kling, G.W. & Kratz, T.K. 1994. Carbon dioxide supersaturation in the surface waters of lakes. *Science,* 265:1568–1570.

Compton, J. S. 2006. *The Rocks and Mountains of Cape Town*. Double Storey Books, Cape Town.

Conrad, J. 2011. *Geohydrological assessment related to a manure / methane project – Zandam Piggery, Western Cape*. GEOSS Report No. G2011 – 9/04. Geohydrological and Spatial Solutions International (Pty) Ltd.

Couceiro, S.R.M., Hamada, N., Luz, S.L.B., Forsberg, B.R. & Pimentel, T.P. 2007. Deforestation and sewage effects on aquatic macroinvertebrates in urban streams in Manaus, Amazonas, Brazil. *Hydrobiologia,* 575:271–284.

Dallas, H.F. 1998. Water Chemistry. in Brown, C. & Day, E. (eds) *Assessment of the Instream Flow Requirements for the Palmiet River and the Freshwater Requirements for the Palmiet Estuary, Final Report. Volume 1: Introduction, Social Aspects, Water Quality and Biology.* pp 65-98. Unpublished Report, Southern Waters Ecological Research and Consulting, Fresh Water Research Unit, University of Cape Town, Cape Town.

Daniel, M.H.B., Montebelo, A.A., Bernardes, M.C.; Ometto, J.P.H.B., De Camargo, P.B., Krusche, A.V., Ballester, M.V., Victoria, R.L. & Martinelli, L.A. 2002. Effects of urban sewage on dissolved oxygen, dissolved inorganic and organic carbon, and electrical conductivity of small streams along a gradient of urbanization in the Piracicaba River basin. *Water, Air, and Soil Pollution*, 136:189–206.

Davies, B. & Day, J. 1998. *Vanishing Waters.* University of Cape Town Press, Cape Town.

Day, J.A. 1990. Pitfalls in the presentation of chemical data. *Southern African Journal of Aquatic Sciences*, 16: 2-15.

Dawson, E.K. 2003. *A River Health Assessment of Selected South-Western Cape Rivers: Index of habitat Integrity, Water Quality and the Influence of Surrounding Land Use*. MSc. Thesis, University of Stellenbosch.

Del Rosario, R.B., Betts, E.A. & Resh, V.H. 2002. Cow Manure in Headwater Streams: Tracing Aquatic Insect Responses to Organic Enrichment. *Journal of the North American Benthological Society*, 21(2):278-289.

Demlie, M, Jovanovic, N. & Naicker, S. 2011. *Origin of groundwater salinity in the Sandspruit catchment, Berg River basin (South Africa).* International Conference on Groundwater: Our source of security in an uncertain future, CSIR International Convention Centre, Pretoria, South Africa, September 2011. Available on the internet at: http://researchspace.csir.co.za/dspace/handle/10204/5441 (Accessed 23 October 2012).

Doble, R., Simmons, C., Jolly, I. & Walker, G. 2006. Spatial relationships between vegetation cover and irrigation-induced groundwater discharge on a semi-arid floodplain, Australia. *Journal of Hydrology,* 329:75– 97.

Department of Water Affairs and Forestry (DWAF), 1996a. *South African Water Quality Guidelines. Volume 7: Aquatic Ecosystems.* Department of Water Affairs and Forestry, Pretoria, Republic of South Africa.

Department of Water Affairs and Forestry, 1996b. *South African Water Quality Guidelines (second edition). Volume 4: Agricultural Use: Irrigation.* Department of Water Affairs and Forestry, Pretoria, Republic of South Africa.

Edwards, J., Giles, M. & Tindal, C. 2003. The Effects of Burning and Mowing on Soil Moisture, Soil pH, and Percent of Carbon and Nitrogen in Soil and *Andropogon gerardii. Tillers*, 4:15-19.

Flügel, W. 1989. *Groundwater dynamics influenced by irrigation and associated problems of river salination; Breede River, Western Cape Province*, R.S.A. Groundwater Contamination (Proceedings of the Symposium held during the Third IAHS Scientific Assembly, Baltimore, MD, May 1989), IAHS Publ. no. 185. Available on the internet at: http://iahs.info/redbooks/a185/iahs_185_0137.pdf (Accessed 23 October 2012).

Goberna, M., García, C., Insam, H., Hernández, M.T. & Verdú, M. 2012. Burning Fire-Prone Mediterranean Shrublands: Immediate Changes in Soil Microbial Community Structure and Ecosystem Functions. *Microbial Ecology*, 64:242–255.

Gresse, P.G. & Theron, J.N. 1992. *The geology of the Worcester area.* Government Printer, Pretoria.

Hamada, N., McCreadie, J.W. & Adler, P.H. 2002. Species richness and spatial distribution of blackflies (Diptera: Simuliidae) in streams of Central Amazonia, Brazil. *Freshwater Biology,* 47:31–40.

Herman, J.S., and M.M. Lorah. 1987. $CO_2$ outgassing and calcite precipitation in Falling Spring Creek, Virginia, U.S.A. *Chemical Geology*, 62:251-262.

Holmes, R.M. 2000. The Importance of Ground Water to Stream Ecosystem Function. *Streams and Ground Waters*, Academic Press.

Johnson, F.A. 1971. Stream Temperatures in an Alpine Area. *Journal of Hydrology*, 14:322-336. North-Holland Publishing Company.

Jones, J.B. & P.J. Mulholland. 1998. Carbon dioxide variation in a hardwood stream: An integrative measure of whole catchment soil respiration. *Ecosystems*, 1:183-196.

Jones, J. B.(Jr)., Stanley, E.H. & Mulholland, P. J. 2003. *Long-term decline in carbon dioxide supersaturation in rivers across the contiguous United States*. Geophysical research Letters, 30(10). Available on the internet at: http://trogdor2.ocean.washington.edu/lc/CLOCEAN582B/jones_et_al_lomgterm_decline_co2.pdf (Accessed 23 October 2012).

Kelting, R.W. 1954. Effects of moderate grazing on the composition and plant production of a native tall-grass prairie in central Oklahoma. *Ecology,* 35(2):200-207.

Kirchner, J., Moolman, J.H., du Plessis, H.M. & Reynders, A.G. 1997. Causes and management of Salinity in the Breede River Valley, South Africa. *Hydrogeology Journal,* 5(1):98-108.

Kling, G.W., Kipphut, G.W. & Miller, M.C. 1991. Arctic lakes and streams as gas conduits to the atmosphere: Implications for tundra carbon budgets. *Science*, 251:298–301.

Knicker, H. 2007. How does fire affect the nature and stability of soil organic nitrogen and carbon? A review. *Biogeochemistry*, 85:91–118.

Krause, S., Bronstert, A. & Zehe, E. 2007. Groundwater–surface water interactions in a North German lowland floodplain – Implications for the river discharge dynamics and riparian water balance. *Journal of Hydrology*, 347:404– 417.

Kroening, S.E., 2004. *Streamflow and Water-Quality Characteristics at Selected Sites of the St. Johns River in Central Florida, 1933 to 2002*. U.S. Geological Survey Scientific Investigations Report 2004-5177.

Kutiel, P. & Shaviv, A. 1989. Effect of simulated forest fire on the availability of N and P in Mediterranean soils. *Plant and Soil*, 120: 57-63.

Kutiel, P. & Inbar, M. 1993. Fire impacts on soil nutrients and soil erosion in a Mediterranean pine forest plantation. *Catena*, 20:129–139.

Mattsson, T., Kortelainen, P., Lepistö, A. & Räike, A. 2007. Organic and minerogenic acidity in Finnish rivers in relation to land use and deposition. *Science of the Total Environment*, 383:183–192.

McCauley, A., Jones, C. & Jacobsen, J. 2009. Soil pH and Organic Matter. *Nutrient Management Module No. 8.* Montana State University Extension. Available on the internet at: http://landresources.montana.edu/NM/Modules/Module8.pdf (Accessed 10 November 2012).

Michaud, J.P. 1991. *A citizen's guide to understanding and monitoring lakes and streams.* Washington State Dept. of Ecology, Publications Office, Olympia, WA, USA. Available on the internet at: https://fortress.wa.gov/ecy/publications/publications/94149.pdf (Accessed 23 October 2012).

Mitchell, C. 2002. *An African Perspective on aglime*. In: 7th North American Industrial Minerals Annual Meeting: Lime and Carbonates VII, Colorado, USA, 29 Sept - 1 Oct 2002. (Unpublished). Available on the internet at: http://nora.nerc.ac.uk/8833/1/An_African_Perspective_on_Aglime_conference_paper.pdf (Accessed 23 October 2012).

Mohseni, O. & Stefan, H.G. 1999. Stream temperature/air temperature relationship: a physical interpretation. *Journal of Hydrology*, 218:128–141.

Moore, R.D., Sutherland, P., Gomi, T. & Dhakal, A. 2005. Thermal regime of a headwater stream within a clear-cut, coastal British Columbia, Canada. *Hydrological Processes*, 19:2591–2608.

Muhl, S.A. 2008. *Alien grass invasion of Renosterveld: Influence of soil variable gradients.* M.Sc. Thesis, Stellenbosch University.

O'Driscoll, M.A. & DeWalle, D.R. 2006. Stream–air temperature relations to classify stream–ground water interactions in a karst setting, central Pennsylvania, USA. *Journal of Hydrology*, 29:140– 153.

Pyne, S. J. 2001. *Fire, a brief history.* University of Washington Press, Seattle, WA.

Rosewarne, P. N. 1981. *Geohydrological Investigation Breë River Valley Between Wolseley and Brandvleidam.* Department of water Affairs, Geohydrological division, Report GH 3186.

Sinokrot, B. A. & Stefan, H. G. 1993. Stream temperature dynamics: Measurements and modelling, *Water Resources Research*, 29(7):2299–2312.

Tank, S.E., Lesack, L.F.W. & McQueen D.J. 2009. Elevated pH Regulates Bacterial Carbon Cycling in Lakes with High Photosynthetic Activity. *Ecology*, 90(7):1910-1922.

Tester, J.R. 1989. Effects of fire frequency on oak savanna in east-central Minnesota. *Bulletin of the Torrey Botanical Club,* 116(2): 134-144.

Tharme, R., Ratcliffe, G. & Day, J.A. 1997. *An Assessment of the Present Ecological Condition of the Lourens River, Western Cape, with Particular Reference to Proposals for Stormwater Management, Final Report*. Unpublished Report, Southern Waters Ecological Research and Consulting cc., Fresh Water Research Unit, University of Cape Town, Cape Town.

Thorne, R. St. J. & Williams, W.P. 1997. The response of benthic macroinvertebrates to pollution in developing countries: a multimetric system of bioassessment. *Freshwater Biology*, 37: 671–686.

Tisdale, S.L. & Nelson, W.A. 1975. *Soil fertility and fertilizers, 3rd ed*. Macmillan and Sons., Inc., New York.

Ulery, A.L. 1993. Wood-ash composition and soil pH following intense burning. *Soil Science*, 56:358–364.

Webb, B.W., Hannah, D.M., Moore, R.D., Brown, L.E. & Nobilis, F. 2008. Recent advances in stream and river temperature research. *Hydrological Processes,* 22:902–918.

Wilcock, R.J., 1986. Agriculture runoff: a source of water pollution in New Zealand. N.Z. *Agric. Sci.*, 20:8103.

Wooldridge, J. 2005. Geology of the Breede River Valley: Worcester and Robertson. *Wynboer: Technical Yearbook,* 6:35-38.

Wright, H.A. & Bailey, A.W. 1982. *Fire ecology, United States and southern Canada*. John Wiley and Sons, Wiley-Interscience Publication, New York.

# Chapter 5: Results & Discussion: Habitat- and biological indices

## 5.1 Habitat condition and indices

### 5.1.1 Local catchment & channel condition

Tables 10 – 13 provide a summary of the local catchment- and channel condition at the various sampling sites throughout the study area.

**Table 10:** Condition of local catchment at Sampling Sites 1 – 3. (Adapted from RHP: Site Characterisation Field-data Sheets, Dallas 2005.)

| | **SAMPLING SITE 1** | | | | | **SAMPLING SITE 2 (Reference Site)** | | | | | **SAMPLING SITE 3** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Land-use** | **WRZ** | **BRZ** | **PIoR** | **LoC** | **Comments** | **WRZ** | **BRZ** | **PIoR** | **LoC** | **Comments** | **WRZ** | **BRZ** | **PIoR** | **LoC** | **Comments** |
| Agriculture crops | | | | | | 0 | 0 | | H | | 2 u/s | 3 | 2 | H | Right bank, u/s in rip. zone |
| Agriculture livestock | 1 | 2 | 1 | M | 50 - 100 m u/s | 0 | 0 | | H | | 1 | 1 | 1 | H | cattle |
| Agriculture irrigation | 0 | 1 | 1 | M | Gardens | 0 | 0 | | H | | 3 | 3 | 3 | H | in summer |
| Alien vegetation | 2 | 2 | 2 | H | Hakea, Wattle | 2 | 2 | 1+ | H | Hakea (slopes) seedlings in riverbed, wattle | 2 | 2 | 2 | H | Kikuyu grass |
| Construction | 1 | 1 | 1 | H | | 1 | 1 | 1 | H | Low flow causeway 20 m d/s | 1 | 0 | 1 | H | Low flow causeway 20 m d/s |
| Roads | 1 | 1 | 1 | H | | 1 | 1 | 1 | H | Gravel rd. crosses 20 m d/s | 0 | 1 | 0 | H | Gravel rd. crosses 20 m d/s |
| Impoundment | 3 | 2 | 3 | H | Dam 200 m u/s; Weir 3 m d/s | 0 | 0 | | H | | 2 | 2 | 2 | H | Cobblestone weirs |
| Rural development | 1 | 1 | 1 | H | | 0 | 0 | | H | | 0 | 2 | 2 | H | Right bank |
| Recreational | 2 | 2 | 2 | H | Trout fishing picnic site | 1 | 1 | 1 | H | Hiking trail: river crossings | 1 | 2 | 1 | H | Trout fishing, hiking trail, mountain-bike trail, camping & accommodation |
| Sewage | ? | ? | prob | ? | | 0 | 0 | | H | | ? | ? | prob | H | Ablution facilities on banks u/s |
| Nature Conservation | 3 | 3 | 3 + | H | Mountains: Limietberg Nature Reserve | 3 | 3 | 3+ | H | Mountains: Limietberg NR | 0 | 0 | | H | Producing farm |
| Litter/debris | 1 | 1 | 1 | H | | 1 | 1 | 1 | H | | 2 | 1 | 1 | H | Dead trees in-stream & on banks |

WRZ – Within riparian zone; BRZ – Beyond riparian zone; PIoR – Potential impact on river (0 - 4: 0 - none, 1 - limited, 2 - moderate, 3 - extensive, 4 – entire; prob = probable; + = positive; - = negative); LoC – Level of confidence (M = medium; H = high; L = low; ? = uncertain); u/s – upstream; d/s – downstream

**Table 11:** Condition of local catchment at Sampling Sites 4 and 5. (Adapted from RHP: Site Characterisation Field-data Sheets, Dallas 2005.)

| | **SAMPLING SITE 4** | | | | | **SAMPLING SITE 5** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Land-use** | **WRZ** | **BRZ** | **PIoR** | **LoC** | **Comments** | **WRZ** | **BRZ** | **PIoR** | **LoC** | **Comments** |
| Agriculture crops | 3 | 4 | 3 | H | vineyards | 3 | 3 | 3 | H | vineyards |
| Agriculture livestock | 0 | 0 | | M | u/s, not at site | 0 | 0 | | H | u/s |
| Agriculture irrigation | 3 | 3 | 3 | H | Boreholes | 0 | 0 | | H | u/s |
| Alien vegetation | 1 | 1 | 1 | H | | 3 | 2 | 3 | H | Wattle, gum, alien Acacia trees |
| Construction | 1 | 0 | 1 | H | Steel river crossing 50 m u/s | 1 | 1 | 1 | H | Road-bridge |
| Roads | 2 | 2 | 1 | H | Gravel farm rd. | 1 | 1 | 1 | H | |
| Impoundment | 0 | 0 | 1 | L | Stone weir about 1 km u/s | 3 | 0 | 3 | H | Abstract to Brandvlei Dam |
| Rural development | 0 | 1 | 1 | H | Sewage? | 0 | 2 | 2 | H | Sewage? |
| Recreational | 1 | 1 | 0 | H | holiday home u/s | 3 | 3 | ? | H | Camping -, picnic sites u/s |
| Sewage | 0 | 0 | | L | | ? | ? | prob | M | u/s |
| Nature Conservation | 0 | 0 | | H | Producing farm | 0 | 0 | | H | Producing farm |
| Litter/debris | 1 | 2 | 1 | H | | 0 | | | H | |

WRZ – Within riparian zone; BRZ – Beyond riparian zone

PIoR – Potential impact on river (0 — 4: 0 — none, 1 — limited, 2 — moderate, 3 — extensive, 4 – entire;

prob = probable; + = positive; - = negative)

LoC – Level of confidence (M = medium; H = high; L = low; ? = uncertain)

u/s – upstream; d/s – downstream

**Table 12:** Channel condition at Sampling Sites 1 – 3. (Adapted from RHP: Site Characterisation Field-data Sheets, Dallas 2005.)

| | **Sampling Site 1** | | | | | **Sampling Site 2 (Reference Site)** | | | | | **Sampling Site 3** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **In-channel & bank modifications** | **Upstream** | | **Downstream** | | **Comments** | **Upstream** | | **Downstream** | | **Comments** | **Upstream** | | **Downstream** | | **Comments** |
| | **Impact score** | **Dist.** | **Impact score** | **Dist.** | | **Impact score** | **Dist.** | **Impact score** | **Dist.** | | **Impact score** | **Dist.** | **Impact score** | **Dist.** | |
| Bridge - elevated; in channel supports | | | 2 | 3 m | | | | | | | | | | | |
| Bridge - elevated; side channel supports | | | 2 | 10 m | | | | | | | | | | | |
| Causeway / low-flow bridges | | | | | | | | 1 | 50 m | | | | | | |
| Bulldozing | | | | | | | | | | | 2 | | 3 | At site | |
| Canalisation - concrete / gabion | | | | | | | | 1 | 50 m | | | | | | |
| Canalisation - earth / natural | | | | | | | | | | | | | 2 | At site | |
| Gravel, cobble and/or sand extraction | | | | | | | | | | | | | | | |
| Roads in riparian zone | 1 | | 1 | | Road fairly high | | | 1 | At site | | | | | | |
| Dams (large) | 3 | 200m | | | | | | | | | | | | | |
| Dams (small) / weir | | | 3 | At site | | | | | | | 2 | 5 m | | At site | Cobble-stone weir |

Impact score (1 — limited, 2 — moderate, 3 — extensive, 4 – entire); Dist. – Distance; m – meter; u/s – upstream; d/s – downstream

**Table 13:** Channel condition at Sampling Sites 4 and 5. (Adapted from RHP: Site Characterisation Field-data Sheets, Dallas 2005.)

| | **Sampling Site 4** | | | | | **Sampling Site 5** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **In-channel & bank modifications** | **Upstream** | | **Downstream** | | **Comments** | **Upstream** | | **Downstream** | | **Comments** |
| | **Impact score** | **Dist.** | **Impact score** | **Dist.** | | **Impact score** | **Dist.** | **Impact score** | **Dist.** | |
| Bridge - elevated; in channel supports | | | 1 | At site | | 1 | 500 m | 1 | | |
| Bridge - elevated; side channel supports | | | | | | 1 | 500 m | 1 | | |
| Causeway / low-flow bridges | 1 | 50 m | | | | | | | | |
| Bulldozing | 3 | | 3 | | New vineyard established | 4 | | 4 | At site | |
| Canalisation - concrete / gabion | | | | | | | | | | |
| Canalisation - earth / natural | 3 | | 3 | | Result of bulldozing | 3 | | 3 | | Result of bulldozing |
| Gravel, cobble and/or sand extraction | 2? | | 3? | | Planned in near future | 2? | | 3? | | Planned in near future |
| Roads in riparian zone | 2 | | 2 | | | 2 | | 2 | | Farm rd. |
| Dams (large) | | | | | | | | | | |
| Dams (small) / weir | 2 | 1.2 km | 2 | vary | Cobblestone weirs | 2 | vary | 2 | | Various cobble stone weirs,<br>d/s off-take Brandvlei Dam |

Impact score (1 - limited, 2 - moderate, 3 - extensive, 4 – entire); Dist. – Distance; m – meter; u/s – upstream; d/s – downstream

The vast mountainous area that forms the upper catchment of the Holsloot River is in a natural state and part of the Limietberg Nature Reserve, managed by CapeNature (Tables 10 & 12). Invader plant species affect some areas (Tables 10 & 11) - especially *Hakea sericea* (on the slopes) and *Acacia mearnsii* (in the riparian zone) have impacts on the natural vegetation and water availability. Alien vegetation clearing operations by Working For Water were successfully done in the past and are still on-going (D. Rossouw personal communication, February 2011).

Human related impacts at Sampling Site 1 involve the Stettynskloof Dam (Tables 10 & 12), which, apart from the loss of vegetation due to permanent inundation and construction, affects the physical and chemical attributes of the river (Figures 12-14).

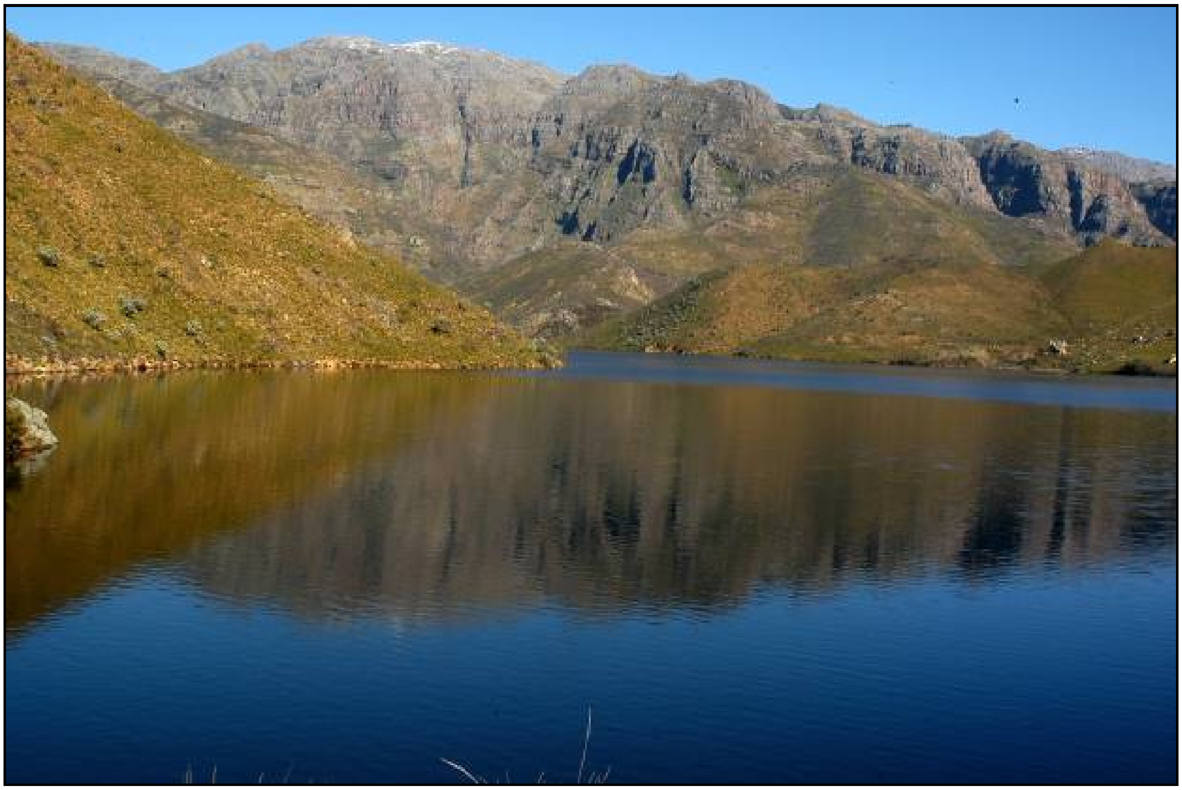

**Figure 47:** The Stettynskloof Dam in the upper reaches of the Holsloot River – 100% full in spring of 2012.

The natural water levels and flow of the Holsloot River in the immediate area of the Stettynskloof Dam had been changed due to the construction of the dam and storage of a proportion of runoff therein. A comparison of the present character of the river downstream of the dam (Figure 12; Table 12;) and an assemblage of aerial photographs from 1942 of the upper catchment area of the Holsloot River shows how the divided, braided stream character of the river changed to a single stream/run after the dam was built (Figures 13 & 14).

When not overflowing, the hypo-limnetic discharge from the dam lowers the water temperature of the river in the upper reaches. Because various natural streams drain into the river in the upper catchment area, the influence of cold-water discharge from the dam only affects a limited stretch of the river and is reduced as groundwater and runoff from natural streams discharge downstream. To measure water levels, a gauging weir was constructed under the high-water bridge over the river downstream of the dam (Figures 12, 22 & 48; Tables 10 & 12).

**Figure 48:** The gauging weir under the high-water bridge over the river downstream of the Stettynskloof Dam. The weir creates a large pool upstream where organic debris accumulates.

Although the dam just upstream of Sampling Site 1 has an impact on river flow, the impact is not considered severe. Apart from groundwater, a number of perennial streams constantly flow into the river below the dam. The river that flows through the Kaaimansgatkloof joining the Holsloot River at Sampling Site 1 (Figures 2, 6 & 13) is one of a few streams, which even during dry seasons had not stopped flowing for the past 55 years (H. Groenewald personal communication, October 2012).

The management and staff at the dam live at a small settlement just north of the dam wall (Tables 10 & 12; Figures 49 & 50). This small human settlement involves infrastructure such as houses, roads, bridges, power lines, as well as sewage and waste disposal facilities. It also comprises gardens and domestic animals. The area between Sampling Site 1 and the dam is often used for picnicking, fishing and/or camping. Trout is periodically released at the dam for sport fishing in the river (Table 10).

**Figure 49:** Man-made structures in the upper reaches of the Holsloot river: The personnel village at the Stettynskloof dam and high-water bridge over the Holsloot River in the background. The pipeline providing water to Worcester as well as the road and power line high above the riparian zone are visible on the left hand side of the picture. This picture was taken during the previous study in 2008, before the fire swept through the kloof in 2011.

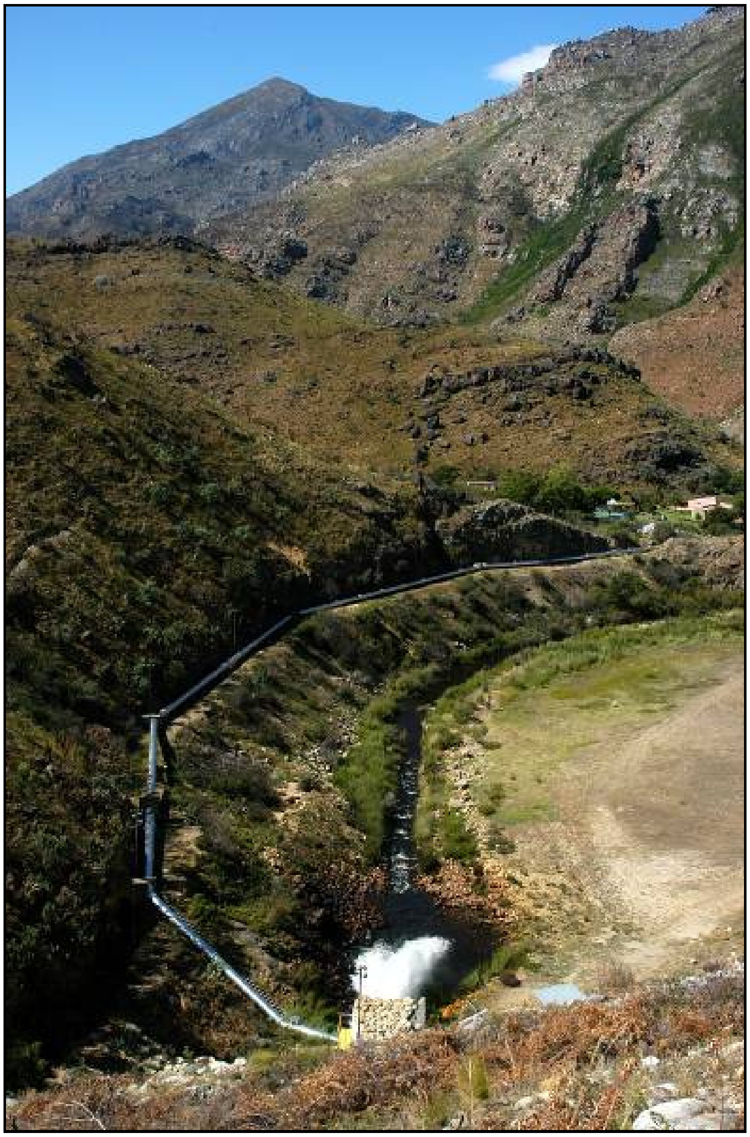

**Figure 50:** The staff village at the Stettynskloof Dam with the pipeline to Worcester and hypo-limnetic discharge point in the foreground (spring 2012). The effect of the fire in 2011 is still visible on the slopes.

Apart from the presence of invader plant species, the kloof through which the river meanders between Sampling Site 1 and Sampling Site 2 is a natural area with no human impacts in the riparian zone (Tables 10 & 12). A well-managed road, power line and pipeline providing the town of Worcester with water run high along the slope to the eastern side of the river. The road never crosses through the riparian zone, but the pipeline crosses though the riparian zone (mounted on high supports) between Sampling Sites 1 & 2 (Figure 12; Tables 10 & 12).

Sampling Site 2 (the Reference Site) is located in a mountain stream at the western end of the Hartmanskloof (Figures 2 & 6). The area is natural and protected as part of the Limietberg Nature Reserve (Table 10). Vast infestations of the alien invader plant *Hakea sericea* is a problem on the slopes. These infestations are expected to reduce the amount of runoff that reaches the river (Table 10). From the road, a narrow footpath leads to a waterfall about one kilometre to the east (Table 10; Figure 51). The footpath crosses the river several times as it flows through the narrow kloof (Figure 52).

**Figure 51:** The waterfall upstream of Sampling Site 2 in the Hartmanskloof (autumn 2012).

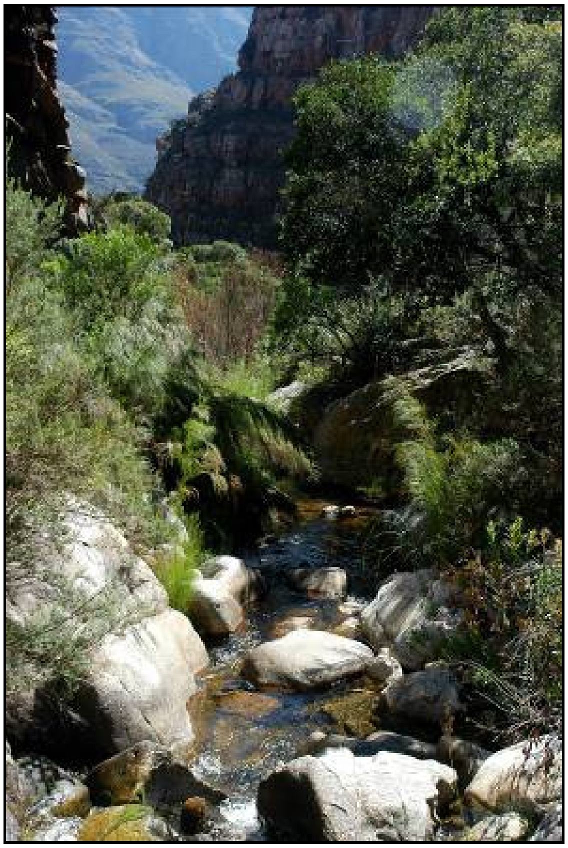

**Figure 52:** The Hartmanskloof – a narrow kloof in pristine condition (autumn 2012).

Small infestations of alien invader *Acacia mearnsii* trees are found in the riparian zone at the Sampling Site and downstream thereof, but not upstream to the waterfall. A relatively large amount of seedlings of *Hakea sericea* was observed establishing in the riparian zone after the fire in 2011, not only at Sampling Site 2, but also upstream to the waterfall. The larger parts of the slopes on either side of the stream, as well as large extents of the riparian zone burnt down in the fire. Densely vegetated parts in the kloof and other sheltered areas did not burn.

A low-flow causeway with gabions for support is found just downstream of Sampling Site 2 where the road crosses the stream. Because the pipes beneath the road cannot handle floodwater, the causeway efficiently forms a barrier to runoff in the area. This causes flooding at the site and erosion of the northern bank where the tributary enters the river (Figure 53; Table 10).

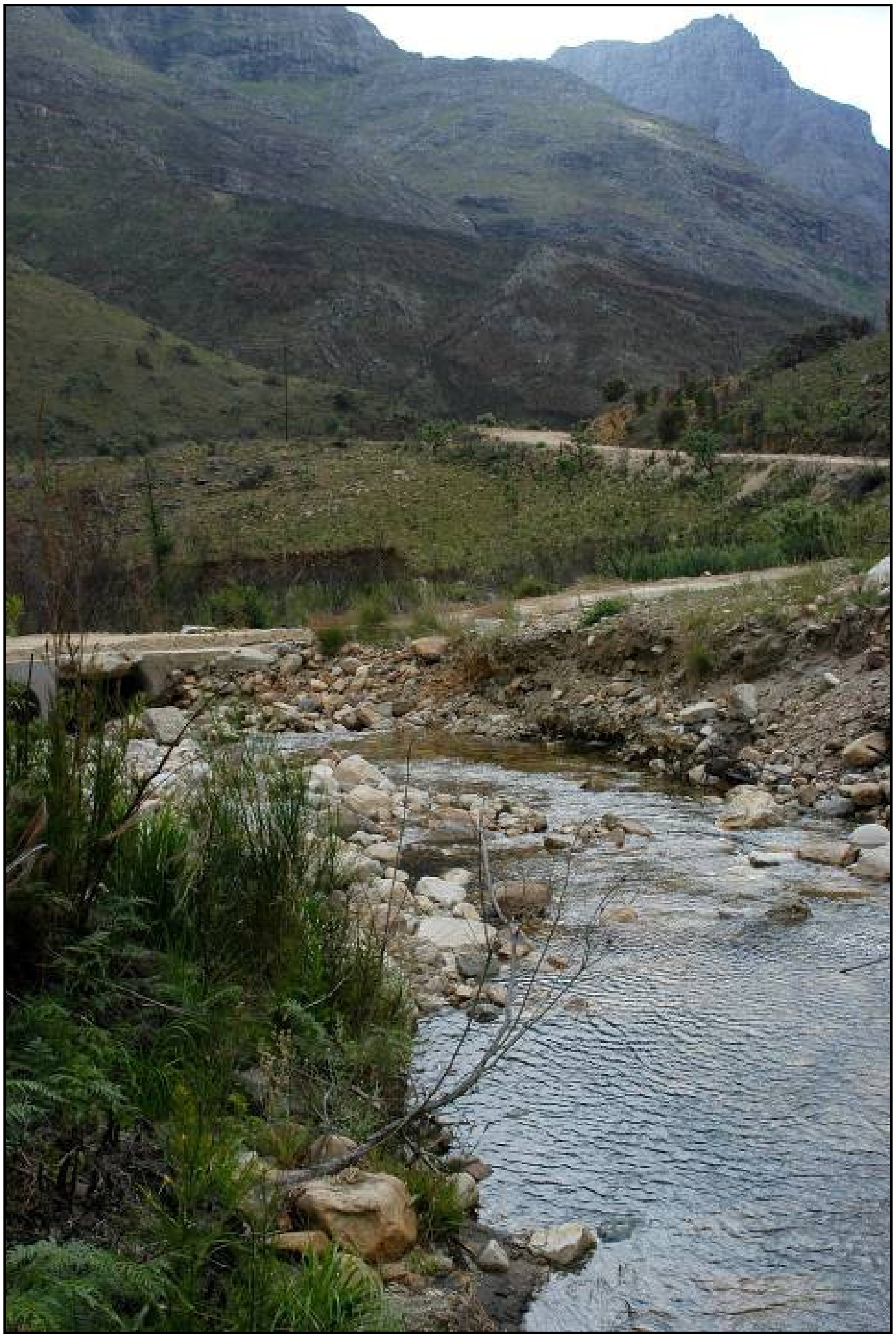

**Figure 53:** The low-flow causeway at Sampling Site 2 on the left-hand side of the picture (taken in summer 2011). Erosion of the northern bank is visible due to the pipes below the road not being able to let floodwater through efficiently. The effect of the fire in 2011 is visible on the slopes in the distance.

Despite being used by trout anglers, the vast area through which the river flows between Sampling Site 2 and Sampling Site 3 is natural (Figure 15). The road, power line and pipeline to Worcester run along the eastern slope high above the riparian zone. The pipeline crosses the river once again between Sampling Sites 2 and 3 (Figure 54).

**Figure 54:** The upper catchment of the Holsloot River between Sampling Sites 2 and 3 (autumn 2012). The road and power line run high above the riparian zone, but the pipeline, mounted on high supports, crosses through the riparian zone.

As depicted by aerial photographs taken in 1942, agricultural development started on the hills to the east of the river at Sampling Site 3 (Figure16). Farming activities had however expanded since 1942 with vineyards and orchards extending within the riparian zone upstream of Sampling Site 3 (Figures 15 & 17).

A tributary, that drains the kloof depicted at the bottom right hand corner in Figure16, was dammed for storage of winter runoff to supply irrigation water in summer, but the earth wall gave way during a thunderstorm in January 2012 (this particular dam is indicated “farm dam” in Figure 15). This event caused severe erosion with the consequence that loads of sediment washed down the river (A. le Roux personal observation).

Upstream of Sampling Site 3, stream-flow is slowed where water is dammed by means of several cobblestone weirs for the purpose of water abstraction (Tables 10 & 12).

The area around Sampling Site 3 is marked by developments and activities associated with a working farm. The different farming activities here include cattle, vineyards and fruit orchards. Construction involves farm buildings, houses and staff residences with gardens and domesticated animals (Table 10). Infrastructure involves the usual farm necessities such as roads and pipelines. A large farm dam stores runoff from a kloof. Several smaller farm dams are used for additional water storage (Figure 15). Cobblestone weirs in the river slow down stream flow and dam water for abstraction (Figure 55; Table 10). This part of the river is popular for trout fishing. Tourist attractions on the farm include a resort with accommodation and camping sites as well as conference facilities and a wedding venue. It is uncertain how waste disposal and sewage is managed, but campsites with ablution facilities on the banks of the river could possibly generate the problem of overspill into the river.

Alien vegetation is a problem at Sampling Site 3 (Figure 55). The problem is enhanced due to the effects of the 2011 fire as dense stands of young *Acacia mearnsii* are established in the riparian zone downstream, at the site, as well as upstream thereof. According to the farmer (E. Stofberg personal communication, April 2012), *Acacia mearnsii* (black wattle) was not a particular problem in the area before the dam was built and it is believed that seeds were introduced into the catchment with the building of the dam and associated infrastructure. *Sesbania punicea* (sesbania) is problematic in the riparian zone, while vast stands of *Hakea sericea* (silky hakea) are found on the slopes in some areas. Cooper *et al*. (2012) state that exotic species often thrive in Mediterranean rivers altered by human activity, where they can create homogenous river communities. Dense invasions of alien *A. mearnsii* (black wattle) in the riparian zone of the Holsloot River can furthermore influence the stream ecosystem adversely through a reduction in light and temperature levels as well as the restriction or obstruction of water flow. (Tabacchi, Correl, Hauer, Pinay, Planty-Tabacchi, Wissmar 1998; Holmes, Esler, Richardson & Witkowski 2008; Le Maitre, Gaertner, Marchante, Ens, Holmes, Pauchard, O'Farrell, Rogers, Blanchard, Blignaut & Richardson 2012).

**Figure 55:** A cobblestone weir creates a pool at a picnic area at Sampling Site 3. *Acacia mearnsii* invasion is a problem in this area of the catchment.

Although alien vegetation infestation (mainly *Acacia mearnsii* and *Sesbania punicea*) is a problem in this area, the river flows through a fairly natural area between Sampling Sites 3 & 4 (Figure 17).

The surroundings of Sampling Site 4, in the middle reaches of the Holsloot River, marks the start of intensive farming activities as the valley expands from here northwards towards the Breede River (Figure 12 & 18). Where the river historically divided into a braided network of streams, and where vineyards were established in various areas between the streams (as depicted in Figure 19), the middle reaches of the river is completely covered in vineyards today and the river canalised to a single stream at the foot of the mountains to the west (Figure 18).

Grape producing farms with associated farm buildings, houses and staff residences, gardens, domesticated animals, waste and sewage disposal and infrastructure such as roads, low water bridges, farm dams, boreholes and pipelines shape the character of the valley from this point onwards. Cobblestone weirs are regularly used to slow down stream flow and facilitate damming points for water abstraction. The removal of riparian vegetation and bulldozing frequently take place in this area of the river. Impson *et al.* (2007) underline the importance of riparian zones: "Healthy riparian zones provide a large number of important goods and services in rivers, such as the provision of food and habitat. Changes in riparian vegetation structure or function are commonly associated with changes in river flow and invasion of the riparian zone by alien invasive plants. Healthy riparian zones also provide an important buffer between the impacts of land-use activities and rivers. The status of the riparian vegetation is therefore a good indicator of the ecological status of the rivers and the levels of modification by urban and agricultural activities in particular."

Because natural riparian vegetation also provides shading, bank stability, and allochthonous inputs to streams as well as filters sediment and contaminants from upstream areas, human-induced changes to riparian zones can have far-ranging effects on invertebrate communities by altering environmental conditions, food sources, and adult habitat (Couceiro *et al.* 2007; Cooper *et al.* 2012). Alien invader plant infestations such as *Acacia mearnsii* (black wattle), *Sesbania punicea* (sesbania) and *Pinus pinaster* (pine trees) are problematic in this area because apart from reducing the water availability, the dense stands of invader trees have the ability to replace natural vegetation and cause destabilization of the banks with consequent erosion (Figure 56; Table 11).

**Figure 56:** The condition of the Holsloot River near Sampling Site 4 with alien invader vegetation replacing natural vegetation in some places and marks of bulldozing in the riparian zone. Erosion is visible where banks are destabilized due to dense stands of especially *Acacia mearnsii*. In most areas, no buffer zone is maintained between vineyards and the riparian zone (autumn 2012).

Where a buffer zone is to various extents maintained between the vineyards and the riparian zone in some areas downstream of Sampling Site 4, no buffer zone is evident immediately upstream of Sampling Site 5 as well as downstream thereof (Figure 15). As the river is seasonally bulldozed and the stream canalised, no vegetated riparian zone with associated habitat exits around Sampling Site 5 (Figure 57; Table 13).

Because the Breede River Valley is a popular tourist destination, many farms offer campsites or other reception venues on the banks of the river. Because ablution facilities are often constructed on the banks of the river or in the riparian zone (A. le Roux personal observation) and waste disposal methods are in some cases uncertain, sewage overspill into the river could possibly be a problem in some areas - especially in the dry season.

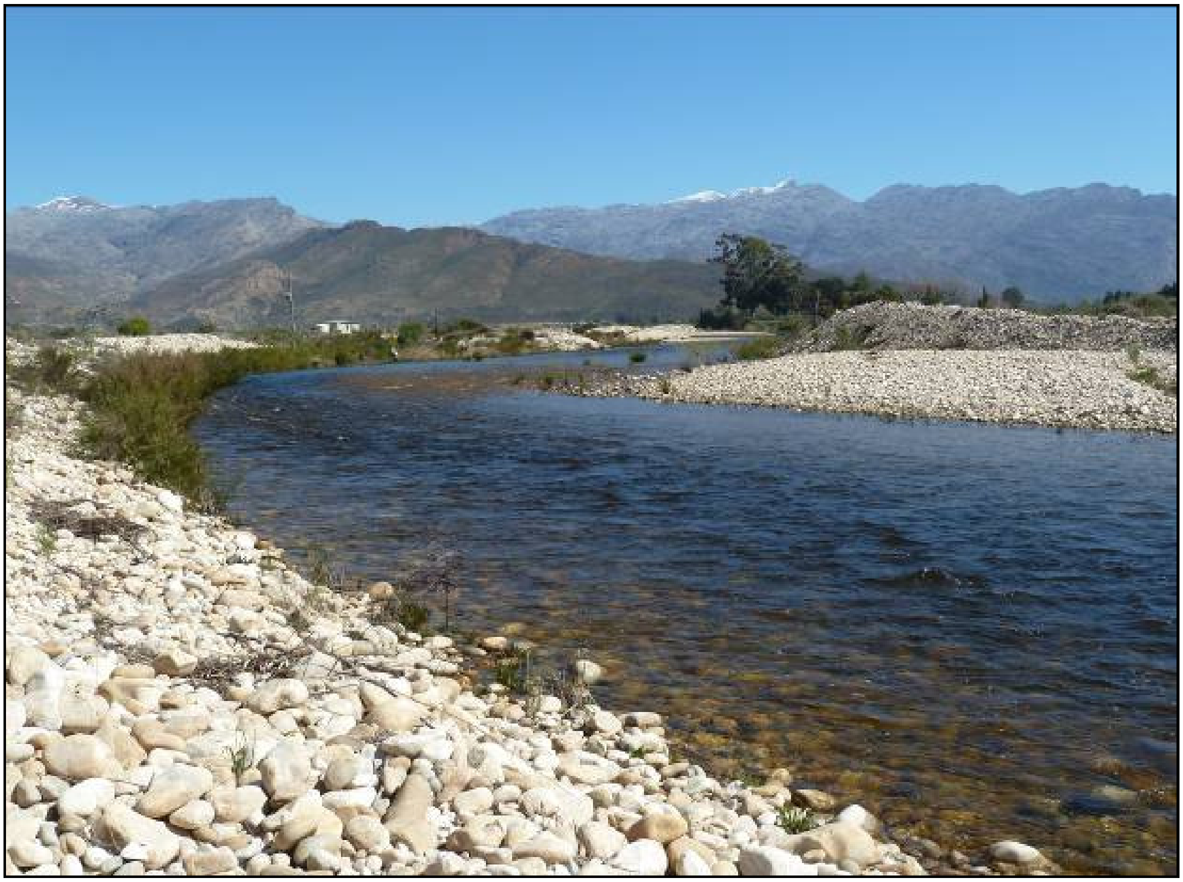

**Figure 57:** Due to seasonal bulldozing of the riverbed in the catchment area of Sampling Site 5, almost no riparian vegetation with associated habitat is left (Photo ME Brand, spring 2012).

Impson *et al.* 2007 state that geomorphological processes determine river channel morphology which provides the physical environment within which stream biota live. Changes to a river channel can be a result of natural or man-made changes to rivers or their catchments (e.g. impoundments and agricultural activities). Once rivers leave mountain catchments and enter intensively farmed areas, their geomorphological condition generally progressively deteriorates (Impson *et al.* 2007).

In-channel and bank modifications in the Holsloot River involve the Stettynskloof Dam and a road (high-water bridge) crossing the river at Sampling Site 1 (Table 12). The bridge has in-channel and side-channel supports. As these supports do not obstruct water flow, they only affect the river moderately (Figure 48). The weir at Sampling Site 1 have an extensive effect on the river at that point as it dams the river upstream and creates a fairy deep pool and run where natural habitat in the mountainous upper reaches of the river would have expected to have a fast flowing, divided stream character (Figure 21 & 48; Table 12).

The road and low water bridge at Reference Site (Sampling Site 2) have a small effect on the river under moderate flow conditions, but cause damming and flow alteration during flood conditions which can cause erosion (Figure 53; Table 12).

Removal of riparian vegetation and occasional bulldozing to canalize the stream and create cobblestone weirs, disturbs the riverbed, alters natural habitat and can cause adverse impacts at the site as well as downstream of Sampling Site 3 (Figure 58; Table 10). Cobblestone weirs slow down flow across the riverbed and create pool habitats. Levels of primary production, accumulation of organic material with consequent decomposition adding nutrients to the river system, are higher in sheltered pools than in fast flowing water.

An elevated low-water bridge at Sampling Site 4 has fewer effects on the stream than the practice of bulldozing a road across the river as done at Sampling Site 5 in the dry season (Figures 40 & 41; Table 11). The road obstructs surface flow and causes shallow standing water on both sides thereof. Evaporation enhanced by strong winds in the dry season can cause concentration of dissolved compounds. Seasonal bulldozing has destroyed the riparian vegetation to only a fringe at the edge of the water in some places.

An application for the extraction of cobble from the riverbed between Sampling Sites 4 & 5 was made recently and is currently considered by the Department of Environmental Affairs and Development Planning (DEA & DP).

**Figure 58**: The effects of damming and occasional bulldozing can be seen at Sampling Site 3 in spring 2012 (Photo ME Brand).

### 5.1.2 Index of Habitat Integrity (IHI)

The Index of Habitat Integrity (IHI) provides a good overall indication of the ecological status of the rivers as it assesses the impact of disturbances on a river and the capacity of that river to provide suitable habitats for organisms (Impson *et al.* 2007). Kleynhans *et al.* (2008) states "the habitat integrity of a river refers to the maintenance of a balanced composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region"

The instream habitat integrity of the sampling sites are given in Table 14, the riparian zone habitat integrity in Table 15 and the overall habitat integrity in Table 16.

**Table 14:** Instream habitat integrity (Kleynhans *et al.* 2008). Colour coding refers to Tables 6 & 8.

| **SAMPLING SITE** | **U/S1** | **D/S1** | **U/S2** | **D/S2** | **U/S3** | **D/S3** | **U/S4** | **D/S4** | **U/S5** | **D/S5** |
|---|---|---|---|---|---|---|---|---|---|---|
| WATER ABSTRACTION (IMPACT 1 - 25) | 1 | 0 | 0 | 0 | 5 | 8 | 18 | 20 | 20 | 21 |
| FLOW MODIFICATION ( (IMPACT 1 - 25) | 6 | 0 | 0 | 1 | 3 | 8 | 16 | 20 | 21 | 21 |
| BED MODIFICATION (IMPACT 1 - 25) | 5 | 0 | 0 | 1 | 1 | 6 | 16 | 20 | 21 | 25 |
| CHANNEL MODIFICATION (IMPACT 1 - 25) | 5 | 0 | 0 | 0 | 6 | 10 | 15 | 20 | 21 | 21 |
| WATER QUALITY (IMPACT 1 - 25) | 10 | 5 | 0 | 5 | 5 | 6 | 18 | 20 | 21 | 21 |
| INUNDATION (IMPACT 1 - 25) | 5 | 0 | 0 | 2 | 2 | 6 | 18 | 20 | 20 | 21 |
| **TOTAL (OUT OF 150)** | **32** | **5** | **0** | **9** | **22** | **44** | **101** | **120** | **124** | **130** |
| | | | | | | | | | | |
| SECONDARY | | | | | | | | | | |
| EXOTIC MACROPHYTES (IMPACT 1 - 25) | 5 | 2 | 3 | 5 | 5 | 7 | 15 | 15 | 17 | 20 |
| EXOTIC FAUNA (IMPACT 1 - 25) | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 5 |
| RUBBISH DUMPING (IMPACT 1 - 25) | 3 | 0 | 0 | 2 | 1 | 3 | 6 | 6 | 8 | 15 |
| **TOTAL (OUT OF 75)** | **8** | **2** | **3** | **7** | **11** | **15** | **26** | **18** | **30** | **40** |
| | | | | | | | | | | |
| **INSTREAM HABITAT INTEGRITY SCORE** | **82** | **97** | **99** | **94** | **85** | **72** | **21** | **14** | **9** | **5** |
| **INTEGRITY CLASS** | **B** | **A** | **A** | **A** | **B** | **C** | **E** | **F** | **F** | **F** |

Evaluation: None (0); Small (1-5); Moderate (6-10); Large (11-15); Serious (16-20), Critical (21-25)

**Table 15:** Riparian zone habitat integrity (Kleynhans *et al.* 2008). Colour coding refers to Tables 6 & 8.

| **SAMPLING SITE** | **U/S1** | **D/S1** | **U/S2** | **D/S2** | **U/S3** | **D/S3** | **U/S4** | **D/S4** | **U/S5** | **D/S5** |
|---|---|---|---|---|---|---|---|---|---|---|
| VEGETATION REMOVAL (IMPACT 1 - 25) | 0 | 0 | 0 | 0 | 0 | 5 | 15 | 20 | 20 | 20 |
| EXOTIC VEGETATION (IMPACT 1 - 25) | 15 | 0 | 0 | 3 | 3 | 6 | 15 | 20 | 20 | 22 |
| BANK EROSION (IMPACT 1 - 25) | 5 | 0 | 0 | 3 | 1 | 5 | 11 | 20 | 20 | 20 |
| CHANNEL MODIFICATION (IMPACT 1 - 25) | 5 | 0 | 0 | 0 | 5 | 10 | 10 | 20 | 20 | 22 |
| WATER ABSTRACTION (IMPACT 1 - 25) | 10 | 5 | 0 | 0 | 3 | 6 | 20 | 20 | 20 | 20 |
| INUNDATION (IMPACT 1 - 25) | 0 | 0 | 0 | 0 | 0 | 3 | 10 | 20 | 22 | 23 |
| FLOW MODIFICATION (IMPACT 1 - 25) | 3 | 1 | 1 | 6 | 5 | 7 | 20 | 20 | 20 | 20 |
| WATER QUALITY (IMPACT 1 - 25) | 0 | 0 | 0 | 8 | 0 | 2 | 5 | 10 | 10 | 10 |
| **TOTAL (OUT OF 200)** | **38** | **6** | **1** | **20** | **17** | **44** | **106** | **150** | **152** | **157** |
| | | | | | | | | | | |
| **RIPARIAN ZONE HABITAT INTEGRITY SCORE** | **82** | **97** | **100** | **90** | **92** | **78** | **48** | **26** | **25** | **34** |
| **INTEGRITY CLASS** | **B** | **A** | **A** | **A** | **A** | **C** | **D** | **E** | **E** | **E** |

Evaluation: None (0); Small (1-5); Moderate (6-10); Large (11-15); Serious (16-20), Critical (21-25)

**Table 16:** Over all habitat integrity (Kleynhans *et al.* 2008). Colour coding refers to Tables 6 & 8.

| **SAMPLING SITE** | **U/S1** | **D/S1** | **U/S2** | **D/S2** | **U/S3** | **D/S3** | **U/S4** | **D/S4** | **U/S5** | **D/S5** |
|---|---|---|---|---|---|---|---|---|---|---|
| Instream habitat integrity % | 82 | 97 | 99 | 94 | 85 | 72 | 21 | 14 | 9 | 5 |
| Instream habitat integrity Class | **B** | **A** | **A** | **A** | **B** | **C** | **E** | **F** | **F** | **F** |
| Riparian habitat integrity % | **82** | **97** | **100** | **90** | **92** | **78** | **48** | **26** | **25** | **34** |
| Riparian habitat integrity Class | **B** | **A** | **A** | **A** | **A** | **C** | **D** | **E** | **E** | **E** |
| | | | | | | | | | | |
| **Over all IHI %** | **81.88** | **97.30** | **99.22** | **91.70** | **88.42** | **75.26** | **34.43** | **19.99** | **16.56** | **19.40** |
| **Over all IHI category** | **B** | **A** | **A** | **A** | **B** | **C** | **E** | **E** | **F** | **F** |

According to the National River Health Programme, the availability and diversity of habitats are major determinants of the aquatic biota found in the river (RHP 2011). In the recent State of Rivers Report for the Breede Water Management Area, The National River Health Programme (2011) categorised the upper reaches of the Holsloot River as “good”, which means that although there are some human-related disturbance, the ecosystem is essentially in a good state and the biodiversity and integrity thereof is largely intact (RHP 2011).

For the upper catchment of the Holsloot River, results from this study agree with the findings of the National River Health Programme (2011). Interpreted according to Habitat Integrity Classes (Table 6) (Kleynhans 1999; Kleynhans *et al.* 2008) the instream, as well as the riparian zone habitat integrity of the Reference Site was found to be in ***Category A: Natural****, unmodified* (Tables 14-16). Due to localised impacts at the dam (limited human related impacts such as water abstraction, flow modification, channel modification and its impacts on water quality and inundation), the habitat integrity upstream of Sampling Site 1, although in the Habitat Integrity Class B (Largely Natural), did not match that of the Reference Site.

Though also falling in Habitat Integrity Class B (*Largely Natural*), the habitat integrity upstream of Sampling Site 3 did not match that of the Reference Site due to the localised impacts of farming activities and water abstraction (Tables14-16). The result of intensive farming activities and human related impacts at Sampling Site 3 caused the habitat integrity downstream of Sampling Site 3 to diverge from that of the Reference Site to Habitat Integrity Class C (*Moderately Modified*). For similar reasons, but with more extensive levels of human related impacts, disturbance and habitat loss, the habitat integrity upstream of Sampling Site 4 is classified as Habitat Integrity Class E (*Seriously Modified*). The habitat integrity of the river downstream of Sampling Site 4 moves farther away from conditions at the Reference Site as the habitat integrity at Sampling Site 5 falls in Habitat Integrity Class F (*Critically Modified*) (Tables14-16).

The RHP (2011) categorised the lower reaches of the Holsloot River as *fair*, meaning that multiple disturbances associated with the need for socio-economic development likely led to loss of sensitive species, while tolerant or opportunistic species dominate the river system (RHP 2011). The results of this habitat integrity study of the lower reaches do not agree with the findings of the RHP (2011). The results of this study found that *an almost complete loss of natural habitat and biota, due to critical level of modifications is evident* (Kleynhans 1999; Kleynhans *et al.* 2008) in the lower reaches of the Holsloot River.

### 5.1.3 Invertebrate Habitat Assessment System (IHAS) Index

The Invertebrate Habitat Assessment System (IHAS) Index assesses the condition and availability of invertebrate habitats of the site being sampled. According to Van Staden (2003), the IHAS Index reflects the quantity, quality and diversity of biotopes available for habitation by invertebrates. However most aquatic scientists do not regard the IHAS model useful (Dr C. J. Kleynhans personal communication, February 2012), Van Staden (2008) regards it valuable in interpreting the SASS5 scores and the effects of habitat variation on aquatic macro-invertebrate community integrity. The IHAS Index is included in this study as indication of the changeability of available habitat in the Holsloot River in different seasons.

The availability of different habitats differs seasonally, mainly because of fluctuations in water level. At times of high water levels and strong flow conditions, as encountered during data collection in spring, habitat limitations would for example comprise less/no gravel and sand to sample at most Sampling Sites due to the high level of inundation or limited accessibility to the biotopes.

Interpreted according to the guidelines of IHAS percentage scores given by McMillan (1998) (Table 7), even the impacted sampling sites, rendered scores indicating the habitats to be “highly suited for supporting a diverse aquatic macro-invertebrate community” at certain times of the study period (Table 17).

**Table 17:** Seasonal variation in invertebrate habitat (IHAS)

| | | Stones In Current | Vegetation | Other Habitat | Habitat Total | Total IHAS Score (%) |
|---|---|---|---|---|---|---|
| **Sampling Site 1** | Spring | 9 | 9 | 10 | 28 | **51** |
| | Summer | 20 | 9 | 14 | 43 | **78** |
| | Autumn | 20 | 14 | 16 | 50 | **91** |
| | Winter | 20 | 14 | 16 | 50 | **91** |
| **Sampling Site 2 (Reference Site)** | Spring | 20 | 13 | 19 | 52 | **95** |
| | Summer | 20 | 13 | 18 | 51 | **93** |
| | Autumn | 20 | 14 | 18 | 52 | **95** |
| | Winter | 20 | 14 | 20 | 54 | **98** |
| **Sampling Site 3** | Spring | 16 | 12 | 20 | 48 | **87** |
| | Summer | 15 | 11 | 15 | 41 | **75** |
| | Autumn | 20 | 14 | 14 | 48 | **87** |
| | Winter | 20 | 14 | 17 | 51 | **93** |
| **Sampling Site 4** | Spring | 15 | 9 | 11 | 35 | **64** |
| | Summer | 16 | 11 | 14 | 41 | **75** |
| | Autumn | 12 | 13 | 11 | 36 | **65** |
| | Winter | 20 | 14 | 14 | 48 | **87** |
| **Sampling Site 5** | Spring | 17 | 12 | 9 | 38 | **69** |
| | Summer | 20 | 11 | 14 | 45 | **82** |
| | Autumn | 14 | 10 | 10 | 34 | **62** |
| | Winter | 19 | 12 | 13 | 44 | **80** |

Due to high water levels and strong flow conditions in spring (Figure 11), only the Reference Site, according to the IHAS percentage score, rendered conditions highly suited for supporting a diverse aquatic macro-invertebrate community throughout the study period. According to the IHAS percentage score, Sampling Site 1, which normally falls in the *highly suited* category, was found to be in the *inadequate* category due to elevated water levels in spring. Low water levels also affect the availability of habitat (especially of marginal vegetation) as it reduces the width of the inundated area with the result that some parts of the riverbed are moist, but not inundated. According to the IHAS percentage score, Sampling Site 4 only provided *highly suited* conditions in winter due to a combination of the character of the site and fluctuating water levels that were found to be high in spring (Figure 61), but low in summer (Figure 37) and autumn (Figure 39) (Table 17).

According to the IHAS percentage score, Sampling Site 5 is *highly suited for supporting a diverse aquatic macro-invertebrate* community at times of moderate water levels during summer (Figures 29 & 30) and winter. The high level of inundation during spring rendered the site *adequate for supporting a diverse aquatic macro-invertebrate community* (Figure 57). Low water level in autumn, together with flow-obstruction created by the bulldozing of a road through the riverbed caused the site to be *inadequate for supporting a diverse aquatic macro-invertebrate community* in autumn. (Figures 40 – 41; Table 17).

## 5.2 Biological parameters and indices

### 5.2.1 South African Scoring System (SASS5): Seasonal variation in ASPT and number of taxa.

SASS is a qualitative, multi-habitat, rapid, field-based method that requires identification of macro-invertebrates mostly to family level. Sensitivity weightings are used to calculate the biotic index. These have been pre-assigned to individual taxa according to the water quality conditions each taxon is known to tolerate (DWAF 2008). Because they are ubiquitous in rivers, have a wide range of sensitivities and have a suitable life-cycle duration that indicates short- to medium term impacts on water quality and habitat, macro-invertebrate communities are a good indicator of many impacts of human activities on rivers. Water insects respond relatively quickly to localised conditions in a river, especially water quality (Dallas 2000; Impson *et al.* 2007). Because their existence also depends on habitat diversity, they are good indicators of levels of environmental disturbances in many different types of aquatic systems and in most habitats/biotopes, particularly in intensively farmed areas (Dallas 2000; Impson *et al.* 2007). Particular invertebrate families and orders, defined as indicator taxa, are scored using a point system according to their sensitivity with respect to the general water quality rather than to specific groups of pollutants (Dallas 1997; Dickens & Graham 2002; Thiere & Schulz 2004).

Davies & Day (1998) state the number of taxa as a measure of biodiversity at the site, while the average score per taxon (ASPT) reflects the overall sensitivity of the organisms living in that particular site. According to Thiere & Schulz (2004), high values of SASS scores (above 80) and ASPT (above 5) indicate sensitive invertebrate communities depending on good water quality and low general pollution.

As the SASS score depends primarily on water quality and habitat availability (Murray 1999), a positive relationship between SASS Scores and IHAS scores is therefore assumed. Because habitat availability greatly affects the IHAS score, unsatisfactory and variable performance of the IHAS was found in Mpumalanga and the Western Cape where no significant correlations could be found between IHAS- and SASS scores at reference sites. Ollis, Boucher, Dallas & Esler (2006) suggest: "This macro-invertebrate habitat scoring system cannot in these regions be used with a great deal of confidence in SASS-based bio-assessment studies." According to the same authors, until the IHAS is scientifically validated, SASS data should preferably be interpreted by plotting both SASS5 scores and ASPT values relative to 'biological bands'.

To prevent the misinterpretation of SASS data because of differences in macro-invertebrate habitat, Ollis *et al.* (2006) further suggest that more emphasis should be placed on the ASPT rather than the SASS5 score because (except in cases where very low SASS scores are recorded) biotope availability has less effect on the ASPT. Van Staden (2008) also suggests not using SASS5 scores in isolation, but rather in comparison with relevant habitat scores, for the reason that some sites have a less desirable habitat or fewer biotopes than others do. Van Staden (2008) further points out that "a low SASS5 score is not necessarily regarded as poor in conjunction with a low habitat score. In addition, a high SASS5 score in conjunction with a low habitat score can be regarded as better than a high SASS5 score in conjunction with a high habitat score. A low SASS5 score together with a high habitat score would be indicative of poor conditions."

Thiere & Schulz (2004) emphasize that "the ecological effects of pollution in Western Cape Rivers have to be considered carefully since many of the aquatic invertebrate and fish species occurring in these rivers are endemic to a relatively small area, and their extinction cannot be compensated by recolonisation from other regions."

Results from the SASS5 data are presented as follows:

- Seasonal variation in the Average Score per Taxon (ASPT) is presented in Figure 59,
- SASS5 scores as well as seasonal variation in the number of taxa are given in Figure 60.

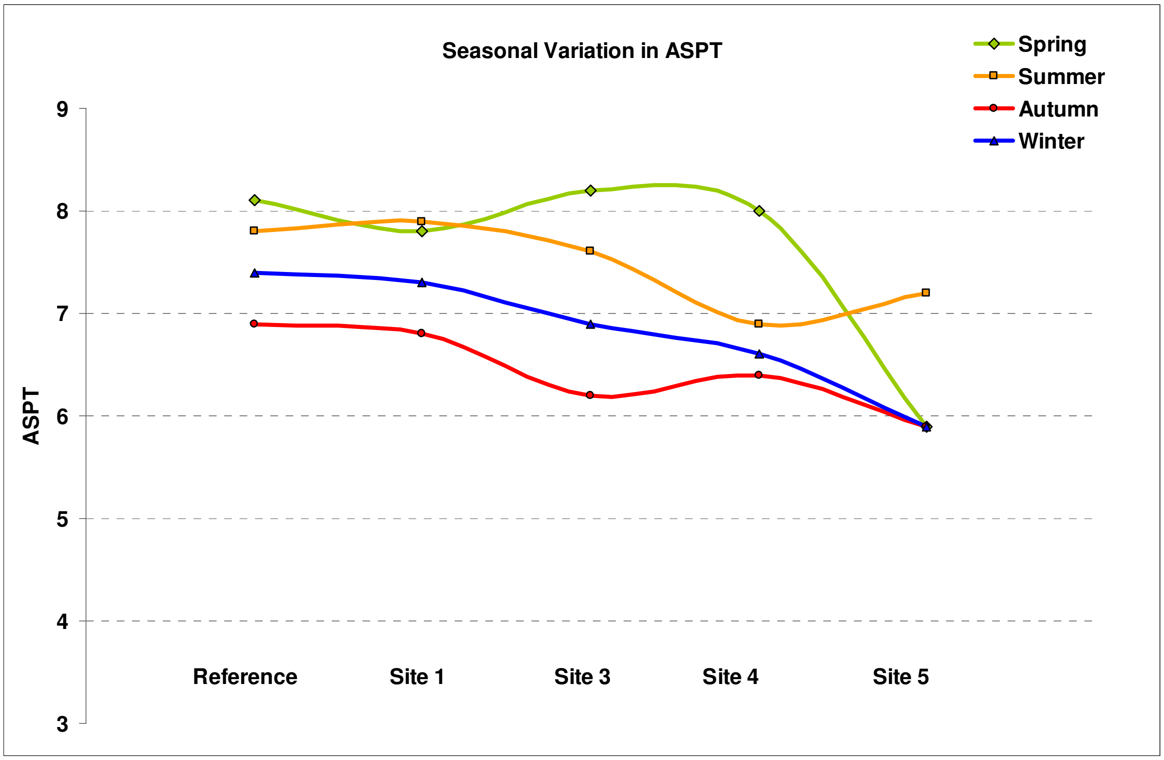

**Figure 59:** Seasonal variation in Average Score per Taxon (ASPT) (2011 – 2012).

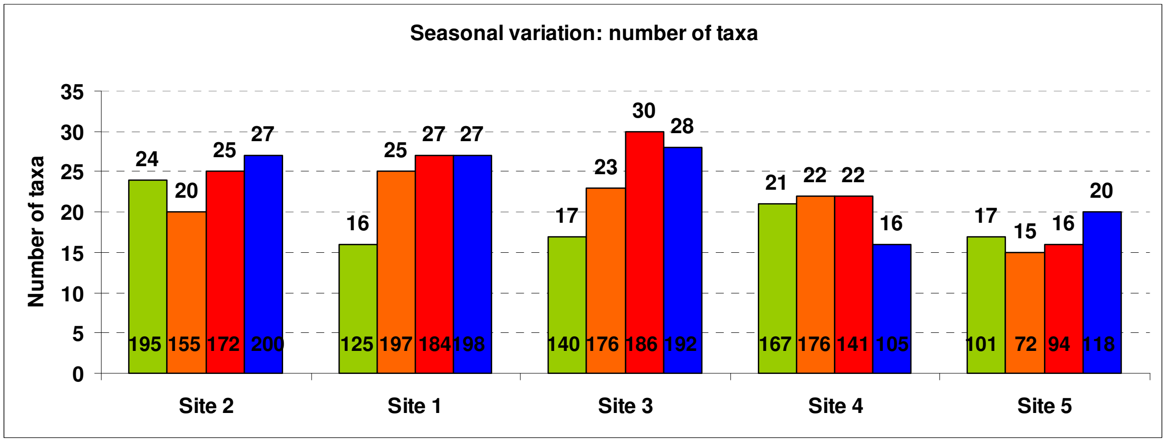

**Figure 60:** Seasonal variation in number of taxa (2011 – 2012). Number of taxa indicated above the bars and SASS score in the bars (green = spring, orange = summer; red = autumn; blue = winter).

### 5.2.1.a Reference Site (Sampling Site 2).

SASS and ASPT scores were high at the Reference Site. SASS scores ranged from 155 – 200. The highest ASPT (8.1) was found in spring, the second highest in summer (7.8), followed by winter (7.4) and autumn (6.9) (Figures 59 & 60). Although the Reference Site of this study rendered higher SASS scores and numbers of taxa present, the ASPT values correspond with SASS5 data obtained at a RHP reference site in the Holsloot River (H1HOLS-BRAND) that was used for the calculation of statistics and biological bands: SASS score of 121, 14 taxa present and a ASPT value of 7.9 (DWAF 2008)

Although high numbers of taxa were counted together with little variation in numbers throughout the study, the highest number of taxa/season was obtained during spring, and at the Reference Site.

As expected, the high ASPT scores found at Reference Site indicate the sensitivity of the organisms that are adapted to cool, clear, fast flowing mountain streams in the south-western Cape (Davies & Day 1998). The lower number of taxa found here indicates less biodiversity at the Reference Site compared to Sampling Sites 1 and 3. Although clear high quality water is present, the environment at the Reference Site is relatively hostile because of low water temperature and fast flow rate as water surges down a rather narrow channel. The character of the stream limits available habitat and organisms need special adaptations to inhabit such an environment as they can easily be swept downstream.

The high HI index (natural unmodified), high IHAS (highly suited to support a diverse aquatic macro-invertebrate community), high ASPT (high number of sensitive taxa) and relatively high number of taxa (high biodiversity) values found at the Reference Site underlines the pristine condition of the upper reaches of the river.

### 5.2.1.b Sampling Site 1.

High SASS scores (ranging from 125-198) were found at Sampling Site 1. With the exception of summer and autumn, slightly lower ASPT scores were found at Sampling Site 1 in comparison to that found at the Reference Site. The higher ASPT at Sampling Site 1 during the warm, dry months could relate to water levels being higher at Sampling

Site 1 (due to compensation releases from the dam) compared to that the Reference Site in the dry season (Figures 59 & 60).

The number of taxa found at Sampling Site 1 was generally higher than the number counted at the Reference Site. As many as 24 taxa were however found at the Reference Site in spring, compared to the 16 at Sampling Site 1 (Figure 60). As is reflected in the IHAS, the lower SASS score as well as number of taxa for Sampling Site 1 in spring relates to the fact that some of the regular sampling habitats were inaccessible because of the high water level and strong stream flow after good rainfall. While sampled in all other seasons, the biotope stones in current (SIC), gravel and sand could not be sampled in spring.

Compared to the Reference Site, the lower ASPT scores, but higher numbers of taxa found at Sampling Site 1 in the dry season (summer and autumn) shows that Sampling Site 1 is able to support a greater diversity of taxa in the dry season. This greater diversity of aquatic invertebrates is probably due to the availability of diverse habitats and greater level of inundation during the dry season at Sampling Site 1, such as the large, calm and fairly deep pool upstream of the gauging weir as well as run and riffles downstream thereof. These findings highlight the effects that human related structures (however moderate at Sampling Site 1) and activities may have on the ecology of the Holsloot River.

### 5.2.1.c Sampling Site 3.

Even with farming activities, adequate habitat is available for aquatic organisms (Table 17), and SASS scores were high at Sampling Site 3 (140-192) (Figure 60). ASPT scores were generally found to be lower than that at Sampling Site 1 and also lower than that found at the Reference Site. In spring however, the highest ASPT (8.2) for the study was found at Sampling Site 3 (also higher than the Reference for the same sampling time) (Figure 59).

The highest numbers of taxa were found at Sampling Site 3: 30 taxa in autumn and 28 taxa in winter. In summer more taxa were recorded at Sampling Site 3 than at the Reference Site, but spring had seven taxa less in comparison to the Reference Site. The high number of taxa found is indicative of the biodiversity at the site and reflects the variety of available habitat at Sampling Site 3 (Table 3).

Opposed to the harsh environment of a cold, fast flowing, oligotrophic mountain stream where nutrients are mostly of allochthonous origin (such as the Reference Site), human impacts can create a more diverse and productive environment. These impacts include the opening of the river channel through removal of riparian vegetation, damming through cobblestone weirs or a change in stream flow (causing sediment deposits to establish vegetated islands). A diverse habitat (such as Sampling Site 3) generates a greater variety of niches and higher amount of nutrients (mostly autochthonous) available for aquatic organisms. Even human-made structures in rivers or objects perceived as pollution can supply shelter or suitable habitat in a strong flowing current.

Couceiro *et al.* (2007) agree with Dodds (2002) and Allan (1995) that elevated water temperature, with consequent lower dissolved oxygen concentrations are associated with the removal of riparian vegetation.

Removal of riparian vegetation opens the river channel and brings more sunlight in contact with water at the surface of the stream. Consequent higher water temperatures lead to less dissolved oxygen but higher autotrophic productivity. Damming, facilitated by cobblestone weirs, slows down stream-flow and creates habitats for various aquatic invertebrates.

These, together with a vegetated island in the stream at Sampling Site 3, create a more diverse and productive environment with a greater number and variety of niches available. The higher ASPT at Sampling Site 3 in comparison with the Reference Site likely relates to habitat availability and higher productivity.

The high HI index (moderately unmodified), high IHAS (highly – adequately suited to support a diverse aquatic macro-invertebrate community), seasonally variable ASPT and high number of taxa (high biodiversity) values found at the Sampling Site 3, reflect that although a habitat may be impacted as a result of human related activities, biodiversity can be maintained when natural stream flow and sustained water levels are maintained.

### 5.2.1.d Sampling Site 4.

Although the SASS scores were still high (105-176), seasonal samples showed a decline in ASPT from Sampling Site 3 to Sampling Site 4 (Figure 35). Although ASPT values at Sampling Site 4 are mostly lower than that for the Reference Site, an ASPT value of 8.0 in spring compares well with the Reference Site (Figure 60).

A higher number of taxa (two more than the Reference Site) was found in summer, but three taxa less than the number at the Reference Site were found in spring as well as in autumn, and as many as 11 taxa less than the Reference Site were found in winter (Figure 60).

The low HI indices (seriously modified – critically/extremely modified); seasonally variable IHAS (seasonally highly to mostly adequately to inadequately suited to support a diverse aquatic macro-invertebrate community); relative low ASPT scores together with relatively low numbers of taxa found at Sampling Site 4 indicate moderate – low biodiversity and moderate – low tolerance levels of the taxa found at this Sampling Site.

### 5.2.1.e Sampling Site 5.

Much lower SASS and ASPT scores in comparison to those at the Reference Site were found (Figures 59 & 60). The same ASPT score (5.9) was recorded in autumn, winter and interestingly, also in spring. The summer sample showed a higher ASPT score, also higher than that found at Sampling Site 3 for the same season (but lower than the Reference Site).

Compared to the Reference Site, Sampling Site 5 had lower numbers of taxa for all seasons. The lowest numbers of taxa for summer and for autumn were found here (Figure 60).

The low HI indices (critically/extremely modified), seasonally variable IHAS (seasonally highly – adequately – inadequately suited to support a diverse aquatic macro-invertebrate community), low ASPT scores together with low number of taxa found reflect low biodiversity in the lower stretches of the river and low tolerance levels of the taxa at Sampling Site 5. Relatively high numbers of taxa found for this severely impacted site coincide with times of high water levels and strong stream flow (winter and spring) (Figures 10 & 11).

Cooper *et al.* (2012) agree that the high seasonal human demand for water in Mediterranean climate regions leads to intense competition for water with riverine communities. Ground- and surface water abstraction may be detrimental to sensitive macro-invertebrate species because of reduced dry season flows that consequently concentrate contaminants, allow for the accumulation of detritus, algae as well as causing higher water temperatures and lower DO levels (Cooper *et al.* 2012). The macro-invertebrate communities in the lower stretches of the Holsloot River are furthermore at risk of being affected by pesticides used on vineyards and orchards. According to Thiere & Schulz (2004) the most important routes leading to non-point-source pesticide contamination of aquatic systems are runoff and spray drift. The authors studied runoff-related agricultural impact in relation to macro-invertebrate communities of the Lourens River in the Western Cape and found that while upstream of agricultural activities had been free of current-use insecticide contamination, the downstream parts of the river surrounded by orchard areas had received temporary insecticide peaks. Bollmohr & Schulz (2009) studied seasonal changes of macro-invertebrate communities at three different sites along the Lourens River (Western Cape) that receive nonpoint-source insecticide pollution. The authors report that particularly in the dry season, sensitive insect species (mainly mayflies and caddisflies) were less abundant at a site containing high concentrations of organo-phosphorous pesticides associated with suspended sediment than at less contaminated sites.

### 5.2.2 Macro-invertebrates: Sensitivity

The sensitivity and abundance of aquatic macro-invertebrate families found at a specific site in the river forms the basis of the SASS5 method of measuring river health. Each taxon, typically a family, has been weighted on a scale of 1 to 15 according to its estimated tolerance of polluted conditions meaning that those least tolerant (i.e. most sensitive) are weighted (scored) higher (Murray 1999).

In order to determine the distribution of highly sensitive, moderately sensitive, less sensitive, and least sensitive taxa in the river, SASS5 data for aquatic macro-invertebrates was organised into the following sensitivity classes on the basis of water quality preferences (indicated by the SASS5 weightings specified for the families) as suggested in Thirion (2007):

- **Highly sensitive**: taxa with high water quality preferences (SASS5 weightings 15 – 11) (Table 18)
- **Moderately sensitive**: taxa with moderate water quality preferences, but can tolerate lower water quality (SASS5 weightings 10 – 8) (Table 19)
- **Less sensitive**: taxa with low water quality preferences (SASS5 weightings 7 – 5) (Table 20)
- **Least sensitive**: taxa with very low water quality preferences (SASS5 weightings 4 – 1) (Table 21)

On the basis of sensitivity to water quality, the presence of macro-invertebrate families is discussed by using the following ratio as found per sampling site throughout the study: **highly sensitive : moderately sensitive : less sensitive : least sensitive.**

**Table 18:** Sampling site variation and abundance of 'sensitive' families of macro-invertebrates with high water quality preferences as suggested in Thirion (2007).

| **Macro-invertebrate Families** | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seasons** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** |
| **Sampling sites** | **2 (Reference)** | | | | **1** | | | | **3** | | | | **4** | | | | **5** | | | |
| **<u>Highly sensitive</u>: taxa with high water quality preferences** | | | | | | | | | | | | | | | | | | | | |
| Blephariceridae (15) | | | | | | A | | | 1 | 1 | | | 1 | | | | | | | |
| Notonemouridae (14) | B | | | A | 1 | | | B | | | | 1 | | | | | 1 | | | |
| | A | | | A | 1 | | | B | | | | A | | | | | | | | |
| | | | | | | | | A | | | | | | | | | | | | 1 |
| Barbarochthonidae SWC (13) | A | 1 | | | A | B | B | B | | | | 1 | 1 | | | | | | | |
| | A | 1 | | A | B | B | A | B | 1 | 1 | | 1 | | | | | | A | 1 | |
| | B | | 1 | | B | 1 | B | B | | A | | | | | | | | A | | |
| Heptageniidae (13) | A | | | C | 1 | B | | C | B | 1 | B | C | B | B | 1 | A | | | | 1 |
| | | | | A | | | | A | | | A | A | | | | | | | | |
| | | | | B | | 1 | | B | | | A | A | | 1 | | 1 | | | | |
| Sericostomatidae SWC (13) | 1 | | A | | B | A | B | A | | A | B | B | | A | | 1 | A | | | |
| | A | | 1 | | B | A | B | B | 1 | A | A | B | A | B | | | | | | |
| | B | 1 | A | | B | 1 | B | B | 1 | A | 1 | B | | | | | | | | |
| Baetidae > 2 sp (12) | B | | B | B | | B | | | | | | B | C | | B | B | C | B | | C |
| | B | | A | B | | 1 | | | | | | B | B | | B | B | B | B | | A |
| | B | | B | | | B | | | | | | A | B | | 1 | A | A | B | | A |
| Helodidae (12) | | | | | | | | 1 | | | | | | | | | | | | |
| | | | | | | | | 1 | | 1 | | 1 | | | | | | | | |
| | | 1 | | | | | A | A | | | | | | | | | | | | |
| Hydropsychidae > 2 sp (12) | B | A | B | B | | A | | B | | A | B | B | | | | | | | B | |
| | | 1 | | 1 | | 1 | | B | | 1 | | A | | | | | | | | |
| | | A | 1 | A | | 1 | | 1 | | 1 | | | | | | | | | | |
| Teloganodidae SWC (12) | B | 1 | | | A | 1 | | | C | A | | | C | | | | A | | | |
| | A | | | | | 1 | | | | 1 | | | | 1 | | | | | | |
| | | A | | | A | A | A | | 1 | 1 | | | A | | | | | | | |
| Glossosomatidae SWC (11) | | | 1 | 1 | | | A | | 1 | | 1 | A | 1 | 1 | 1 | | | | | |
| | | | | | | 1 | | | | | | | | | | | | | | |
| | | | | | | 1 | | | | | | | | | | | | 1 | | |
| Petrothrincidae SWC (11) | | | | | | | A | | | | | | | | | | | A | | |
| Biotope: Stones | 7 | 3 | 4 | 5 | 5 | 7 | 3 | 6 | 4 | 5 | 4 | 7 | 6 | 3 | 3 | 3 | 4 | 1 | 1 | 2 |
| Biotope: Vegetation | 5 | 2 | 2 | 5 | 3 | 6 | 3 | 6 | 2 | 5 | 2 | 7 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 |
| Biotope: GSM | 3 | 4 | 4 | 2 | 3 | 7 | 4 | 6 | 2 | 4 | 2 | 3 | 2 | 1 | 1 | 2 | 1 | 4 | 0 | 2 |
| Ratio<br>Stones : Vegetation : GSM | 19:14:13 | | | | 21:18:20 | | | | 20:16:11 | | | | 15:6:6 | | | | 8:5:7 | | | |

A: Count 2 to 10; B: Count 10 – 100; C: Count 100 – 1 000; S = Spring, U = Summer; A = Autumn; W = Winter; GSM - Gravel/sand/mud; * - Air-breathers

**Table 19:** Sampling site variation and abundance of families of macro-invertebrates with moderate water quality preferences as suggested in Thirion (2007).

| **Macro-invertebrate Families** | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seasons** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** |
| **Sampling sites** | **2 (Reference)** | | | | **1** | | | | **3** | | | | **4** | | | | **5** | | | |
| **<u>Moderately sensitive</u>: Taxa with moderate water quality preferences but can tolerate lower water quality.** | | | | | | | | | | | | | | | | | | | | |
| Platycnemidae (10) | | 🟦 1 | | | | | | | | | | | | | | | | | | |
| | | | | 🟩 1 | | | | | | | | | | | | | | | | |
| Pisuliidae (10) | 🟦 1 | | | | | | 🟦 A | | | | | | | | 🟦 1 | | | | | |
| | 🟩 B | | | | | | 🟩 A | | | | | 🟩 A | | | 🟩 1 | | | | | |
| | 🟨 B | | | | 🟨 A | 🟨 1 | 🟨 1 | | | | | 🟨 A | | | | | | | | |
| Dixidae (10) | | | | 🟩 1 | | | | | | | | | 🟩 1 | 🟩 1 | | | | 🟩 1 | | |
| Athericidae (10) | | | | 🟦 A | | | | 🟦 1 | | | | 🟦 1 | | 🟦 1 | 🟦 A | | 🟦 1 | | | 🟦 A |
| | | | | | | | | | | | | | 🟩 A | | 🟩 1 | | | | | |
| | | | | 🟨 1 | | | | 🟨 1 | | | | 🟨 1 | | | | | | | | |
| Philopotamidae (10) | 🟦 B | 🟦 A | 🟦 B | 🟦 B | | 🟦 1 | | 🟦 1 | | | 🟦 A | 🟦 A | | | | | | | | |
| | 🟩 1 | | | 🟩 1 | | | | | | | | | | | | | | | | |
| | 🟨 1 | | | | | | | | | | | | | | | | | | | |
| Lepidostomatidae (10) | | 🟩 1 | | | | | | | | | | | | | | | | | | |
| | | 🟨 1 | | | | | | | | | | | | | | | | | | |
| Leptophlebiidae (9) | 🟦 B | 🟦 B | 🟦 B | 🟦 B | 🟦 A | 🟦 1 | 🟦 1 | 🟦 A | 🟦 B | 🟦 B | 🟦 B | | 🟦 B | 🟦 B | 🟦 1 | 🟦 1 | 🟦 1 | | | |
| | 🟩 B | 🟩 A | 🟩 1 | 🟩 B | 🟩 1 | | | 🟩 A | 🟩 A | 🟩 1 | 🟩 A | | 🟩 A | 🟩 A | | 🟩 A | | | | |
| | 🟨 1 | 🟨 A | 🟨 B | 🟨 1 | 🟨 1 | 🟨 1 | 🟨 1 | | | 🟨 A | 🟨 A | | | 🟨 1 | | | | | | |
| Tricorythidae (9) | | | | | | | | | | 🟦 1 | | | | | | | | | | |
| | | | | | | | | | | 🟨 1 | | | | | | | | | | |
| Ecnomidae = Paracnomina (8) | | 🟦 1 | 🟦 B | | | 🟦 A | 🟦 1 | | | 🟦 A | 🟦 1 | | | 🟦 A | 🟦 1 | | | | | |
| | | | | | | | | | | 🟩 A | 🟩 1 | | | 🟩 1 | | | | | | |
| | | 🟨 1 | | | | | 🟨 A | | | | | | | | 🟨 1 | | | | | |
| Aeshnidae (8) | 🟦 1 | | 🟦 B | 🟦 B | | | | | 🟦 1 | | 🟦 A | 🟦 B | 🟦 A | | 🟦 A | | | | 🟦 A | 🟦 A |
| | | | 🟩 B | 🟩 1 | | | | | | | | 🟩 A | | | 🟩 1 | 🟩 A | | | 🟩 1 | 🟩 B |
| | | | 🟨 A | 🟨 1 | | | | | | | | | | | | 🟨 1 | | | | |
| Corydalidae (8) | 🟦 A | 🟦 A | 🟦 B | 🟦 A | | 🟦 A | 🟦 B | 🟦 B | 🟦 A | 🟦 A | 🟦 B | 🟦 B | | | | 🟦 1 | | | | |
| | | 🟩 1 | | | | 🟩 A | | | | 🟩 1 | | 🟩 A | | | | | | | | |
| | | | 🟨 B | | | 🟨 A | 🟨 A | 🟨 1 | | | | | | | | | | | | |
| Elmidae* (8) | | | 🟦 A | 🟦 A | | 🟦 A | 🟦 A | 🟦 A | | 🟦 1 | 🟦 1 | | | 🟦 1 | 🟦 1 | | | 🟦 1 | | |
| | 🟩 1 | | | 🟩 A | | | 🟩 1 | | | | | | | 🟩 1 | 🟩 1 | | | | | |
| | 🟨 1 | | 🟨 A | | | | 🟨 1 | 🟨 1 | | 🟨 1 | | | | | | | | | | 🟨 1 |
| Hydracarina (8) | 🟦 1 | | 🟦 A | | | | | | | | | | | | | | | | 🟩 1 | |
| Hydraenidae (8) | | | | 🟦 1 | | | | | | | | | | | | | | | | |
| | | | | | | | | 🟩 1 | | | | | | | | 🟩 1 | | | | |
| | | | | 🟨 1 | | | | | | | | | | | | | | | | |
| 🟦 Biotope: Stones | 6 | 5 | 7 | 7 | 1 | 5 | 5 | 5 | 3 | 5 | 6 | 4 | 2 | 4 | 6 | 2 | 2 | 1 | 1 | 2 |
| 🟩 Biotope: Vegetation | 4 | 3 | 2 | 6 | 1 | 1 | 2 | 2 | 1 | 3 | 2 | 3 | 3 | 4 | 4 | 3 | 0 | 1 | 2 | 1 |
| 🟨 Biotope: GSM | 4 | 3 | 4 | 4 | 2 | 3 | 5 | 3 | 0 | 3 | 1 | 2 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| Ratio<br>Stones : Vegetation : GSM | 25:15:15 | | | | 16:6:13 | | | | 18:9:6 | | | | 14:14:3 | | | | 6:4:1 | | | |

A: Count 2 to 10; B: Count 10 – 100; C: Count 100 – 1 000; S = Spring, U = Summer; A = Autumn; W = Winter; GSM - Gravel/sand/mud; * - Air-breathers

**Table 20:** Sampling site variation and abundance of families of macro-invertebrates with low water quality preferences as suggested in Thirion (2007).

| **Macro-invertebrate Families** | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seasons** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** |
| **Sampling sites** | **2** | | | | **1** | | | | **3** | | | | **4** | | | | **5** | | | |
| **<u>Less sensitive</u>: taxa with low water quality preferences** | | | | | | | | | | | | | | | | | | | | |
| Naucoridae* (7) | | | | | | | A | A | | | | | | | | | A | | | |
| | | | | | | | 1 | 1 | | | | | | | | | | | | |
| | | | | | | | 1 | | | | | | | | | | | | | |
| Gomphidae (6) | | | A | | | | | B | | | 1 | | | | | | | | | |
| | 1 | | 1 | | | | | A | | | 1 | A | 1 | | A | | | 1 | | |
| | | | B | | | | | 1 | | 1 | B | A | A | 1 | A | A | | A | A | 1 |
| Hydropsychidae 2 sp (6) | | | | | | | B | | A | A | | | | A | | | | | | |
| | | | | | | | B | | | | | | | | | | | | | |
| Leptoceridae 6 | | | | | A | | B | B | | 1 | | | | | | | 1 | | | |
| | | | | | B | | B | C | A | A | A | A | A | A | | | B | 1 | | |
| | | A | | | B | | B | B | | A | A | A | 1 | | | | A | | | |
| Baetidae 2 sp 6 | | B | | | A | | B | | B | C | B | | | | | | | | A | |
| | | 1 | | | A | | A | | A | A | | | | A | | | | | | |
| | | 1 | | | A | | A | | 1 | B | A | | | A | | | | | | |
| Caenidae (6) | | | 1 | | | A | | A | | | | | | | | | | B | | |
| | | | B | | 1 | | | | | | 1 | | | | | | 1 | | | |
| | | | 1 | | A | | | B | | | 1 | | | | 1 | 1 | | | | |
| Hydroptilidae (6) | | | | | | | | | | | | | | | | | | | | A |
| | | | | | | | | | | | | | | | | | | | | 1 |
| | | | | | | | | | | | | | | | | | | | | 1 |
| Hydrometridae (6) | | | | | | | | | | | 1 | | | | | | | | | |
| Ceratopogonidae (5) | | | | 1 | | | | | | | | | | | 1 | | | A | 1 | |
| | | 1 | | | | | | | | | | | | 1 | | | | 1 | | |
| | 1 | 1 | | | 1 | 1 | 1 | 1 | | 1 | | | | | | | | | | |
| Tabanidae (5) | A | | 1 | | | | | | | | 1 | 1 | | | | | | | | |
| | 1 | | | 1 | | | A | | | | 1 | | | | | | | | | |
| Dytiscidae * (5) | | | | | | | 1 | | | | 1 | | | | | | | 1 | | |
| | | | A | | | 1 | 1 | A | | | A | 1 | A | | A | A | | | A | |
| | | A | | | B | | A | 1 | | | | | | | | | | | | |
| Gerridae* (5) | | | | | | | | | | | 1 | | | | | | | | A | |
| Gyrinidae (5) | | | | | | A | 1 | | | 1 | B | 1 | | | 1 | | 1 | B | | 1 |
| | | | | | | 1 | 1 | | | | | A | A | A | 1 | | 1 | A | | 1 |
| | | | | | 1 | | | 1 | | 1 | | | 1 | | | | | | | |
| Hydrophilidae* (5) | | | | | | | | | | | | | | | | | | | A | |
| Simuliidae (5) | A | 1 | B | B | | C | B | A | A | A | A | B | B | A | A | | C | B | | C |
| | A | | 1 | A | 1 | B | | A | | 1 | | A | A | | | | | B | | B |
| | | | | | | B | B | | | A | | | A | | | | | | | |
| Tipulidae (5) | A | | | 1 | | | 1 | A | 1 | | 1 | | | | | | | | | 1 |
| | | | | | | | | | | 1 | | | | | | | | | | |
| | | A | 1 | 1 | | A | 1 | A | | 1 | 1 | | | | | | | | | |
| Veliidae * (5) | | | | | | | | | | | A | | | | | | | | | |
| | | | | | | A | | | B | 1 | A | A | | | A | | | | A | |
| | | | 1 | | | | | | | | | 1 | | | | | | | | |
| Biotope: Stones | 3 | 2 | 4 | 3 | 2 | 3 | 8 | 6 | 4 | 5 | 8 | 3 | 1 | 2 | 3 | 0 | 4 | 5 | 2 | 4 |
| Biotope: Vegetation | 3 | 2 | 4 | 1 | 4 | 4 | 5 | 5 | 3 | 5 | 7 | 6 | 5 | 4 | 4 | 1 | 3 | 5 | 4 | 3 |
| Biotope: GSM | 1 | 5 | 4 | 2 | 6 | 3 | 9 | 7 | 1 | 7 | 6 | 3 | 4 | 2 | 2 | 2 | 1 | 1 | 1 | 2 |
| Ratio Stones :Vegetation :GSM | 12:10:12 | | | | 19:18:25 | | | | 20:21:17 | | | | 6:14:10 | | | | 15:15:5 | | | |

A: Count 2 to 10; B: Count 10 – 100; C: Count 100 – 1 000; S = Spring, U = Summer; A = Autumn; W = Winter; GSM - Gravel/sand/mud; * - Air-breathers

**Table 21:** Sampling site variation and abundance of families of macro-invertebrates with very low water quality preferences as suggested in Thirion (2007).

| **Macro-invertebrate Families** | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seasons** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** | **S** | **U** | **A** | **W** |
| **Sampling sites** | **2** | | | | **1** | | | | **3** | | | | **4** | | | | **5** | | | |
| **<u>Least sensitive</u>: taxa with very low water quality preferences** | | | | | | | | | | | | | | | | | | | | |
| Baetidae 1sp (4) | | | | | | | | 🟦 1 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | 🟨 1 | | | | | | | | | | | | |
| Pleidae (4) | | | | | | | | | | | | | | | | | | | | 🟨 1 |
| Coenagrionidae (4) | | | 🟦 1 | | | | | 🟦 A | | 🟦 1 | | | | | | 🟦 1 | | | | |
| | 🟩 1 | | 🟩 B | 🟩 A | | | | | | 🟩 1 | 🟩 B | 🟩 B | 🟩 1 | 🟩 1 | 🟩 A | 🟩 B | 🟩 A | | 🟩 A | 🟩 1 |
| | | | | | | | | | | | | | | | | | 🟨 1 | | | |
| Hydropsychidae 1 sp (4) | | | | | | | | | | | | | 🟦 A | | | | | | | 🟦 A |
| | | | | | | | | | | | | | 🟨 1 | | | | | | | |
| Libellulidae (4) | | | 🟦 A | | | | 🟦 1 | 🟦 B | | | 🟦 A | 🟦 A | | 🟦 A | 🟦 1 | 🟦 A | | 🟦 A | 🟦 A | 🟦 A |
| | | | 🟩 B | 🟩 A | | | 🟩 A | 🟩 A | | | 🟩 B | 🟩 A | | | 🟩 1 | 🟩 A | 🟩 A | | 🟩 1 | 🟩 B |
| | | | | 🟨 1 | | | | 🟨 A | | | 🟨 B | 🟨 1 | | | | 🟨 1 | | | 🟨 A | 🟨 1 |
| Belostomatidae* (3) | | | | | | 🟩 1 | | | | | | | | | | | | | | |
| Corixidae* (3) | | | | 🟦 1 | | | | | | | | | | | 🟦 B | 🟦 1 | | | | 🟦 1 |
| | | | | | | | | | | | | 🟩 A | | | 🟩 A | 🟩 1 | 🟩 1 | | 🟩 1 | 🟩 1 |
| | | | | 🟨 1 | | | | | | | 🟨 1 | | | | 🟨 B | | 🟨 1 | | 🟨 1 | |
| Nepidae* (3) | | | | | | | | | | | | | 🟩 1 | | | | | | | |
| Notonectidae (3) | | | | | | | 🟨 1 | | | | 🟩 1 | | | | 🟩 A | | | | 🟩 A | |
| Potamonautidae* (3) | 🟦 A | 🟦 A | 🟦 1 | | | | 🟦 1 | | 🟦 A | | 🟦 A | 🟦 1 | | | 🟦 A | 🟦 1 | | | | 🟦 1 |
| | | | 🟩 1 | 🟩 A | | | | | | | | 🟩 A | | | 🟩 1 | | | | | |
| | | | 🟨 1 | | | | 🟨 1 | 🟨 1 | | | 🟨 1 | | | | | | | | | |
| Chironomidae (2) | 🟦 1 | | 🟦 B | 🟦 A | | 🟦 A | 🟦 A | 🟦 A | | | 🟦 1 | | 🟦 A | 🟦 1 | 🟦 A | 🟦 A | 🟦 A | 🟦 A | | |
| | 🟩 1 | | | 🟩 A | 🟩 A | 🟩 1 | 🟩 A | 🟩 B | 🟩 1 | 🟩 A | 🟩 1 | 🟩 A | | 🟩 1 | | 🟩 1 | 🟩 B | 🟩 B | | 🟩 A |
| | | 🟨 A | 🟨 1 | 🟨 A | 🟨 A | 🟨 1 | 🟨 A | 🟨 A | | 🟨 A | 🟨 1 | 🟨 A | 🟨 A | | 🟨 1 | 🟨 A | 🟨 1 | | 🟨 A | 🟨 1 |
| Culicidae* (1) | | | 🟦 1 | | | 🟦 1 | | | | | | | | | | 🟦 1 | | | | 🟦 1 |
| | 🟩 1 | 🟩 1 | | 🟩 1 | | | | | | | | 🟩 1 | | | | | 🟩 A | | | 🟩 A |
| | | | | | | 🟨 1 | 🟨 A | 🟨 1 | | 🟨 1 | 🟨 A | 🟨 1 | | 🟨 1 | | | | | | |
| Psychodidae (1) | | | | | | | | | | | | | | 🟦 A | | | | | | |
| Oligochaeta (1) | | | | | | 🟦 A | 🟦 A | | | | 🟦 A | 🟦 A | | | | | | | | 🟦 A |
| | | | | | 🟩 1 | 🟩 1 | 🟩 A | | | | | | | | | | | | | |
| | 🟨 A | | | | | 🟨 1 | 🟨 A | | | 🟨 1 | 🟨 A | | 🟨 A | | 🟨 A | | 🟨 1 | | | 🟨 A |
| 🟦 Biotope: Stones | 2 | 1 | 5 | 2 | 0 | 3 | 4 | 4 | 1 | 1 | 4 | 3 | 2 | 3 | 4 | 6 | 1 | 2 | 1 | 6 |
| 🟩 Biotope: Vegetation | 3 | 1 | 3 | 5 | 2 | 3 | 3 | 2 | 1 | 2 | 4 | 6 | 2 | 2 | 5 | 4 | 5 | 1 | 4 | 5 |
| 🟨 Biotope: GSM | 1 | 1 | 2 | 3 | 1 | 3 | 5 | 5 | 0 | 3 | 6 | 3 | 3 | 1 | 3 | 2 | 4 | 0 | 3 | 4 |
| Ratio<br>Stones : Vegetation : GSM | 10:12:7 | | | | 11:10:14 | | | | 9:13:12 | | | | 15:13:9 | | | | 10:15:11 | | | |

A: Count 2 to 10; B: Count 10 – 100; C: Count 100 – 1 000; S = Spring, U = Summer; A = Autumn; W = Winter; GSM - Gravel/sand/mud; * - Air-breathers

Seasonal variation and abundance of macro-invertebrate families with different water quality preferences is given in Appendix 2 (pp. 183-185).

### 5.2.2.a Reference Site (Sampling Site 2).

**Results for the Reference Site provided the ratio 9 : 13 : 10 : 7.**

Throughout the study, moderately sensitive families dominated the habitat of the Reference Site, while less sensitive and highly sensitive families formed a large part of the community. A small part of the community was occupied by least sensitive families (Tables 18-21).

Because the larger part of the highly sensitive as well as moderately sensitive taxa were found in the stones, this biotope is an important habitat at the Reference Site. Vegetation as well as sand/gravel/mud are also important habitats for highly sensitive and moderately sensitive taxa. Less sensitive taxa are almost evenly distributed in all three biotopes (stones, vegetation and sand/gravel/mud) (Tables 18-21).

### 5.2.2.b Sampling Site 1.

**Results for Sampling Site 1 provided the ratio 11 : 8 : 13 : 9.**

Moderately sensitive and highly sensitive families dominated the habitat at Sampling Site 1, while the remainder of the community consisted of less sensitive and least sensitive families (Tables 18-21).

Stones, together with sand/gravel/mud are important habitats at Sampling Site 1 as highly sensitive and moderately sensitive taxa were mostly found in these two habitats. Vegetation is also important as a high number of highly sensitive taxa were found in the marginal vegetation. The less sensitive and least sensitive taxa were dominant in the sand/gravel/mud habitat (Tables 18-21).

### 5.2.2.c Sampling Site 3.

**Results for Sampling Site 3 provided the ratio 10 : 9 : 14 : 8.**

Similar to Sampling Site 1, moderately sensitive and highly sensitive families dominated the habitat at Sampling Site 3, while the remainder of the community consisted of less sensitive and least sensitive families (Tables 18-21).

At Sampling Site 3, stones and marginal vegetation were the habitats preferred by the highly sensitive families. Moderately sensitive taxa were concentrated in the stones, while less sensitive taxa were almost evenly present in all three biotopes. The least sensitive taxa were mainly found in marginal vegetation as well as sand/gravel/mud (Tables 18-21).

### 5.2.2.d Sampling Site 4.

**Results for Sampling Site 4 provided the ratio 7 : 9 : 10 : 11.**

Least sensitive and less sensitive families dominated the habitat at Sampling Site 4. Moderately sensitive families formed a large part of the community. Highly sensitive families occupied a small part of the community (Tables 18-21). The highly sensitive taxa were mainly found in the stones habitat at Sampling Site 4. For moderately sensitive taxa, the habitats stones and vegetation were equally important. Less sensitive taxa were mainly found in marginal vegetation and sand/gravel/mud, while least sensitive families preferred stones and vegetation (Tables 18-21).

### 5.2.2.e Sampling Site 5.

**Results for Sampling Site 5 provided the ratio 9 : 6 : 14 : 10.**

Almost similar to Sampling Site 4, less sensitive and least sensitive families dominated the habitat at Sampling Site 5. The remainder consisted of highly sensitive and moderately sensitive families, where highly sensitive families were better represented than moderately sensitive families (Tables 18-21).

The largest portion of the few highly sensitive taxa was found in stones (the dominant habitat at Sampling Site 5), while sand/gravel/mud as well as the little marginal vegetation also provided habitat for the highly sensitive families (Table 18). Moderately sensitive taxa were also mainly found in the stones, while some were find in the marginal vegetation and only one in sand/gravel/mud (Table 19). Less sensitive taxa were equally concentrated in stones and vegetation, with only a small number found in sand/gravel/mud (Table 20). The least sensitive taxa utilized all three biotopes (Table 21).

### Highly sensitive: taxa with high water quality preferences (SASS5 weightings 15 – 11)

The most sensitive macro-invertebrate family found in the Holsloot River during this study is the net-winged mountain midges of the family Blephariceridae (Diptera). Blepharicerid larvae inhabit fast-flowing streams and have suckers to hold on to rocks in the fast-moving water in which they live (Gerber & Gabriel 2002). Blephariceridae larvae were surprisingly not found at the Reference Site, but were present in the stones at Sampling Sites 1, 3 & 4 (Table 18).

The second most sensitive family, the notonemourid stoneflies (Plecoptera) which inhabits fast flowing mountain streams (Gerber & Gabriel 2002) was found at all the sampling sites, but not at Sampling Site 4 (Table 18).

Other highly sensitive taxa were mostly well represented in all the samples at the Sampling Sites in the upper reaches (Sampling Sites 1-3) with fewer at Sampling Site 4 and less at Sampling Site 5 (Table 18).

Although highly sensitive taxa were not expected to be found at Sampling Site 5 due to unfavourable habitat conditions and water quality, several of the taxa with high water quality preferences were present especially during periods of high water levels and strong stream flow, as in spring. The highly sensitive taxa present at Sampling Site 5 demonstrates the ability of the Holsloot River to, if habitat conditions improve, restock impacted downstream sites with organisms from upstream sites in times of uninterrupted flow.

<u>Moderately sensitive: taxa with moderate water quality preferences, but can tolerate lower water quality (SASS5 weightings 10 – 8)</u>

Other than what was expected, moderately sensitive taxa were better represented at the Reference Site than highly sensitive taxa. Two macro-invertebrate families namely Platycnemidae, (the brook damselflies/featherlegs) (Odonata) and one of the cased caddisfly families, the Lepidostomatidae (Trichoptera) were found only at the Reference Site during this study (Table 20).

Different to the highly sensitive taxa, the moderately sensitive taxa were not evenly distributed in the upper reaches of the river as most were found at the Reference Site (Table 18). While almost similar numbers of moderately sensitive families were found at Sampling Site 1 (16 taxa), Sampling Site 3 (18 taxa) & Sampling Site 4 (14 taxa), only six families were found at Sampling Site 5 (Table 19).

### Less sensitive: taxa with low water quality preferences (SASS5 weightings 7 – 5)

The less sensitive macro-invertebrate families were relatively evenly distributed from the upper reaches downstream to the lower reaches of the river. The micro caddisflies, Hydroptilidae (Trichoptera), which prefer slow to very slow flowing streams (Gerber & Gabriel 2002), were found only at Sampling Site 5. Creeping water bugs of the family Naucoridae (Hemiptera) which inhabit dense vegetation at the edges of streams (Gerber & Gabriel 2002), were in the upper reaches only found at Sampling Site 1, but were also found at Sampling Site 5 during the spring sample. Because there is no appropriate habitat for these water bugs at Sampling Site 5, they most likely washed down from the upper reaches of the river due to the strong current and high water level after good rains in spring, and will probably not be able to survive in the lower reaches. Water scavenger beetles of the Hydrophilidae family (Coleoptera) which are found amongst vegetation in muddy patches of quiet shallow pools or slow flowing water at the edges of streams (Gerber & Gabriel 2002), were found only at Sampling Site 5 during this study. Because of the variety of habitat available at Sampling Site 3, water measurers/marsh treaders of the family Hydrometridae (Hemiptera), which prefer floating vegetation in the backwaters of streams (Gerber & Gabriel 2002), were found only at this sampling site (Table 20).

### Least sensitive: taxa with very low water quality preferences (SASS5 weightings 4 – 1)

Crabs (Crustacea: Potamonautidae), midge larvae (Diptera: Chironomidae), mosquito larvae (Diptera: Culicidae), aquatic earthworms (Annelida: Oligochaeta), and nymphs of dragonflies (Odonata: Libellulidae) were found at all the Sampling Sites (Table 21). Moth flies of the family Psychodidae (Diptera), which prefer stagnant puddles with decaying organic material in streams (Gerber & Gabriel 2002), were only once found during this study and at Sampling Site 4 in summer when the water level was moderately low. A giant water bug (Hemiptera: Belostomatidae) was found only in summer, and at Sampling Site 1 which provides the appropriate habitat as giant water bugs prefer the bottom of shallow pools in backwater areas or quiet areas of streams (Gerber & Gabriel 2002). Water scorpions, representatives of the family Nepidae (Hemiptera), were only found at Sampling Site 4 in spring. Although they can survive in conditions with low water quality, water scorpions are known to prefer shallow pools or slow flowing streams (Gerber & Gabriel 2002), but as the water level was high and the flow strong in spring, this taxa had supposedly washed down from an upper area in the river where appropriate habitat features are present (Figure 61). Similarly, is it possible that a pigmy backswimmer (Hemiptera: Pleidae), which prefers dense vegetation and shallow clear water (Gerber & Gabriel 2002) found at Sampling Site 5 in winter, had been washed down from an appropriate upstream-habitat because of strong stream flow after rains prior to the sampling time (Figure 7; Table 21).

**Figure 61:** High water levels and strong flow, experienced in spring 2012 after good rains prior to the sampling, could have resulted in aquatic organisms being washed downstream with the strong current (Photo: ME Brand – Sampling Site 4).

### 5.2.3 Riparian Vegetation: Riparian Vegetation Response Index (VEGRAI) (Kleynhans *et al.* 2007).

According to the National Water Act (Act No 36 of 1998) a riparian habitat is defined as follows: “riparian habitat includes the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas.” (RSA 1989; Kleynhans *et al.* 2007).

Apart from the protection of water resources, DWAF (2005) gives the following functions of riparian habitats:

- store water and help reduce floods;
- stabilize stream banks;
- improve water quality by trapping sediment and nutrients;
- maintain natural water temperature for aquatic species;
- provide shelter and food for birds and other animals;
- provide corridors for movement and migration of different species;
- act as a buffer between aquatic ecosystems and adjacent land uses;
- can be used as recreational sites; and
- provide material for building, muti, crafts and curios.

According to Kleynhans *et al.* (2007), VEGRAI “is designed for qualitative assessment of the response of riparian vegetation to impacts in such a way that qualitative ratings translate into quantitative and defensible results.” The authors further state that “the products of VEGRAI are more than a measure of Ecological Category (EC) as the process and data are valuable in and of themselves.”

Dallas (2000) explains that the establishment of ecological reference conditions “enable the degree of degradation or deviation from natural conditions to be ascertained”. Comparing present status monitoring information to an expected ecological reference condition can provide a measure of the change/damage that human related disturbances potentially inflict on the system (Dallas 2000).

Table 22 lists the VEGRAI EcoStatus scores obtained for the five study sites.

**Table 22:** The VEGRAI EcoStatus score with corresponding Ecological Category per sampling site (according to Kleynhans *et al.* 2007). The description of the Ecological Categories in this table matches the Habitat Integrity Classes given in Table 6.

| **Sampling Site** | **VEGRAI Ecostatus score** | **Ecological Category** |
|---|---|---|
| 2 (Reference) | 70.3 | **C** |
| 1 | 69.2 | **C** |
| 3 | 59.2 | **C/D** |
| 4 | 55 | **D** |
| 5 | 33.3 | **D** |

According to Kleynhans *et al.* (2007), reference conditions often do not exist in the present state and therefore need to be reconstructed. Reconstruction of reference conditions involve information about the site and the specific system in which it occurs, together with an assessment of how the riparian zone would have responded in the absence of the various impacts (and their responses) present at the site (Kleynhans *et al.* 2007).

Dallas 2000 gives ten abiotic and biotic disturbances that can potentially cause degradation of a river ecosystem:

- Water abstraction
- Inundation
- Water quality
- Flow modification
- Bed modifications
- Channel modifications
- Presence of exotic aquatic fauna
- Presence of exotic macrophytes
- Solid waste disposal
- Indigenous vegetation removal
- Exotic vegetation encroachment
- Bank erosion

Riparian zones of ephemeral streams in mountainous catchment areas of the Western Cape are dynamic systems influenced by natural disturbances such as periodic floods, droughts and fire (Tabacchi *et al.* 1998). Such ephemeral streams are also characterised by variable conditions such as high water levels and strong flows during the rainy season, flooding after thunderstorms, as well as low water levels and flows during the dry season (Mucina & Rutherford 2006; Kleynhans *et al.* 2007).

Mucina & Rutherford (2006) describes *azonal* vegetation as units where “special substrates and/or hydrogeological conditions exert an overriding influence on floristic composition, structure and dynamics over macroclimate”. If such a vegetation unit however occurs exclusively within a biome, Mucina & Rutherford (2006) regard it as *intrazonal*. On a regional scale, alluvial Fynbos Riparian Vegetation, such as the vegetation found in the upper catchment area of the Holsloot River, is classified as such an *intrazonal* vegetation unit (Mucina & Rutherford 2006).

The expected reference state, impacts and/ disturbances, and the present state of the riparian vegetation as found in the marginal zone and non-marginal zone (a combination of the lower- and upper riparian zones) at the respective Sampling Sites are given in Table 23. Colour coding of the Sampling Sites refer to the present Ecological Category as found in the VEGRAI analysis (Table 22).

**Table 23:** The expected reference state, impacts and/ disturbances and the present state of riparian vegetation per sampling site.

| Sampling Sites | Riparian zones | Reference state | Impacts and/or Disturbances | Present state |
|---|---|---|---|---|
| **Reference Site (Sampling Site 2)** | Marginal zone | Alluvial Fynbos Riparian Vegetation (AZa 1) (Mucina & Rutherford 2006) is expected to be found along the narrow, fast flowing mountain stream with the canopy partially open, or completely closed in places (Figures 23 & 24, 62 & 63). Dense woody (trees and shrubs) and non-woody plants (sedges, grasses and herbaceous perennials) associated with Fynbos Riparian Vegetation is expected in more or less equal quantities of cover. Some degree of natural disturbance caused by floods and fire is expected. | Indigenous vegetation removal (natural)<br>Exotic vegetation encroachment<br>Flow modification<br>Channel modification<br>Bank erosion<br>(Tables 10, 12 & 15) | Alluvial Fynbos Riparian Vegetation limitedly interspersed with alien invader plants. Riparian vegetation canopy partially open to closed in places, but open where the riparian zone had burnt in 2011 (Figures 23 & 24, 62 & 63). A large amount of dead branches (due to fire) is present, new recruitment and post-fire re-growth observed. Non-woody plants (sedges, grasses and herbaceous perennials) in higher quantities due to reduction of competition and their rapid re-establishment following the recycling of nutrients as result of fire. Dominant plants include *Brabejum stellatifolium*, *Brachylaena neriifolia*, *Erica caffra* var. *caffra*, *Metrosideros angustifolia*, *Morella integra*, *Psoralea aphylla*, *Searsia angustifolia*, *Elegia capensis*, *Calopsis paniculata*, *Monopsis lutea*, *Hymenolepis parviflora*, *Isolepis prolifera*, *Pteridium aquilinum* subsp. *aquilinum* and *Juncus lomatophyllus.* Recruitment of alien invader species such as *Hakea sericea* and *Acacia mearnsii* in post-fire environment. Because of deposition of sand and accumulation of debris due to flow obstruction upstream of the low-flow causeway during flooding, bulldozing was done to channel the stream in the direction of the pipe under the low-flow causeway. Flow obstruction caused erosion of the riverbed at the site and downstream thereof. |
| | Non-marginal zone | Expect indigenous Hawequas Sandstone Fynbos on the mountain slopes to intrazonal Alluvial Fynbos Riparian Vegetation (AZa 1) (Mucina & Rutherford 2006) in the riparian zone with a natural cover of trees, shrubs, herbaceous perennials and geophytes. Dense cover of woody and non- | Indigenous vegetation removal (natural)<br>Exotic vegetation encroachment<br>(Tables 10, 12 & 15) | A gradual change of Indigenous Hawequas Sandstone Fynbos on the slopes to Fynbos Riparian Vegetation in riparian zone is evident.<br>Infestations of *Hakea sericea* is a problem on the slopes, especially on the northern side of the river. The vegetation cover is more open than expected due to the effect of fire, and erosion of the right bank is evident after flooding.<br>Dominant plants are *Searsia angustifolia, Halleria elliptica*, *Lobostemon glaucophyllus*, *Arctotis acuminata*, *Nerine humilis*, *Notobubon galbanum*, *Pelargonium crispum*, *Salvia chamelaeagnea*, and *Ursinia pinnata.* Moderate infestations of *A. mearnsii and A longifolia* are present in the riparian zone. |

Table 23 continue

| | | | | |
|---|---|---|---|---|
| **Sampling Site 1** | Marginal zone | A wide braided system of meandering streams is expected, especially because the area is situated just downstream of the confluence of three large drainage lines (Figures 13 & 14). Indigenous Hawequas Sandstone Fynbos is expected on the mountain slopes, and intrazonal Alluvial Fynbos Riparian Vegetation in the riparian zone. A mixture of these two vegetation types (with plants adapted to wet and dry phases) is expected on floodplain areas. Large, open and sparsely vegetated riparian areas (more densely vegetated marginal zones but less dense floodplains) reflect the dynamic nature of the alluvial system, which is characterised by periodic flooding. | Water quantity<br>Inundation<br>Flow modification (absence of frequent floods)<br>Exotic vegetation encroachment<br>(Tables 10, 12 & 15) | The construction of the dam and associated infrastructures destroyed vast areas of indigenous vegetation in the area.<br>The expected natural braided stream character is transformed to a single stream where the riparian zone is densely vegetated by woody and herbaceous Fynbos Riparian Vegetation (Figure 12). Dominant plants are *Brabejum stellatifolium*, *Psoralea aphylla*, *Metrosideros angustifolia, Morella integra*, *Elegia capensis*, *Calopsis paniculata* and *Brachylaena neriifolia.*<br>Moderate infestations of *Acacia mearnsii* and *Sesbania punicea* occur. |
| | Non-marginal zone | A wide braided system of meandering streams is expected (Figure 13) with large sparsely vegetated riparian areas, which are periodically flooded. ). Indigenous Hawequas Sandstone Fynbos is expected on the mountain slopes, and intrazonal Alluvial Fynbos Riparian Vegetation in the riparian zone. A mixture of these two vegetation types (with plants adapted to wet and dry phases) is expected on floodplain areas. | Water quantity<br>Inundation<br>Exotic vegetation encroachment<br>(Tables 10, 12 & 15) | The river is a single stream/run at the site where the natural sparsely vegetated lower- and upper zones is transformed to a riverine thicket with moderate infestations of *A. mearnsii* and *S. punicea* (Figure 12).<br>Indigenous Hawequas Sandstone Fynbos on the slopes is moderately infested with *H. sericea.* |

Table 23 continue

| | | | | |
|---|---|---|---|---|
| **Sampling Site 3** | Marginal zone | A dynamic broad alluvial area with a braided system of streams and floodplains, supporting Alluvial Fynbos Riparian Vegetation, is expected (Figure 16). A mixture of Alluvial Fynbos Riparian Vegetation and Hawequas Sandstone Fynbos (with plants adapted to wet and dry phases) is expected on floodplain areas. | Indigenous vegetation removal<br>Exotic vegetation encroachment<br>Flow modification<br>Channel modification<br>Agriculture<br>Water abstraction<br>Water quality<br>(Tables 10, 12 & 15) | Compared to Figure 16, a narrower, more densely vegetated riparian zone is evident in Figure 17. The riparian area is characterised by mostly broad, open divided streams, pools and marshy areas that support woody-, herbaceous-and aquatic plants of Fynbos Riparian Vegetation. Dominants are *Brabejum stellatifolium*, *Brachylaena neriifolia*, *Cliffortia strobilifera*, *Freylinia lanceolata*, *Metrosideros angustifolia*, *Morella integra*, *Psoralea aphylla*, *Searsia angustifolia*, *Salix mucronata*, *Juncus lomatophyllus*, *Elegia capensis* and *Calopsis paniculata*. Severe infestations of *A. mearnsii, Rubus fruticosus* and *S. punicea* are problematic. Successful recruitment of especially *A. mearnsii* is a problem and many stands of young trees are evident after fire swept through the kloof in 2011. |
| | Non-marginal zone | A dynamic broad alluvial area with a braided system of streams supporting Natural Fynbos Riparian Vegetation (Figure 16) is expected.<br>A gradual changeover from Indigenous Hawequas Sandstone Fynbos on the mountain slopes to Natural Fynbos Riparian Vegetation in the alluvial area is likely to occur. | Indigenous vegetation removal<br>Exotic vegetation Encroachment<br>Flow modification<br>Channel modification<br>Agriculture<br>Water abstraction<br>Water quality<br>Waste disposal<br>(Tables 10, 12 & 15) | A well-vegetated alluvial zone, supporting Fynbos Riparian Vegetation interspersed with exotics (Figure 17), is evident. Severe infestations of *A. mearnsii* and *S. punicea* are found in areas. Other exotics at the site include lawns (*Pennisetum clandestinum*) with ornamental *Quercus robur* and *Eucalyptus cladocalyx* trees. Indigenous Hawequas Sandstone Fynbos on the mountain slopes gradually change to Natural Fynbos Riparian Vegetation in the alluvial area on the western side of the river, but agricultural development marks the eastern side of the river. Gardens with abovementioned lawn and shade trees are planted between the stream and public facilities. A dense stand of *Phragmites australis* grows at the site. |

Table 23 continue

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| **Sampling Site 4** | Marginal zone | A dynamic broad alluvial area with a braided system of streams and associated floodplains (Figure 19), supporting a mixture of Natural Fynbos Riparian Vegetation, Cape Lowland Alluvial Vegetation and Breede Alluvium Fynbos (Mucina & Rutherford 2006) is expected. | Indigenous vegetation removal<br>Exotic vegetation encroachment<br>Inundation<br>Flow modification (absence of frequent floods)<br>Channel modification<br>Agriculture<br>Water abstraction<br>Water quality<br>Waste disposal<br>(Tables 11, 13 & 15) | A narrow riparian area supporting Fynbos Riparian Vegetation interspersed with exotic plants is found. The stream is confined to a channel with a narrow border of riparian vegetation fringing the stream. Where representatives of the Restionaceae (*Elegia capensis* and *Calopsis paniculata*) were prominent in the herbaceous layer at the upper sampling sites, grasses such as *Pennisetum macrourum* dominate this site. Vegetation includes woody-, herbaceous- and aquatic plants. Dominants are *Acacia mearnsii*, *Metrosideros angustifolia*, *Morella integra*, *Salix mucronata*, *Prionium serratum*, *Juncus lomatophyllus* and *Pennisetum macrourum.* Several young *Casuarina cunninghamiana* (frequently planted by farmers to act as windbreaks) have invaded the site. Many young *Salix mucronata* plants are establishing in the shallow cobblestone streambed. |
| | Non-marginal zone | A dynamic, broad alluvial area of a braided system of streams with associated floodplains, supporting Fynbos vegetation that is adapted to wet and dry phases (Figure 19) is expected.<br>Expect a gradual change from Indigenous Breede Sandstone Fynbos on the mountain slopes to the western side of the river, to a mixture of Natural Fynbos Riparian Vegetation, Cape Lowland Alluvial Vegetation and Breede Alluvium Fynbos in the alluvial area. | Indigenous vegetation removal<br>Exotic vegetation encroachment<br>Inundation<br>Flow modification<br>Channel modification<br>Agriculture<br>Water abstraction<br>Water quality<br>Waste disposal<br>(Tables 11, 13 & 15) | Disturbed: cobblestone levees are bulldozed on the eastern bank to facilitate the establishment of vineyards. Due to periodic bulldozing, only a narrow fringe of natural vegetation, interspersed with exotics, exists on both sides of the stream. The indigenous Hawequas Sandstone Fynbos (with irregular *Acacia mearnsii* and *Eucalyptus cladocalyx* infestations) on the mountain slopes to the western side of the river, gradually changes to a disturbed mixture of Natural Fynbos Riparian Vegetation and Breede Alluvium Fynbos in the alluvial area. *Anthospermum spathulatum* subsp. *spathulatum*, *Dicerothamnus rhinocerotis*, *Elytropappus gnaphaloides, Dodonaea viscosa* var. *angustifolia, Diospyros glabra, Seriphium plumosum,* Passerina *corymbosa*, *Searsia angustifolia, Hymenolepis parviflora* and various grass species are dominant at this site. |

Table 23 continue

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| **Sampling Site 5** | Marginal zone | A dynamic, broad alluvial area of a braided system of streams with large associated floodplains, supporting Fynbos vegetation that is adapted to wet and dry phases is expected. The riparian vegetation is expected to be a mixture of Natural Fynbos Riparian Vegetation, Cape Lowland Alluvial Vegetation and Breede Alluvium Fynbos. | Indigenous vegetation removal<br>Exotic vegetation encroachment<br>Flow modification<br>Channel modification<br>Agriculture<br>Water abstraction<br>Water quality<br>Waste disposal<br>(Tables 11, 13 & 15) | The riparian area is greatly disturbed or nearly destroyed. Frequent bulldozing of levees on both sides of the river and channelling of the stream had fragmented and destroyed most of the riparian vegetation. However interspersed with exotics, Fynbos Riparian plant species are still present. Grasses and sedges are prominent in the marginal area. Dominant indigenous species are *Juncus lomatophyllus, Crassula natans, Prionium serratum, Paspalum distichum*, *Digitaria* sp., *Freylinia lanceolata*, and *Salix mucronata.* Alien invader vegetation includes *Acacia longifolia*, *A. mearnsii, Eucalyptus cladocalyx* and *Rubus fruticosus.* |
| | Non-marginal zone | A dynamic, broad alluvial area of a braided system of streams with associated floodplains, supporting Fynbos vegetation that is adapted to wet and dry phases is expected.<br>The riparian vegetation is expected to be a mixture of Natural Fynbos Riparian Vegetation, Cape Lowland Alluvial Vegetation and Breede Alluvium Fynbos. | Indigenous vegetation removal<br>Exotic vegetation encroachment<br>Flow modification<br>Channel modification<br>Agriculture<br>Water abstraction<br>Water quality<br>Waste disposal<br>(Tables 11, 13 & 15) | Disturbed: Frequent bulldozing of levees on both sides of the river and establishment of vineyards had destroyed most of the riparian vegetation. Dominant indigenous species are *Aspalathus rugosa*, *Cliffortia strobilifera*, *Searsia angustifolia*, *Freylinia lanceolata, Salix mucronata, Prionium serratum, Pennisetum macrourum, Hymenolepis parviflora* and *Willdenowia incurvata*. Alien invader vegetation includes *Acacia longifolia, A. mearnsii* and *Eucalyptus cladocalyx*.<br>Disturbed: Frequent bulldozing of levees on both sides of the river and the establishment of vineyards had destroyed most of the riparian vegetation and grass species are prominent in the upper zone. |

### 5.2.3.a Reference Site

Although the Reference Site rendered the highest VEGRAI Ecostatus score (70.3%), the riparian vegetation is classified in the **Ecological Category C**: ***Moderately Modified***: *A loss or change in natural habitat and biota has occurred, but basic ecosystem functioning appears to be predominantly unchanged.* (Tables 6 & 22). Because the riparian area upstream is in a pristine state (Figures 51; 52), the riparian vegetation of Reference Site was expected to be classified in the Ecological Category A or B.

Due to the effects of natural disturbances (fire and flooding), the riparian vegetation at the Reference Site diverge from expected reference conditions in being more open (Figure 62) than the expected riverine thicket, where the canopy is almost completely closed in most places (Figure 63).

**Figure 62:** A partially open vegetation canopy at the Reference Site.

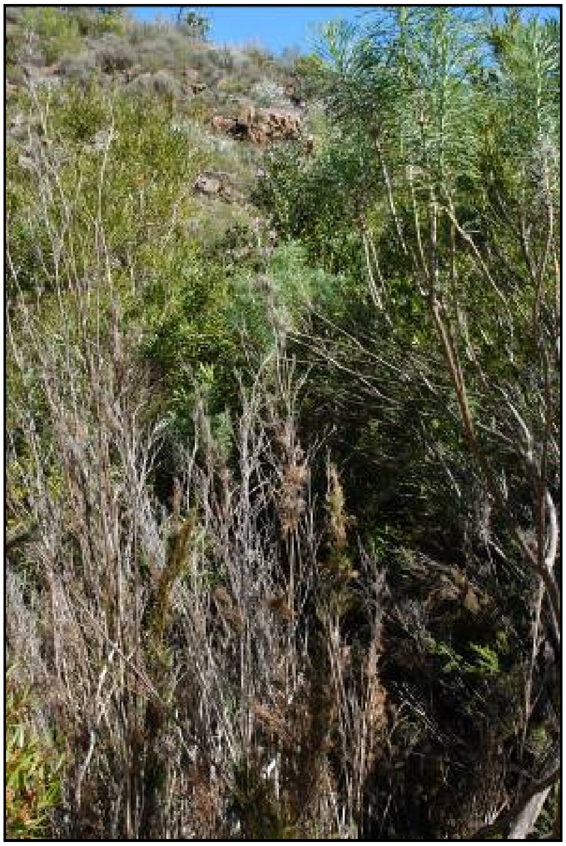


**Figure 63**: The riparian vegetation can completely cover the stream in some areas at the Reference Site.

Natural disturbances such as fires and floods create open areas through removal of indigenous vegetation (Figure 64) and change nutrient and water availability (Le Maitre, Richardson & Chapman 2004). However a natural event, the opening effects of the recent fire played a role in divergence from the expected pristine partially open- to closed canopy of the riparian vegetation at the mountain stream at the Reference Site (Table 23).

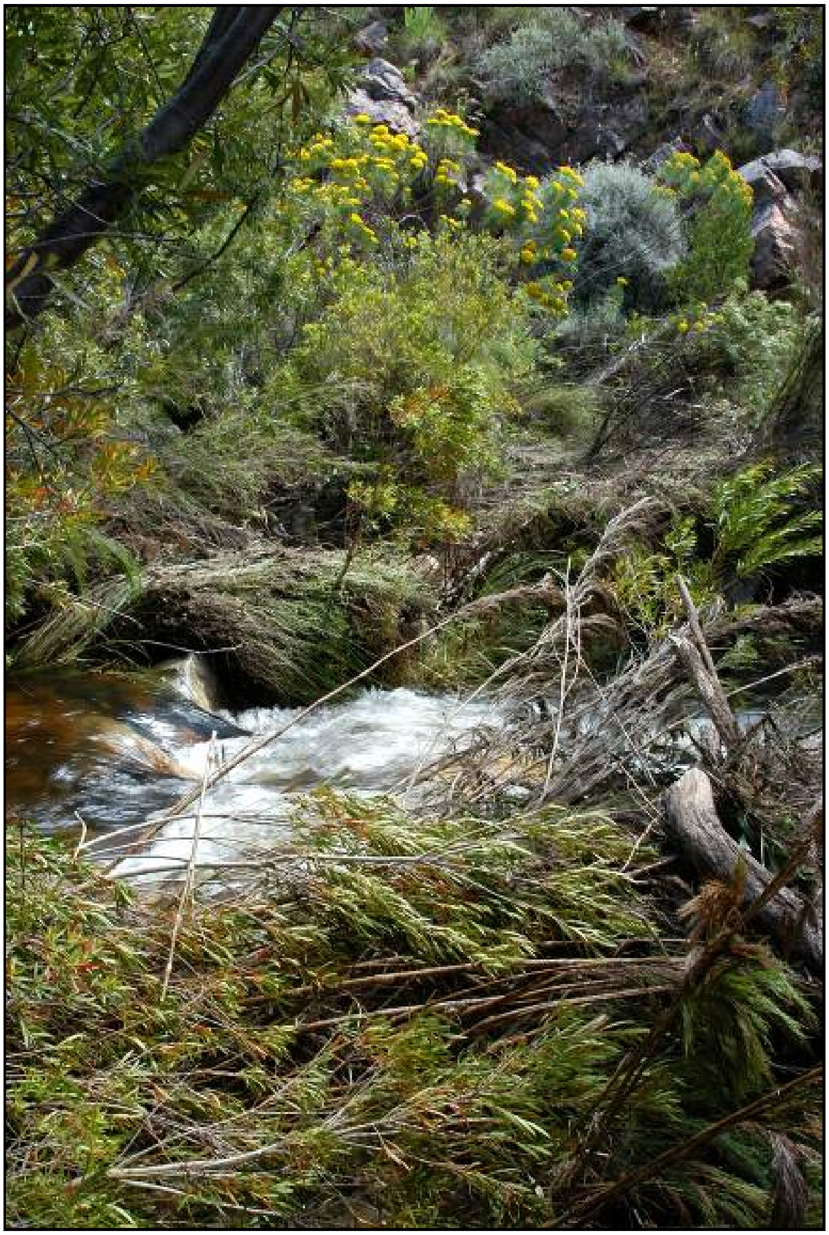


**Figure 64:** Natural floods cause opening of the riparian canopy through removal of indigenous vegetation. Tall *Morella integra* shrubs (in the foreground) and other riparian plants were uprooted during a flood in November 2008 at the Reference Site.

The road and low-flow causeway just downstream of the site obstruct natural stream flow – especially in the rainy season. The pipe under the low-flow causeway seems to be inadequate in facilitating the flow of a large quantity of water within a short period during floods. As a result of flow obstruction, water and woody debris accumulated at the causeway during a flood in November 2008 and led to erosion of the riverbed as well as the northern bank at the site, but also downstream thereof. The erosion is worsened when obstructions suddenly give way and release large quantities of water (Figure 53). Another factor contributing to the lower than expected VEGRAI Ecostatus score for the Reference Site is infrequent bulldozing at the site following the accumulation of sand and debris (deposited during the mentioned flood) to again canalise the stream flow in the direction of the pipe that takes the water under the low-flow causeway (Figure 65; Table 23).

**Figure 65:** Infrequent bulldozing at the Reference Site to canalise stream flow towards the pipe under the low-flow causeway after flooding had caused accumulation of debris and deposition of sand at the causeway.

A complete list of plant species is given in Appendix 1 (pp. 176-182). The national conservation status of rare and endangered plant species is given according to SANBI (2013).

Manders & Richardson (1992) state that forest communities intermingle with Fynbos in the south-western Cape, and that such communities “are usually restricted to sheltered ravines or stream banks”. Forest species include trees/shrubs such as *Brachylaena neriifolia*, *Cassine schinoides, Cunonia capensis*, *Ilex mitis, Kiggelaria africana, Maytenus acuminata, Maytenus oleoides*, *Myrsine africana,* and *Searsia angustifolia* (Manders & Richardson 1992).

Manders & Richardson (1992) found that forest species were mostly dispersed by birds and that seedlings were associated with a tall herb layer, a protected canopy cover of more than 50% and a well-developed layer of leaf litter. All of these characteristics are present in parts of the riparian zone upstream of the Reference Site (Figures 52 & 63). Furthermore had protected areas upstream of the Reference Site not burnt in 2011 (Figure 52). The exclusion of fire, soil moisture, soil nutrient levels, leaf litter and vegetation canopy cover are factors that influence the occurrence of forest species (Moll, McKenzie & McLachlan 1980; Manders & Richardson 1992; Luger & Moll 1993), and may possibly explain why the Reference Site was the only sampling site where the wild peach tree, *Kiggelaria africana*, was observed in the riparian zone.

The riparian vegetation at the Reference Site is functional in storing water, reducing floods, stabilizing stream banks, maintaining natural water temperature for aquatic species, providing shelter and food for animals, providing corridors for movement and migration of different species, as well as acting as a buffer between aquatic ecosystems and adjacent land uses. Because of these functions, the riparian zone at the reference site is able to support forest species. The riparian zone in this part of the river is used as a recreational site.

Woody plant species in the marginal riparian zone at the Reference Site includes (*naturalized exotics): *Acacia longifolia*, A. mearnsii*, Brabejum stellatifolium, Brachylaena neriifolia, Diospyros glabra, Erica caffra* var. *caffra, Hakea sericea*, Metrosideros angustifolia, Morella integra, Morella serrata, Podalyria calyptrata, Psoralea aphylla, Searsia angustifolia* and *Secamone alpini.*

Herbaceous plant species in the marginal riparian zone at the Reference Site includes (*naturalized exotics) *Athanasia trifurcata, Arctotis acuminata, Arctotis flaccida*, *Blechnum capense*, *Calopsis paniculata, Carpha glomerata*, *Dipogon lignosus,* *Dysphania ambrosioides**, *Elegia capensis, Ehrharta calycina, Ehrharta villosa* var. *villosa, Eragrostis curvula*, *Ficinia filiformis, Ficinia indica, Gunnera perpensa* (National conservation status: declining), *Helichrysum indicum, Helichrysum sp., Hymenolepis parviflora, Isolepis prolifera, Juncus lomatophyllus, Monopsis lutea, Moraea ramosissima, Nemesia acuminata, Othonna quinquedentata, Pellaea pteroides, Pennisetum macrourum, Pseudognaphalium luteoalbum** (isolated individuals), *Pteridium aquilinum* subsp. *aquilinum, Senecio rigidus, Silene gallica*, Seriphium cinereum, Sporobolus virginicus, Ursinia pinnata, Vellereophyton dealbatum, Wahlenbergia capensis* and *Wimmerella arabidea.*

Woody plant species in the non-marginal riparian zone at the Reference Site includes *Aspalathus sp., Cunonia capensis, Clutia alaternoides* var. *alaternoides*, *Clutia sp*., *Erica* cf. *armata* var. *armata*, *Gomphocarpus cancellatus, Halleria elliptica, Heeria argentea, Hypocalyptus sophoroides, Ilex mitis.* var. *mitis* (National conservation status: declining), *Indigofera frutescens, Kiggelaria africana, Laurophyllus capensis, Leucadendron sp., Lobostemon glaucophyllus, Maytenus acuminata* var*. acuminata, Maytenus oleoides, Montinia caryophyllacea, Myrsine africana, Notobubon galbanum*, *Osteospermum spinosum* var. *spinosum, Podalyria calyptrata, Prismatocarpus sp., Rafnia sp.* and *Seriphium cinereum.*

Herbaceous plant species in the non-marginal riparian zone at the Reference Site includes (*naturalized exotics) *Arctotis acuminata, Asparagus rubicundus, Asparagus scandens*, *Brunsvigia marginata, Crassula nudicaulis, Dipogon lignosus, Dysphania ambrosioides**, *Ehrharta calycina, Ehrharta villosa* var. *villosa, Ehrharta ramosa* subsp. *ramosa*, *Eragrostis curvula*, *Ficinia sp., Lachenalia orchioides* var. *orchioides*, *Lampranthus sp*., *Nerine humilis*, *Othonna parviflora*, *Othonna quinquedentata, Oscularia deltoides*, *Oxalis cf. livida O. microdonta*, *O. purpurea*, *Pelargonium crispum, Pelargonium patulum* var. *patulum, Pelargonium tabulare, Pseudoselago densifolia, Salvia chamelaeagnea, Senecio pinifolius*, *Senecio pubigerus* and *Ursinia pinnata.*

Six (6) different exotic species were found at the Reference Site. Apart from vast *Hakea sericea* infestation (especially on the mountain slope on the northern side of the stream) as well as the post-fire recruitment of *H. sericea* and *Acacia mearnsii* in marginal zone, the other exotic species were isolated individual plants.

### 5.2.3.b Sampling Site 1

According to Sieben & Reinecke (2008), few rivers in the Western Cape experience natural flood regimes as most are currently dammed in at least one place. The construction of the Stettynskloof Dam (Figure 47) transformed the upper reaches of the Holsloot River from a dynamic braided stream system to a relatively stable, single stream state in the area of Sampling Site 1 (compare Figures 12, 13 & 14). Together with the building of the dam came the construction of associated infrastructures such as roads, bridges as well as buildings related to human settlement (Figure 50; Tables 10 & 12). Humans are known to be drivers of biological invasions (Le Maitre *et al.* 2004; Spear, Foxcroft, Bezuidenhout & McGeoch 2013) and the introduction of alien invader plant species such as *Acacia mearnsii* is linked to the construction of the dam (E. Stofberg personal communication, April 2012).

Because of these impacts, together with damming created by the gauging weir at Sampling Site 1, this site is classified in the **Ecological Category C**: ***Moderately Modified***: *A loss or change in natural habitat and biota has occurred, but basic ecosystem functioning appears to be predominantly unchanged* (Tables 6 & 22). Although the VEGRAI Ecostatus score for Sampling Site 1 (69.2 %) is only slightly lower than that of the Reference Site, the upper two sampling sites acquired the highest riparian vegetation scores. Compared to the VEGRAI Ecostatus scores of the lower three Sampling Sites, this reflects the degree of human related influences on the riparian zones of the Holsloot River.

The dam has a direct influence on riparian zones in the upper reaches of the river. The dynamic nature of the system was destroyed as runoff (and periodic flood events) from three major streams in the upper catchment area is absorbed by the dam (Figures 12 & 13) (Richardson, Holmes, Esler, Galatowitsch, Stromberg, Kirkman, Pyšek & Hobbs, 2007).

Galatowitsch & Richardson (2005) found that seed regeneration of indigenous trees in headwater rivers of the Western Cape is not disturbance-triggered. While alien plant regeneration is favoured on unstable substrates, indigenous trees occur on stable banks and along rock fractures (Galatowitsch & Richardson 2005). Because the riparian zone receives much-reduced amounts of runoff due to the lack of natural disturbance (floods), the stable conditions at Sampling Site 1 facilitate dense riparian growth

(Figures 12 & 66). Because the level of inundation is furthermore maintained (due to continuous irrigation-water releases during the dry season, as well as the damming effect of the gauging weir) (Figures 21, 22 & 48), woody plant species tend to dominate the riparian zone at sampling Site 1 (Figure 67).

Hypo-limnetic releases from the dam generally lower the water temperature of the river and consequently influence the riparian habitat in this area. Furthermore has the construction of the dam introduced alien invader plant species to the area. *Acacia mearnsii* is a major problem in the riparian zone and *Hakea sericea* on the mountain slopes (Table 23). Both these species reduce the amount of runoff and groundwater available to the riparian zone (Versfeld & Van Wilgen 1986; Le Maitre, Van Wilgen, Chapman & McKelly 1996; Le Maitre, Van Wilgen, Gelderblom, Bailey, Chapman & Nel 2002).

Indigenous Hawequas Sandstone Fynbos grows on the slopes at Sampling Site 1 (Figure 68). The human settlement at the dam involves gardens with exotic ornamental plants of which some, such as *Pyracantha angustifolia* (orange firethorn) had spread to the riparian zone (limited occurrence).

The riparian vegetation at the Sampling Site 1 is functional in storing water, reducing floods, stabilizing stream banks, maintaining natural water temperature for aquatic species, providing shelter and food for animals, providing corridors for movement and migration of different species as well as acting as a buffer between aquatic ecosystems and adjacent land uses.

Woody plant species in the riparian zone at Sampling Site 1 includes (*naturalized exotics): *Acacia mearnsii**, *Anthospermum spathulatum* subsp. *spathulatum*, *Aspalathus sp., Brabejum stellatifolium, Brachylaena neriifolia, Cliffortia ruscifolia* var. *ruscifolia*, *Cliffortia strobilifera, Cliffortia sp., Diospyros glabra*, *Elytropappus gnaphaloides, Erica caffra* var. *caffra, Indigofera frutescens, Metrosideros angustifolia, Montinia caryophyllacea, Morella integra, Notobubon galbanum*, *Oedera squarrosa, Podalyria calyptrata, Psoralea aphylla, Pyracantha angustifolia**, *Salix mucronata, Searsia angustifolia* and *Sesbania punicea**.

Herbaceous plant species in the riparian zone at Sampling Site 1 includes (*naturalized exotics): *Anthoxanthum tongo, Athanasia trifurcata, Arctotis acuminata, Arctotis flaccida*, *Asparagus retrofractus*, *Asparagus rubicundus, Briza maxima, B. minor, Calopsis paniculata, Carpha glomerata*, *Chrysocoma ciliata*, *Conyza sumatrensis* var. *sumatrensis**, *Cullumia sp., Dipogon lignosus, Drosera trinervia, Elegia capensis, Ehrharta calycina, Ehrharta villosa* var. *villosa, Eragrostis curvula*, *Erica* cf. *armata* var. *armata*,, *Gomphocarpus cancellatus, Helichrysum indicum, Helichrysum sp.1, Hymenolepis parviflora, Isolepis prolifera, Juncus lomatophyllus, Monopsis lutea, Nemesia acuminata, Oftia africana, Othonna quinquedentata, Oxalis purpurea, Paspalum urvillei, Pennisetum clandestinum*, Persicaria lapathifolia*, Pseudoselago densifolia, Pteridium aquilinum* subsp. *aquilinum, Salvia chamelaeagnea, Senecio pubigerus*, *Senecio rigidus, Solanum retroflexum, Sporobolus virginicus, Ursinia pinnata, Vellereophyton dealbatum* and *Zantedeschia aethiopica.*

Six (6) different exotic species were found at Sampling Site 1. Apart from moderate infestations of *Acacia mearnsii* and *Sesbania punicea* in the riparian zone, the other exotic species were isolated individual plants.

**Figure 66:** The densely vegetated marginal zone at Sampling Site 1 with woody *Brabejum stellatifolium, Morella integra* and *Metrosideros angustifolia* trees. *Elegia capensis, Isolepis prolifera* and *Zantedeschia aethiopica* are visible in the herbaceous layer.

**Figure 67:** Because of the fairly deep pool character, the riparian vegetation at Sampling Site 1 is dominated by woody plants with sedges and grasses only in shallower areas such as on the western, more disturbed bank.

**Figure 68:** The Fynbos Riparian Vegetation in the riparian zone and Hawequas Sandstone Fynbos on the slopes at Sampling Site 1.

#### 5.2.3.c Sampling Site 3

Fynbos Riparian Vegetation (Figure 69), though interspersed with exotics, is found in the riparian zone at Sampling Site 3. The riparian zone is well vegetated with a dense tree- as well as herbaceous layer. In comparison with the Reference Site, the VEGRAI EcoStatus score obtained at Sampling Site 3 (59.2 %) is considerably lower (Table 22). The riparian vegetation here is classified as **Ecological Category C/D**: ***Moderately Modified***: *A loss or change in natural habitat and biota has occurred, but basic ecosystem functioning appears to be predominantly unchanged,* to ***Largely Modified***: *A loss of natural habitat and biota and a reduction in basic ecosystem functioning is assumed* (Tables 6 & 22).

Compared to the larger, more complex ecosystems along unregulated reaches of rivers, regulated rivers are characterised by spatially smaller and less diverse riparian ecosystems (Graf 2006). A comparison of historical images of the river to its present state (Figures 15, 16 & 17) describes the transformation of the dynamic character of the upper reaches of the river. This transformation was likely due to construction of the dam that caused reductions in water availability (Graf 2006). Because indigenous tree regeneration in Western Cape headwater rivers is very slow and not disturbance-triggered, the lack of natural disturbance such as large floods caused the thickening of riparian areas (Galatowitsch & Richardson 2005). Apart from the lack of floods (due to the presence of the dam) and the consequential thickening of natural riparian areas (compare Figures 12 & 14 and Figures 16 & 17), alien invader plant invasions are responsible for large parts of the dense riparian thickets visible in the present satellite images (Figures 12, 15 & 17).

Although bulldozing of the riverbed above Sampling Site 3 is prohibited (Holsloot Irrigation Board personal communication, October 2012), the creation of cobblestone weirs (to facilitate damming for water abstraction) does occur upstream of, and at Sampling Site 3 (Figure 15).

Galatowitsch & Richardson (2005) refer to Richardson, Macdonald, Holmes & Cowling (1992) when they state that the alien invasive Australian Acacia species (which were deliberately introduced to South Africa in the 19th century to be cultivated for a variety of purposes) have since spread extensively and are now widespread along Western Cape rivers.

Meek, Richardson & Mucina (2010) also emphasize the impacts of alien plant invasions in riparian areas. Apart from changes in channel morphology, the changes brought in canopy cover of alien plant invasions can cause reduced recruitment of native indigenous species (Galatowitsch & Richardson 2005), and increased transpiration which leads to reduction in stream flow (Dye and Jarmain 2004).

Due to the high green leaf area maintained by *Acacia mearnsii* infestations as well as by agricultural crops in the dry summer months (compared to mostly small and sclerophyllous leaves of indigenous vegetation), these plants have a high water demand in the dry season and cause vast reductions in the quantity of water available to the riparian vegetation (Dye & Jarmain 2004). According to flow measurements monitored by the Holsloot Irrigation Board (P.D. le Roux personal communication, January 2013), surface flow measured just upstream of Sampling Site 4 is reduced by 100 ℓ/second during the times when farmers upstream (at Sampling Site 3 and upstream thereof) subtract irrigation water from the river in January.

Galatowitsch & Richardson (2005) refer to Pieterse & Boucher (1997) when they mention that “like riparian scrub, Acacia regeneration is triggered by fire: sprouting and recruitment from the seed bank are stimulated by burning.” Galatowitsch & Richardson (2005) also refer to Van der Heyden (1998) and note “high seed production coupled with water dispersal ensures rapid distribution of Acacia propagules downstream of the initial invasion. After establishment, *Acacia mearnsii* is believed to serve as a sediment trap, creating a positive feedback for stand expansion.” The same process has been described for *Sesbania punicea* (Hoffmann & Moran 1988; Galatowitsch & Richardson 2005). Reduced water availability, vast recruitment of *Acacia mearnsii* (Figure 70) and *Sesbania punicea* in particular (especially after the fire in 2011), together with human related impacts (Tables 10 & 12) most probably caused the lowered riparian vegetation score (Table 23).

Abundant post-fire coppicing of *Searsia angustifolia* plants was observed in the non-marginal zone. A dense stand of *Phragmites australis* reeds and algae at the site may be indicative of eutrophication (Figure 71; Table 3).

Although the riparian vegetation at Sampling Site 3 is impacted as mentioned in the preceding paragraphs, the riparian zone can still maintain functions such as storing water, reducing floods, stabilizing stream banks, maintaining natural water temperature for aquatic species, providing shelter and food for animals as well as providing corridors for movement and migration of different species. Because of some of these functions, the riparian zone at this site is able to support forest species. Furthermore is the riparian zone in this part of the river used as a recreational site.

Woody plant species in the riparian zone at Sampling Site 3 includes (*naturalized exotics): *Acacia longifolia**, *A. mearnsii*, Anthospermum spathulatum* subsp. *spathulatum*, *Brabejum stellatifolium, Brachylaena neriifolia, Cassine schinoides, Cliffortia strobilifera, Diospyros glabra, Erica caffra* var. *caffra, Freylinia lanceolata, Metrosideros angustifolia, Montinia caryophyllacea, Morella integra, Podalyria calyptrata, Psoralea aphylla, Salix mucronata, Searsia angustifolia, Searsia glauca, Sesbania punicea*, Seriphium cinereum, S. plumosum* and *Quercus robur*.*

Herbaceous plant species in the riparian zone at Sampling Site 3 includes (*naturalized exotics): *Anthoxanthum tongo*, *Arctotis acuminata, Calopsis paniculata, Carpha glomerata*, *Conyza sumatrensis* var. *sumatrensis**, *Crassula natans*, *Cyperus esculentus* var. *esculentus, Cyathula sp*., *Dianthus sp., Dysphania ambrosioides*, Elegia capensis, Ehrharta calycina, Ehrharta villosa* var. *villosa, Ficinia filiformis, Grammatotheca bergiana* var. *bergiana, Helichrysum indicum, Helichrysum sp.2, Hymenolepis parviflora, Hypochaeris radicata*, Isolepis prolifera, Juncus capensis, J. kraussii* subsp. *kraussii, J. lomatophyllus, Lachenalia sp., Lobelia* cf. *erinus, Manulea rubra, Mentha aquatica, Monopsis lutea, Moraea sp., Nemesia acuminata, Oncosiphon sp., Othonna quinquedentata, Oxalis obtusa, O. purpurea, Paspalum urvillei, Pelargonium tabulare, Pennisetum clandestinum*, Pennisetum macrourum, Persicaria decipiens, Persicaria lapathifolia*, Phytolacca americana*, Pseudognaphalium luteoalbum*, Pseudoselago densifolia, Pseudoselago serrata, Phragmites australis, Prionium serratum* (National conservation status: declining), *Pteridium aquilinum* subsp. *aquilinum, Rubus fruticosus**, *Rumex acetosella* subsp *angiocarpus*, Senecio pubigerus*, *Senecio rigidus, Solanum retroflexum, Sporobolus virginicus, Taraxacum officinale*, Vellereophyton dealbatum, Wahlenbergia cernua, Wimmerella arabidea* and *Zantedeschia aethiopica.*

Where only six (6) different exotic plant species were found in the riparian zone at the Reference Site and at Sampling Site 1, the fourteen (14) different exotic species counted at Sampling Site 3, reflect the higher level of disturbance at this site. Severe infestations of *A. mearnsii, Rubus fruticosus* and *S. punicea* are problematic (Table 23). Where *Conyza sumatrensis* var. *sumatrensis*, *Rumex acetosella* subsp *angiocarpus* and *Persicaria lapathifolia* also occurred in dense stands, the other exotic plants were isolated individuals.

**Figure 69:** The marginal zone at sampling Site 3 with *Elegia capensis, Salix mucronata*, *Juncus lomatophyllus* and *Cliffortia strobilifera* in the foreground. The trees in the background are *Morella integra* and the alien invader *Sesbania punicea*.

**Figure 70:** Recruitment of the invader A*cacia mearnsii* is a problem at Sampling Site 3 after the fire in 2011.

**Figure 71:** Dense riparian vegetation at Sampling Site 3 includes grasses and sedges a stand of *Phragmites australis* reeds, *Salix mucronata* and young *Acacia mearnsii* trees. The large trees are *Quercus robur*.

### 5.2.3.d Sampling Site 4

Where a broad floodplain (which most likely supported a mixture of Natural Fynbos Riparian Vegetation, Cape Lowland Alluvial Vegetation and Breede Alluvium Fynbos) with a braided system of streams historically characterized the middle reaches of the Holsloot River (Figure 19), the present state riparian zone and single channelled stream is confined to bulldozed cobblestone levees. Stella, Rodrı´guez-Gonza´lez, Dufour & Bendix (2012) explain the effects of artificial cobble banks: "levees and river embankments affect channel geometry through width reduction, steepened hydraulic gradients, and coarser grain sizes, leading to drier conditions on colonisable landforms". Narrow borders of a mixture of Natural Fynbos Riparian Vegetation and Breede Alluvium Fynbos, interspersed with alien invader plant species, fringe the stream at this Sampling Site (Figure 72). Due to periodic disturbance and bulldozing of levees, riparian vegetation is less diverse (Stella *et al.* 2012) and grasses and pioneer plants dominate the floodplain areas downstream of this site. *Salix mucronata* plants are establishing in the shallow cobblestone streambed and on the banks (Table 23). Stands of *Prionium serratum* (palmiet) dominate the edges of the water where the extensive root systems of these plants play an important role in stabilizing the banks (Figure 73). In comparison with the Reference Site, the VEGRAI EcoStatus score obtained at Sampling Site 4 (55 %) is noticeably lower (Table 22). The riparian vegetation here is classified as **Ecological Category D**: ***Largely Modified***: *A loss of natural habitat and biota and a reduction in basic ecosystem functioning is assumed* (Tables 6 & 22). The undesired ecological category is a result of the following factors:

- the restriction of the former wide and braided stream and floodplain system to a single, channelled riparian zone,
- periodic bulldozing of levees (Figure 74) and cobblestone weirs
- a narrow buffer zone between the riparian area and the vineyards,
- disappearance of surface water in the dry season,
- water abstraction from the stream at the site as well as from boreholes in the area
- alien invader plant infestations and
- other human related disturbances indicated in Tables 11 & 13.

Although restricted to the edges of the stream, the riparian vegetation at Sampling Site 4 is still to an extent functional in storing water, but limited in reducing floods and stabilizing the stream banks. However limited, the narrow strip of vegetation can still provide shelter and food for animals, provide corridors for movement and migration of different species and act as a small buffer between aquatic ecosystems and adjacent land uses.

Woody plant species within the riparian zone at Sampling Site 4 includes (*naturalized exotics): *Acacia mearnsii*, Anthospermum spathulatum* subsp. *spathulatum*, *Aspalathus sp., Brabejum stellatifolium, Brachylaena neriifolia, Casuarina cunninghamiana*, Cliffortia ruscifolia* var. *ruscifolia*, *Cliffortia strobilifera, Dicerothamnus rhinocerotis, Diospyros glabra*, *Dodonaea viscosa* var. *angustifolia, Elytropappus gnaphaloides, Erica caffra* var. *caffra, Eriocephalus africanus* var. *paniculatus, Freylinia lanceolata, Metrosideros angustifolia, Morella integra, Passerina corymbosa, Psoralea pinnata* var. *pinnata, Salix mucronata, Searsia angustifolia,* and *Seriphium plumosum.*

Marginal herbaceous riparian plant species at Sampling Site 4 includes (*naturalized exotics): *Athanasia trifurcata, Calopsis paniculata, Cassytha ciliolata*, *Chrysocoma ciliata*, *Conyza sumatrensis* var. *sumatrensis**, *Crassula natans, Cyperus esculentus* var. *esculentus, Cyathula sp*., *Digitaria sp., Ehrharta calycina, Ehrharta villosa* var. *villosa, Elegia capensis, Erodium moschatum*, Grammatotheca bergiana* var. *bergiana, Helichrysum sp., Hymenolepis parviflora, Hypochaeris radicata*, Isolepis prolifera, Juncus kraussii* subsp. *kraussii, J. lomatophyllus, Lampranthus sp., Leysera gnaphalodes, Oftia africana, Paspalum urvillei, Pennisetum macrourum, Persicaria decipiens, Persicaria lapathifolia*, Prionium serratum* (National conservation status: declining), *Phytolacca americana*, Polycarpon tetraphyllum*, Pseudognaphalium luteoalbum*, Ruschia diversifolia, Salvia chamelaeagnea, Senecio burchellii*, *Senecio pubigerus*, *Setaria sphacelata* var. *sphacelata*, *Stachys aethiopica, Vellereophyton dealbatum, Wahlenbergia cernua, Willdenowia incurvata* and *Wimmerella arabidea.*

Compared to thirteen (13) different exotic species counted at Sampling Site 3, the vast reduction of the riparian zone at Sampling Site 4 caused that only nine different exotic species were counted at this site. *Eucalyptus cladocalyx* infestations are irregular but dense stands of *Acacia mearnsii* occur. The remainder of the mentioned exotic species at this Sampling Site are isolated individuals.

**Figure 72:** The riparian vegetation on the banks at Sampling Site 4 includes *Brabejum stellatifolium* and *Cliffortia strobilifera* (in the foreground).

**Figure 73:** *Acacia mearnsii* thrives in the lower zone and on the banks at Sampling Site 4, while *Prionium serratum* and *Salix mucronata* dominates the marginal zone.

**Figure 74:** Yellow flowered *Hymenolepis parviflora* can be seen in the disturbed non-marginal zone at Sampling Site 4 where a cobblestone levee is maintained.

### 5.2.3.e Sampling Site 5

The VEGRAI EcoStatus score obtained at Sampling Site 5 (33.3%) is the lowest of all the sampling Sites (Table 22). The riparian vegetation here is classified as **Ecological Category E**: ***Seriously Modified***: *The loss of natural habitat, biota and ecosystem functioning is extensive* (Tables 6 & 22).

The undesirable ecological conditions are due to the severe divergence from the natural/reference conditions. In the lower zone, the river should have been a large, dynamic network of divided streams and floodplains (Figure 19) supporting Cape Lowland Alluvial Vegetation, or a mixture of that, Natural Fynbos Riparian Vegetation and Breede Alluvium Fynbos.

"Alien plants have been shown to induce large-scale changes in riparian habitats, and they pose a major threat to the continued provision of key ecosystem services" (Meek *et al.* 2010). The same authors state that the manner in which human land-use shape the vegetation of riparian zones often creates conditions under which alien plant species thrive. Together with reduced flooding as a result of the dam in the upper catchment area as well as water abstraction for irrigation, the degradation of riparian habitats frequently create ideal conditions for the establishment, proliferation and spread of alien plants (Richardson *et al.* 2007; Meek *et al*. 2010). Because frequent bulldozing of levees on both sides of the river and channelling of the stream fragmented and damaged most of the riparian vegetation, alien invader species simply make use of the recruitment opportunity in the open spaces.

Although most of the riparian vegetation is destroyed through frequent bulldozing, indigenous vegetation (though interspersed with exotics) marks the fringes of the stream (Figure 75) and stands of *Prionium serratum* (palmiet) play an important stabilizing role (Figure 76).

The undesired ecological category is a result of the following factors:

- the restriction of the former wide and braided stream and floodplain system to a single, channelled riparian zone,
- periodic bulldozing of levees, cobblestone weirs and roads,
- no buffer zone between the riparian area and the vineyards,
- water abstraction from the stream as well as from boreholes
- alien invader plant infestations and
- other human related disturbances indicated in Tables 11 & 13.

The riparian zone at Sampling Site 5 is highly disturbed and no more, or to a very small degree functional in storing water and reducing floods. While frequent bulldozing disturbs the eastern banks, it is evident that fragmented stands of *Prionium serratum* stabilize the stream banks on the western side of the river (Figure 76). However extremely limited, the fragmented patches of vegetation, especially on the western side of the stream, can still provide shelter and food for animals, provide limited movement and migration of species, and act as a small and limited buffer between the stream and adjacent land uses (Figures 75 & 76).

Marginal woody riparian plant species at Sampling Site 5 includes (*naturalized exotics): *Acacia longifolia**, *A. mearnsii*, Anthospermum spathulatum* subsp. *spathulatum*, *Aspalathus rugosa*, *Cliffortia cuneata, Cliffortia ruscifolia* var. *ruscifolia*, *Cliffortia strobilifera, Elytropappus gnaphaloides, Eriocephalus africanus* var. *paniculatus,* *Eucalyptus cladocalyx**, *Freylinia lanceolata, Metrosideros angustifolia, Morella integra, Oedera squarrosa, Passerina corymbosa, Salix mucronata, Searsia angustifolia* and *Seriphium plumosum.*

Marginal herbaceous riparian plant species at Sampling Site 5 includes (*naturalized exotics): *Alectra sessiliflora* var. *sessiliflora*, Anthoxanthum tongo, Athanasia trifurcata, Briza minor, Calopsis paniculata, Conyza sumatrensis* var. *sumatrensis**, *Chrysocoma ciliata*, *Crassula natans*, *Cyathula sp*., *Digitaria sp., Elegia capensis, Ehrharta calycina, Ehrharta villosa* var. *villosa, Eragrostis curvula*, *Erodium moschatum*, Ficinia filiformis*, *Grammatotheca bergiana* var. *bergiana, Hymenolepis parviflora, Hypochaeris radicata*, Isolepis prolifera, Isolepis hystrix, Juncus kraussii* subsp. *kraussii, J. lomatophyllus, Lampranthus sp., Lobelia* cf. *erinus, Leysera gnaphalodes, Nymphoides indica* subsp. *occidentalis, Oenothera biennis*, Oftia africana, Paspalum distichum*, *Pennisetum macrourum, Persicaria decipiens, Persicaria lapathifolia*, Phytolacca americana*, Polycarpon tetraphyllum*, Prionium serratum* (National conservation status: declining), *Pseudognaphalium luteoalbum*, Pteridium aquilinum* subsp*. aquilinum, Rubus fruticosus**, *Rumex acetosella* subsp *angiocarpus*, Senecio burchellii*, *Senecio pubigerus*, *Setaria sphacelata* var. *sphacelata*, *Taraxacum officinale*, Ursinia pinnata, Vellereophyton dealbatum, Wahlenbergia cernua, Willdenowia incurvata* and *Wimmerella arabidea.*

Compared to the other Sampling Sites, Sampling Site 5 has the smallest amount of vegetation left in the riparian zone, but holds the highest number of different exotic plant species. The fifteen (15) different exotic plant species found at Sampling Site 5 is a reflection of the highest level of disturbance present at this site. Apart from the high level of invasion caused by *Acacia longifolia*, *A. mearnsii, Eucalyptus cladocalyx*, *Rubus fruticosus, Persicaria lapathifolia* and *Rumex acetosella* subsp *angiocarpus,* the remainder of the mentioned exotic species at this Sampling Site are isolated individuals.

**Figure 75:** The riparian zone at Sampling Site 5 is characterised by disturbance and infested with alien invader plants. Here, *Prionium serratum, Cliffortia strobilifera, Elegia capensis* and *Salix mucronata* are interspersed with alien invaders *Acacia mearnsii* and *Eucalyptus cladocalyx.* The upper zone is covered in grass.

**Figure 76:** *Prionium serratum* (palmiet) plays an important role in stabilization of the riverbanks, not only here at sampling Site 5, but also all along the Holsloot River.

## 5.3 References

Allan, J.D. 1995. Stream Ecology: *Structure and Function of Running Waters*. Chapman & Hall, London.

Bollmohr, S. & Schulz, R. 2009. Seasonal changes of macro-invertebrate communities in a Western Cape river, South Africa, receiving nonpoint-source insecticide pollution. *Environmental Toxicology and Chemistry*, 28:809–817.

Cooper, S.D., Lake, P.S., Sabater, S., Melack, J.M. & Sabo, J.L. 2012. The effects of land use changes on streams and rivers in Mediterranean climates. *Hydrobiologia,* DOI 10.1007/s10750-012-1333-4.

Couceiro, S.R.M., Hamada, N., Luz, S.L.B., Forsberg, B.R. & Pimentel, T.P. 2007. Deforestation and sewage effects on aquatic macroinvertebrates in urban streams in Manaus, Amazonas, Brazil. *Hydrobiologia,* 575:271–284.

Dallas, H.F. 1997. A preliminary evaluation of aspects of SASS (South African Scoring System) for the rapid bioassessment of water quality in rivers, with particular reference to the incorporation of SASS in a national biomonitoring programme. *South African Journal of Aquatic Science*, 23:79–94.

Dallas, H.F. 2000. *Ecological reference conditions for riverine macroinvertebrates and the River Health Programme, South Africa*. Proceedings of 1st WARFSA/WaterNet Symposium: Sustainable Use of Water Resources, Maputo.
Available on the internet at: http://www.bvsde.paho.org/bvsacd/cd46/dallas.pdf
(Accessed 10 November 2012).

Davies, B. & Day, J. 1998. *Vanishing Waters.* University of Cape Town Press, Cape Town.

Department of Water Affairs and Forestry (DWAF). 2005. *A practical field procedure for identification and delineation of wetland and riparian areas.* Department of Water Affairs and Forestry, Pretoria, Republic of South Africa.
Available on the internet at:
http://www.capetown.gov.za/en/CSRM/Documents/A_practical_field_procedure_for_identification_and_delineati.pdf (Accessed 6 October 2012).

Department of Water Affairs and Forestry (DWAF), 2008. National Aquatic Ecosystem Health Monitoring Programme (NAEHMP): *River Health Programme (RHP) Implementation Manual. Version 2*. Department of Water Affairs and Forestry, Pretoria, South Africa.

Dickens, C.W.S. & Graham, P.M. 2002. The South African Scoring System (SASS) Version 5 rapid bioassessment method for rivers. *African Journal of Aquatic Science*, 27:1–10.

Dodds, W.K. 2002. *Freshwater Ecology, concepts and Environmental Applications. Aquatic Ecological Series.* Academic Press, USA, San Diego.

Dye, P & Jarmain, C. 2004. Water use by black wattle (*Acacia mearnsii*): implications for the link between removal of invading trees and catchment streamflow response. *South African Journal of Science*, 100:40-44.

Galatowitsch, S. & Richardson, D.M. 2005. Riparian scrub recovery after clearing of invasive alien trees in headwater streams of the Western Cape, South Africa. *Biological Conservation*, 122:509–521.

Gerber, A. & Gabriel, M.J.M. 2002. *Aquatic Invertebrates of South African Rivers. Field Guide*. Resource Quality Services, Department of Water Affairs and Forestry.

Graf, W.L. 2006. Downstream hydrologic and geomorphic effects of large dams on American rivers. *Geomorphology,* 79:336–360.

Hoffmann, J.H. & Moran, V.C., 1988. The invasive weed Sesbania punicea in South Africa and prospects for its biological control. *South African Journal of Science*, 84:740–742.

Holmes, P.M., Esler, K.J., Richardson, D.M. & Witkowski, E.T.F. 2008. Guidelines for improved management of riparian zones invaded by alien plants in South Africa. *South African Journal of Botany,* 74:538–552.

Impson, N.D., Herdien, E. & Belcher, A. 2007. Status of River Health in *Western Cape Province State of Biodiversity 2007*, CapeNature Scientific Services Report.

Kleynhans, C.J. 1999. *Comprehensive Habitat Integrity Assessment.* Institute for Water Quality studies, Department of Water Affairs and Forestry.

Kleynhans C.J., Mackenzie J. & Louw M.D. 2007. *Module F: Riparian Vegetation Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2).* Joint Water Research Commission and Department of Water Affairs and Forestry report.

Kleynhans, C. J., Louw, M. D. & Graham, M. 2008. *Module G: EcoClassification and EcoStatus determination in River EcoClassification: Index of Habitat Integrity (Section 1, Technical manual)* Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 377-08

Le Maitre, D.C.,Van Wilgen, B.W., Chapman, R.A. & McKelly, D.H. 1996. Invasive plants in the Western Cape, South Africa: modelling the consequences of a lack of management. *Journal of Applied Ecology*, 33:161–172.

Le Maitre, D.C., Van Wilgen, B.W., Gelderblom, C.M., Bailey, C., Chapman, R.A. & Nel, J.A. 2002. Invasive alien trees and water resources in South Africa: case studies of the costs and benefits of management. *Forest Ecology and Management,* 160:143–159.

Le Maitre, D.C., Richardson, D.M. & Chapman, R.A. 2004. Alien plant invasions in South Africa: driving forces and the human dimension. *South African Journal of Science*, 100:103-112.

Le Maitre, D.C., Gaertner, M., Marchante, E., Ens, P., Holmes, P.M., Pauchard, A., O'Farrell, P.J., Rogers, A.M., Blanchard, R., Blignaut, J. & Richardson D.M. 2012. Impacts of invasive Australian acacias: implications for management and restoration. *Diversity and Distributions*, 17:1015–1029.

Luger, A.D. & Moll, E.J. 1993. Fire protection and afromontane forest expansion in Cape Fynbos. *Biological Conservation,* 64:51-56

Manders, P.T. & Richardson, D.M., 1992. Colonization of Cape fynbos communities by forest species. *Forest Ecology and Management*, 48:277–293.

McMillan, P.H. 1998. *An integrated habitat assessment system (IHAS v2) for the rapid biological assessment of rivers and streams.* A CSIR research project. Number ENVP-1 98132 for the water resources management programme. CSIR.

Meek, C.S., Richardson, D.M. & Mucina, L. 2010. A river runs through it: Land-use and the composition of vegetation along a riparian corridor in the Cape Floristic Region, South Africa. *Biological Conservation*, 143(1):156-164.

Moll, E.J., McKenzie, B. & McLachlan, D. 1980. A possible explanation for the lack of trees in the Fynbos, Cape Province, South Africa. *Biological Conservation,* 17:221-228.

Murray, K. 1999. *National Aquatic Ecosystem Biomonitoring Programme: National Implementation Assessment*. NAEBP Report Series No 8. Institute for Water Quality Studies, Department of Water Affairs and Forestry. Pretoria, South Africa.

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

Ollis, D.J., Boucher, C., Dallas, H.F. & Esler, K.J. 2006. Preliminary testing of the Integrated Habitat Assessment System (IHAS) for aquatic macroinvertebrates. *African Journal of Aquatic Science* 2006, 31(1):1–14.

Pieterse, P.J. & Boucher, C., 1997. Is burning a standing population of invasive legumes a viable control method? Effects of a wildfire on *Acacia mearnsii* population. *South African Forestry Journal*, 180:15–21.

Republic of South Africa (RSA). 1989. National water Act, 1998. *Government Gazette*, 398 (19182):1-101, Cape Town.

Richardson, D.M., Macdonald, I.A.W., Holmes, P.M. & Cowling, R.M., 1992. Plant and animal invasions. in: Cowling, R.M. (ed.), *The Ecology of Fynbos: Nutrients, Fire and Diversity.* pp. 271–308. Oxford University Press, Cape Town.

Richardson, D.M., Holmes, P.M., Esler, K.J., Galatowitsch, S.M., Stromberg, J.C., Kirkman, S.P., Pyšek, P. & Hobbs, R.J., 2007. Riparian vegetation: degradation, alien plant invasions, and restoration prospects. *Diversity and Distributions*, 13:126–139.

River Health Programme. 2011. *State of Rivers Report: Rivers of the Breede Water Management Area. Department of Water Affairs, Western Cape, Republic of South Africa.* Available on the internet at: http://www.dwaf.gov.za (Accessed 15 September 2012).

SANBI. 2013. Red List of South African plants version 2013.1. Available on the internet at: http://redlist.sanbi.org/ (Accessed January 2013).

Sieben, E.J.J. & Reinecke, M.K. 2008. Description of reference conditions for restoration projects of riparian vegetation from the species-rich fynbos biome. *South African Journal of Botany*, 74:401–411.

Spear, D., Foxcroft, L.C., Bezuidenhout, H. & McGeoch, M.A. 2013. Human population density explains alien species richness in protected areas. *Biological Conservation*, 159:137–147.

Stella, J.C., Rodrı´guez-Gonza´lez, P.M., Dufour, S. & Bendix J. 2012. Riparian vegetation research in Mediterranean-climate regions: common patterns, ecological processes, and considerations for management. *Hydrobiologia,* DOI: 10.1007/s10750-012-1304-9.

Tabacchi, E., Correl, D.L., Hauer, R., Pinay, G., Planty-Tabacchi, A.M. & Wissmar, R.C. 1998. Development, maintenance and role of riparian vegetation in the river landscape. *Freshwater Biology*, 40:497-516.

Thiere, G. & Schulz, R. 2004. Runoff-related agricultural impact in relation to macroinvertebrate communities of the Lourens River, South Africa. *Water Research*, 38:3092–3102.

Thirion, C. 2007. *Module E: Macroinvertebrate Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2).* Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria, South Africa.

Van der Heyden, F. (Ed.), 1998. *Rehabilitation following clearing of invasive alien vegetation in South African ecosystems: a preliminary review of best management* *practices.* CSIR Report ENV/S-C 98108, Division of Water, Environment and Forestry Technology, Stellenbosch, South Africa.

Van Staden, S. 2003. *A Case Study on the Use of Habitat Assessments and Biological Indices for the Management of Recreational Stream Fisheries*. MSc Dissertation, Rand Afrikaans University.

Van Staden, S. 2008. *Aquatic Ecological Study prior to the Proposed Development of the Ingula Bridge*, Scientific Aquatic Services CC. http://www.eskom.co.za. (Accessed 12 March 2010).

Versfeld, D.B. & Van Wilgen, B.W. 1986. *Impacts of woody aliens on ecosystem properties.* In: Macdonald, I.A.W., Kruger, F.J. & Ferrar, A.A. *The Ecology and Control of Biological Invasions in South Africa* (eds) pp. 239-246. Oxford University Press, Cape Town.

# Chapter 6: Conclusion & Recommendations

## 6.1 A comparison of 2008/9 & 2011/12 data

Since the previous 2008/2009 study, agricultural expansion on the farms in the part where water supply is managed by the Holsloot Irrigation Board (from the farms in the upper reaches to just downstream of Sampling Site 4) involved the establishment of approximately 150 hectares of vineyards as well as orchards to a lesser extent. According to DWAF guidelines, the amount of water needed by one hectare of vineyard is estimated at 6 500 $m^3$ per year (6 500 $m^3$ water = 6 500 000 ℓ) (PD le Roux personal communication, November 2012). According to the Holsloot Irrigation Board (HIB), 7 309 420 $m^3$ of water, registered for irrigation of 1 124.52 hectares, is abstracted from the river each year. This registered volume of water was calculated according to water availability during extremely dry periods and is an estimated maximum that can be abstracted. Because the total volume of registered water is currently abstracted and used by farmers, expansion of vineyards is facilitated by using water more efficiently through changing to water-saving irrigation methods such as the use of drippers instead of sprayers/spitters (HIB unpublished data; PD le Roux personal communication, November 2012).

In addition to the water abstracted from the river, an additional amount of 6 265 870 $m^3$ (registered for 963.98 hectares) is obtained from other sources such as mountain streams, boreholes, fountains, as well as the accumulation of irrigation return-flow (channelled to farm dams for re-use) (HIB unpublished data). Although the current quantity of registered water is estimated to be the maximum that can be abstracted from the river, further demand due to agricultural expansion should not put more pressure on the Holsloot River as farmers use their registered water more sparingly by means of efficient irrigation methods and store water in farm dams. It is however expected, that continued groundwater abstraction will negatively affect the amount of groundwater discharged into the river. This will be most pronounced during the hot summer months when irrigation demand is high.

The HIB manages the water supply of seventeen (17) farms from the first producing farm downstream of the Stettynskloof Dam in the upper reaches of the Holsloot River (upstream of Sampling Site 3) (Figure 15), to almost halfway between Sampling Sites 4 & 5. Water abstraction and the use of the river is not managed downstream from this point, but an additional seven (7) farms abstract water from the stream, boreholes and wells. Water for Goudini Wine Cellar is also abstracted from the stream at Sampling Site 5 (HIB unpublished data).

*Acacia mearnsii* (black wattle), is one of the top ten alien invader plant species that are mutually responsible for 81% of the water used by all invader plants in South Africa (Le Maitre, Versfeld, & Chapman 2000). The unfavourable effect of dense stands of *A. mearnsii* (black wattle) on the ecosystem and hydrology in and outside of riparian zones, as well as the effect of disturbances, such as floods, removal of indigenous vegetation and fire, on the regeneration and increase of these invasive plants is extensively documented (Versfeld & Van Wilgen 1986; Le Maitre, Van Wilgen, Chapman & McKelly 1996; Le Maitre 2004; Van Wilgen & Richardson 1985; Le Maitre *et al.* 2000; Van Wilgen, Richardson & Higgins 2001; Cullis, Görgens & Marais 2007; Marais & Wannenburgh 2008; Le Maitre, Gaertner, Marchante, Ens, Holmes, Pauchard, O'Farrell, Rogers, Blanchard, Blignaut & Richardson 2011).

Marais & Wannenburgh (2008) estimate the impact of alien invasives on water resources, and Cullis *et al.* (2007) report that infestations of riparian zones of seasonal rivers in mountain catchments (such as the Holsloot River), can lead to reduction in stream flow of 3 000 $m^3$/hectare/year. Dye & Jarmain (2004) state that a significant feature of black wattle trees is the year-round high green leaf area that permits continuous high rates of total evaporation. The authors found a correlation between the daily transpiration of black wattle, the mean daytime humidity as well as number of daylight hours. They further report that the maximum daily water use of a stand of black wattle trees come near 7 mm. Dye & Jarmain (2004) predict that the annual total evaporation from black wattle infested sites in riparian zones in the Western Cape may exceed 1 500 mm, a figure that exceeds the mean annual precipitation for the area (Table 2). The increase of alien plant invasions, especially black wattle infestations in the riparian zone, but also beyond the riparian zone, will increase the amount of water lost through total evaporation and cause les water to be available for irrigation purposes, especially in the dry season (Dye & Jarmain 2004).

Apart from an additional vineyard that was recently established on the eastern bank of the river at Sampling Site 4, the general information per sampling site as well as channel morphology and overall features had not changed drastically since the 2008/9 study period. Water temperature readings found at the sampling sites in 2011/12 correspond to that found in the previous study. The spring sample rendered the lowest temperatures during both study periods. Just as in 2011/12, water temperature at Sampling Site 1 was predominantly colder in comparison to the Reference Site. Stream temperature did similarly increase downstream along the course of the river. Higher stream temperatures downstream are due to the smaller effect that cold upstream water has on the stream temperature as water move farther away from the source. This is however also due to the greater amount of radiation reaching the water as a result of less shade due to removal of riparian vegetation as well as widening of the riverbed in the middle- and lower reaches.

It must be noted that only one temperature reading per season at each sample site in all probability does not reflect the seasonal temperature variation of the stream. An average of various readings throughout all seasons would render a more functional value.

Dissolved oxygen levels found in 2011/12 compare well with those found in 2008/9. Sampling Sites 4 & 5 mostly showed the lowest percentage of DO. During the wet season, DO at Sampling Site 4 was mostly lower than that downstream at Sampling Site 5. Respiration of aquatic organisms as well as decomposition of organic material in the deep murky pool at Sampling Site 4 most likely caused reduced oxygen levels at this site.

The uncontrolled fire in 2011 had a considerable effect on the recycling of nutrients in the study area. In 2011/12, the water pH was found to be higher at times of increased runoff in the wet seasons (winter and spring) due to the “liming” effect of the fire. In 2008/9, the water pH at Sampling Site 1 was acidic, with a relatively constant pH in autumn, winter and spring (pH 5 – 5.7), but neutral in summer (pH 7) which could have been due to photosynthesis of algae that uses dissolved carbon dioxide which reduces the acidity of the water. In 2011/12, the large differences in water pH measured at this sampling site could be ascribed to the liming effect of the fire, but also to the effects of photosynthesis and respiration. The water pH was found to be acidic in the dry season in summer 2011 (pH 6.2), even more so in autumn 2012 (pH 5.6), increased to alkaline water in winter 2012 (pH 7.9) and decreased again to almost neutral in spring 2012 (pH 6.8). While the liming effect of the fire most probably caused runoff to be more alkaline with consequent higher water pH values in the river, respiration of aquatic and riparian organisms produces $CO_2$ that dissolves in water as carbonic acid and thereby lowering the stream pH. With less runoff entering the stream, elevated levels of respiration of aquatic organisms as well as decomposition in the warm, dry season could explain the lower pH.

For both study periods, electrical conductivity (EC) of the stream was generally found to be below 50 µS/m. Due to the nutrient recycling effect of the fire in its catchment, a higher EC was found at the Reference Site in spring 2012. Apart from the nutrient enriched runoff after the fire, the higher concentration of dissolved salts from the upper zone to the lower zone is possibly due to a combination of natural downstream accumulation of salts, especially during low water levels and very low flow, as well as irrigation return-flow and human-related pollution. A parallel was found between the TDS measures and EC. TDS was not measured in the 2008/9 study.

Concerning the macro-invertebrates found in both studies, ASPT scores calculated for the sampling sites are generally comparable. The highest ASPT scores found in the upper reaches of the river at the Reference Site and Sampling Site 1 indicate that most of the sensitive organisms live in the relatively undisturbed upper reaches of the river. The high ASPT scores that were also found at Sampling Sites 3 & 4 during the rainy season indicate that the availability of diverse habitats, although sometimes created by human activities, and preferable levels of inundation can support sensitive organisms in the middle reaches of the river. The low ASPT at Sampling Site 5 is indicative of the loss of habitat and water quality that can be ascribed to the direct or indirect effects of human activities in the area.

## 6.2 The condition of physical drivers that determine biological responses and habitat integrity

Data obtained at the Reference Site (Sampling Site 2) indicate a **Habitat Integrity class A**: *natural, unmodified, oligotrophic, fast flowing mountain stream highly suited to sustain a diverse community of aquatic biota* (Tables 6, 14-16). The Riparian Vegetation Response Assessment Index however, classified the Reference Site in the **Ecological Category C** (Tables 6 & 22) due to the effects of natural disturbances (flooding and fire), the presence of alien invasive plants and limited human related impacts at the site

(Table 23). These impacts are however limited to the immediate area downstream of the Sampling Site. Apart from *Hakea sericea* seedlings that are establishing in the riverbed after the fire, the natural integrity of the narrow, fast flowing mountain stream is maintained upstream of the Sampling Site.

The purpose of analysing macro-invertebrate biological response was to provide an indication of river health and potential deterioration thereof. Healthy riparian zones maintain channel form and serve as important filters for light, nutrients and sediment. Riparian vegetation regulates river flow, improves water quality, provides habitats for faunal species and corridors for their movement, controls water temperature, provides nutrients and maintain bank stability (Murray 1999). Healthy riparian zones exist at the Reference Site and at Sampling Site 1, but loss of riparian vegetation is evident from where farming activities start upstream of and at Sampling Site 3, upstream of Sampling Site 4, and to a great extent all the way downstream to Sampling Site 5.

### Sampling Site 1

### Geomorphology and hydrology

Although water from the Kaaimansgatkloof drains into the river between the dam and Sampling Site 1 (Figures 2 & 13), the quantity and dynamics of flow at this site is affected by outlet/overflow of the Stettynskloof Dam. Construction of the dam, as well as the gauging weir changed the character of the river in the area of Sampling Site 1 (compare Figures 12, 13 & 14). Trapping and accumulation of sediment in the dam results in less sediment supplied to the river than would naturally have been the case. Because overflow at the gauging-weir at Sampling Site 1 never stops, migration of aquatic invertebrates is not seriously impaired by the structure, but sediment transport would be directly affected, so would the upstream migration of fish (Figure 48). The dam, weir and in-channel bridge supports influence channel pattern, width and depth as well as flow velocities. Damming, caused by the weir, create a more stable pool/run habitat that support more dense riparian vegetation on its edges (Figures 12, 21 & 22) in contrast with a natural divided stream character and less dense vegetation (Figures 13 & 14).

Water quality

Hypo-limnetic outlet of water from the dam can reduce water temperature at Sampling Site 1. Accumulation of organic debris in the large pool/run at the site, as well as the possibility of a low level of organic- and chemical pollution originating from the households and animals kept just upstream of the site, may possibly affect water quality at this point.

Biology

The Riparian Vegetation Response Assessment Index classified Sampling Site 1 in the **Ecological Category C** (Tables 6 & 22) due to the transformation of the river (from an open, broad braided stream system with associated floodplains to a single stream and riparian thicket) in this part of the catchment caused by the construction of the dam (Table 23). The Habitat Integrity of the site is classified in **Class B**: *Largely Natural with few* modifications (Tables 6, 14-16). The high number of taxa found at this site implies a high biodiversity. IHAS scores reveal the habitat ‘adequate to support a diverse aquatic macro-invertebrate community. High ASPT scores reflect the dominance of highly and moderately sensitive macro-invertebrates at Sampling Site 1. Compared to the Reference Site, the more stable conditions and limitation of sediment transport by the weir facilitate a considerably higher ratio of highly- and moderately sensitive taxa found in the GSM biotope at Sampling Site 1 (Table 18). Although transformation of the broad braided stream and associated floodplain character of the river had been transformed in the area of sampling Site 1 (as shown by results of the VEGRAI) after the dam was constructed, a largely natural ecological integrity is still maintained in this part of the river.

Sampling Site 3

As shown in an aerial photograph from 1942 (Figure 16), farming in the area of Sampling Site 3 was historically limited to the hills to the east of the river. More recent developments in the area, which include the establishment of vineyards and construction of camping sites with ablution facilities in the riparian zone upstream of Sampling Site 3, as well as a public venue at the site, will possibly have an effect on water quality and riparian ecology (Figure 15).

Geomorphology and hydrology

Farming activities beyond the riparian zone at the site, and in the riparian zone upstream of the site influence the river in the following ways:

- Water abstraction as well as dense stands of alien invader plants are likely to influence flow patterns in the dry summer months
- Removal of and damage to riparian vegetation can destabilize banks and increase the impact of floods
- Erosion cause larger than natural sediment inputs to the river
- Dense stands of alien invasive vegetation trap sediment and alter the configuration of the water channel and riverbed
- Bulldozing in the riparian zone modifies the channel and affects stream flow in that area

Water quality

- At times of heavy rain, cultivated slopes erode and carry high sediment loads to the river causing turbid waters
- Non-point-source pollution: irrigation return-flow enriched with leached organic and inorganic nutrients from fertilizers may cause eutrophication
- Point-source pollution from possible sewage, domestic effluent and chemical cleaning products (originating from domestic and tourist facilities) draining into the river may impair water quality.

Biology

The Riparian Vegetation Response Assessment Index however, classified Sampling Site 3 in the **Ecological Category C/D** (Tables 6 & 22) due to the presence of human related disturbances. These disturbances include the removal of indigenous riparian vegetation, agricultural development, water abstraction, channel- and flow modifications and lower water quality, which possibly relate to agricultural return-flow and waste management practices (Table 23). Although the upstream Habitat Integrity of Sampling Site 3 is classified as **Class C**: *Moderately Modified*, and the downstream, as well as overall Habitat Integrity is classified as **Class E**: *Seriously Modified*, the high number of taxa found at this site implies a high biodiversity. Opposed to the narrow fast flowing stream of the Reference Site, the high biodiversity at Sampling Site 3 is likely due to a larger variety of habitat available at the site, and nutrient inputs form CPOM and FPOM, not only supplied form upstream, but also on site due to greater productivity. Although ten (10) highly sensitive micro-invertebrate taxa were found at Sampling Site 3 opposed to nine (9) at the Reference Site (Table 17), there were much less moderately sensitive taxa and more less- and least sensitive taxa found at Sampling Site 3. This cause ASPT scores to be usually lower in comparison to the Reference Site, reflecting a lower overall sensitivity of organisms living at Sampling Site 3.

### Sampling Site 4

### Geomorphology and hydrology

Farming activities beyond and in the riparian zone influence the river in the following ways:

- Extensive water abstraction puts pressure on the river in the dry summer months, surface flow often stop at this site.
- The disturbance and removal of riparian vegetation due to cultivation of vines in the riparian zone cause the destabilization of banks and increase the impact of floods.
- Erosion causes more than natural sediment inputs into the river.
- The dense stands of alien invasive vegetation can trap sediment and alter the configuration of the water channel and riverbed
- Bulldozing in the riparian zone affects the channel as well as alters stream flow.

The proposed mining of stones from this point downstream could greatly influence the hydrology of the river.

### Water quality

Increased sediment inputs due to destabilized agricultural land cause turbid waters in times of heavy rain.

Point-source pollution from possible upstream sewage, domestic effluent and chemical cleaning products (originating from tourist facilities) draining into the river may impair water quality. Non-point-source pollution from irrigation return-flow or runoff enriched with organic and inorganic nutrients (as result of manure or fertilizers used in orchards or vineyards), as well as applications of lime may cause eutrophication, more saline water conditions and fluctuations in water pH.

### Biology

The Riparian Vegetation Response Assessment Index classified Sampling Site 4 in the **Ecological Category D** (Tables 6 & 22) due to the impacts of human related disturbances, which include the removal of indigenous riparian vegetation, agricultural development, water abstraction, channel- and flow modifications and lower water quality, which possibly relate to agricultural return-flow and waste management practices (Table 23). Due to canalization, bulldozing, and establishment of vineyards in the riparian zone, the Habitat Integrity of the site is classified as **Class E**: *Seriously modified* (Table 6, Table 16). The lower number of taxa found at this site implies a lower biodiversity. The extent of inundation and effect of water abstraction greatly affects this part of the river and according to different flow conditions, IHAS scores differ seasonally at this site. Apart from the spring sample, the lower ASPT scores in comparison to the Reference Site reflect a lower overall sensitivity of organisms living at Sampling Site 4. Although less than at the Reference Site, the highly sensitive taxa found at Sampling Site 4 were concentrated in the stones biotope (Table 18). This stresses the importance of this biotope and its contribution to the health of the Holsloot River ecosystem. Highly sensitive and moderately sensitive taxa were lower than at the Reference Site, less sensitive taxa were the same and least sensitive taxa were more than at the Reference Site. These findings imply that not only water quality, but also the level of inundation and stream flow had contributed to the loss of biodiversity at Sampling Site 4. The important cleansing properties of riparian vegetation is pointed out by the ability of vegetation and wetlands in the riverbed between Sampling Site 3 and Sampling Site 4 to remove excess nutrients from non-point-source pollution (and possible sporadic point-source pollution) at Sampling Site 3, and provide water of relative good quality at Sampling Site 4. Being fed by mountain streams along its upper reaches most probably contribute to increased resilience of the river to buffer human related impacts and the extent to which these factors influence the ecological status of the aquatic habitats.

## Sampling Site 5

### Geomorphology and hydrology

Extensive agricultural activities, that includes extensive drainage systems greatly affect the hydrology of the river downstream of Sampling Site 4. Due to bulldozing and canalization, the habitat is not natural. Apart from a few areas with natural riparian vegetation, now mostly dominated by *Prionium serratum* (palmiet), riparian vegetation in this part of the river is either completely removed, or interspersed by alien invader plants, or replaced by alien invader plants.

Water abstraction greatly influences the level of inundation in the dry months.

### Water quality

Not only water abstraction, but also irrigation return-flow from extensive drainage systems, greatly influences water quality, especially in the dry months.

### Biology

The Riparian Vegetation Response Assessment Index classified Sampling Site 5 in the **Ecological Category E** (Tables 6 & 22) due to the effects of human related disturbances, which include the destruction of indigenous riparian vegetation, agricultural development, water abstraction, channel- and flow modifications and lower water quality, which possibly relate to agricultural return-flow and waste management practices (Table 23). In comparison with the Reference Site, the higher numbers of less- and least sensitive macro-invertebrate taxa indicate low water quality and probable high level of pollution in the lower stretch of the river (Tables 18-21). Due to canalization, bulldozing, and just about complete loss of riparian vegetation, the Habitat Integrity of the site is classified as **Class F**: *Critically modified* with an almost complete loss of natural habitat and subsequent loss of basic ecosystem functioning due to human related influences (Tables 6 & 16). However, the occurrence of a few highly sensitive and moderately sensitive taxa at Sampling Site 5, indicates that organisms washed from lower impacted upstream habitats might probably be able to again occupy habitats downstream if water quality and habitat availability improve.

## Seasonal Variation

Plotting the ASPT values and SASS5 scores from both sets of data to Biological Bands (Dallas 2007; Figures 31 & 32), rendered similar, or improved Biological Band-categories in the 2011/12 sampling period compared to that of 2008/9. The Reference Site organised into Biological Band/Ecological **Category A**, *Natural (unmodified natural)* (Dallas 2007; Table 8; Figures 31 & 32) during times of higher levels of inundation (spring & winter), and in Biological Band/Ecological **Category B**, *Good (largely natural with few modifications*) (Dallas 2007; Table 8; Figures 31 & 32) during the dry season at lower levels of inundation (summer and autumn). This again illustrates the effect that seasonal fluctuations of the level of inundation can have on the ecology of the river. Sampling Site 1 corresponds to the Reference Site in summer, autumn and winter, but fell in Biological Band/Ecological **Category B** *(Good)* in spring due to a reduction in the variety of habitat available when the water level was the highest and flow the strongest. Sampling Site 3, interestingly, organised into Biological Band/Ecological **Category A** *(Natural)* in spring, was on the border between **Categories A & B** in winter and Biological Band/Ecological **Category B** in summer and in autumn. Sampling Site 3 is not natural and although the Habitat Integrity Index organised the upstream habitat into **Class B** *(Largely natural),* the downstream habitat was organised into **Class C** *(Moderately modified)* (Tables 6 & 16). Because of the variety of habitat for aquatic macro-invertebrates and increased productivity (not only due to the variety of habitats, but also due to supplementary nutrient inputs through human activities) at the site, SASS5 data alone does not provide a true reflection of the state of the river at this particular site. The same is true for Sampling Sites 4 & 5. Although the Habitat Integrity Index provides a truthful reflection of conditions at these lowland sites, the Biological Band categories underline the fact that sensitive macro-invertebrate taxa can inhabit seemingly unfavourable habitats impacted by human related activities. This signify the resilience and restoration capability of the Holsloot River.

The objectives of this study were:

1. To determine how bio-monitoring protocols and river health measurements applied at selected sites in the upper, middle and lower reaches of the Holsloot River compare to an undisturbed reference site.

Although alien plant invasions in the upper reaches provide propagules that could be dispersed to downstream areas, the Sampling Sites in the upper reaches of the Holsloot River (the Reference Site and Sampling Site 1) were found to be least disturbed by human-related impacts. Results obtained from Sampling Site 1 correspond with conditions at the Reference Site. The start of farming activities at Cross Mountain Creek Farm the upstream of sampling Site 3 (Figure 15) marks the start of divergence from Reference Site conditions. Due to water abstraction, alien plant infestations, removal of riparian vegetation and other human related disturbances, this divergence increases as farming- and other human related activities expand downstream. Sampling Site 3 shows a moderate divergence, Sampling Site 4 shows a larger divergence, and Sampling Site 5 shows the largest divergence from the Reference Site.

2. To determine how seasonal changes, catchment characteristics and -events are reflected in the ecological status of habitats in upper, middle and lower reaches of the river.

Results of both studies showed how seasonal variations in water temperature, stream-flow and the level of inundation could influence the habitat availability in the riparian zone, which consequently influence the diversity and abundance of macro-invertebrates at the respective sampling sites.

3. To determine how data gathered in 2011/2012 compare with data gathered in 2008/2009 and determine if the ecological state of the river had changed in the period between the two sampling times.

**Results of the 2008/9 study compare well with that of the 2011/12 study. Although the removal of riparian vegetation and expansion of vineyards with associated drainage systems had an effect on the river, the hypothesis ($H_1$) is accepted as the Index of Habitat Integrity and results from the SASS5 data indicate that the ecological status of the river has not deteriorated in the period between two sampling times.**

This short term study can only assess human impacts and the potential short term effects thereof, but long term monitoring is necessary to be able to identify seasonal trends and the extent to which human related impacts influence the ecological status of the upper-, middle- and lower reaches of the Holsloot River. Regular monitoring over the long term could recognize adverse practices so that their impact could be ameliorated in order to prevent further degradation of the Holsloot River, especially in the middle and lower reaches.

Where vines are cultivated in the riparian zone, most farmers welcome the proposed mining of cobblestone in the riverbed between Sampling Site 4 and Sampling Site 5, as removal of stones deepen the channel and reduce the risk of flood damage to vines on the banks. SASS5 data show that the cobblestones provide an important habitat for sensitive macro-invertebrate taxa (Tables 18 & 19). Mining of stone implies further destruction of natural riparian and in-stream vegetation (important for stabilization of banks as well as for biodiversity). Furthermore could the mining of stones disturb surface as well as subsurface flow through impairment of infiltration due to a potential increase in flow rate, degrade water quality and subsequently impair ecosystem functioning.

Nel *et al.* (2007) state that since tributaries are generally less regulated than main rivers, options may exist for conserving critically endangered ecosystems in intact tributaries. Despite the need for managing main rivers, Nel *et al.* (2007) highlight the importance of healthy tributaries for achieving river conservation targets. The mining of stones in the Holsloot River could therefore have a profound impact on the Breede River system.

## 6.3 Recommendations

Long-term maintenance of diverse biotic assemblages in river systems requires many different habitats, including high-quality riffles, riparian vegetation, stable banks and natural hydrology. Results for this study identified problem areas where efforts for improvement or at least maintenance of the present ecological status of the Holsloot River are recommended. To improve the ecological integrity of the river, especially in the middle and lower reaches, the following actions are suggested:

- An investigation into the possibility of supplying an ecological reserve from the Stettynskloof Dam and ensure the maintenance of such a reserve downstream to where the river joins the Breede River. Although the lower reaches of the Holsloot River are not natural anymore, this could maintain favourable levels of inundation as near possible to natural conditions in order to maintain the functioning of the river ecosystem.
- To ensure the maintenance of healthy, natural, well-vegetated riparian zones to buffer floods, neutralize low levels of organic pollution and the maintenance of ecosystem functioning by:
    - The removal and management of alien invasions, especially black wattle in the riparian zone (removal actions should start upstream)
    - Bringing further removal of riparian vegetation to an end and rehabilitate disturbed areas where possible with natural riparian vegetation

- The implementation and maintenance of natural buffer zones up to the 100-year flood mark. This implies the encouragement of restoration of natural riparian vegetation.
- Ensuring the appropriate treatment of organic waste and domestic effluent.
- The prevention of the mining of stones as well as the mining of metals which consequently would not only influence the ecological status of the Holsloot River negatively, but also that of the larger Breede River system.
- Continuous biological monitoring, especially in the dry season.

## 6.4 References

Cullis, J.D.S., Görgens, A.H.M. & Marais, C. 2007. A strategic study of the impact of invasive alien plants in the high rainfall catchments and riparian zones of South Africa on total surface Water Yield. W*ater South Africa*, 33:35–42.

Dallas, H.F. 2007. *River Health Programme: South African Scoring System (SASS) Data Interpretation Guidelines*. Department of Water Affairs and Forestry.

Dye, P. & Jarmain, C. 2004. Water use by black wattle (*Acacia mearnsii*): implications for the link between removal of invading trees and catchment streamflow response. *South African Journal of Science*, 100:40-44.

Le Maitre, D.C., Van Wilgen, B.W., Chapman, R.A. & McKelly, D.H. 1996. nvasive plants in the Western Cape, South Africa: modelling the consequences of a lack of management. *Journal of Applied Ecology*, 33:161–172.

Le Maitre, D.C., Versfeld, D.B. & Chapman, R.A. 2000. The impact of invading alien plants on surface water resources in South Africa: a preliminary assessment. *Water SA*, 26:397–408.

Le Maitre, D.C. 2004. Predicting invasive species impacts on hydrological processes: the consequences of plant physiology for landscape processes. *Weed Technology,* 18:1408–1410.

Le Maitre, D.C., Gaertner, M., Marchante, E., Ens, E., Holmes, P.M., Pauchard, A., O'Farrell, P.J., Rogers, A.M., Blanchard, R., Blignaut, J. & Richardson, D.M. 2011.

Impacts of invasive Australian acacias: implications for management and restoration. *Diversity and Distributions,* 17:1015–1029.

Marais, C. & Wannenburgh, A.M. 2008. Restoration of water resources (natural capital) through the clearing of invasive alien plants from riparian areas in South Africa — Costs and water benefits. *South African Journal of Botany,* 74:526–537.

Murray, K. 1999. *National Aquatic Ecosystem Biomonitoring Programme: National Implementation Assessment*. NAEBP Report Series No 8. Institute for Water Quality Studies, Department of Water Affairs and Forestry. Pretoria, South Africa.

Nel, J.L., Roux, D.J., Maree, G., Kleynhans, C.J., Moolman, J., Reyers, B., Rouget, M. & Cowling, R.M. 2007. Rivers in peril inside and outside protected areas: a systematic approach to conservation assessment of river ecosystems. *Diversity and Distributions*, 13:341–352.

Van Wilgen, B.W. & Richardson, D.M. 1985. The effect of alien shrub invasions on vegetation structure and fire behaviour in South African fynbos shrublands: a simulation study. *Journal of Applied Ecology,* 22:955-966.

Van Wilgen, B., Richardson, D. & Higgins, S. 2001. Integrated control of invasive alien plants in terrestrial ecosystems. *Land Use and Water Resources Research,* 1(5):1–6.

Versfeld, D.B. & Van Wilgen, B.W. 1986. *Impacts of woody aliens on ecosystem properties.* In: Macdonald, I.A.W., Kruger, F.J. & Ferrar, A.A. *The Ecology and Control of Biological Invasions in South Africa* (eds), pp. 239-246. Oxford University Press, Cape Town.

Appendix 1 Plant species list.

| **PLANTS: Families and species**<br>Exotics * highlighted in yellow; **Red data species** highlighted in red | **Common name** |
|---|---|
| BLECHNACEAE | |
| *Blechnum capense* Burm.f. | Deerfern |
| | |
| DENNSTAEDTIACEAE | |
| *Pteridium aquilinum* (L.) Kuhn subsp. *aquilinum* | Bracken |
| | |
| SINOPTERIDACEAE | |
| *Pellaea pteroides* (L.) Prantl | Myrtle Fern |
| | |
| AMARYLLIDACEAE | |
| *Brunsvigia marginata* (Jacq.) Aiton | Koningskandelaar |
| *Nerine humilis* (Jacq.) Herb. | Berg Lily |
| | |
| ARACEAE | |
| *Zantedeschia aethiopica* (L.) Spreng. | Arum Lily |
| | |
| ASPARAGACEAE | |
| *Asparagus rubicundus* P.J.Bergius | Wild asparagus |
| *Asparagus scandens* Thunb. | Asparagus ‘fern’ |
| *Asparagus retrofractus* L. | Katdoring |
| | |
| CYPERACEAE | |
| *Carpha glomerata* (Thunb.) Nees | Vleibiesie / Vleiriet |
| *Cyperus esculentus* L. var. *esculentus* | Nutgrass |
| *Ficinia filiformis* (Lam.) Schrad. | Star Grass |
| *Ficinia indica* (Lam.) Pfeiff. | Swartkopbiesie / Biesiekweek |
| *Ficinia* sp. | |
| *Isolepis prolifera* (Rottb.) R.Br. | Creeping Sedge / Vleigras |
| *Isolepis hystrix* (Thunb.) Nees | Mat Sedge |
| | |
| HYACINTHACEAE | |
| *Lachenalia orchioides* (L.) Aiton var. *orchioides* | Wild Hyacinth |
| | |
| IRIDACEAE | |
| *Moraea ramosissima* (L.f.) Druce | Vlei-uintjie |
| *Moraea* sp. | |

| | |
|---|---|
| JUNCACEAE | |
| *Juncus lomatophyllus* Spreng. | Leafy Juncus |
| *Juncus kraussii* Hochst. subsp*. kraussii* | Matting Rush |
| | |
| POACEAE | |
| *Anthoxanthum tongo* (Trin.) Stapf | |
| **Briza maxima* L. | Big Quaking Grass |
| **Briza minor* L. | Little Quaking-grass |
| *Digitaria* sp. | |
| *Ehrharta calycina* Sm. | Rooisaadgras |
| *Ehrharta ramosa* (Thunb.) Thunb. subsp. *ramosa* | |
| *Ehrharta villosa* J.H.Schult. var. *villosa* | Pipe Grass / Muggiegras |
| *Eragrostis curvula* (Schrad.) Nees | African Love Grass |
| *Paspalum distichum* L. | Buffelsgras |
| *Paspalum urvillei* Steud. | Giant Paspalum |
| **Pennisetum clandestinum* Hochst. ex Chiov. | Kikuyu |
| *Pennisetum macrourum* Trin. | Beddinggras |
| *Phragmites australis* (Cav.) Steud. | Common Reed / Fluitjiesriet |
| *Setaria sphacelata* (Schumach.) Stapf & C.E.Hubb. ex M.B.Moss var. *sphacelata* | Common Bristle Grass |
| *Sporobolus virginicus* (L.) Kunth | Brakgras |
| | |
| PRIONIACEAE | |
| **Prionium serratum (L.f.) Drège ex E.Mey. (declining)** | Palmiet |
| | |
| RESTIONACEAE | |
| *Willdenowia incurvata* (Thunb.) H.P.Linder | Sonkwasriet |
| *Elegia capensis* (Burm.f.) Schelpe | Fonteinriet |
| *Calopsis paniculata* (Rottb.) Desv. | Besemgoed |
| | |
| ACHARIACEAE | |
| *Kiggelaria africana* L. | Wild peach / Wildeperske |
| | |
| AIZOACEAE | |
| *Lampranthus* sp. | |
| *Oscularia deltoides* (L.) Schwantes | |
| *Ruschia diversifolia* L.Bolus | |
| | |
| AMARANTHACEAE | |
| **Dysphania ambrosioides* (L.) Mosyakin & Clemants | Wormseed |
| *Cyathula* sp. | |

| | |
|---|---|
| ANACARDIACEAE | |
| *Heeria argentea* (Thunb.) Meisn. | Kliphout |
| *Laurophyllus capensis* Thunb. | Iron Martin |
| *Searsia angustifolia* (L.) F.A.Barkley | Willow Karee |
| *Searsia glauca* (Thunb.) Moffett | Blue kuni-bush |
| | |
| APIACEAE | |
| *Notobubon galbanum* (L.) Magee | Blister bush |
| | |
| APOCYNACEAE | |
| *Gomphocarpus cancellatus* (Burm.f.) Bruyns | Bergmelkbos |
| *Secamone alpini* Schult. | Bostou |
| | |
| AQUIFOLIACEAE | |
| ***Ilex mitis* (L.) Radlk. var. *mitis* (declining)** | Cape Holly |
| | |
| ASTERACEAE | |
| *Arctotis acuminata* K.Lewin | |
| *Arctotis flaccida* Jacq. | |
| *Athanasia trifurcata* (L.) L. | Klaaslouwbos |
| *Brachylaena neriifolia* (L.) R.Br. | Waterwitels |
| *Chrysocoma ciliata* L. | Beesbos |
| **Conyza sumatrensis* (Retz.) E.Walker var. *sumatrensis* | Tall fleabane / Vaalskraalhans |
| *Cullumia* sp. | |
| *Elytropappus gnaphaloides* (L.) Levyns | |
| *Dicerothamnus rhinocerotis (L.f.) Koekemoer* | Renosterbos |
| *Eriocephalus africanus* L. var. *paniculatus* (Cass.) M.A.N.Müll.,P.P.J.Herman & Kolberg | Wild Rosemary / Kapokbos |
| *Helichrysum indicum* (L.) Grierson | |
| *Helichrysum* sp.1 | |
| *Helichrysum* sp.2 | |
| *Hymenolepis parviflora* (L.) DC. | Pokbos |
| **Hypochaeris radicata* L. | Hairy wild lettuce / Skaapslaai / Kat-oor |
| *Leysera gnaphalodes* (L.) L. | Skilpad Teebossie |
| *Oedera squarrosa* (L.) Anderb. & K.Bremer | Koorsbos |
| *Oncosiphon* sp. | |
| *Osteospermum spinosum* L. var. *spinosum* | |
| *Othonna parviflora* P.J.Bergius | Bobbejaankool |
| *Othonna quinquedentata* Thunb. | |
| **Pseudognaphalium luteoalbum* (L.) Hilliard & B.L.Burtt | Jersey cudweed / Roerkruid |
| *Senecio burchellii* DC. | Burchell-senecio |

| | |
|---|---|
| *Senecio pinifolius* (L.) Lam. | |
| *Senecio pubigerus* L. | Takluisbosje |
| *Senecio rigidus* L. | Poisonous Ragwort |
| *Seriphium cinereum* L. | |
| *Seriphium plumosum* L. | Slangbos |
| **Taraxacum officinale* Weber | Dandelion |
| *Ursinia pinnata* (Thunb.) Prassler | |
| *Vellereophyton dealbatum* (Thunb.) Hilliard & B.L.Burtt | |
| | |
| BORAGINACEAE | |
| *Lobostemon glaucophyllus* (Jacq.) H.Buek | |
| | |
| CAMPANULACEAE | |
| *Prismatocarpus* sp. | |
| *Wahlenbergia capensis* (L.) A.DC. | |
| *Wahlenbergia cernua* (Thunb.) A.DC. | |
| | |
| CARYOPHYLLACEAE | |
| *Dianthus* sp. | Wilde-angelier |
| **Polycarpon tetraphyllum* (L.) L | Fourleaf manyseed |
| **Silene gallica* L. | French Catchfly |
| | |
| CASUARINACEAE | |
| **Casuarina cunninghamiana* Miq. | Beefwood / Horsetail tree |
| | |
| CELASTRACEAE | |
| *Maytenus oleoides* (Lam.) Loes. | Klipkershout |
| *Cassine schinoides* (Spreng.) R.H.Archer | Spoon-wood / Lepelhout |
| *Maytenus acuminata* (L.f.) Loes. var. *acuminata* | Silky Bark |
| | |
| CRASSULACEAE | |
| *Crassula natans* Thunb., | Watergras |
| *Crassula nudicaulis* L. | |
| | |
| CUNONIACEAE | |
| *Cunonia capensis* L. | Butter-spoon tree / Rooi-els |
| | |
| DROSERACEAE | |
| *Drosera trinervia* Spreng. | |
| | |
| EBENACEAE | |

| | |
|---|---|
| *Diospyros glabra* (L.) De Winter | Blueberry bush |
| | |
| ERICACEAE | |
| *Erica caffra* L. var. *caffra* | Water Heath |
| *Erica* cf. *armata* var. *armata* | |
| | |
| EUPHORBIACEAE | |
| *Clutia alaternoides* L. var. *alaternoides* | |
| *Clutia* sp. | |
| | |
| FABACEAE | |
| **Acacia longifolia* (Andrews) Willd. | Port Jackson Willow |
| **Acacia mearnsii* De Wild. | Black Wattle |
| *Aspalathus rugosa* Thunb. | |
| *Aspalathus* sp. | |
| *Dipogon lignosus* (L.) Verdc. | Cape Sweet Pea / Bosklimop |
| *Hypocalyptus sophoroides* (P.J.Bergius) Baill. | Red Keur |
| *Indigofera frutescens* L.f. | Mountain Indigo |
| *Podalyria calyptrata* (Retz.) Willd. | Sweet-pea Bush |
| *Psoralea aphylla* L. | Fonteinbos |
| *Psoralea pinnata* L. var. *pinnata* | Blue Pea |
| **Sesbania punicea* (Cav.) Benth. | Brasilean Glory Pea |
| | |
| FAGACEAE | |
| **Quercus robur* L. | English Oak |
| | |
| GERANIACEAE | |
| **Erodium moschatum* (L.) L'Hér. | Heron's Bill |
| *Pelargonium crispum* (P.J.Bergius) L'Hér. | |
| *Pelargonium patulum* Jacq. var. *patulum* | Storksbill |
| *Pelargonium tabulare* (Burm.f.) L'Hér. | |
| | |
| GUNNERACEAE | |
| ***Gunnera perpensa* L. (declining)** | River Pumpkin |
| | |
| LAMIACEAE | |
| *Mentha aquatica* L. | Water Mint |
| *Salvia chamelaeagnea* P.J.Bergius | Bloublommetjiesalie |
| *Stachys aethiopica* L. | White Salvia |
| | |
| LAURACEAE | |

| | |
|---|---|
| *Cassytha ciliolata* Nees | Bobbejaantou |
| | |
| LOBELIACEAE | |
| *Lobelia* cf. *erinus* L. | Edging Lobelia |
| *Wimmerella arabidea* (C.Presl) L.Serra, M.B.Crespo & Lammers | |
| *Grammatotheca bergiana* (Cham.) C.Presl var. *bergiana* | |
| *Monopsis lutea* (L.) Urb. | Yellow Lobelia |
| | |
| MENYANTHACEAE | |
| *Nymphoides indica* (L.) Kuntze subsp. *occidentalis* A.Raynal | Floating Heart |
| | |
| MONTINIACEAE | |
| *Montinia caryophyllacea* Thunb. | Pepper Bush |
| | |
| MYRICACEAE | |
| *Morella integra* (A.Chev.) Killick | Western Lance-leaved Wax-berry |
| *Morella serrata* (Lam.) Killick | Lance-leaved Wax-berry |
| | |
| MYRSINACEAE | |
| *Myrsine africana* L. | Wild Myrtle |
| | |
| MYRTACEAE | |
| *Metrosideros angustifolia* (L.) Sm. | Smalblaar / Smalblad |
| **Eucalyptus cladocalyx* F.Muell. | Sugar Gum / Suikerbloekom |
| | |
| ONAGRACEAE | |
| *Oenothera biennis* L. | Evening primrose |
| | |
| OROBANCHACEAE | |
| **Alectra sessiliflora* (Vahl) Kuntze var. *sessiliflora* | Verfblommetjie |
| | |
| OXALIDACEAE | |
| *Oxalis obtusa* Jacq. | Suring |
| *Oxalis purpurea* L. | Bobbejaansuring |
| *Oxalis livida* Jacq. | |
| *Oxalis microdonta*T.M.Salter | |
| | |
| PHYTOLACCACEAE | |
| **Phytolacca american*a L. | American Nightshade |
| | |

| | |
|---|---|
| POLYGONACEAE | |
| **Rumex acetosella* L. subsp *angiocarpus* (Murb.) Murb | Sheep sorrel |
| **Persicaria lapathifolia* (L.) Gray | Spotted Knotweed |
| *Persicaria decipiens* (R.Br.) K.L.Wilson | |
| | |
| PROTEACEAE | |
| *Brabejum stellatifolium* L. | African Almond |
| **Hakea sericea* Schrad. & J.C.Wendl. | Needle Bush / Silky Hakea |
| *Leucadendron* sp. | Cone Bush / Tolbos |
| | |
| ROSACEAE | |
| *Cliffortia cuneata* Aiton | |
| *Cliffortia ruscifolia* L. var. *ruscifolia* | Climber's Friend / Steekbos |
| *Cliffortia* sp. | |
| *Cliffortia strobilifera* L. | Pypsteelbos / Vleibos |
| **Pyracantha angustifolia* (Franch.) C.K.Schneid. | Orange Firethorn |
| **Rubus fruticosus* L. | Blackberry |
| | |
| RUBIACEAE | |
| *Anthospermum spathulatum* Spreng. subsp. *spathulatum* | Jakkalsstert |
| | |
| SALICACEAE | |
| *Salix mucronata* Thunb. | African Willow |
| | |
| SAPINDACEAE | |
| *Dodonaea viscosa* Jacq. var. *angustifolia* (L.f.) Benth. | Sandolien |
| | |
| SCROPHULARIACEAE | |
| *Freylinia lanceolata* (L.f.) G.Don | Honey Bells |
| *Halleria elliptica* Thunb. | Bush Honeysuckle |
| *Manulea rubra* (P.J.Bergius) L.f. | Vingertjies |
| *Nemesia acuminata* Benth. | Leeubekkie |
| *Oftia africana* (L.) Bocq. | Koekblommetjiesbos |
| *Pseudoselago densifolia* (Hochst.) Hilliard | Powderpuff |
| *Pseudoselago serrata* (P.J.Bergius) Hilliard | Powderpuff |
| | |
| SOLANACEAE | |
| *Solanum retroflexum* Dunal | Nastergal |
| | |
| THYMELAEACEAE | |
| *Passerina corymbosa* Eckl. ex C.H.Wright | Gonna |

Appendix 2 Seasonal variation and abundance of macro-invertebrate families with different water quality preferences.

Seasonal variation and abundance of 'sensitive' families of macro-invertebrates with high water quality preferences as suggested in Thirion (2007).

| **Macro-invertebrate Families** | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seasons** | **S** | | | | | **U** | | | | | **A** | | | | | **W** | | | | |
| **Sampling sites** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** |
| **<u>Highly sensitive</u>: taxa with high water quality preferences** | | | | | | | | | | | | | | | | | | | | |
| Blephariceridae (15) | | | 1 | 1 | | A | | 1 | | | | | | | | | | | | |
| Prosopistomatidae (15) | | | | | | | | | | | | | | | | | | | | |
| Notonemouridae (14) | 1 | B | | | 1 | | | | | | | | | | | B | A | 1 | | |
| | 1 | A | | | | | | | | | | | | | | B | A | A | | |
| | | | | | | | | | | | | | | | | A | | | | 1 |
| Barbarochthonidae SWC (13) | A | A | | 1 | | B | 1 | | | | B | | | | | B | | 1 | | |
| | B | A | 1 | | | B | 1 | 1 | | A | A | | | | 1 | B | A | 1 | | |
| | B | B | | | | 1 | | A | | A | B | 1 | | | | B | | | | |
| Heptageniidae (13) | 1 | A | B | B | | 1 | | 1 | B | | | | B | 1 | | C | C | C | A | 1 |
| | | | | | | | | | | | | | A | | | A | A | A | | |
| | | | | | | 1 | | | 1 | | | | A | | | B | B | A | 1 | |
| Sericostomatidae SWC (13) | B | 1 | | | A | A | | A | A | | B | A | B | | | A | | B | 1 | |
| | B | A | 1 | A | | A | | A | B | | B | 1 | A | | | B | | B | | |
| | B | B | 1 | | | 1 | 1 | A | | | B | A | 1 | | | B | | B | | |
| Baetidae > 2 sp (12) | | B | | C | C | B | | | | B | | B | | B | | | B | B | B | C |
| | | B | | B | B | 1 | | | | B | | A | | B | | | B | B | B | A |
| | | B | | B | A | B | | | | B | | B | | 1 | | | | A | A | A |
| Helodidae (12) | | | | | | | | | | | | | | | | 1 | | | | |
| | | | | | | | | 1 | | | | | | | | 1 | | 1 | | |
| | | | | | | | 1 | | | | A | | | | | A | | | | |
| Hydropsychidae > 2 sp (12) | | B | | | | A | A | A | | | | B | B | | B | B | B | B | | |
| | | | | | | 1 | 1 | 1 | | | | | | | | B | 1 | A | | |
| | | | | | | 1 | A | 1 | | | | 1 | | | | 1 | A | | | |
| Teloganodidae SWC (12) | A | B | C | C | A | 1 | 1 | A | | | | | | | | | | | | |
| | | A | | | | 1 | | 1 | 1 | | | | | | | | | | | |
| | A | | 1 | A | | A | A | 1 | | | A | | | | | | | | | |
| Glossosomatidae SWC (11) | | | 1 | 1 | | | | | 1 | | A | 1 | 1 | 1 | | | 1 | A | | |
| | | | | | | 1 | | | | | | | | | | | | | | |
| | | | | | | 1 | | | | 1 | | | | | | | | | | |
| Petrothrincidae SWC (11) | | | | | | | | | | A | A | | | | | | | | | |
| Biotope: Stones | 5 | 7 | 4 | 6 | 4 | 7 | 3 | 5 | 3 | 1 | 3 | 4 | 4 | 3 | 1 | 6 | 5 | 7 | 3 | 2 |
| Biotope: Vegetation | 3 | 5 | 2 | 2 | 1 | 6 | 2 | 5 | 2 | 2 | 3 | 2 | 2 | 1 | 1 | 6 | 5 | 7 | 1 | 1 |
| Biotope: GSM | 3 | 3 | 2 | 2 | 1 | 7 | 4 | 4 | 1 | 4 | 4 | 4 | 2 | 1 | 0 | 6 | 2 | 3 | 2 | 2 |
| Ratio<br>Stones : Vegetation : GSM | 26:13:11 | | | | | 19:17:20 | | | | | 15:9:11 | | | | | 23:20:15 | | | | |

A: Count 2 to 10; B: Count 10 – 100; C: Count 100 – 1 000; S - Spring, U - Summer;

A - Autumn; W - Winter; GSM - Gravel/sand/mud; * Air-breathers

Seasonal variation and abundance of families of macro-invertebrates with moderate water quality preferences as suggested in Thirion (2007).

| **Macro-invertebrate Families** | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seasons** | **S** | | | | | **U** | | | | | **A** | | | | | **W** | | | | |
| **Sampling sites** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** |
| **<u>Moderately sensitive</u>: Taxa with moderate water quality preferences but can tolerate lower water quality.** | | | | | | | | | | | | | | | | | | | | |
| Platycnemidae (10) | | | | | | | 🟦 1 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | 🟩 1 | | | |
| Pisuliidae (10) | | 🟦 1 | | | | | | | | | 🟦 A | | | 🟦 1 | | | | | | |
| | | 🟩 B | | | | | | | | | 🟩 A | | | 🟩 1 | | | | 🟩 A | | |
| | 🟨 A | 🟨 B | | | | 🟨 1 | | | | | 🟨 1 | | | | | | | 🟨 A | | |
| Dixidae (10) | | | | 🟩 1 | | | | | 🟩 1 | 🟩 1 | | | | | | | 🟩 1 | | | |
| Athericidae (10) | | | | | 🟦 1 | | | | 🟦 1 | | | | | 🟦 A | | 🟦 1 | 🟦 A | 🟦 1 | | 🟦 A |
| | | | | 🟩 A | | | | | | | | | | 🟩 1 | | | | | | |
| | | | | | | | | | | | | | | | | 🟨 1 | 🟨 1 | 🟨 1 | | |
| Chlorocyphidae (10) | | | | | | | | | | | | | | | | | | | | |
| Philopotamidae (10) | | 🟦 B | | | | 🟦 1 | 🟦 A | | | | | 🟦 B | 🟦 A | | | 🟦 1 | 🟦 B | 🟦 A | | |
| | | 🟩 1 | | | | | | | | | | | | | | | 🟩 1 | | | |
| | | 🟨 1 | | | | | | | | | | | | | | | | | | |
| Lepidostomatidae (10) | | | | | | | 🟩 1 | | | | | | | | | | | | | |
| | | | | | | | 🟨 1 | | | | | | | | | | | | | |
| Leptophlebiidae (9) | 🟦 A | 🟦 B | 🟦 B | 🟦 B | 🟦 1 | 🟦 1 | 🟦 B | 🟦 B | 🟦 B | | 🟦 1 | 🟦 B | 🟦 B | 🟦 1 | | 🟦 A | 🟦 B | | 🟦 1 | |
| | 🟩 1 | 🟩 B | 🟩 A | 🟩 A | | | 🟩 A | 🟩 1 | 🟩 A | | | 🟩 1 | 🟩 A | | | 🟩 A | 🟩 B | | 🟩 A | |
| | 🟨 1 | 🟨 1 | | | | 🟨 1 | 🟨 A | 🟨 A | 🟨 1 | | 🟨 1 | 🟨 B | 🟨 A | | | | 🟨 1 | | | |
| Tricorythidae (9) | | | | | | | | 🟦 1 | | | | | | | | | | | | |
| | | | | | | | | 🟨 1 | | | | | | | | | | | | |
| Ecnomidae = Paranocmina (8) | | | | | | 🟦 A | 🟦 1 | 🟦 A | 🟦 A | | 🟦 1 | 🟦 B | 🟦 1 | 🟦 1 | | | | | | |
| | | | | | | | | 🟩 A | 🟩 1 | | | | 🟩 1 | | | | | | | |
| | | | | | | | 🟨 1 | | | | 🟨 A | | | 🟨 1 | | | | | | |
| Aeshnidae (8) | | 🟦 1 | 🟦 1 | 🟦 A | | | | | | | | 🟦 B | 🟦 A | 🟦 A | 🟦 A | | 🟦 B | 🟦 B | | 🟦 A |
| | | | | | | | | | | | | 🟩 B | | 🟩 1 | 🟩 1 | | 🟩 1 | 🟩 A | 🟩 A | 🟩 B |
| | | | | | | | | | | | | 🟨 A | | | | | 🟨 1 | | 🟨 1 | |
| Corydalidae (8) | | 🟦 A | 🟦 A | | | 🟦 A | 🟦 A | 🟦 A | | | 🟦 B | 🟦 B | 🟦 B | | | 🟦 B | 🟦 A | 🟦 B | 🟦 1 | |
| | | | | | | 🟩 A | 🟩 1 | 🟩 1 | | | | | | | | | | 🟩 A | | |
| | | | | | | 🟨 A | | | | | 🟨 A | 🟨 B | | | | 🟨 1 | | | | |
| Elmidae* (8) | | | | | | 🟦 A | | 🟦 1 | 🟦 1 | 🟦 1 | 🟦 A | 🟦 A | 🟦 1 | 🟦 1 | | 🟦 A | 🟦 A | | | |
| | | 🟩 1 | | | | | | | 🟩 1 | | 🟩 1 | | | 🟩 1 | | | 🟩 A | | | |
| | | 🟨 1 | | | | | | 🟨 1 | | | 🟨 1 | 🟨 A | | | | 🟨 1 | | | | 🟨 1 |
| Hydracarina (8) | | 🟦 1 | | | | | | | | | | 🟦 A | | | 🟩 1 | | | | | |
| Hydraenidae (8) | | | | | | | | | | | | | | | | | 🟦 1 | | | |
| | | | | | | | | | | | | | | | | 🟩 1 | | | 🟩 1 | |
| | | | | | | | | | | | | | | | | | 🟨 1 | | | |
| 🟦 Biotope: Stones | 1 | 6 | 3 | 2 | 2 | 5 | 5 | 5 | 4 | 1 | 5 | 7 | 6 | 6 | 1 | 5 | 7 | 4 | 2 | 2 |
| 🟩 Biotope: Vegetation | 1 | 4 | 1 | 3 | 0 | 1 | 3 | 3 | 4 | 1 | 2 | 2 | 2 | 4 | 2 | 2 | 6 | 3 | 3 | 1 |
| 🟨 Biotope: GSM | 2 | 4 | 0 | 0 | 0 | 3 | 3 | 3 | 1 | 0 | 5 | 4 | 1 | 1 | 0 | 3 | 4 | 2 | 1 | 1 |
| Ratio<br>Stones : Vegetation : GSM | 14:9:6 | | | | | 20:12:10 | | | | | 25:12:11 | | | | | 20:15:11 | | | | |

A: Count 2 to 10; B: Count 10 – 100; C: Count 100 – 1 000; S - Spring, U - Summer;

A - Autumn; W - Winter; GSM - Gravel/sand/mud; * Air-breathers

Seasonal variation and abundance of families of macro-invertebrates with low water quality preferences as suggested in Thirion (2007).

| **Macro-invertebrate Families** | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seasons** | **S** | | | | | **U** | | | | | **A** | | | | | **W** | | | | |
| **Sampling sites** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** |
| **<u>Less sensitive</u>: taxa with low water quality preferences** | | | | | | | | | | | | | | | | | | | | |
| Naucoridae* (7) | | | | | A | | | | | | A | | | | | A | | | | |
| | | | | | | | | | | | 1 | | | | | 1 | | | | |
| | | | | | | | | | | | 1 | | | | | | | | | |
| Gomphidae (6) | | | | | | | | | | | | A | 1 | | | B | | | | |
| | | 1 | | 1 | | | | | | 1 | | 1 | 1 | A | | A | | A | | |
| | | | | A | | | | 1 | 1 | A | | B | B | A | A | 1 | | A | A | 1 |
| Hydropsychidae 2 sp (6) | | | A | | | | | A | A | | B | | | | | | | | | |
| | | | | | | | | | | | B | | | | | | | | | |
| Leptoceridae 6 | A | | | | 1 | | | 1 | | | B | | | | | B | | | | |
| | B | | A | A | B | | | A | A | 1 | B | | A | | | C | | A | | |
| | B | | | 1 | A | | A | A | | | B | | A | | | B | | A | | |
| Baetidae 2 sp 6 | A | | B | | | | B | C | | | B | | B | | A | | | | | |
| | A | | A | | | | 1 | A | A | | A | | | | | | | | | |
| | A | | 1 | | | | 1 | B | A | | A | | A | | | | | | | |
| Caenidae (6) | | | | | | A | | | | B | | 1 | | | | A | | | | |
| | 1 | | | | 1 | | | | | | | B | 1 | | | | | | | |
| | A | | | | | | | | | | | 1 | 1 | 1 | | B | | | 1 | |
| Hydroptilidae (6) | | | | | | | | | | | | | | | | | | | | A |
| | | | | | | | | | | | | | | | | | | | | 1 |
| | | | | | | | | | | | | | | | | | | | | 1 |
| Hydrometeridae (6) | | | | | | | | | | | | | 1 | | | | | | | |
| Ceratopogonidae (5) | | | | | | | | | | A | | | | 1 | 1 | | 1 | | | |
| | | | | | | | 1 | | 1 | 1 | | | | | | | | | | |
| | 1 | 1 | | | | 1 | 1 | 1 | | | 1 | | | | | 1 | | | | |
| Tabanidae (5) | | A | | | | | | | | | | 1 | 1 | | | | | 1 | | |
| | | 1 | | | | | | | | | A | | 1 | | | | 1 | | | |
| Dytiscidae * (5) | | | | | | | | | | 1 | 1 | | 1 | | | | | | | |
| | | | | A | | 1 | | | | | 1 | A | A | A | A | A | | 1 | A | |
| | B | | | | | | A | | | | A | | | | | 1 | | | | |
| Gerridae* (5) | | | | | | | | | | | | | 1 | | A | | | | | |
| Gyrinidae (5) | | | | | 1 | A | | 1 | | B | 1 | | B | 1 | | | | 1 | | 1 |
| | | | | A | 1 | 1 | | | A | A | 1 | | | 1 | | | | A | | 1 |
| | 1 | | | 1 | | | | 1 | | | | | | | | 1 | | | | |
| Hydrophilidae* (5) | | | | | | | | | | | | | | | A | | | | | |
| Simuliidae (5) | | A | A | B | C | C | 1 | A | A | B | B | B | A | A | | A | B | B | | C |
| | 1 | A | | A | | B | | 1 | | B | | 1 | | | | A | A | A | | B |
| | | | | A | | B | | A | | | B | | | | | | | | | |
| Tipulidae (5) | | A | 1 | | | | | | | | 1 | | 1 | | | A | 1 | | | 1 |
| | | | | | | | | 1 | | | | | | | | | | | | |
| | | | | | | A | A | 1 | | | 1 | 1 | 1 | | | A | 1 | | | |
| Veliidae/M...veliidae* (5) | | | | | | | | | | | | | A | | | | | | | |
| | | | B | | | A | | 1 | | | | | A | A | A | | | A | | |
| | | | | | | | | | | | | 1 | | | | | | 1 | | |
| Biotope: Stones | 2 | 3 | 4 | 1 | 4 | 3 | 2 | 5 | 2 | 5 | 8 | 4 | 8 | 3 | 2 | 6 | 3 | 3 | 0 | 4 |
| Biotope: Vegetation | 4 | 3 | 3 | 5 | 3 | 4 | 2 | 5 | 4 | 5 | 5 | 4 | 7 | 4 | 4 | 5 | 1 | 6 | 1 | 3 |
| Biotope: GSM | 6 | 1 | 1 | 4 | 1 | 3 | 5 | 7 | 2 | 1 | 9 | 4 | 6 | 2 | 1 | 7 | 2 | 3 | 2 | 2 |
| Ratio Stones :Vegetation: GSM | 14:18:13 | | | | | 17:20:18 | | | | | 25:24:22 | | | | | 6:16:16 | | | | |

A: Count 2 to 10; B: Count 10 – 100; C: Count 100 – 1 000; S - Spring, U - Summer;

A - Autumn; W - Winter; GSM - Gravel/sand/mud; * Air-breathers

Seasonal variation and abundance of families of macro-invertebrates with very low water quality preferences as suggested in Thirion (2007).

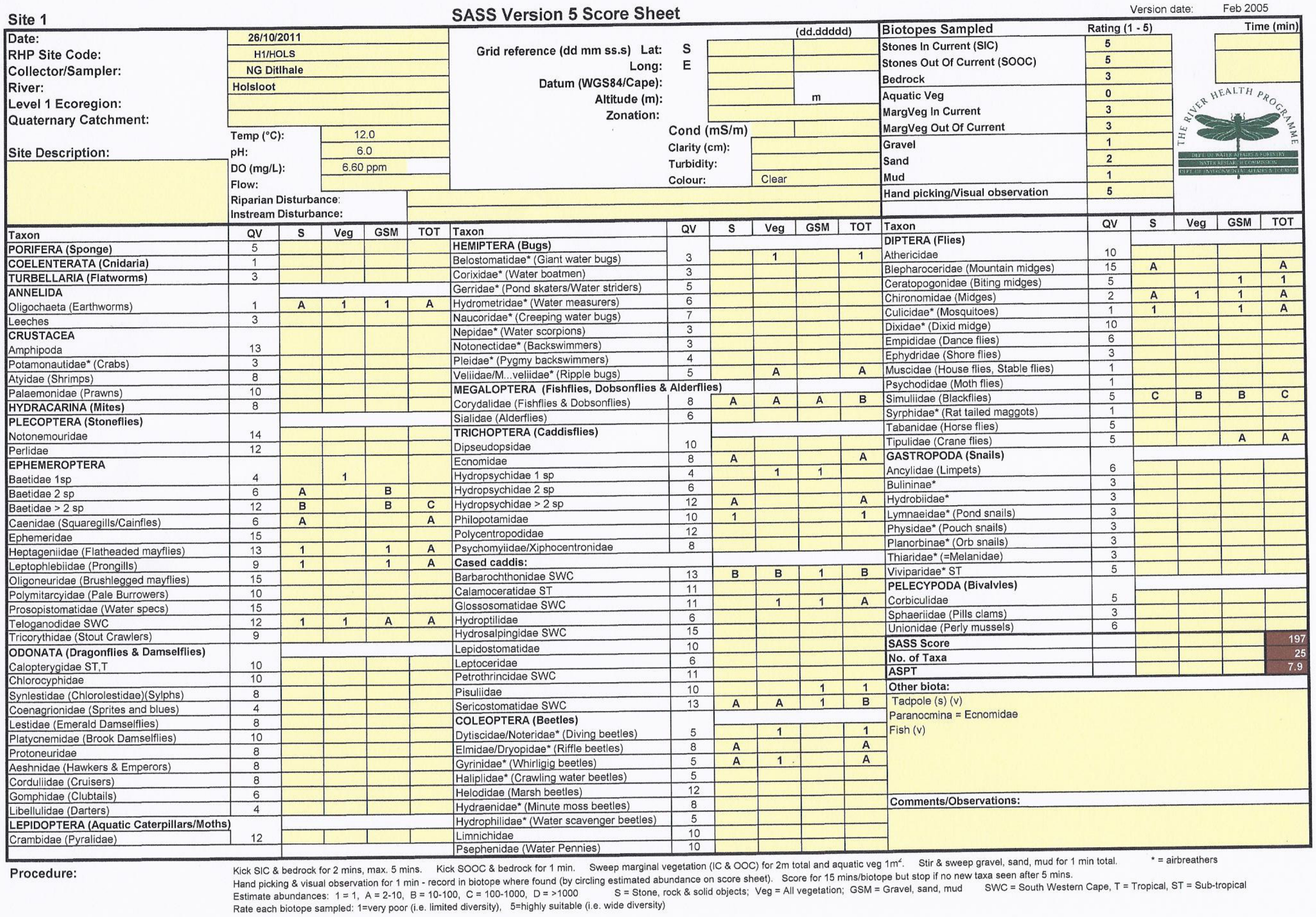
| **Macro-invertebrate Families** | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seasons** | **S** | | | | | **U** | | | | | **A** | | | | | **W** | | | | |
| **Sampling sites** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** |
| **<u>Least sensitive</u>: taxa with very low water quality preferences** | | | | | | | | | | | | | | | | | | | | |
| Baetidae 1sp (4) | | | | | | | | | | | | | | | | 🟦 1 | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | 🟨 1 | | | | |
| Pleidae (4) | | | | | | | | | | | | | | | | | | | | 🟨 1 |
| Coenagrionidae (4) | | | | | | | | 🟦 1 | | | | 🟦 1 | | | | 🟦 A | | | 🟦 1 | |
| | | 🟩 1 | | 🟩 1 | 🟩 A | | | 🟩 1 | 🟩 1 | | | 🟩 B | 🟩 B | 🟩 A | 🟩 A | | 🟩 A | 🟩 B | 🟩 B | 🟩 1 |
| | | | | | 🟨 1 | | | | | | | | | | | | | | | |
| Hydropsychidae 1 sp (4) | | | | 🟦 A | | | | | | | | | | | | | | | | 🟦 A |
| | | | | 🟨 1 | | | | | | | | | | | | | | | | |
| Libellulidae (4) | | | | | | | | | 🟦 A | 🟦 A | 🟦 1 | 🟦 A | 🟦 A | 🟦 1 | 🟦 A | 🟦 B | | 🟦 A | 🟦 A | 🟦 A |
| | | | | | 🟩 A | | | | | | 🟩 A | 🟩 B | 🟩 B | 🟩 1 | 🟩 1 | 🟩 A | 🟩 A | 🟩 A | 🟩 A | 🟩 B |
| | | | | | | | | | | | | | 🟨 B | | 🟨 A | 🟨 A | 🟨 1 | 🟨 1 | 🟨 1 | 🟨 1 |
| Belostomatidae* (3) | | | | | | 🟩 1 | | | | | | | | | | | | | | |
| Hirudinae (3) | | | | | | | | | | | | | | | | | | | | |
| Corixidae* (3) | | | | | | | | | | | | | | 🟦 B | | | 🟦 1 | | 🟦 1 | 🟦 1 |
| | | | | | 🟩 1 | | | | | | | | | 🟩 A | 🟩 1 | | | 🟩 A | 🟩 1 | 🟩 1 |
| | | | | | 🟨 1 | | | | | | | | 🟨 1 | 🟨 B | 🟨 1 | | 🟨 1 | | | |
| Nepidae* (3) | | | | 🟩 1 | | | | | | | | | | | | | | | | |
| Notonectidae (3) | | | | | | | | | | | 🟨 1 | | 🟩 1 | 🟩 A | 🟩 A | | | | | |
| Potamonautidae* (3) | | 🟦 A | 🟦 A | | | | 🟦 A | | | | 🟦 1 | 🟦 1 | 🟦 A | 🟦 A | | | | 🟦 1 | 🟦 1 | 🟦 1 |
| | | | | | | | | | | | | 🟩 1 | | 🟩 1 | | | 🟩 A | 🟩 A | | |
| | | | | | | | | | | | 🟨 1 | 🟨 1 | 🟨 1 | | | 🟨 1 | | | | |
| Chironomidae (2) | | 🟦 1 | | 🟦 A | 🟦 A | 🟦 A | | | 🟦 1 | 🟦 A | 🟦 A | 🟦 B | 🟦 1 | 🟦 A | | 🟦 A | 🟦 A | | 🟦 A | |
| | 🟩 A | 🟩 1 | 🟩 1 | | 🟩 B | 🟩 1 | | 🟩 A | 🟩 1 | 🟩 B | 🟩 A | | 🟩 1 | | | 🟩 B | 🟩 A | 🟩 A | 🟩 1 | 🟩 A |
| | 🟨 A | | | 🟨 A | 🟨 1 | 🟨 1 | 🟨 A | 🟨 A | | | 🟨 A | 🟨 1 | 🟨 1 | 🟨 1 | 🟨 A | 🟨 A | 🟨 A | 🟨 A | 🟨 A | 🟨 1 |
| Culicidae* (1) | | | | | | 🟦 1 | | | | | | 🟦 1 | | | | | | | 🟦 1 | 🟦 1 |
| | | 🟩 1 | | | 🟩 A | | 🟩 1 | | | | | | | | | | 🟩 1 | 🟩 1 | | 🟩 A |
| | | | | | | 🟨 1 | | 🟨 1 | 🟨 1 | | 🟨 A | | 🟨 A | | | 🟨 1 | | 🟨 1 | | |
| Psychodidae (1) | | | | | | | | | 🟦 A | | | | | | | | | | | |
| Oligochaeta (1) | | | | | | 🟦 A | | | | | 🟦 A | | 🟦 A | | | | | 🟦 A | | 🟦 A |
| | 🟩 1 | | | | | 🟩 1 | | | | | 🟩 A | | | | | | | | | |
| | | 🟨 A | | 🟨 A | 🟨 1 | 🟨 1 | | 🟨 1 | | | 🟨 A | | 🟨 A | 🟨 A | | | | | | 🟨 A |
| 🟦 Biotope: Stones | 0 | 2 | 1 | 2 | 1 | 3 | 1 | 1 | 3 | 2 | 4 | 5 | 4 | 4 | 1 | 4 | 2 | 3 | 6 | 6 |
| 🟩 Biotope: Vegetation | 2 | 3 | 1 | 2 | 5 | 3 | 1 | 2 | 2 | 1 | 3 | 3 | 4 | 5 | 4 | 2 | 5 | 6 | 4 | 5 |
| 🟨 Biotope: GSM | 1 | 1 | 0 | 3 | 4 | 3 | 1 | 3 | 1 | 0 | 5 | 2 | 6 | 3 | 3 | 5 | 3 | 3 | 2 | 4 |
| Ratio Stones : Vegetation : GSM | 6:13:9 | | | | | 10:9:8 | | | | | 18:19:19 | | | | | 21:22:17 | | | | |

A: Count 2 to 10; B: Count 10 – 100; C: Count 100 – 1 000; S - Spring, U - Summer;

A - Autumn; W - Winter; GSM - Gravel/sand/mud; * Air-breathers

## Appendix 3 SASS5-Data recorded in the 2011-2012 for all Sampling Sites - standard data sheets (Dallas 2005).

### Summer: October 2011, Sampling Site 1



**Site 1**

**SASS Version 5 Score Sheet**

Version date: Feb 2005

**Date:** 26/10/2011
**RHP Site Code:** H1/HOLS
**Collector/Sampler:** NG Ditlhale
**River:** Holsloot
**Level 1 Ecoregion:**
**Quaternary Catchment:**
**Site Description:**

**Temp (°C):** 12.0
**pH:** 6.0
**DO (mg/L):** 6.60 ppm
**Flow:**
**Riparian Disturbance:**
**Instream Disturbance:**

**Grid reference (dd mm ss.s) Lat:** S (dd.ddddd)
**Long:** E
**Datum (WGS84/Cape):**
**Altitude (m):** m
**Zonation:**
**Cond (mS/m)**
**Clarity (cm):**
**Turbidity:**
**Colour:** Clear

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 5 | |
| Stones Out Of Current (SOOC) | 5 | |
| Bedrock | 3 | |
| Aquatic Veg | 0 | |
| MargVeg In Current | 3 | |
| MargVeg Out Of Current | 3 | |
| Gravel | 1 | |
| Sand | 2 | |
| Mud | 1 | |
| Hand picking/Visual observation | 5 | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | A | 1 | 1 | A |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | | | | |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | 1 | | |
| Baetidae 2 sp | 6 | A | | B | |
| Baetidae > 2 sp | 12 | B | | B | C |
| Caenidae (Squaregills/Cainfles) | 6 | A | | | A |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | 1 | | 1 | A |
| Leptophlebiidae (Prongills) | 9 | 1 | | 1 | A |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | 1 | 1 | A | A |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | | | |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | | | | |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | | | |
| Libellulidae (Darters) | 4 | | | | |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | 1 | | 1 |
| Corixidae* (Water boatmen) | 3 | | | | |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | A | | A |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | A | A | A | B |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | A | | | A |
| Hydropsychidae 1 sp | 4 | | 1 | 1 | |
| Hydropsychidae 2 sp | 6 | | | | |
| Hydropsychidae > 2 sp | 12 | A | | | A |
| Philopotamidae | 10 | 1 | | | 1 |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | B | B | 1 | B |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | | 1 | 1 | A |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | | | |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | 1 | 1 |
| Sericostomatidae SWC | 13 | A | A | 1 | B |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | 1 | | 1 |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | A | | | A |
| Gyrinidae* (Whirligig beetles) | 5 | A | 1 | | A |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

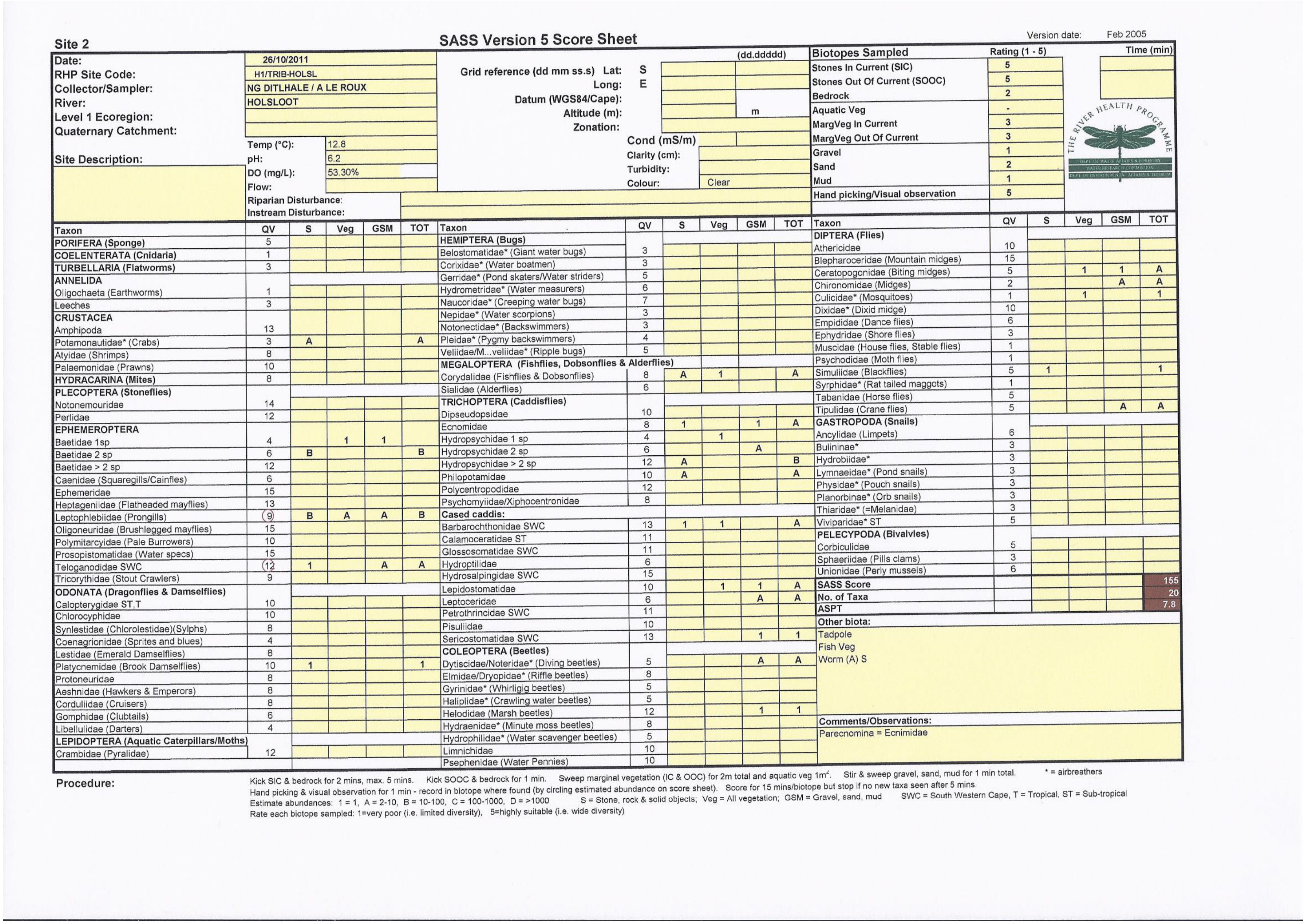
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | | | | |
| Blepharoceridae (Mountain midges) | 15 | A | | | A |
| Ceratopogonidae (Biting midges) | 5 | | | 1 | 1 |
| Chironomidae (Midges) | 2 | A | 1 | 1 | A |
| Culicidae* (Mosquitoes) | 1 | 1 | | 1 | A |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | C | B | B | C |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | | | A | A |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvles)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 197 |
| **No. of Taxa** | | | | | 25 |
| **ASPT** | | | | | 7.9 |

**Other biota:**
Tadpole (s) (v)
Paranocmina = Ecnomidae
Fish (v)

**Comments/Observations:**

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg $1m^2$. Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Summer: October 2011, Sampling Site 2



**Site 2**

## SASS Version 5 Score Sheet

Version date: Feb 2005

**Date:** 26/10/2011
**RHP Site Code:** H1/TRIB-HOLSL
**Collector/Sampler:** NG DITLHALE / A LE ROUX
**River:** HOLSLOOT
**Level 1 Ecoregion:**
**Quaternary Catchment:**
**Site Description:**

Temp (°C): 12.8
pH: 6.2
DO (mg/L): 53.30%
Flow:
Riparian Disturbance:
Instream Disturbance:

Grid reference (dd mm ss.s) Lat: S (dd.ddddd)
Long: E
Datum (WGS84/Cape):
Altitude (m): m
Zonation:
Cond (mS/m)
Clarity (cm):
Turbidity:
Colour: Clear

| **Biotopes Sampled** | **Rating (1 - 5)** | **Time (min)** |
|---|---|---|
| Stones In Current (SIC) | 5 | |
| Stones Out Of Current (SOOC) | 5 | |
| Bedrock | 2 | |
| Aquatic Veg | - | |
| MargVeg In Current | 3 | |
| MargVeg Out Of Current | 3 | |
| Gravel | 1 | |
| Sand | 2 | |
| Mud | 1 | |
| Hand picking/Visual observation | 5 | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | | | | |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | A | | | A |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | 1 | 1 | |
| Baetidae 2 sp | 6 | B | | | B |
| Baetidae > 2 sp | 12 | | | | |
| Caenidae (Squaregills/Cainfles) | 6 | | | | |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | | | | |
| Leptophlebiidae (Prongills) | 9 | B | A | A | B |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | 1 | | A | A |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | | | |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | 1 | | | 1 |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | | | | |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | | | |
| Libellulidae (Darters) | 4 | | | | |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | | | |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | | |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | A | 1 | | A |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | 1 | | 1 | A |
| Hydropsychidae 1 sp | 4 | | 1 | | |
| Hydropsychidae 2 sp | 6 | | | A | |
| Hydropsychidae > 2 sp | 12 | A | | | B |
| Philopotamidae | 10 | A | | | A |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | 1 | 1 | | A |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | | | | |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | 1 | 1 | A |
| Leptoceridae | 6 | | | A | A |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | | | 1 | 1 |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | | A | A |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | | | | |
| Gyrinidae* (Whirligig beetles) | 5 | | | | |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | 1 | 1 |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

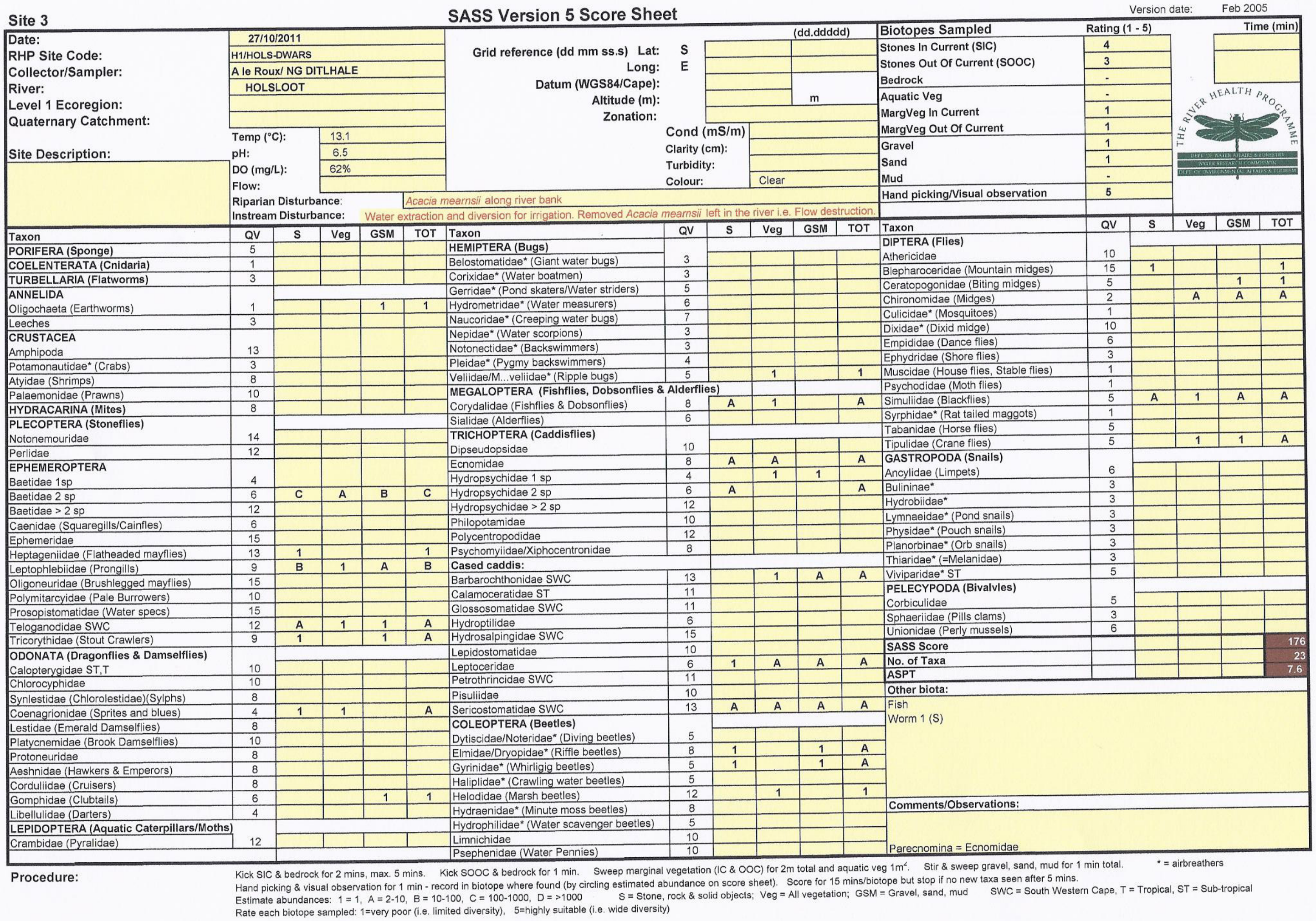
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | | | | |
| Blepharoceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | | 1 | 1 | A |
| Chironomidae (Midges) | 2 | | | A | A |
| Culicidae* (Mosquitoes) | 1 | | 1 | | 1 |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | 1 | | | 1 |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | | | A | A |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvles)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 155 |
| **No. of Taxa** | | | | | 20 |
| **ASPT** | | | | | 7.8 |

**Other biota:**
Tadpole
Fish Veg
Worm (A) S

**Comments/Observations:**
Parecnomina = Ecnimidae

**Procedure:** Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Summer: October 2011, Sampling Site 3



Site 3

## SASS Version 5 Score Sheet

Version date: Feb 2005

Date: 27/10/2011
RHP Site Code: H1/HOLS-DWARS
Collector/Sampler: A le Roux/ NG DITLHALE
River: HOLSLOOT
Level 1 Ecoregion:
Quaternary Catchment:
Site Description:

Temp (°C): 13.1
pH: 6.5
DO (mg/L): 62%
Flow:
Riparian Disturbance: *Acacia mearnsii* along river bank
Instream Disturbance: Water extraction and diversion for irrigation. Removed *Acacia mearnsii* left in the river i.e. Flow destruction.

Grid reference (dd mm ss.s) Lat: S (dd.ddddd)
Long: E
Datum (WGS84/Cape):
Altitude (m): m
Zonation:
Cond (mS/m)
Clarity (cm):
Turbidity:
Colour: Clear

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 4 | |
| Stones Out Of Current (SOOC) | 3 | |
| Bedrock | - | |
| Aquatic Veg | - | |
| MargVeg In Current | 1 | |
| MargVeg Out Of Current | 1 | |
| Gravel | 1 | |
| Sand | 1 | |
| Mud | - | |
| Hand picking/Visual observation | 5 | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | | | 1 | 1 |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | | | | |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | | |
| Baetidae 2 sp | 6 | C | A | B | C |
| Baetidae > 2 sp | 12 | | | | |
| Caenidae (Squaregills/Cainfles) | 6 | | | | |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | 1 | | | 1 |
| Leptophlebiidae (Prongills) | 9 | B | 1 | A | B |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | A | 1 | 1 | A |
| Tricorythidae (Stout Crawlers) | 9 | 1 | | 1 | A |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | 1 | 1 | | A |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | | | | |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | | 1 | 1 |
| Libellulidae (Darters) | 4 | | | | |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | | | |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | 1 | | 1 |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | A | 1 | | A |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | A | A | | A |
| Hydropsychidae 1 sp | 4 | | 1 | 1 | |
| Hydropsychidae 2 sp | 6 | A | | | A |
| Hydropsychidae > 2 sp | 12 | | | | |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | | 1 | A | A |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | | | | |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | 1 | A | A | A |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | A | A | A | A |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | | | |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | 1 | | 1 | A |
| Gyrinidae* (Whirligig beetles) | 5 | 1 | | 1 | A |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | 1 | | 1 |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

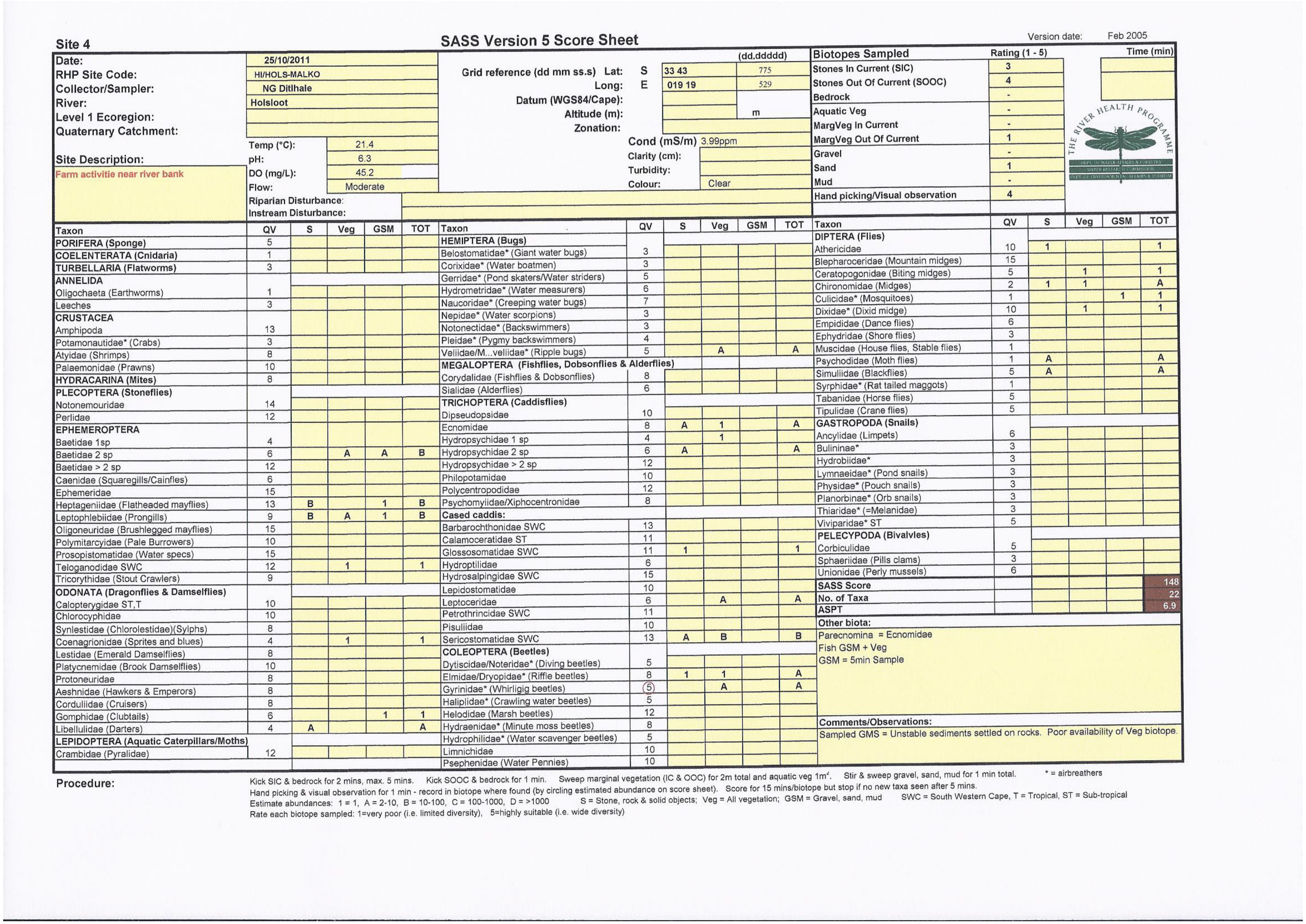
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | | | | |
| Blepharoceridae (Mountain midges) | 15 | 1 | | | 1 |
| Ceratopogonidae (Biting midges) | 5 | | | 1 | 1 |
| Chironomidae (Midges) | 2 | | A | A | A |
| Culicidae* (Mosquitoes) | 1 | | | | |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | A | 1 | A | A |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | | 1 | 1 | A |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvles)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 176 |
| **No. of Taxa** | | | | | 23 |
| **ASPT** | | | | | 7.6 |

**Other biota:**
Fish
Worm 1 (S)

**Comments/Observations:**
Parecnomina = Ecnomidae

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg $1m^2$. Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Summer: October 2011, Sampling Site 4



**Site 4**

# SASS Version 5 Score Sheet

Version date: Feb 2005

**Date:** 25/10/2011
**RHP Site Code:** HI/HOLS-MALKO
**Collector/Sampler:** NG Ditlhale
**River:** Holsloot
**Level 1 Ecoregion:**
**Quaternary Catchment:**

**Site Description:**
Farm activitie near river bank

Temp (°C): 21.4
pH: 6.3
DO (mg/L): 45.2
Flow: Moderate
Riparian Disturbance:
Instream Disturbance:

**Grid reference (dd mm ss.s)** (dd.ddddd)
**Lat:** S 33 43 775
**Long:** E 019 19 529
**Datum (WGS84/Cape):**
**Altitude (m):** m
**Zonation:**

**Cond (mS/m)** 3.99ppm
Clarity (cm):
Turbidity:
Colour: Clear

| **Biotopes Sampled** | **Rating (1 - 5)** | **Time (min)** |
|---|---|---|
| Stones In Current (SIC) | 3 | |
| Stones Out Of Current (SOOC) | 4 | |
| Bedrock | - | |
| Aquatic Veg | - | |
| MargVeg In Current | - | |
| MargVeg Out Of Current | 1 | |
| Gravel | - | |
| Sand | 1 | |
| Mud | - | |
| Hand picking/Visual observation | 4 | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | | | | |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | | | | |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | | |
| Baetidae 2 sp | 6 | | A | A | B |
| Baetidae > 2 sp | 12 | | | | |
| Caenidae (Squaregills/Cainfles) | 6 | | | | |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | B | | 1 | B |
| Leptophlebiidae (Prongills) | 9 | B | A | 1 | B |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | | 1 | | 1 |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | 1 | | 1 |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | | | | |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | | 1 | 1 |
| Libellulidae (Darters) | 4 | A | | | A |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | | | |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | A | | A |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | | | | |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | A | 1 | | A |
| Hydropsychidae 1 sp | 4 | | 1 | | |
| Hydropsychidae 2 sp | 6 | A | | | A |
| Hydropsychidae > 2 sp | 12 | | | | |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | | | | |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | 1 | | | 1 |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | A | | A |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | A | B | | B |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | | | |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | 1 | 1 | | A |
| Gyrinidae* (Whirligig beetles) | ⑤ | | A | | A |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

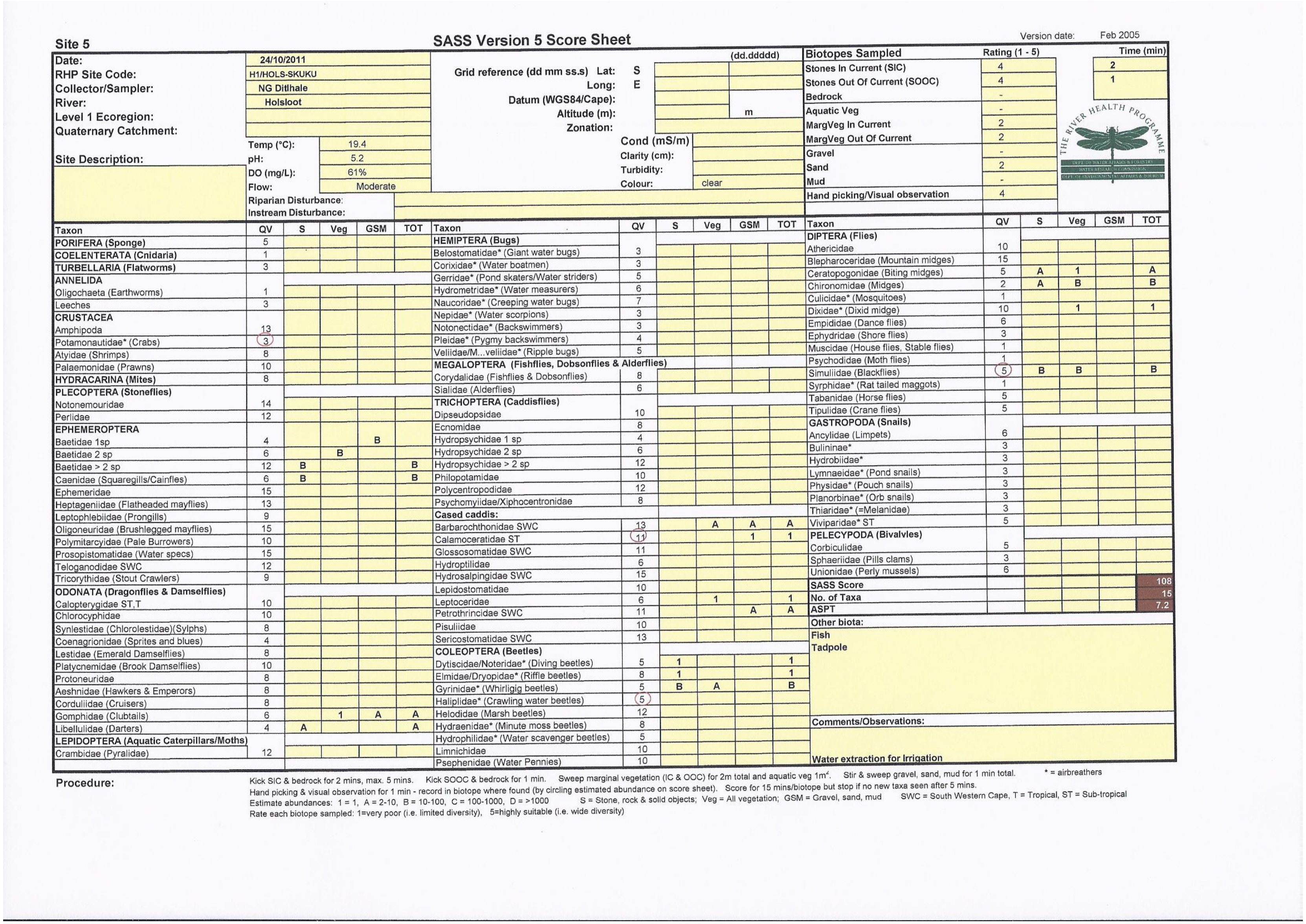
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | 1 | | | 1 |
| Blepharoceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | | 1 | | 1 |
| Chironomidae (Midges) | 2 | 1 | 1 | | A |
| Culicidae* (Mosquitoes) | 1 | | | 1 | 1 |
| Dixidae* (Dixid midge) | 10 | | 1 | | 1 |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | A | | | A |
| Simuliidae (Blackflies) | 5 | A | | | A |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | | | | |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvles)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 148 |
| **No. of Taxa** | | | | | 22 |
| **ASPT** | | | | | 6.9 |

**Other biota:**
Parecnomina = Ecnomidae
Fish GSM + Veg
GSM = 5min Sample

**Comments/Observations:**
Sampled GMS = Unstable sediments settled on rocks. Poor availability of Veg biotope.

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

# Summer: October 2011, Sampling Site 5



**Site 5**

## SASS Version 5 Score Sheet

Version date: Feb 2005

**Date:** 24/10/2011
**RHP Site Code:** H1/HOLS-SKUKU
**Collector/Sampler:** NG Ditlhale
**River:** Holsloot
**Level 1 Ecoregion:**
**Quaternary Catchment:**
**Site Description:**

Temp (°C): 19.4
pH: 5.2
DO (mg/L): 61%
Flow: Moderate
Riparian Disturbance:
Instream Disturbance:

Grid reference (dd mm ss.s) Lat: S (dd.ddddd)
Long: E
Datum (WGS84/Cape):
Altitude (m): m
Zonation:
Cond (mS/m)
Clarity (cm):
Turbidity:
Colour: clear

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 4 | 2 |
| Stones Out Of Current (SOOC) | 4 | 1 |
| Bedrock | - | |
| Aquatic Veg | - | |
| MargVeg In Current | 2 | |
| MargVeg Out Of Current | 2 | |
| Gravel | - | |
| Sand | 2 | |
| Mud | - | |
| Hand picking/Visual observation | 4 | |

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| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | | | | |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | | | | |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | B | |
| Baetidae 2 sp | 6 | | B | | |
| Baetidae > 2 sp | 12 | B | | | B |
| Caenidae (Squaregills/Cainfles) | 6 | B | | | B |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | | | | |
| Leptophlebiidae (Prongills) | 9 | | | | |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | | | | |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | | | |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | | | | |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | 1 | A | A |
| Libellulidae (Darters) | 4 | A | | | A |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | | | |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | | |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | | | | |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | | | | |
| Hydropsychidae 2 sp | 6 | | | | |
| Hydropsychidae > 2 sp | 12 | | | | |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | | A | A | A |
| Calamoceratidae ST | 11 | | | 1 | 1 |
| Glossosomatidae SWC | 11 | | | | |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | 1 | | 1 |
| Petrothrincidae SWC | 11 | | | A | A |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | | | | |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | 1 | | | 1 |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | 1 | | | 1 |
| Gyrinidae* (Whirligig beetles) | 5 | B | A | | B |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

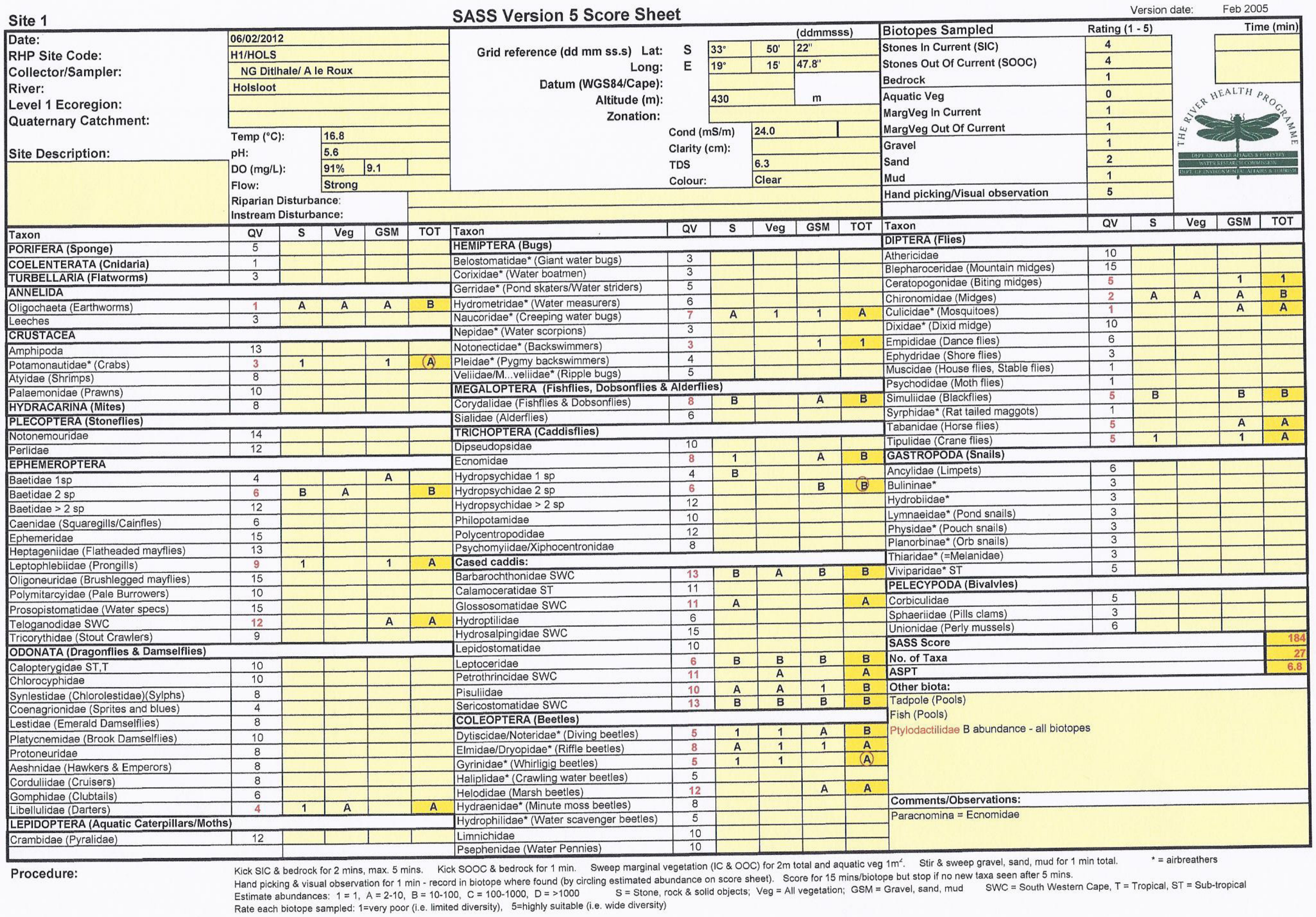
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | | | | |
| Blepharoceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | A | 1 | | A |
| Chironomidae (Midges) | 2 | A | B | | B |
| Culicidae* (Mosquitoes) | 1 | | | | |
| Dixidae* (Dixid midge) | 10 | | 1 | | 1 |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | B | B | | B |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | | | | |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvles)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 108 |
| **No. of Taxa** | | | | | 15 |
| **ASPT** | | | | | 7.2 |

**Other biota:**
**Fish**
**Tadpole**

**Comments/Observations:**
**Water extraction for Irrigation**

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Autumn: February 2012, Sampling Site 1



**Site 1**

## SASS Version 5 Score Sheet

Version date: Feb 2005

**Date:** 06/02/2012
**RHP Site Code:** H1/HOLS
**Collector/Sampler:** NG Ditlhale/ A le Roux
**River:** Holsloot
**Level 1 Ecoregion:**
**Quaternary Catchment:**
**Site Description:**

Temp (°C): 16.8
pH: 5.6
DO (mg/L): 91% 9.1
Flow: Strong
Riparian Disturbance:
Instream Disturbance:

| | | | | |
|---|---|---|---|---|
| | | | | (ddmmsss) |
| **Grid reference (dd mm ss.s) Lat:** | S | 33° | 50' | 22" |
| **Long:** | E | 19° | 15' | 47.8" |
| **Datum (WGS84/Cape):** | | | | |
| **Altitude (m):** | | 430 | | m |
| **Zonation:** | | | | |

Cond (mS/m): 24.0
Clarity (cm):
TDS 6.3
Colour: Clear

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 4 | |
| Stones Out Of Current (SOOC) | 4 | |
| Bedrock | 1 | |
| Aquatic Veg | 0 | |
| MargVeg In Current | 1 | |
| MargVeg Out Of Current | 1 | |
| Gravel | 1 | |
| Sand | 2 | |
| Mud | 1 | |
| Hand picking/Visual observation | 5 | |

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| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | A | A | A | B |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | 1 | | 1 | Ⓐ |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | A | |
| Baetidae 2 sp | 6 | B | A | | B |
| Baetidae > 2 sp | 12 | | | | |
| Caenidae (Squaregills/Cainfles) | 6 | | | | |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | | | | |
| Leptophlebiidae (Prongills) | 9 | 1 | | 1 | A |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | | | A | A |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | | | |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | | | | |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | | | |
| Libellulidae (Darters) | 4 | 1 | A | | A |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | | | |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | A | 1 | 1 | A |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | 1 | 1 |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | | |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | B | | A | B |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | 1 | | A | B |
| Hydropsychidae 1 sp | 4 | B | | | |
| Hydropsychidae 2 sp | 6 | | | B | Ⓑ |
| Hydropsychidae > 2 sp | 12 | | | | |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | B | A | B | B |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | A | | | A |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | B | B | B | B |
| Petrothrincidae SWC | 11 | | A | | A |
| Pisuliidae | 10 | A | A | 1 | B |
| Sericostomatidae SWC | 13 | B | B | B | B |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | 1 | 1 | A | B |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | A | 1 | 1 | A |
| Gyrinidae* (Whirligig beetles) | 5 | 1 | 1 | | Ⓐ |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | A | A |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

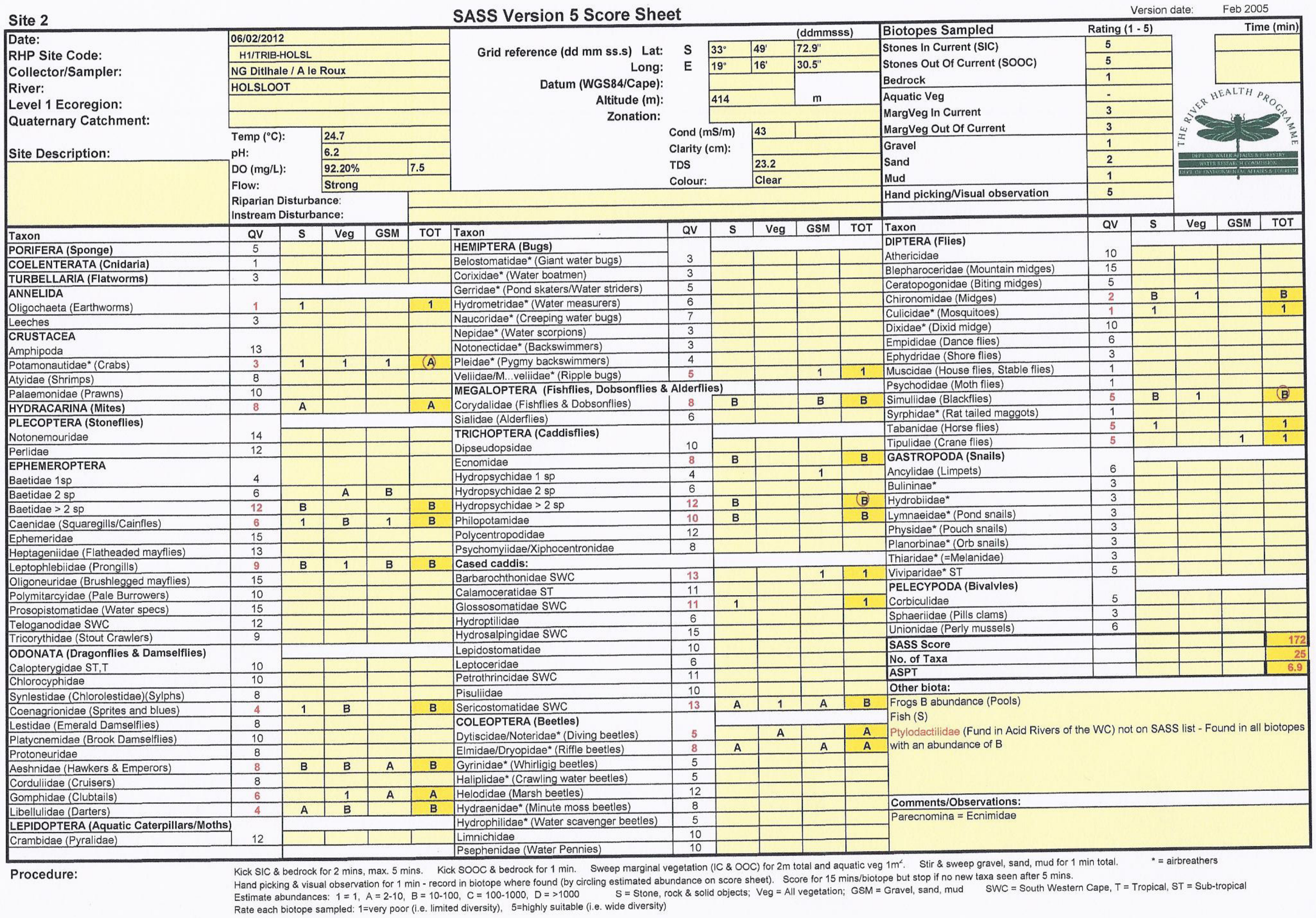
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | | | | |
| Blepharoceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | | | 1 | 1 |
| Chironomidae (Midges) | 2 | A | A | A | B |
| Culicidae* (Mosquitoes) | 1 | | | A | A |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | B | | B | B |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | A | A |
| Tipulidae (Crane flies) | 5 | 1 | | 1 | A |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvles)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 184 |
| **No. of Taxa** | | | | | 27 |
| **ASPT** | | | | | 6.8 |

**Other biota:**
Tadpole (Pools)
Fish (Pools)
Ptylodactilidae B abundance - all biotopes

**Comments/Observations:**
Paracnomina = Ecnomidae

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg $1m^2$. Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Autumn: February 2012, Sampling Site 2



**Site 2**

## SASS Version 5 Score Sheet

Version date: Feb 2005

**Date:** 06/02/2012
**RHP Site Code:** H1/TRIB-HOLSL
**Collector/Sampler:** NG Ditlhale / A le Roux
**River:** HOLSLOOT
**Level 1 Ecoregion:**
**Quaternary Catchment:**
**Site Description:**

Temp (°C): 24.7
pH: 6.2
DO (mg/L): 92.20% 7.5
Flow: Strong
Riparian Disturbance:
Instream Disturbance:

**Grid reference (dd mm ss.s)** (ddmmsss)
**Lat:** S 33° 49' 72.9"
**Long:** E 19° 16' 30.5"
**Datum (WGS84/Cape):**
**Altitude (m):** 414 m
**Zonation:**

Cond (mS/m): 43
Clarity (cm):
TDS: 23.2
Colour: Clear

| **Biotopes Sampled** | **Rating (1 - 5)** | **Time (min)** |
|---|---|---|
| **Stones In Current (SIC)** | 5 | |
| **Stones Out Of Current (SOOC)** | 5 | |
| **Bedrock** | 1 | |
| **Aquatic Veg** | - | |
| **MargVeg In Current** | 3 | |
| **MargVeg Out Of Current** | 3 | |
| **Gravel** | 1 | |
| **Sand** | 2 | |
| **Mud** | 1 | |
| **Hand picking/Visual observation** | 5 | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | 1 | | | 1 |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | 1 | 1 | 1 | A |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | A | | | A |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | | |
| Baetidae 2 sp | 6 | | A | B | |
| Baetidae > 2 sp | 12 | B | | | B |
| Caenidae (Squaregills/Cainfles) | 6 | 1 | B | 1 | B |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | | | | |
| Leptophlebiidae (Prongills) | 9 | B | 1 | B | B |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | | | | |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | 1 | B | | B |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | B | B | A | B |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | 1 | A | A |
| Libellulidae (Darters) | 4 | A | B | | B |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | | | |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | 1 | 1 |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | B | | B | B |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | B | | | B |
| Hydropsychidae 1 sp | 4 | | | 1 | |
| Hydropsychidae 2 sp | 6 | | | | |
| Hydropsychidae > 2 sp | 12 | B | | | B |
| Philopotamidae | 10 | B | | | B |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | | | 1 | 1 |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | 1 | | | 1 |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | | | |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | A | 1 | A | B |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | A | | A |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | A | | A | A |
| Gyrinidae* (Whirligig beetles) | 5 | | | | |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

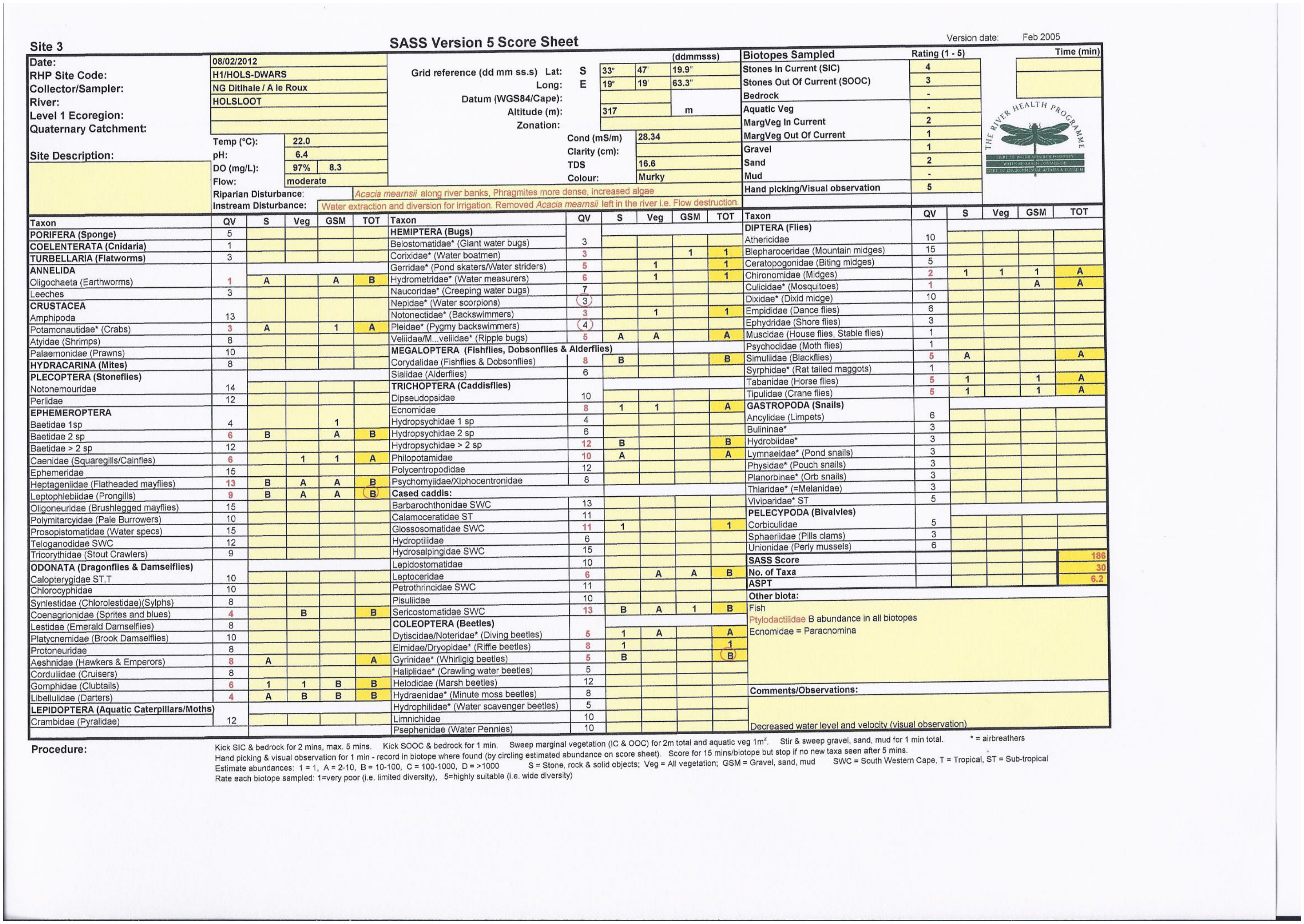
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | | | | |
| Blepharoceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | | | | |
| Chironomidae (Midges) | 2 | B | 1 | | B |
| Culicidae* (Mosquitoes) | 1 | 1 | | | 1 |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | B | 1 | | B |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | 1 | | | 1 |
| Tipulidae (Crane flies) | 5 | | | 1 | 1 |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvles)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 172 |
| **No. of Taxa** | | | | | 25 |
| **ASPT** | | | | | 6.9 |

**Other biota:**
Frogs B abundance (Pools)
Fish (S)
Ptylodactilidae (Fund in Acid Rivers of the WC) not on SASS list - Found in all biotopes with an abundance of B

**Comments/Observations:**
Parecnomina = Ecnimidae

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

# Autumn: February 2012, Sampling Site 3



Site 3

## SASS Version 5 Score Sheet

Version date: Feb 2005

Date: 08/02/2012
RHP Site Code: H1/HOLS-DWARS
Collector/Sampler: NG Ditlhale / A le Roux
River: HOLSLOOT
Level 1 Ecoregion:
Quaternary Catchment:

Site Description:

Temp (°C): 22.0
pH: 6.4
DO (mg/L): 97% 8.3
Flow: moderate
Riparian Disturbance: *Acacia mearnsii* along river banks, Phragmites more dense, increased algae
Instream Disturbance: Water extraction and diversion for irrigation. Removed *Acacia mearnsii* left in the river i.e. Flow destruction.

| Grid reference (dd mm ss.s) |  |  |  | (ddmmsss) |
|---|---|---|---|---|
| Lat: | S | 33° | 47' | 19.9" |
| Long: | E | 19° | 19' | 63.3" |

Datum (WGS84/Cape):
Altitude (m): 317 m
Zonation:

Cond (mS/m): 28.34
Clarity (cm):
TDS 16.6
Colour: Murky

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 4 |  |
| Stones Out Of Current (SOOC) | 3 |  |
| Bedrock | - |  |
| Aquatic Veg | - |  |
| MargVeg In Current | 2 |  |
| MargVeg Out Of Current | 1 |  |
| Gravel | 1 |  |
| Sand | 2 |  |
| Mud | - |  |
| Hand picking/Visual observation | 5 |  |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 |  |  |  |  |
| **COELENTERATA (Cnidaria)** | 1 |  |  |  |  |
| **TURBELLARIA (Flatworms)** | 3 |  |  |  |  |
| **ANNELIDA** |  |  |  |  |  |
| Oligochaeta (Earthworms) | 1 | A |  | A | B |
| Leeches | 3 |  |  |  |  |
| **CRUSTACEA** |  |  |  |  |  |
| Amphipoda | 13 |  |  |  |  |
| Potamonautidae* (Crabs) | 3 | A |  | 1 | A |
| Atyidae (Shrimps) | 8 |  |  |  |  |
| Palaemonidae (Prawns) | 10 |  |  |  |  |
| **HYDRACARINA (Mites)** | 8 |  |  |  |  |
| **PLECOPTERA (Stoneflies)** |  |  |  |  |  |
| Notonemouridae | 14 |  |  |  |  |
| Perlidae | 12 |  |  |  |  |
| **EPHEMEROPTERA** |  |  |  |  |  |
| Baetidae 1sp | 4 |  |  | 1 |  |
| Baetidae 2 sp | 6 | B |  | A | B |
| Baetidae > 2 sp | 12 |  |  |  |  |
| Caenidae (Squaregills/Cainfles) | 6 |  | 1 | 1 | A |
| Ephemeridae | 15 |  |  |  |  |
| Heptageniidae (Flatheaded mayflies) | 13 | B | A | A | B |
| Leptophlebiidae (Prongills) | 9 | B | A | A | B |
| Oligoneuridae (Brushlegged mayflies) | 15 |  |  |  |  |
| Polymitarcyidae (Pale Burrowers) | 10 |  |  |  |  |
| Prosopistomatidae (Water specs) | 15 |  |  |  |  |
| Teloganodidae SWC | 12 |  |  |  |  |
| Tricorythidae (Stout Crawlers) | 9 |  |  |  |  |
| **ODONATA (Dragonflies & Damselflies)** |  |  |  |  |  |
| Calopterygidae ST,T | 10 |  |  |  |  |
| Chlorocyphidae | 10 |  |  |  |  |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 |  |  |  |  |
| Coenagrionidae (Sprites and blues) | 4 |  | B |  | B |
| Lestidae (Emerald Damselflies) | 8 |  |  |  |  |
| Platycnemidae (Brook Damselflies) | 10 |  |  |  |  |
| Protoneuridae | 8 |  |  |  |  |
| Aeshnidae (Hawkers & Emperors) | 8 | A |  |  | A |
| Corduliidae (Cruisers) | 8 |  |  |  |  |
| Gomphidae (Clubtails) | 6 | 1 | 1 | B | B |
| Libellulidae (Darters) | 4 | A | B | B | B |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** |  |  |  |  |  |
| Crambidae (Pyralidae) | 12 |  |  |  |  |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** |  |  |  |  |  |
| Belostomatidae* (Giant water bugs) | 3 |  |  |  |  |
| Corixidae* (Water boatmen) | 3 |  |  | 1 | 1 |
| Gerridae* (Pond skaters/Water striders) | 5 |  | 1 |  | 1 |
| Hydrometridae* (Water measurers) | 6 |  | 1 |  | 1 |
| Naucoridae* (Creeping water bugs) | 7 |  |  |  |  |
| Nepidae* (Water scorpions) | ③ |  |  |  |  |
| Notonectidae* (Backswimmers) | 3 |  | 1 |  | 1 |
| Pleidae* (Pygmy backswimmers) | ④ |  |  |  |  |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | A | A |  | A |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** |  |  |  |  |  |
| Corydalidae (Fishflies & Dobsonflies) | 8 | B |  |  | B |
| Sialidae (Alderflies) | 6 |  |  |  |  |
| **TRICHOPTERA (Caddisflies)** |  |  |  |  |  |
| Dipseudopsidae | 10 |  |  |  |  |
| Ecnomidae | 8 | 1 | 1 |  | A |
| Hydropsychidae 1 sp | 4 |  |  |  |  |
| Hydropsychidae 2 sp | 6 |  |  |  |  |
| Hydropsychidae > 2 sp | 12 | B |  |  | B |
| Philopotamidae | 10 | A |  |  | A |
| Polycentropodidae | 12 |  |  |  |  |
| Psychomyiidae/Xiphocentronidae | 8 |  |  |  |  |
| **Cased caddis:** |  |  |  |  |  |
| Barbarochthonidae SWC | 13 |  |  |  |  |
| Calamoceratidae ST | 11 |  |  |  |  |
| Glossosomatidae SWC | 11 | 1 |  |  | 1 |
| Hydroptilidae | 6 |  |  |  |  |
| Hydrosalpingidae SWC | 15 |  |  |  |  |
| Lepidostomatidae | 10 |  |  |  |  |
| Leptoceridae | 6 |  | A | A | B |
| Petrothrincidae SWC | 11 |  |  |  |  |
| Pisuliidae | 10 |  |  |  |  |
| Sericostomatidae SWC | 13 | B | A | 1 | B |
| **COLEOPTERA (Beetles)** |  |  |  |  |  |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | 1 | A |  | A |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | 1 |  |  | 1 |
| Gyrinidae* (Whirligig beetles) | 5 | B |  |  | B |
| Haliplidae* (Crawling water beetles) | 5 |  |  |  |  |
| Helodidae (Marsh beetles) | 12 |  |  |  |  |
| Hydraenidae* (Minute moss beetles) | 8 |  |  |  |  |
| Hydrophilidae* (Water scavenger beetles) | 5 |  |  |  |  |
| Limnichidae | 10 |  |  |  |  |
| Psephenidae (Water Pennies) | 10 |  |  |  |  |

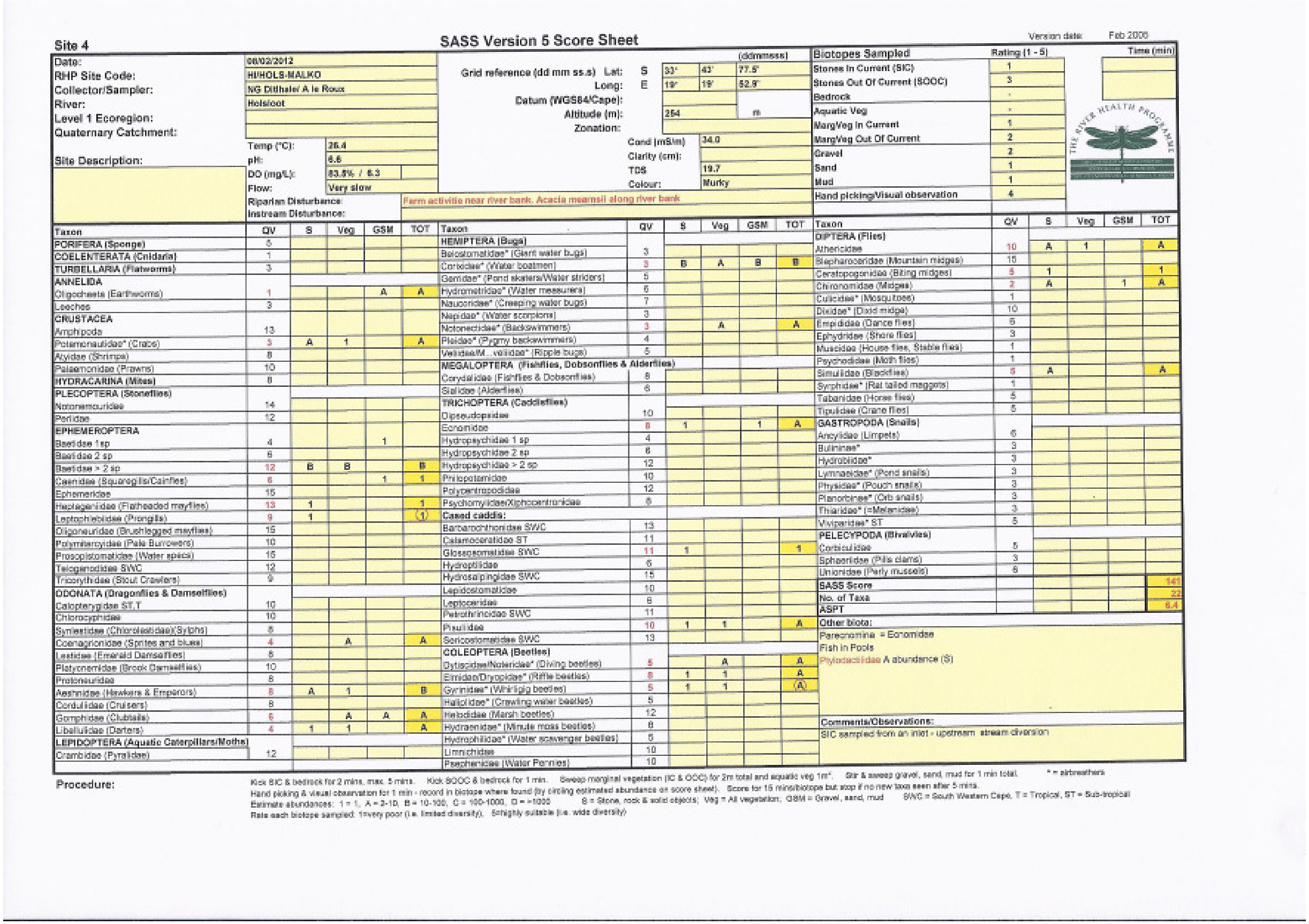
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** |  |  |  |  |  |
| Athericidae | 10 |  |  |  |  |
| Blepharoceridae (Mountain midges) | 15 |  |  |  |  |
| Ceratopogonidae (Biting midges) | 5 |  |  |  |  |
| Chironomidae (Midges) | 2 | 1 | 1 | 1 | A |
| Culicidae* (Mosquitoes) | 1 |  |  | A | A |
| Dixidae* (Dixid midge) | 10 |  |  |  |  |
| Empididae (Dance flies) | 6 |  |  |  |  |
| Ephydridae (Shore flies) | 3 |  |  |  |  |
| Muscidae (House flies, Stable flies) | 1 |  |  |  |  |
| Psychodidae (Moth flies) | 1 |  |  |  |  |
| Simuliidae (Blackflies) | 5 | A |  |  | A |
| Syrphidae* (Rat tailed maggots) | 1 |  |  |  |  |
| Tabanidae (Horse flies) | 5 | 1 |  | 1 | A |
| Tipulidae (Crane flies) | 5 | 1 |  | 1 | A |
| **GASTROPODA (Snails)** |  |  |  |  |  |
| Ancylidae (Limpets) | 6 |  |  |  |  |
| Bulininae* | 3 |  |  |  |  |
| Hydrobiidae* | 3 |  |  |  |  |
| Lymnaeidae* (Pond snails) | 3 |  |  |  |  |
| Physidae* (Pouch snails) | 3 |  |  |  |  |
| Planorbinae* (Orb snails) | 3 |  |  |  |  |
| Thiaridae* (=Melanidae) | 3 |  |  |  |  |
| Viviparidae* ST | 5 |  |  |  |  |
| **PELECYPODA (Bivalvles)** |  |  |  |  |  |
| Corbiculidae | 5 |  |  |  |  |
| Sphaeriidae (Pills clams) | 3 |  |  |  |  |
| Unionidae (Perly mussels) | 6 |  |  |  |  |
| **SASS Score** |  |  |  |  | 186 |
| **No. of Taxa** |  |  |  |  | 30 |
| **ASPT** |  |  |  |  | 6.2 |

**Other biota:**
Fish
Ptylodactilidae B abundance in all biotopes
Ecnomidae = Paracnomina

**Comments/Observations:**
Decreased water level and velocity (visual observation)

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg $1m^2$. Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

# Autumn: February 2012, Sampling Site 4



Site 4

## SASS Version 5 Score Sheet

Version date: Feb 2005

Date: 08/02/2012
RHP Site Code: HI/HOLS-MALKO
Collector/Sampler: NG Dithale/ A le Roux
River: Holsloot
Level 1 Ecoregion:
Quaternary Catchment:
Site Description:

Temp (°C): 26.4
pH: 6.6
DO (mg/L): 83.5% / 6.3
Flow: Very slow
Riparian Disturbance: Farm activitie near river bank. Acacia mearnsii along river bank
Instream Disturbance:

Grid reference (dd mm ss.s) (ddmmss.s) Lat: S 33° 43' 77.5"
Long: E 19° 19' 52.9"
Datum (WGS84/Cape):
Altitude (m): 254 m
Zonation:
Cond (mS/m): 34.0
Clarity (cm):
TDS: 19.7
Colour: Murky

| Biotopes Sampled | Rating (1 - 5) |
|---|---|
| Stones In Current (SIC) | 1 |
| Stones Out Of Current (SOOC) | 3 |
| Bedrock | - |
| Aquatic Veg | - |
| MargVeg In Current | 1 |
| MargVeg Out Of Current | 2 |
| Gravel | 2 |
| Sand | 1 |
| Mud | 1 |
| Hand picking/Visual observation | 4 |

Time (min):

THE RIVER HEALTH PROGRAMME

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | | | A | A |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | A | 1 | | A |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | 1 | |
| Baetidae 2 sp | 6 | | | | |
| Baetidae > 2 sp | 12 | B | B | | B |
| Caenidae (Squaregills/Cainflies) | 6 | | | 1 | 1 |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | 1 | | | 1 |
| Leptophlebiidae (Prongills) | 9 | 1 | | | ① |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | | | | |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | A | | A |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | A | 1 | | B |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | A | A | A |
| Libellulidae (Darters) | 4 | 1 | 1 | | A |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | B | A | B | B |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | A | | A |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | | |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | | | | |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | 1 | | 1 | A |
| Hydropsychidae 1 sp | 4 | | | | |
| Hydropsychidae 2 sp | 6 | | | | |
| Hydropsychidae > 2 sp | 12 | | | | |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | | | | |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | 1 | | | 1 |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | | | |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | 1 | 1 | | A |
| Sericostomatidae SWC | 13 | | | | |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | A | | A |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | 1 | 1 | | A |
| Gyrinidae* (Whirligig beetles) | 5 | 1 | 1 | | Ⓐ |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

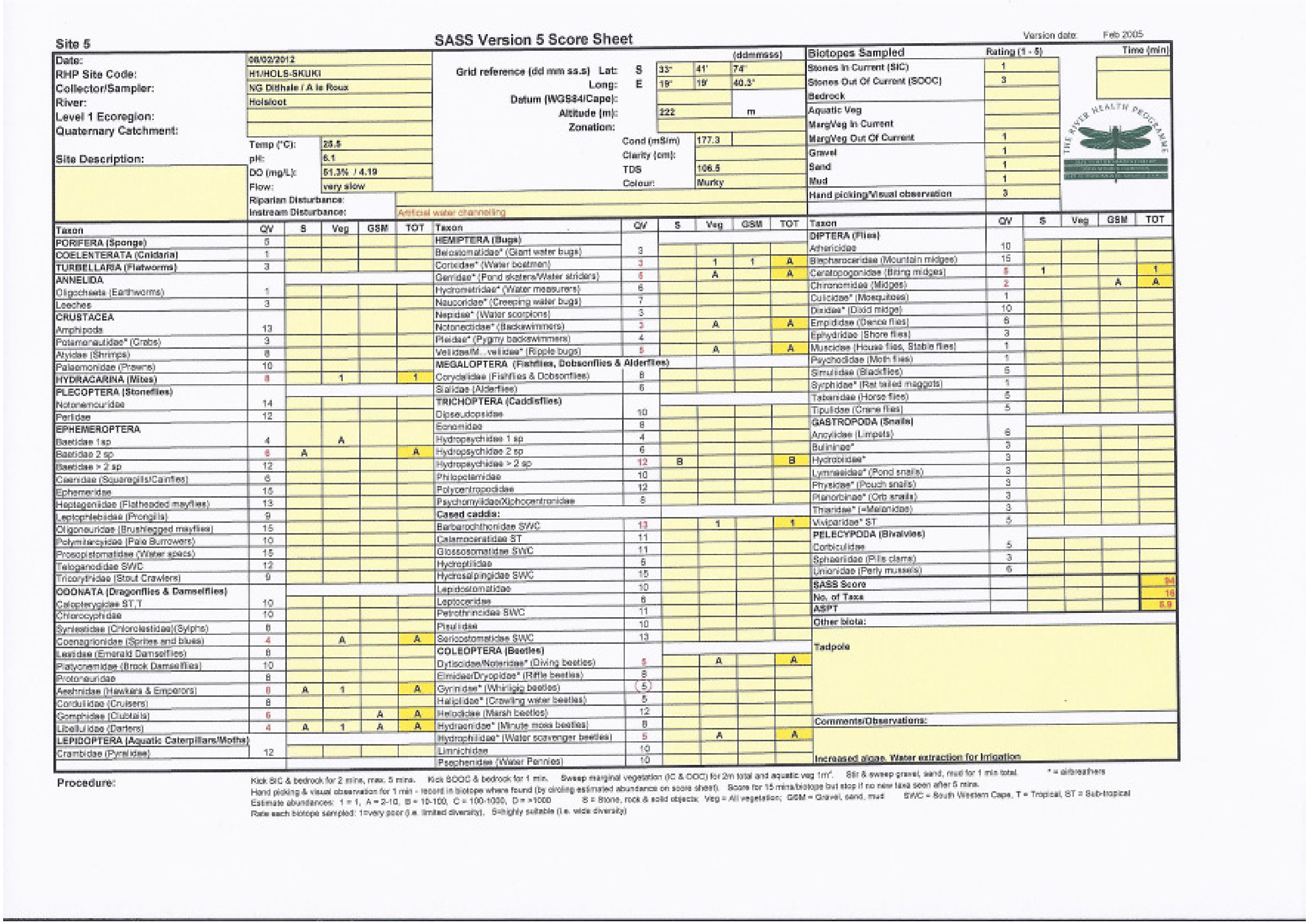
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | A | 1 | | A |
| Blephariceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | 1 | | | 1 |
| Chironomidae (Midges) | 2 | A | | 1 | A |
| Culicidae* (Mosquitoes) | 1 | | | | |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | A | | | A |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | | | | |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvles)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 141 |
| **No. of Taxa** | | | | | 22 |
| **ASPT** | | | | | 6.4 |

Other biota:
Parecnomina = Ecnomidae
Fish in Pools
Phylodactilidae A abundance (S)

Comments/Observations:
SIC sampled from an inlet - upstream stream diversion

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Autumn: February 2012, Sampling Site 5



Site 5

## SASS Version 5 Score Sheet

Version date: Feb 2005

Date: 08/02/2012
RHP Site Code: H1/HOLS-SKUKI
Collector/Sampler: NG Dithale / A le Roux
River: Holsloot
Level 1 Ecoregion:
Quaternary Catchment:
Site Description:

Grid reference (dd mm ss.s) (ddmmss)
Lat: S 33° 41' 74"
Long: E 19° 19' 40.3"
Datum (WGS84/Cape):
Altitude (m): 222 m
Zonation:

Temp (°C): 25.5
pH: 8.1
DO (mg/L): 51.3% / 4.19
Flow: very slow
Cond (mS/m) 177.3
Clarity (cm):
TDS 106.5
Colour: Murky
Riparian Disturbance:
Instream Disturbance: Artificial water channelling

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 1 | |
| Stones Out Of Current (SOOC) | 3 | |
| Bedrock | | |
| Aquatic Veg | | |
| MargVeg In Current | | |
| MargVeg Out Of Current | 1 | |
| Gravel | 1 | |
| Sand | 1 | |
| Mud | 1 | |
| Hand picking/Visual observation | 3 | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | | | | |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | | | | |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | 1 | | 1 |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | A | | |
| Baetidae 2 sp | 6 | A | | | A |
| Baetidae > 2 sp | 12 | | | | |
| Caenidae (Squaregills/Cainflies) | 6 | | | | |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | | | | |
| Leptophlebiidae (Prongills) | 9 | | | | |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | | | | |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | A | | A |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | A | 1 | | A |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | | A | A |
| Libellulidae (Darters) | 4 | A | 1 | A | A |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | 1 | 1 | A |
| Gerridae* (Pond skaters/Water striders) | 5 | | A | | A |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | A | | A |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | A | | A |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | | | | |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | | | | |
| Hydropsychidae 2 sp | 6 | | | | |
| Hydropsychidae > 2 sp | 12 | B | | | B |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | | 1 | | 1 |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | | | | |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | | | |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | | | | |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | A | | A |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | | | | |
| Gyrinidae* (Whirligig beetles) | 5 | | | | |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | A | | A |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | | | | |
| Blepharoceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | 1 | | | 1 |
| Chironomidae (Midges) | 2 | | | A | A |
| Culicidae* (Mosquitoes) | 1 | | | | |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | | | | |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | | | | |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvies)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 94 |
| **No. of Taxa** | | | | | 16 |
| **ASPT** | | | | | 5.9 |

**Other biota:**

Tadpole

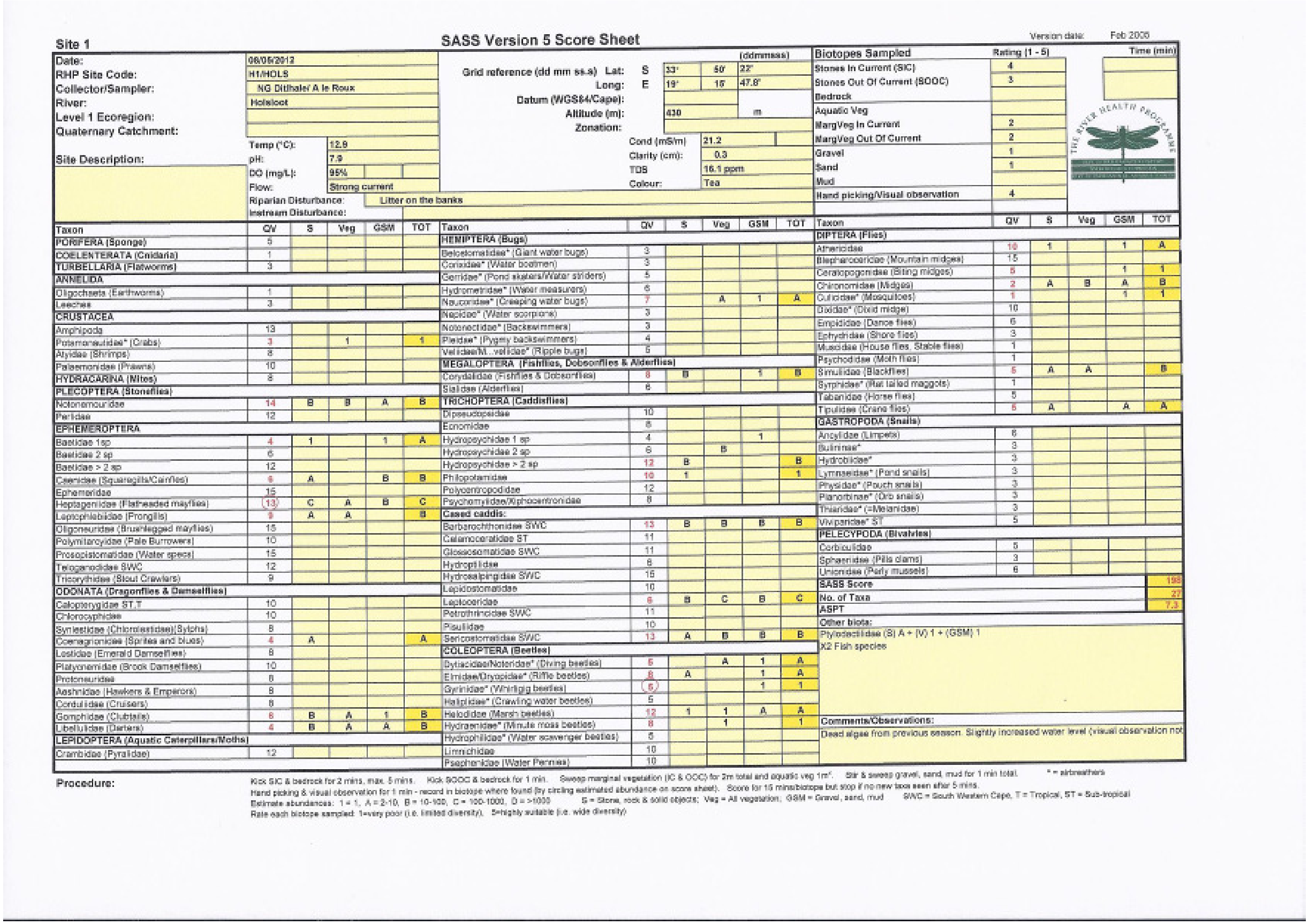
**Comments/Observations:**

Increased algae. Water extraction for Irrigation

**Procedure:**

Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Winter: May 2012, Sampling Site 1



Site 1

## SASS Version 5 Score Sheet

Version date: Feb 2005

Date: 08/05/2012
RHP Site Code: H1/HOLS
Collector/Sampler: NG Dithale/ A le Roux
River: Holsloot
Level 1 Ecoregion:
Quaternary Catchment:
Site Description:

Temp (°C): 12.8
pH: 7.9
DO (mg/L): 95%
Flow: Strong current
Riparian Disturbance: Litter on the banks
Instream Disturbance:

| | | | (ddmmss.s) |
|---|---|---|---|
| Grid reference (dd mm ss.s) Lat: S | 33° | 50' | 22" |
| Long: E | 19° | 18' | 47.8" |
| Datum (WGS84/Cape): | | | |
| Altitude (m): | 430 | | m |
| Zonation: | | | |

Cond (mS/m) 21.2
Clarity (cm): 0.3
TDS 16.1 ppm
Colour: Tea

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 4 | |
| Stones Out Of Current (SOOC) | 3 | |
| Bedrock | | |
| Aquatic Veg | | |
| MargVeg In Current | 2 | |
| MargVeg Out Of Current | 2 | |
| Gravel | 1 | |
| Sand | 1 | |
| Mud | | |
| Hand picking/Visual observation | 4 | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | | | | |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | | 1 | | 1 |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | B | B | A | B |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | 1 | | 1 | A |
| Baetidae 2 sp | 6 | | | | |
| Baetidae > 2 sp | 12 | | | | |
| Caenidae (Squaregills/Cainflies) | 6 | A | | B | B |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | C | A | B | C |
| Leptophlebiidae (Prongills) | 9 | A | A | | B |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | | | | |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | A | | | A |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | | | | |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | B | A | 1 | B |
| Libellulidae (Darters) | 4 | B | A | A | B |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | | | |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | A | 1 | A |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | | |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | B | | 1 | B |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | | | 1 | |
| Hydropsychidae 2 sp | 6 | | B | | |
| Hydropsychidae > 2 sp | 12 | B | | | B |
| Philopotamidae | 10 | 1 | | | 1 |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | B | B | B | B |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | | | | |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | B | C | B | C |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | A | B | B | B |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | A | 1 | A |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | A | | 1 | A |
| Gyrinidae* (Whirligig beetles) | 5 | | | 1 | 1 |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | 1 | 1 | A | A |
| Hydraenidae* (Minute moss beetles) | 8 | | 1 | | 1 |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

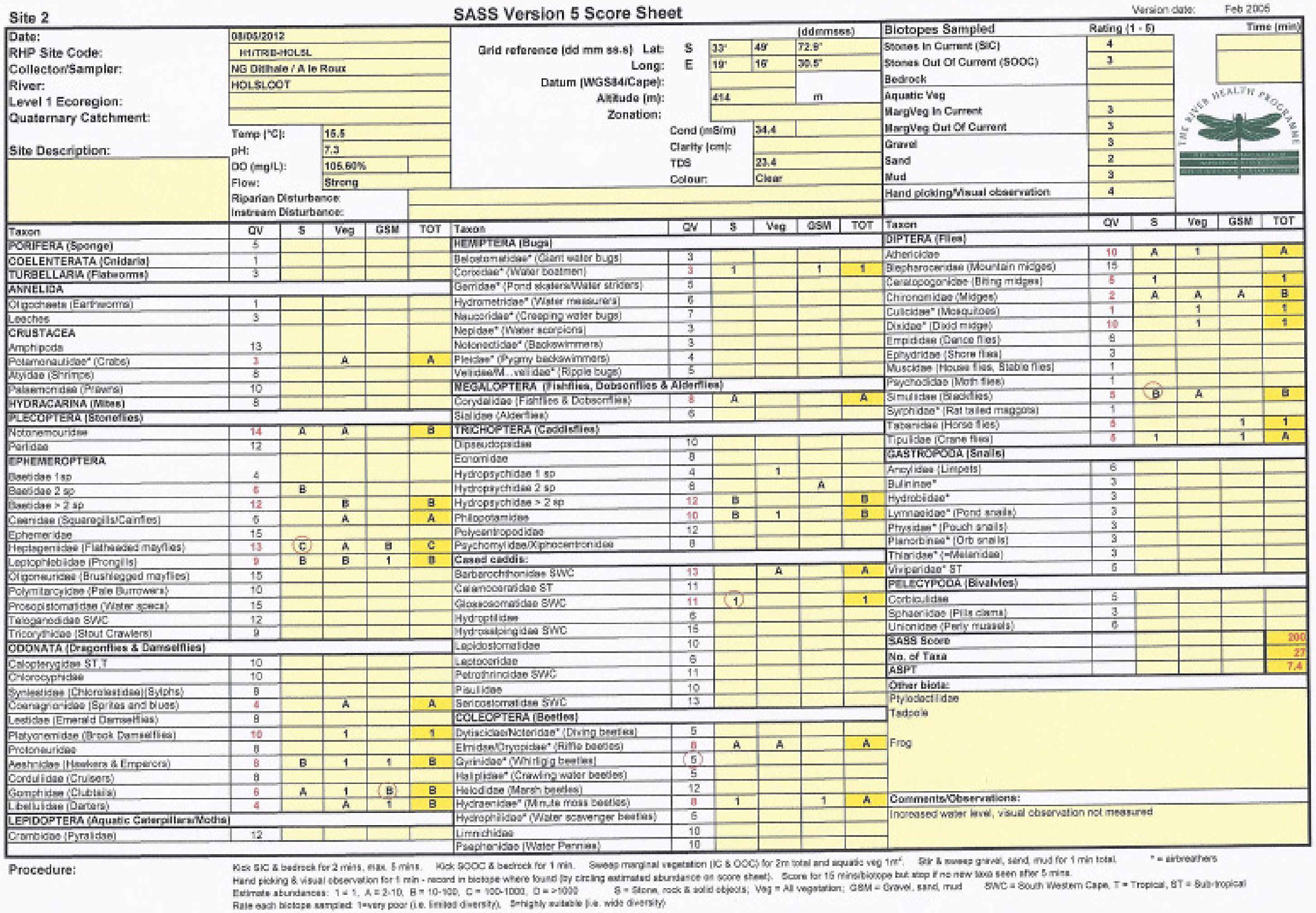
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | 1 | | 1 | A |
| Blephariceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | | | 1 | 1 |
| Chironomidae (Midges) | 2 | A | B | A | B |
| Culicidae* (Mosquitoes) | 1 | | | 1 | 1 |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | A | A | | B |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | A | | A | A |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvles)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 198 |
| **No. of Taxa** | | | | | 27 |
| **ASPT** | | | | | 7.3 |

**Other biota:**
Ptyloodactilidae (S) A + (V) 1 + (GSM) 1
X2 Fish species

**Comments/Observations:**
Dead algae from previous season. Slightly increased water level (visual observation not

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Winter: May 2012, Sampling Site 2



Site 2

## SASS Version 5 Score Sheet

Version date: Feb 2005

Date: 08/05/2012
RHP Site Code: H1/TRIB-HOLSL
Collector/Sampler: NG Ditlhale / A le Roux
River: HOLSLOOT
Level 1 Ecoregion:
Quaternary Catchment:
Site Description:

Temp (°C): 15.5
pH: 7.3
DO (mg/L): 105.60%
Flow: Strong
Riparian Disturbance:
Instream Disturbance:

| | | | | (ddmmss) |
|---|---|---|---|---|
| Grid reference (dd mm ss.s) Lat: | S | 33° | 49' | 72.9" |
| Long: | E | 19° | 16' | 30.5" |
| Datum (WGS84/Cape): | | | | |
| Altitude (m): | | 414 | | m |
| Zonation: | | | | |

Cond (mS/m): 34.4
Clarity (cm):
TDS: 23.4
Colour: Clear

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 4 | |
| Stones Out Of Current (SOOC) | 3 | |
| Bedrock | | |
| Aquatic Veg | | |
| MargVeg In Current | 3 | |
| MargVeg Out Of Current | 3 | |
| Gravel | 3 | |
| Sand | 2 | |
| Mud | 3 | |
| Hand picking/Visual observation | 4 | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | | | | |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | | A | | A |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | A | A | | B |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | | |
| Baetidae 2 sp | 6 | B | | | |
| Baetidae > 2 sp | 12 | | B | | B |
| Caenidae (Squaregills/Cainfles) | 6 | | A | | A |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | C | A | B | C |
| Leptophlebiidae (Prongills) | 9 | B | B | 1 | B |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | | | | |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | A | | A |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | 1 | | 1 |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | B | 1 | 1 | B |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | A | 1 | B | B |
| Libellulidae (Darters) | 4 | | A | 1 | B |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | 1 | | 1 | 1 |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | | |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | A | | | A |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | | 1 | | |
| Hydropsychidae 2 sp | 6 | | | A | |
| Hydropsychidae > 2 sp | 12 | B | | | B |
| Philopotamidae | 10 | B | 1 | | B |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | | A | | A |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | 1 | | | 1 |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | | | |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | | | | |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | | | |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | A | A | | A |
| Gyrinidae* (Whirligig beetles) | 5 | | | | |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | 1 | | 1 | A |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

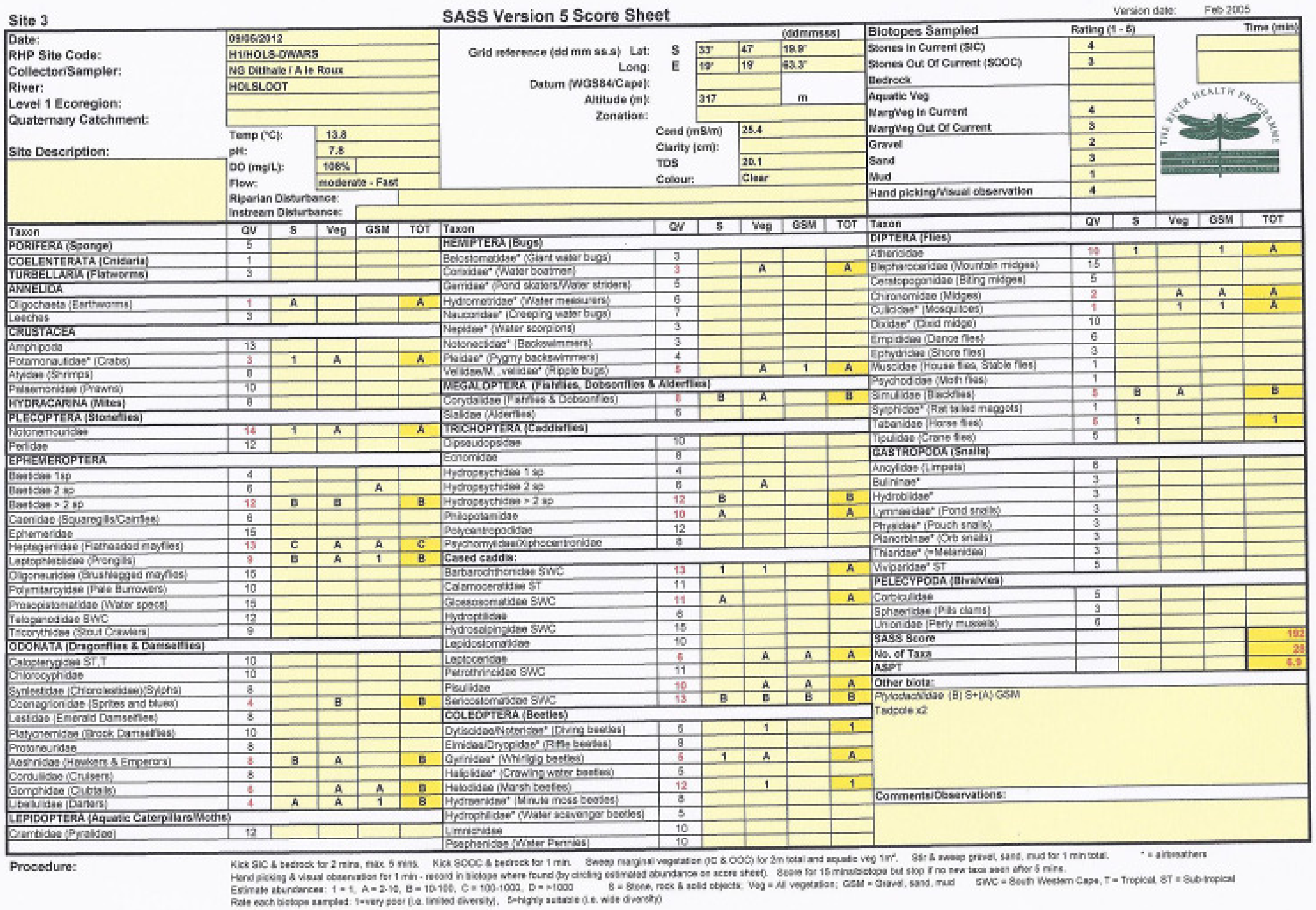
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | A | 1 | | A |
| Blepharoceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | 1 | | | 1 |
| Chironomidae (Midges) | 2 | A | A | A | B |
| Culicidae* (Mosquitoes) | 1 | | 1 | | 1 |
| Dixidae* (Dixid midge) | 10 | | 1 | | 1 |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | B | A | | B |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | 1 | 1 |
| Tipulidae (Crane flies) | 5 | 1 | | 1 | A |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvies)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 200 |
| **No. of Taxa** | | | | | 27 |
| **ASPT** | | | | | 7.4 |

**Other biota:**
Ptylodactilidae
Tadpole
Frog

**Comments/Observations:**
Increased water level, visual observation not measured

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Winter: May 2012, Sampling Site 3



Site 3

## SASS Version 5 Score Sheet

Version date: Feb 2005

Date: 09/06/2012
RHP Site Code: H1/HOLS-DWARS
Collector/Sampler: NG Dithale / A le Roux
River: HOLSLOOT
Level 1 Ecoregion:
Quaternary Catchment:
Site Description:

Temp (°C): 13.8
pH: 7.8
DO (mg/L): 108%
Flow: moderate - Fast
Riparian Disturbance:
Instream Disturbance:

Grid reference (dd mm ss.s) (ddmmsss) Lat: S 33° 47' 19.9"
Long: E 19° 19' 63.3"
Datum (WGS84/Cape):
Altitude (m): 317 m
Zonation:
Cond (mS/m) 25.4
Clarity (cm):
TDS 20.1
Colour: Clear

| Biotopes Sampled | Rating (1 - 5) |
|---|---|
| Stones In Current (SIC) | 4 |
| Stones Out Of Current (SOOC) | 3 |
| Bedrock | |
| Aquatic Veg | |
| MargVeg In Current | 4 |
| MargVeg Out Of Current | 3 |
| Gravel | 2 |
| Sand | 3 |
| Mud | 1 |
| Hand picking/Visual observation | 4 |

Time (min)

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | A | | | A |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | 1 | A | | A |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | 1 | A | | A |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | | |
| Baetidae 2 sp | 6 | | | A | |
| Baetidae > 2 sp | 12 | B | B | | B |
| Caenidae (Squaregills/Cainflies) | 6 | | | | |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | C | A | A | C |
| Leptophlebiidae (Prongills) | 9 | B | A | 1 | B |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | | | | |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | B | | B |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | B | A | | B |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | A | A | B |
| Libellulidae (Darters) | 4 | A | A | 1 | B |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | A | | A |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | A | 1 | A |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | B | A | | B |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | | | | |
| Hydropsychidae 2 sp | 6 | | A | | |
| Hydropsychidae > 2 sp | 12 | B | | | B |
| Philopotamidae | 10 | A | | | A |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | 1 | 1 | | A |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | A | | | A |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | A | A | A |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | A | A | A |
| Sericostomatidae SWC | 13 | B | B | B | B |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | 1 | | 1 |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | | | | |
| Gyrinidae* (Whirligig beetles) | 5 | 1 | A | | A |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | 1 | | 1 |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

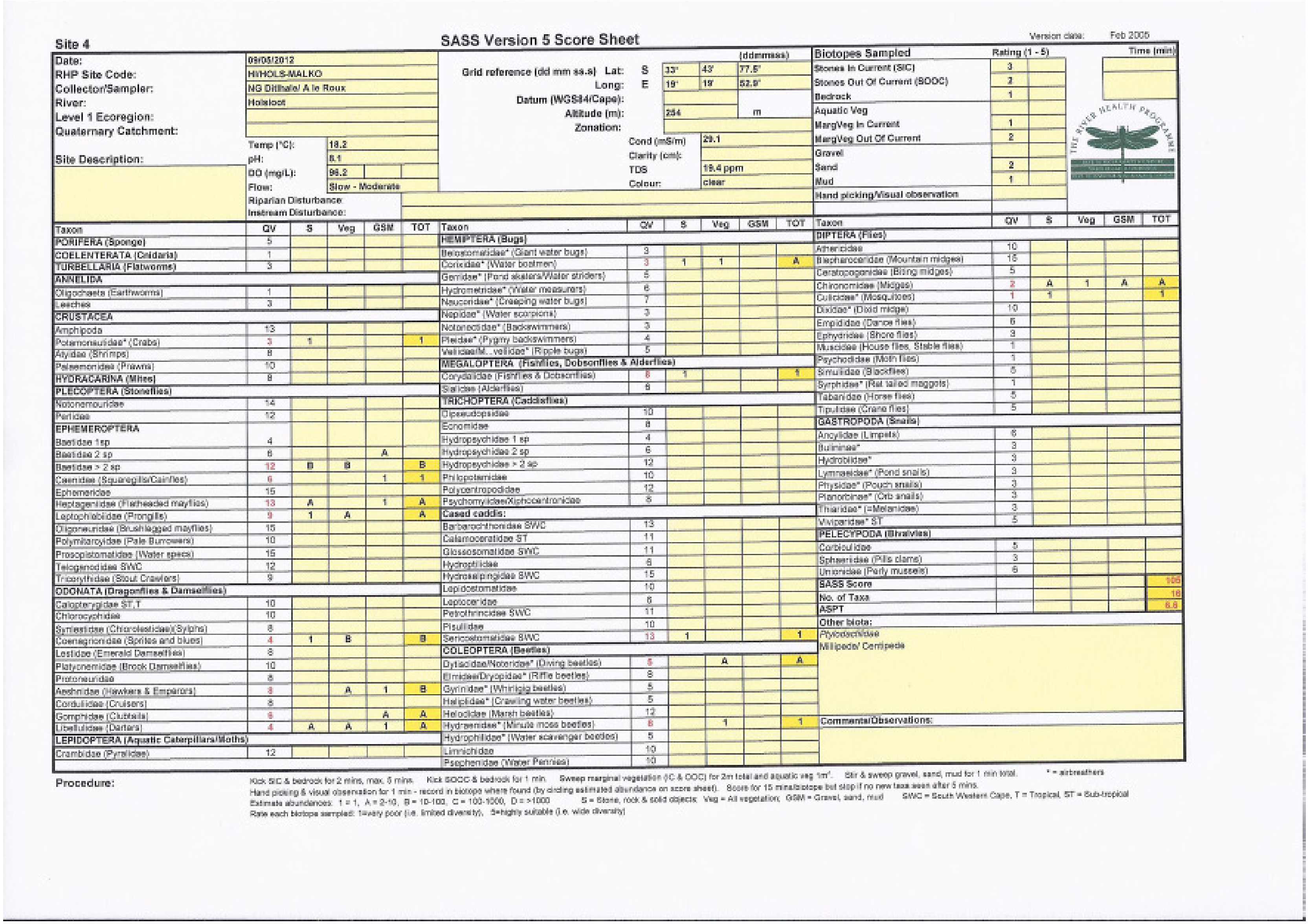
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | 1 | | 1 | A |
| Blephariceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | | | | |
| Chironomidae (Midges) | 2 | | A | A | A |
| Culicidae* (Mosquitoes) | 1 | | 1 | 1 | A |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | B | A | | B |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | 1 | | | 1 |
| Tipulidae (Crane flies) | 5 | | | | |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvies)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 192 |
| **No. of Taxa** | | | | | 28 |
| **ASPT** | | | | | 6.9 |

**Other biota:**
Ptyloctachidae (B) S+(A) GSM
Tadpole x2

**Comments/Observations:**

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Winter: May 2012, Sampling Site 4



Site 4

## SASS Version 5 Score Sheet

Version date: Feb 2005

Date: 09/05/2012
RHP Site Code: HI/HOLS-MALKO
Collector/Sampler: NG Dithlale/ A le Roux
River: Holsloot
Level 1 Ecoregion:
Quaternary Catchment:
Site Description:

Temp (°C): 18.2
pH: 8.1
DO (mg/L): 96.2
Flow: Slow - Moderate
Riparian Disturbance:
Instream Disturbance:

| | | | (ddmmss) |
|---|---|---|---|
| Grid reference (dd mm ss.s) Lat: S | 33° | 43' | 77.5" |
| Long: E | 19° | 19' | 52.9" |
| Datum (WGS84/Cape): | | | |
| Altitude (m): | 254 | | m |
| Zonation: | | | |

Cond (mS/m): 29.1
Clarity (cm):
TDS: 19.4 ppm
Colour: clear

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 3 | |
| Stones Out Of Current (SOOC) | 2 | |
| Bedrock | 1 | |
| Aquatic Veg | | |
| MargVeg In Current | 1 | |
| MargVeg Out Of Current | 2 | |
| Gravel | | |
| Sand | 2 | |
| Mud | 1 | |
| Hand picking/Visual observation | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| PORIFERA (Sponge) | 5 | | | | |
| COELENTERATA (Cnidaria) | 1 | | | | |
| TURBELLARIA (Flatworms) | 3 | | | | |
| ANNELIDA | | | | | |
| Oligochaeta (Earthworms) | 1 | | | | |
| Leeches | 3 | | | | |
| CRUSTACEA | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | 1 | | | 1 |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| HYDRACARINA (Mites) | 8 | | | | |
| PLECOPTERA (Stoneflies) | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| EPHEMEROPTERA | | | | | |
| Baetidae 1sp | 4 | | | | |
| Baetidae 2 sp | 6 | | | A | |
| Baetidae > 2 sp | 12 | B | B | | B |
| Caenidae (Squaregills/Cainflies) | 6 | | | 1 | 1 |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | A | | 1 | A |
| Leptophlebiidae (Prongills) | 9 | 1 | A | | A |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | | | | |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| ODONATA (Dragonflies & Damselflies) | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | 1 | B | | B |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | | A | 1 | B |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | | A | A |
| Libellulidae (Darters) | 4 | A | A | 1 | A |
| LEPIDOPTERA (Aquatic Caterpillars/Moths) | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| HEMIPTERA (Bugs) | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | 1 | 1 | | A |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | | |
| MEGALOPTERA (Fishflies, Dobsonflies & Alderflies) | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | 1 | | | 1 |
| Sialidae (Alderflies) | 6 | | | | |
| TRICHOPTERA (Caddisflies) | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | | | | |
| Hydropsychidae 2 sp | 6 | | | | |
| Hydropsychidae > 2 sp | 12 | | | | |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| Cased caddis: | | | | | |
| Barbarochthonidae SWC | 13 | | | | |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | | | | |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | | | |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | 1 | | | 1 |
| COLEOPTERA (Beetles) | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | A | | A |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | | | | |
| Gyrinidae* (Whirligig beetles) | 5 | | | | |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | 1 | | 1 |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

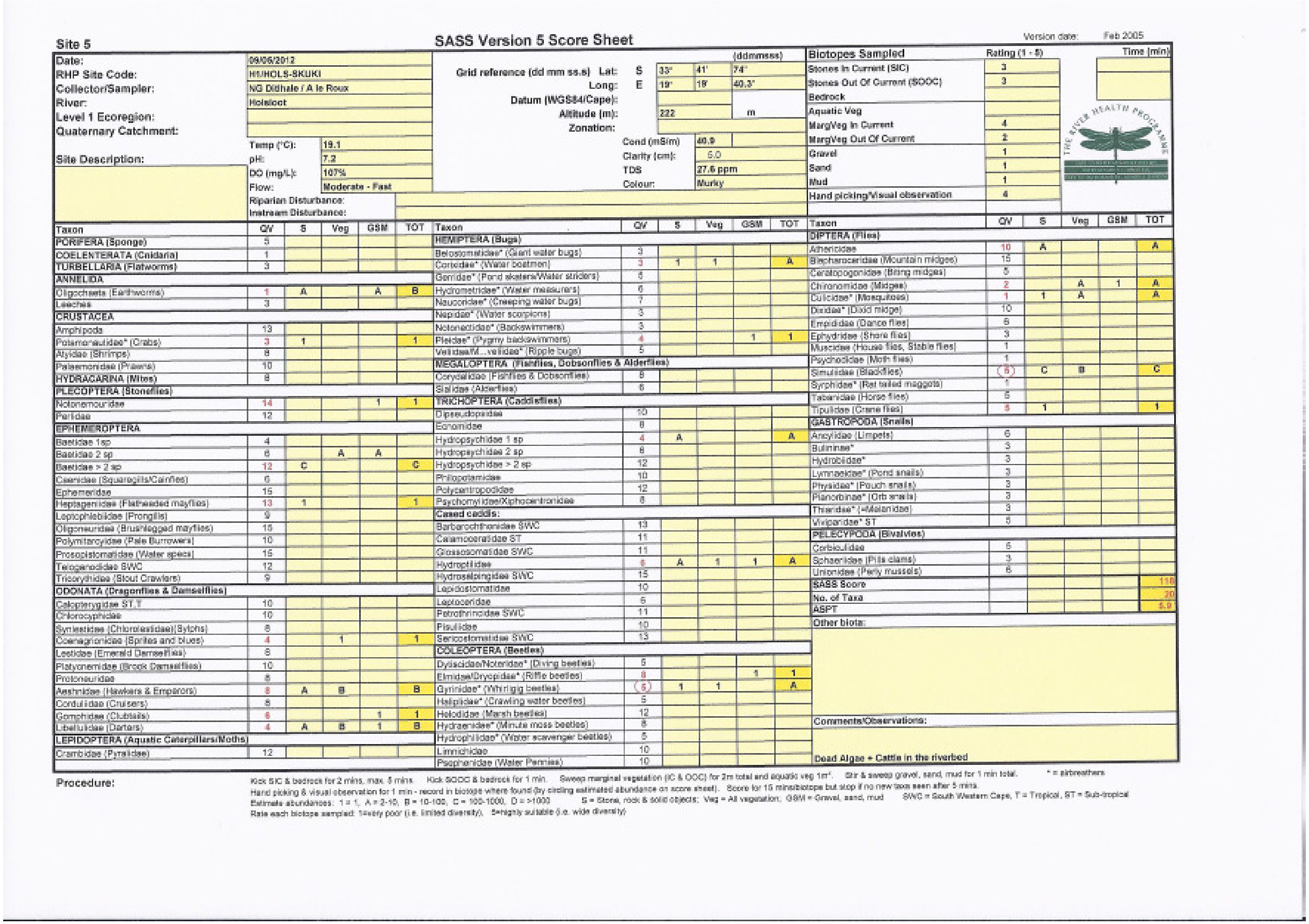
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| DIPTERA (Flies) | | | | | |
| Athericidae | 10 | | | | |
| Blephariceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | | | | |
| Chironomidae (Midges) | 2 | A | 1 | A | A |
| Culicidae* (Mosquitoes) | 1 | 1 | | | 1 |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | | | | |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | | | | |
| GASTROPODA (Snails) | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| PELECYPODA (Bivalvles) | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| SASS Score | | | | | 105 |
| No. of Taxa | | | | | 16 |
| ASPT | | | | | 6.6 |

Other biota:
Ptyodactilidae
Millipede/ Centipede

Comments/Observations:

Procedure: Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Winter: May 2012, Sampling Site 5



Site 5

## SASS Version 5 Score Sheet

Version date: Feb 2005

| | |
|---|---|
| Date: | 09/06/2012 |
| RHP Site Code: | H1/HOLS-SKUKI |
| Collector/Sampler: | NG Dithale / A le Roux |
| River: | Holsloot |
| Level 1 Ecoregion: | |
| Quaternary Catchment: | |
| Site Description: | |
| Temp (°C): | 19.1 |
| pH: | 7.2 |
| DO (mg/L): | 107% |
| Flow: | Moderate - Fast |
| Riparian Disturbance: | |
| Instream Disturbance: | |

| | | | | |
|---|---|---|---|---|
| Grid reference (dd mm ss.s) | | | | (ddmmss) |
| Lat: | S | 33° | 41' | 74" |
| Long: | E | 19° | 18' | 40.3" |
| Datum (WGS84/Cape): | | | | |
| Altitude (m): | | 222 | m | |
| Zonation: | | | | |

| | |
|---|---|
| Cond (mS/m) | 40.9 |
| Clarity (cm): | 5.0 |
| TDS | 27.6 ppm |
| Colour: | Murky |

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 3 | |
| Stones Out Of Current (SOOC) | 3 | |
| Bedrock | | |
| Aquatic Veg | | |
| MargVeg In Current | 4 | |
| MargVeg Out Of Current | 2 | |
| Gravel | 1 | |
| Sand | 1 | |
| Mud | 1 | |
| Hand picking/Visual observation | 4 | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | A | | A | B |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | 1 | | | 1 |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | | | 1 | 1 |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | | |
| Baetidae 2 sp | 6 | | A | A | |
| Baetidae > 2 sp | 12 | C | | | C |
| Caenidae (Squaregills/Cainflies) | 6 | | | | |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | 1 | | | 1 |
| Leptophlebiidae (Prongills) | 9 | | | | |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | | | | |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | 1 | | 1 |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | A | B | | B |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | | 1 | 1 |
| Libellulidae (Darters) | 4 | A | B | 1 | B |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | 1 | 1 | | A |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | 1 | 1 |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | | |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | | | | |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | A | | | A |
| Hydropsychidae 2 sp | 6 | | | | |
| Hydropsychidae > 2 sp | 12 | | | | |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | | | | |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | | | | |
| Hydroptilidae | 6 | A | 1 | 1 | A |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | | | |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | | | | |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | | | |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | | | 1 | 1 |
| Gyrinidae* (Whirligig beetles) | ⑤ | 1 | 1 | | A |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | A | | | A |
| Blephariceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | | | | |
| Chironomidae (Midges) | 2 | | A | 1 | A |
| Culicidae* (Mosquitoes) | 1 | 1 | A | | A |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | ⑤ | C | B | | C |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | 1 | | | 1 |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvies)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 118 |
| **No. of Taxa** | | | | | 20 |
| **ASPT** | | | | | 5.9 |

**Other biota:**

**Comments/Observations:**

**Dead Algae + Cattle in the riverbed**

**Procedure:**

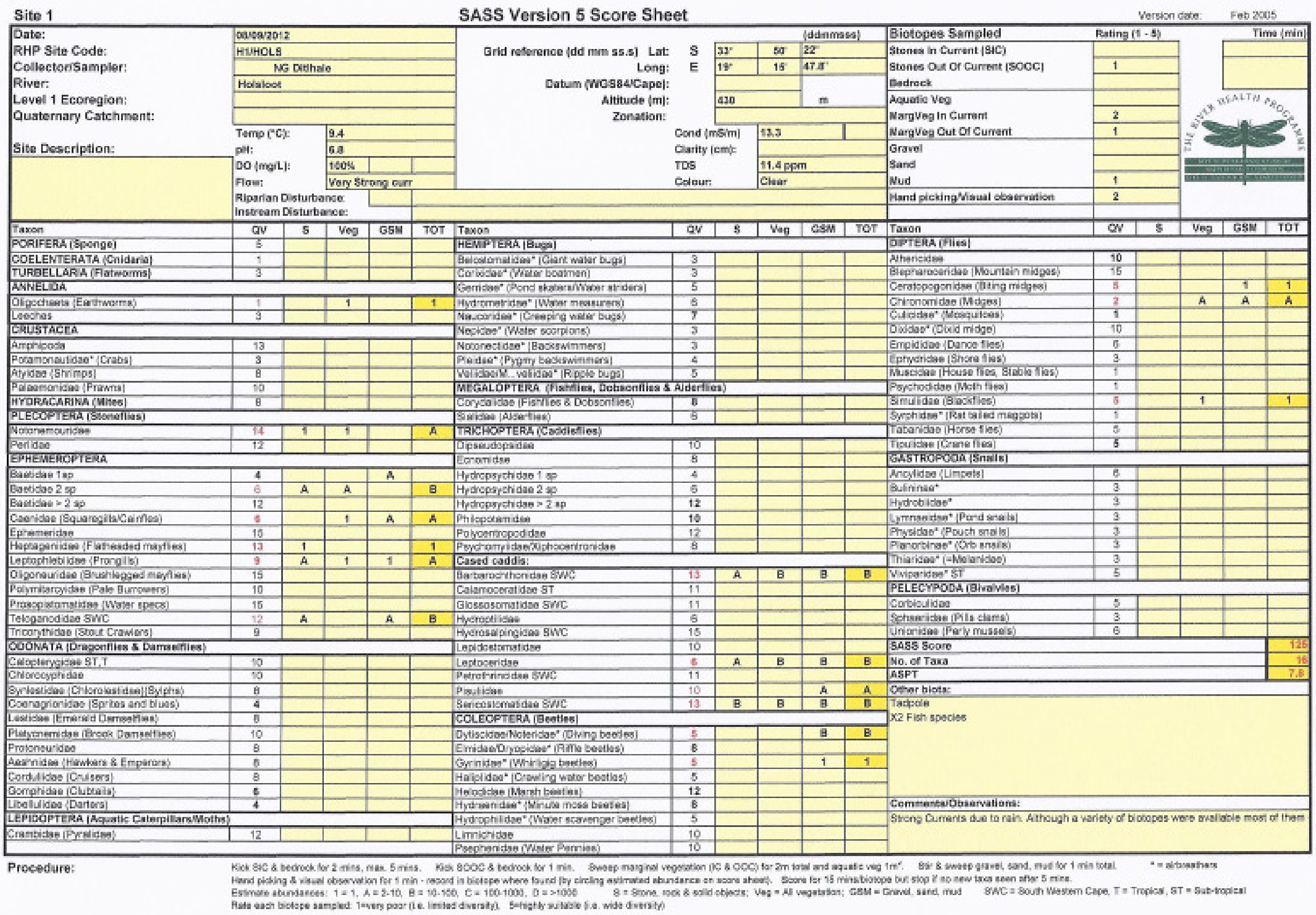
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers

Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.

Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical

Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Spring: September 2012, Sampling Site 1



**Site 1**

## SASS Version 5 Score Sheet

Version date: Feb 2005

|  |  |
|---|---|
| Date: | 08/09/2012 |
| RHP Site Code: | H1/HOLS |
| Collector/Sampler: | NG Dithale |
| River: | Holsloot |
| Level 1 Ecoregion: |  |
| Quaternary Catchment: |  |
| Site Description: |  |
| Temp (°C): | 9.4 |
| pH: | 6.8 |
| DO (mg/L): | 100% |
| Flow: | Very Strong curr |
| Riparian Disturbance: |  |
| Instream Disturbance: |  |

(ddmmss.s)

| Grid reference (dd mm ss.s) |  |  |  |  |
|---|---|---|---|---|
| Lat: | S | 33° | 50' | 22" |
| Long: | E | 19° | 15' | 47.8" |
| Datum (WGS84/Cape): |  |  |  |  |
| Altitude (m): |  | 430 | m |  |
| Zonation: |  |  |  |  |

|  |  |
|---|---|
| Cond (mS/m) | 13.3 |
| Clarity (cm): |  |
| TDS | 11.4 ppm |
| Colour: | Clear |

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) |  |  |
| Stones Out Of Current (SOOC) | 1 |  |
| Bedrock |  |  |
| Aquatic Veg |  |  |
| MargVeg In Current | 2 |  |
| MargVeg Out Of Current | 1 |  |
| Gravel |  |  |
| Sand |  |  |
| Mud | 1 |  |
| Hand picking/Visual observation | 2 |  |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 |  |  |  |  |
| **COELENTERATA (Cnidaria)** | 1 |  |  |  |  |
| **TURBELLARIA (Flatworms)** | 3 |  |  |  |  |
| **ANNELIDA** |  |  |  |  |  |
| Oligochaeta (Earthworms) | 1 |  | 1 |  | 1 |
| Leeches | 3 |  |  |  |  |
| **CRUSTACEA** |  |  |  |  |  |
| Amphipoda | 13 |  |  |  |  |
| Potamonautidae* (Crabs) | 3 |  |  |  |  |
| Atyidae (Shrimps) | 8 |  |  |  |  |
| Palaemonidae (Prawns) | 10 |  |  |  |  |
| **HYDRACARINA (Mites)** | 8 |  |  |  |  |
| **PLECOPTERA (Stoneflies)** |  |  |  |  |  |
| Notonemouridae | 14 | 1 | 1 |  | A |
| Perlidae | 12 |  |  |  |  |
| **EPHEMEROPTERA** |  |  |  |  |  |
| Baetidae 1sp | 4 |  |  | A |  |
| Baetidae 2 sp | 6 | A | A |  | B |
| Baetidae > 2 sp | 12 |  |  |  |  |
| Caenidae (Squaregills/Cainfles) | 6 |  | 1 | A | A |
| Ephemeridae | 15 |  |  |  |  |
| Heptageniidae (Flatheaded mayflies) | 13 | 1 |  |  | 1 |
| Leptophlebiidae (Prongills) | 9 | A | 1 | 1 | A |
| Oligoneuridae (Brushlegged mayflies) | 15 |  |  |  |  |
| Polymitarcyidae (Pale Burrowers) | 10 |  |  |  |  |
| Prosopistomatidae (Water specs) | 15 |  |  |  |  |
| Teloganodidae SWC | 12 | A |  | A | B |
| Tricorythidae (Stout Crawlers) | 9 |  |  |  |  |
| **ODONATA (Dragonflies & Damselflies)** |  |  |  |  |  |
| Calopterygidae ST,T | 10 |  |  |  |  |
| Chlorocyphidae | 10 |  |  |  |  |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 |  |  |  |  |
| Coenagrionidae (Sprites and blues) | 4 |  |  |  |  |
| Lestidae (Emerald Damselflies) | 8 |  |  |  |  |
| Platycnemidae (Brook Damselflies) | 10 |  |  |  |  |
| Protoneuridae | 8 |  |  |  |  |
| Aeshnidae (Hawkers & Emperors) | 8 |  |  |  |  |
| Corduliidae (Cruisers) | 8 |  |  |  |  |
| Gomphidae (Clubtails) | 6 |  |  |  |  |
| Libellulidae (Darters) | 4 |  |  |  |  |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** |  |  |  |  |  |
| Crambidae (Pyralidae) | 12 |  |  |  |  |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** |  |  |  |  |  |
| Belostomatidae* (Giant water bugs) | 3 |  |  |  |  |
| Corixidae* (Water boatmen) | 3 |  |  |  |  |
| Gerridae* (Pond skaters/Water striders) | 5 |  |  |  |  |
| Hydrometridae* (Water measurers) | 6 |  |  |  |  |
| Naucoridae* (Creeping water bugs) | 7 |  |  |  |  |
| Nepidae* (Water scorpions) | 3 |  |  |  |  |
| Notonectidae* (Backswimmers) | 3 |  |  |  |  |
| Pleidae* (Pygmy backswimmers) | 4 |  |  |  |  |
| Veliidae/M...veliidae* (Ripple bugs) | 5 |  |  |  |  |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** |  |  |  |  |  |
| Corydalidae (Fishflies & Dobsonflies) | 8 |  |  |  |  |
| Sialidae (Alderflies) | 6 |  |  |  |  |
| **TRICHOPTERA (Caddisflies)** |  |  |  |  |  |
| Dipseudopsidae | 10 |  |  |  |  |
| Ecnomidae | 8 |  |  |  |  |
| Hydropsychidae 1 sp | 4 |  |  |  |  |
| Hydropsychidae 2 sp | 6 |  |  |  |  |
| Hydropsychidae > 2 sp | 12 |  |  |  |  |
| Philopotamidae | 10 |  |  |  |  |
| Polycentropodidae | 12 |  |  |  |  |
| Psychomyiidae/Xiphocentronidae | 8 |  |  |  |  |
| **Cased caddis:** |  |  |  |  |  |
| Barbarochthonidae SWC | 13 | A | B | B | B |
| Calamoceratidae ST | 11 |  |  |  |  |
| Glossosomatidae SWC | 11 |  |  |  |  |
| Hydroptilidae | 6 |  |  |  |  |
| Hydrosalpingidae SWC | 15 |  |  |  |  |
| Lepidostomatidae | 10 |  |  |  |  |
| Leptoceridae | 6 | A | B | B | B |
| Petrothrincidae SWC | 11 |  |  |  |  |
| Pisuliidae | 10 |  |  | A | A |
| Sericostomatidae SWC | 13 | B | B | B | B |
| **COLEOPTERA (Beetles)** |  |  |  |  |  |
| Dytiscidae/Noteridae* (Diving beetles) | 5 |  |  | B | B |
| Elmidae/Dryopidae* (Riffle beetles) | 8 |  |  |  |  |
| Gyrinidae* (Whirligig beetles) | 5 |  |  | 1 | 1 |
| Haliplidae* (Crawling water beetles) | 5 |  |  |  |  |
| Helodidae (Marsh beetles) | 12 |  |  |  |  |
| Hydraenidae* (Minute moss beetles) | 8 |  |  |  |  |
| Hydrophilidae* (Water scavenger beetles) | 5 |  |  |  |  |
| Limnichidae | 10 |  |  |  |  |
| Psephenidae (Water Pennies) | 10 |  |  |  |  |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** |  |  |  |  |  |
| Athericidae | 10 |  |  |  |  |
| Blephariceridae (Mountain midges) | 15 |  |  |  |  |
| Ceratopogonidae (Biting midges) | 5 |  |  | 1 | 1 |
| Chironomidae (Midges) | 2 |  | A | A | A |
| Culicidae* (Mosquitoes) | 1 |  |  |  |  |
| Dixidae* (Dixid midge) | 10 |  |  |  |  |
| Empididae (Dance flies) | 6 |  |  |  |  |
| Ephydridae (Shore flies) | 3 |  |  |  |  |
| Muscidae (House flies, Stable flies) | 1 |  |  |  |  |
| Psychodidae (Moth flies) | 1 |  |  |  |  |
| Simuliidae (Blackflies) | 5 |  | 1 |  | 1 |
| Syrphidae* (Rat tailed maggots) | 1 |  |  |  |  |
| Tabanidae (Horse flies) | 5 |  |  |  |  |
| Tipulidae (Crane flies) | 5 |  |  |  |  |
| **GASTROPODA (Snails)** |  |  |  |  |  |
| Ancylidae (Limpets) | 6 |  |  |  |  |
| Bulininae* | 3 |  |  |  |  |
| Hydrobiidae* | 3 |  |  |  |  |
| Lymnaeidae* (Pond snails) | 3 |  |  |  |  |
| Physidae* (Pouch snails) | 3 |  |  |  |  |
| Planorbinae* (Orb snails) | 3 |  |  |  |  |
| Thiaridae* (=Melanidae) | 3 |  |  |  |  |
| Viviparidae* ST | 5 |  |  |  |  |
| **PELECYPODA (Bivalvles)** |  |  |  |  |  |
| Corbiculidae | 5 |  |  |  |  |
| Sphaeriidae (Pills clams) | 3 |  |  |  |  |
| Unionidae (Perly mussels) | 6 |  |  |  |  |
| **SASS Score** |  |  |  |  | 125 |
| **No. of Taxa** |  |  |  |  | 16 |
| **ASPT** |  |  |  |  | 7.8 |

**Other biota:**

Tadpole
X2 Fish species

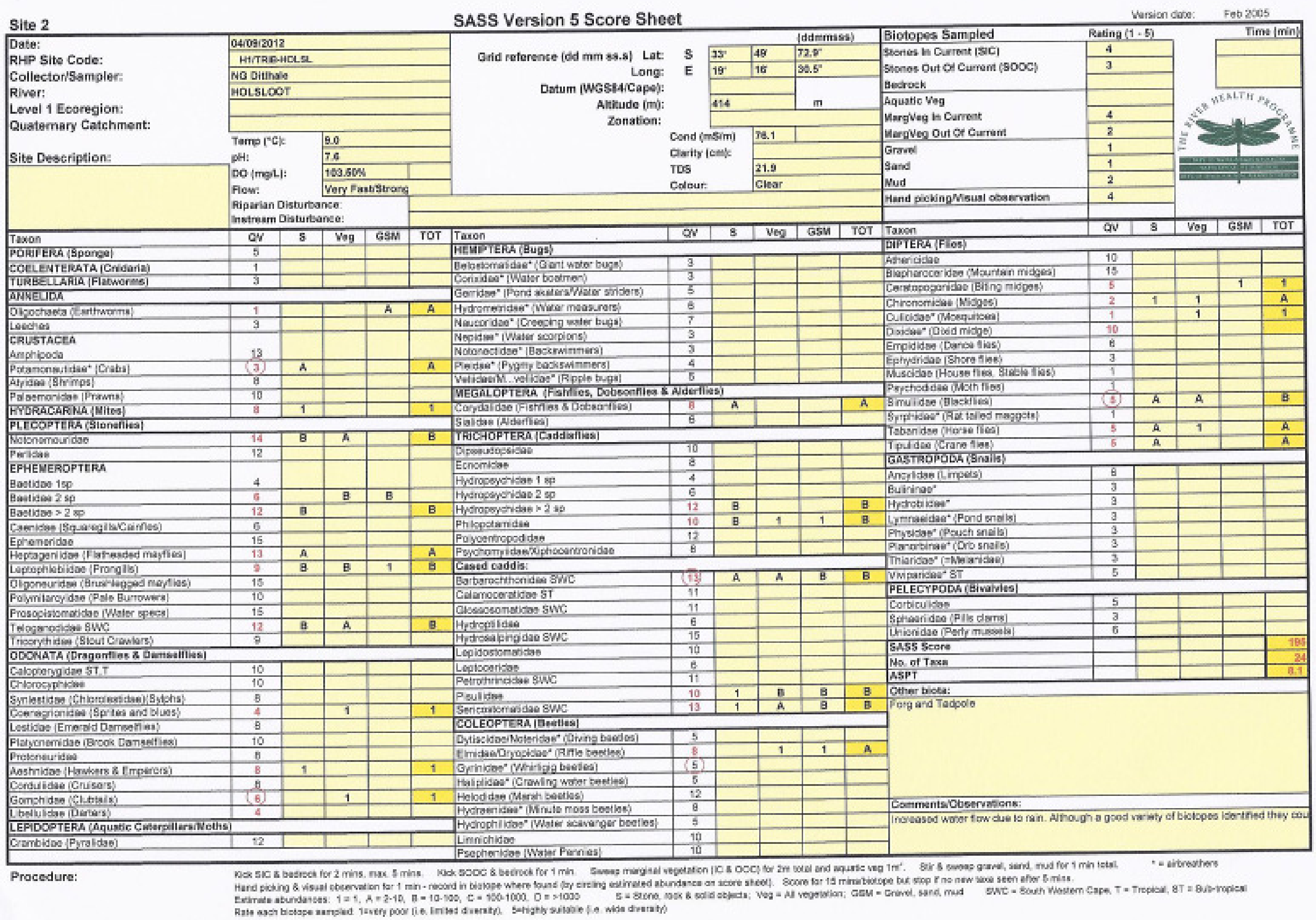
**Comments/Observations:**

Strong Currents due to rain. Although a variety of biotopes were available most of them

**Procedure:**

Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Spring: September 2012, Sampling Site 2



**Site 2**

## SASS Version 5 Score Sheet

Version date: Feb 2005

| | |
|---|---|
| **Date:** | 04/09/2012 |
| **RHP Site Code:** | H1/TRIB-HOLSL |
| **Collector/Sampler:** | NG Ditlhale |
| **River:** | HOLSLOOT |
| **Level 1 Ecoregion:** | |
| **Quaternary Catchment:** | |
| **Site Description:** | |
| Temp (°C): | 9.0 |
| pH: | 7.6 |
| DO (mg/L): | 103.50% |
| Flow: | Very Fast/Strong |
| Riparian Disturbance: | |
| Instream Disturbance: | |

| | | | | (ddmmss) |
|---|---|---|---|---|
| Grid reference (dd mm ss.s) Lat: | S | 33' | 49' | 72.9" |
| Long: | E | 19' | 16' | 30.5" |
| Datum (WGS84/Cape): | | | | |
| Altitude (m): | | 414 | | m |
| Zonation: | | | | |
| Cond (mS/m) | 76.1 | | | |
| Clarity (cm): | | | | |
| TDS | 21.9 | | | |
| Colour: | Clear | | | |

| **Biotopes Sampled** | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 4 | |
| Stones Out Of Current (SOOC) | 3 | |
| Bedrock | | |
| Aquatic Veg | | |
| MargVeg In Current | 4 | |
| MargVeg Out Of Current | 2 | |
| Gravel | 1 | |
| Sand | 1 | |
| Mud | 2 | |
| Hand picking/Visual observation | 4 | |

THE RIVER HEALTH PROGRAMME

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | | | A | A |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | ③ | A | | | A |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | 1 | | | 1 |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | B | A | | B |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | | |
| Baetidae 2 sp | 6 | | B | B | |
| Baetidae > 2 sp | 12 | B | | | B |
| Caenidae (Squaregills/Cainflies) | 6 | | | | |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | A | | | A |
| Leptophlebiidae (Prongills) | 9 | B | B | 1 | B |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | B | A | | B |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | 1 | | 1 |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | 1 | | | 1 |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | ⑥ | | 1 | | 1 |
| Libellulidae (Darters) | 4 | | | | |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | | | |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | | |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | A | | | A |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | | | | |
| Hydropsychidae 2 sp | 6 | | | | |
| Hydropsychidae > 2 sp | 12 | B | | | B |
| Philopotamidae | 10 | B | 1 | 1 | B |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | ⑬ | A | A | B | B |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | | | | |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | | | |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | 1 | B | B | B |
| Sericostomatidae SWC | 13 | 1 | A | B | B |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | | | |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | | 1 | 1 | A |
| Gyrinidae* (Whirligig beetles) | ⑤ | | | | |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | | | | |
| Blephariceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | | | 1 | 1 |
| Chironomidae (Midges) | 2 | 1 | 1 | | A |
| Culicidae* (Mosquitoes) | 1 | | 1 | | 1 |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | ⑤ | A | A | | B |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | A | 1 | | A |
| Tipulidae (Crane flies) | 5 | A | | | A |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalves)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 195 |
| **No. of Taxa** | | | | | 24 |
| **ASPT** | | | | | 8.1 |

**Other biota:**

Forg and Tadpole

**Comments/Observations:**

Increased water flow due to rain. Although a good variety of biotopes identified they cou

**Procedure:**

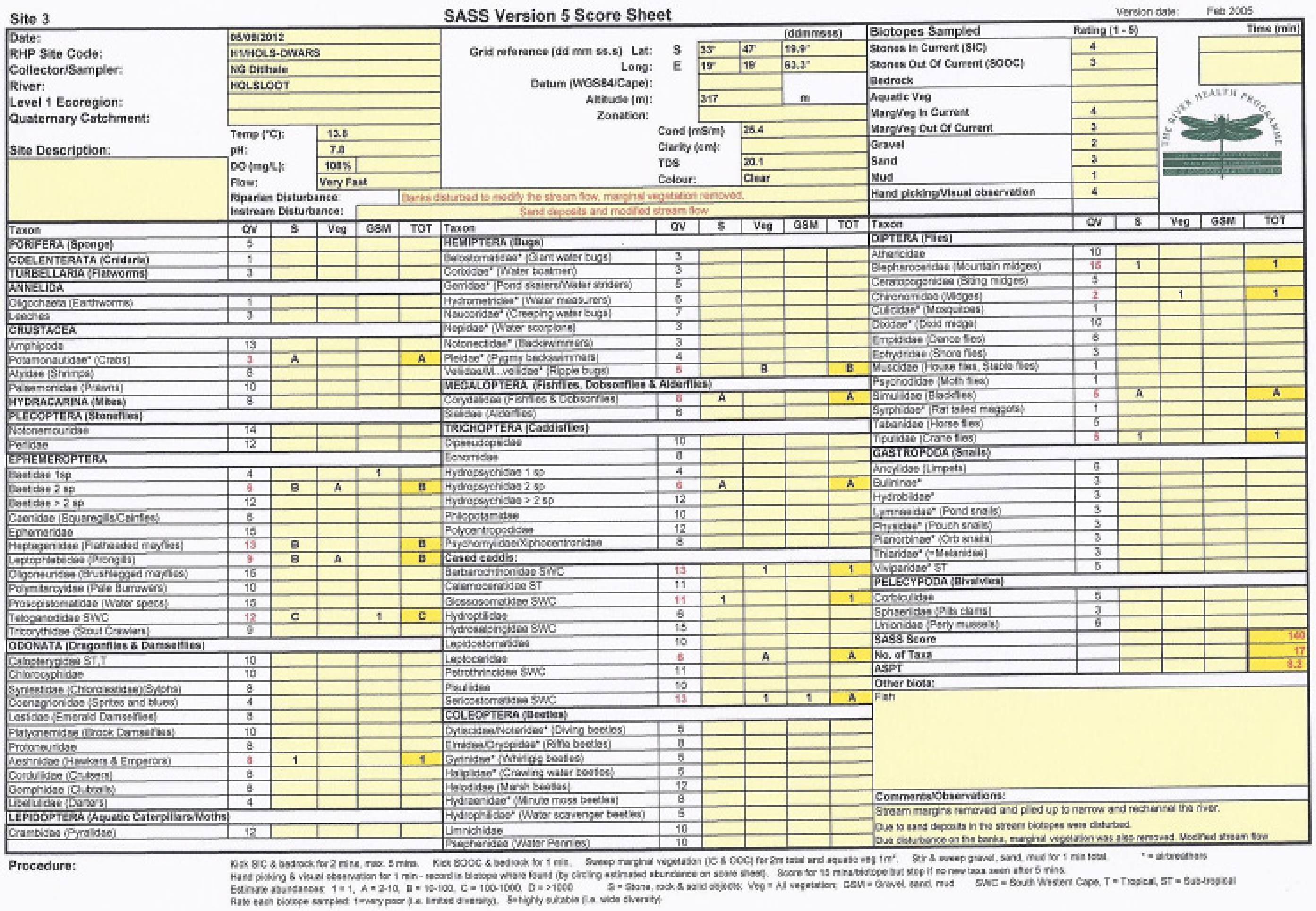
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers

Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.

Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical

Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Spring: September 2012, Sampling Site 3



Site 3

## SASS Version 5 Score Sheet

Version date: Feb 2005

Date: 05/09/2012
RHP Site Code: H1/HOLS-DWARS
Collector/Sampler: NG Dithale
River: HOLSLOOT
Level 1 Ecoregion:
Quaternary Catchment:
Site Description:

Temp (°C): 13.8
pH: 7.8
DO (mg/L): 108%
Flow: Very Fast
Riparian Disturbance: Banks disturbed to modify the stream flow, marginal vegetation removed.
Instream Disturbance: Sand deposits and modified stream flow

Grid reference (dd mm ss.s) (ddmmss.s)
Lat: S 33° 47' 19.9"
Long: E 19° 19' 63.3"
Datum (WGS84/Cape):
Altitude (m): 317 m
Zonation:
Cond (mS/m): 25.4
Clarity (cm):
TDS 20.1
Colour: Clear

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 4 | |
| Stones Out Of Current (SOOC) | 3 | |
| Bedrock | | |
| Aquatic Veg | | |
| MargVeg In Current | 4 | |
| MargVeg Out Of Current | 3 | |
| Gravel | 2 | |
| Sand | 3 | |
| Mud | 1 | |
| Hand picking/Visual observation | 4 | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| PORIFERA (Sponge) | 5 | | | | |
| COELENTERATA (Cnidaria) | 1 | | | | |
| TURBELLARIA (Flatworms) | 3 | | | | |
| ANNELIDA | | | | | |
| Oligochaeta (Earthworms) | 1 | | | | |
| Leeches | 3 | | | | |
| CRUSTACEA | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | A | | | A |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| HYDRACARINA (Mites) | 8 | | | | |
| PLECOPTERA (Stoneflies) | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| EPHEMEROPTERA | | | | | |
| Baetidae 1sp | 4 | | | 1 | |
| Baetidae 2 sp | 6 | B | A | | B |
| Baetidae > 2 sp | 12 | | | | |
| Caenidae (Squaregills/Cainflies) | 6 | | | | |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | B | | | B |
| Leptophlebiidae (Prongills) | 9 | B | A | | B |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | C | | 1 | C |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| ODONATA (Dragonflies & Damselflies) | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | | | |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | 1 | | | 1 |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | | | |
| Libellulidae (Darters) | 4 | | | | |
| LEPIDOPTERA (Aquatic Caterpillars/Moths) | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| HEMIPTERA (Bugs) | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | | | |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | B | | B |
| MEGALOPTERA (Fishflies, Dobsonflies & Alderflies) | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | A | | | A |
| Sialidae (Alderflies) | 6 | | | | |
| TRICHOPTERA (Caddisflies) | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | | | | |
| Hydropsychidae 2 sp | 6 | A | | | A |
| Hydropsychidae > 2 sp | 12 | | | | |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| Cased caddis: | | | | | |
| Barbarochthonidae SWC | 13 | | 1 | | 1 |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | 1 | | | 1 |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | A | | A |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | | 1 | 1 | A |
| COLEOPTERA (Beetles) | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | | | |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | | | | |
| Gyrinidae* (Whirligig beetles) | 5 | | | | |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

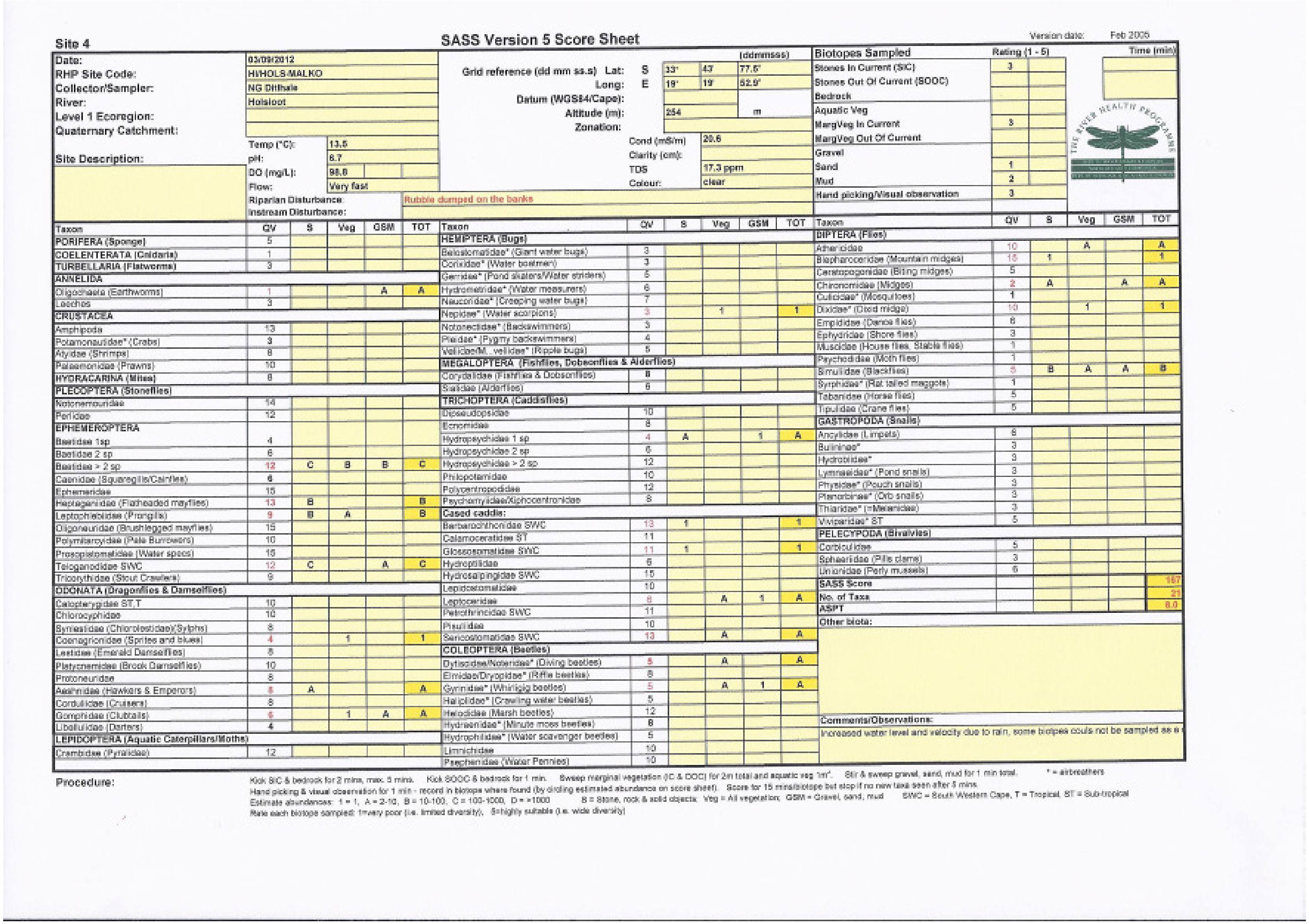
| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| DIPTERA (Flies) | | | | | |
| Athericidae | 10 | | | | |
| Blephariceridae (Mountain midges) | 15 | 1 | | | 1 |
| Ceratopogonidae (Biting midges) | 5 | | | | |
| Chironomidae (Midges) | 2 | | 1 | | 1 |
| Culicidae* (Mosquitoes) | 1 | | | | |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | A | | | A |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | 1 | | | 1 |
| GASTROPODA (Snails) | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| PELECYPODA (Bivalvies) | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| SASS Score | | | | | 140 |
| No. of Taxa | | | | | 17 |
| ASPT | | | | | 8.2 |

Other biota:
Fish

Comments/Observations:
Stream margins removed and piled up to narrow and rechannel the river.
Due to sand deposits in the stream biotopes were disturbed.
Due disturbance on the banks, marginal vegetation was also removed. Modified stream flow

**Procedure:**
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Spring: September 2012, Sampling Site 4



**Site 4**

## SASS Version 5 Score Sheet

Version date: Feb 2005

Date: 03/09/2012
RHP Site Code: H/HOLS-MALKO
Collector/Sampler: NG Dithale
River: Holsloot
Level 1 Ecoregion:
Quaternary Catchment:
Site Description:

Temp (°C): 13.5
pH: 6.7
DO (mg/L): 98.8
Flow: Very fast
Riparian Disturbance: Rubble dumped on the banks
Instream Disturbance:

Grid reference (dd mm ss.s) (ddmmsss)
Lat: S 33° 43' 77.5"
Long: E 19° 19' 52.9"
Datum (WGS84/Cape):
Altitude (m): 254 m
Zonation:
Cond (mS/m) 20.6
Clarity (cm):
TDS 17.3 ppm
Colour: clear

| Biotopes Sampled | Rating (1 - 5) | | Time (min) |
|---|---|---|---|
| Stones In Current (SIC) | 3 | | |
| Stones Out Of Current (SOOC) | | | |
| Bedrock | | | |
| Aquatic Veg | | | |
| MargVeg In Current | 3 | | |
| MargVeg Out Of Current | | | |
| Gravel | | | |
| Sand | 1 | | |
| Mud | 2 | | |
| Hand picking/Visual observation | 3 | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| PORIFERA (Sponge) | 5 | | | | |
| COELENTERATA (Cnidaria) | 1 | | | | |
| TURBELLARIA (Flatworms) | 3 | | | | |
| ANNELIDA | | | | | |
| Oligochaeta (Earthworms) | 1 | | | A | A |
| Leeches | 3 | | | | |
| CRUSTACEA | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | | | | |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| HYDRACARINA (Mites) | 8 | | | | |
| PLECOPTERA (Stoneflies) | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| EPHEMEROPTERA | | | | | |
| Baetidae 1sp | 4 | | | | |
| Baetidae 2 sp | 6 | | | | |
| Baetidae > 2 sp | 12 | C | B | B | C |
| Caenidae (Squaregills/Cainfles) | 6 | | | | |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | B | | | B |
| Leptophlebiidae (Prongills) | 9 | B | A | | B |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | C | | A | C |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| ODONATA (Dragonflies & Damselflies) | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | 1 | | 1 |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | A | | | A |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | 1 | A | A |
| Libellulidae (Darters) | 4 | | | | |
| LEPIDOPTERA (Aquatic Caterpillars/Moths) | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| HEMIPTERA (Bugs) | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | | | |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | | | | |
| Nepidae* (Water scorpions) | 3 | | 1 | | 1 |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | | |
| MEGALOPTERA (Fishflies, Dobsonflies & Alderflies) | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | | | | |
| Sialidae (Alderflies) | 6 | | | | |
| TRICHOPTERA (Caddisflies) | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | A | | 1 | A |
| Hydropsychidae 2 sp | 6 | | | | |
| Hydropsychidae > 2 sp | 12 | | | | |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| Cased caddis: | | | | | |
| Barbarochthonidae SWC | 13 | 1 | | | 1 |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | 1 | | | 1 |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | A | 1 | A |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | | A | | A |
| COLEOPTERA (Beetles) | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | A | | A |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | | | | |
| Gyrinidae* (Whirligig beetles) | 5 | | A | 1 | A |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| DIPTERA (Flies) | | | | | |
| Athericidae | 10 | | A | | A |
| Blephariceridae (Mountain midges) | 15 | 1 | | | 1 |
| Ceratopogonidae (Biting midges) | 5 | | | | |
| Chironomidae (Midges) | 2 | A | | A | A |
| Culicidae* (Mosquitoes) | 1 | | | | |
| Dixidae* (Dixid midge) | 10 | | 1 | | 1 |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | B | A | A | B |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | | | | |
| GASTROPODA (Snails) | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| PELECYPODA (Bivalvies) | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pill clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| SASS Score | | | | | 167 |
| No. of Taxa | | | | | 21 |
| ASPT | | | | | 8.0 |

Other biota:

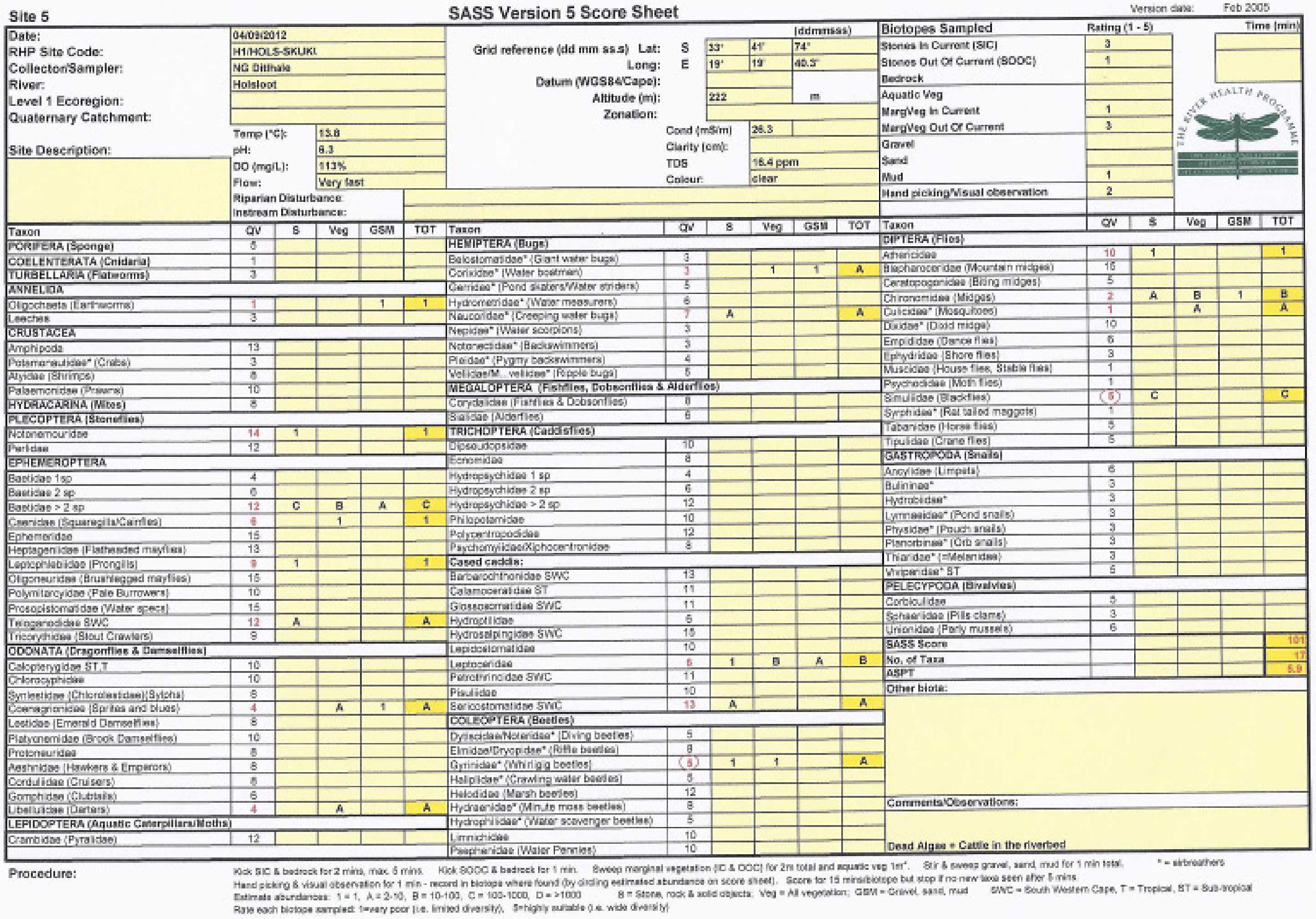
Comments/Observations:

Increased water level and velocity due to rain, some biotpes couls not be sampled as a

Procedure:

Kick SIC & bedrock for 2 mins, max. 5 mins.  Kick SOOC & bedrock for 1 min.  Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m².  Stir & sweep gravel, sand, mud for 1 min total.  * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet).  Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000  S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud  SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Spring: September 2012, Sampling Site 5



**Site 5**

## SASS Version 5 Score Sheet

Version date: Feb 2005

Date: 04/09/2012
RHP Site Code: H1/HOLS-SKUKI
Collector/Sampler: NG Ditlhale
River: Holsloot
Level 1 Ecoregion:
Quaternary Catchment:
Site Description:

Temp (°C): 13.8
pH: 8.3
DO (mg/L): 113%
Flow: Very fast
Riparian Disturbance:
Instream Disturbance:

| | | (ddmmss.s) | | |
|---|---|---|---|---|
| Grid reference (dd mm ss.s) Lat: | S | 33' | 41' | 74" |
| Long: | E | 19' | 19' | 40.3" |
| Datum (WGS84/Cape): | | | | |
| Altitude (m): | | 222 | | m |
| Zonation: | | | | |

Cond (mS/m): 26.3
Clarity (cm):
TDS: 16.4 ppm
Colour: clear

| Biotopes Sampled | Rating (1 - 5) | Time (min) |
|---|---|---|
| Stones In Current (SIC) | 3 | |
| Stones Out Of Current (SOOC) | 1 | |
| Bedrock | - | |
| Aquatic Veg | | |
| MargVeg In Current | 1 | |
| MargVeg Out Of Current | 3 | |
| Gravel | | |
| Sand | | |
| Mud | 1 | |
| Hand picking/Visual observation | 2 | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA (Sponge)** | 5 | | | | |
| **COELENTERATA (Cnidaria)** | 1 | | | | |
| **TURBELLARIA (Flatworms)** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta (Earthworms) | 1 | | | 1 | 1 |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* (Crabs) | 3 | | | | |
| Atyidae (Shrimps) | 8 | | | | |
| Palaemonidae (Prawns) | 10 | | | | |
| **HYDRACARINA (Mites)** | 8 | | | | |
| **PLECOPTERA (Stoneflies)** | | | | | |
| Notonemouridae | 14 | 1 | | | 1 |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | | |
| Baetidae 2 sp | 6 | | | | |
| Baetidae > 2 sp | 12 | C | B | A | C |
| Caenidae (Squaregills/Cainflies) | 6 | | 1 | | 1 |
| Ephemeridae | 15 | | | | |
| Heptageniidae (Flatheaded mayflies) | 13 | | | | |
| Leptophlebiidae (Prongills) | 9 | 1 | | | 1 |
| Oligoneuridae (Brushlegged mayflies) | 15 | | | | |
| Polymitarcyidae (Pale Burrowers) | 10 | | | | |
| Prosopistomatidae (Water specs) | 15 | | | | |
| Teloganodidae SWC | 12 | A | | | A |
| Tricorythidae (Stout Crawlers) | 9 | | | | |
| **ODONATA (Dragonflies & Damselflies)** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Synlestidae (Chlorolestidae)(Sylphs) | 8 | | | | |
| Coenagrionidae (Sprites and blues) | 4 | | A | 1 | A |
| Lestidae (Emerald Damselflies) | 8 | | | | |
| Platycnemidae (Brook Damselflies) | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae (Hawkers & Emperors) | 8 | | | | |
| Corduliidae (Cruisers) | 8 | | | | |
| Gomphidae (Clubtails) | 6 | | | | |
| Libellulidae (Darters) | 4 | | A | | A |
| **LEPIDOPTERA (Aquatic Caterpillars/Moths)** | | | | | |
| Crambidae (Pyralidae) | 12 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA (Bugs)** | | | | | |
| Belostomatidae* (Giant water bugs) | 3 | | | | |
| Corixidae* (Water boatmen) | 3 | | 1 | 1 | A |
| Gerridae* (Pond skaters/Water striders) | 5 | | | | |
| Hydrometridae* (Water measurers) | 6 | | | | |
| Naucoridae* (Creeping water bugs) | 7 | A | | | A |
| Nepidae* (Water scorpions) | 3 | | | | |
| Notonectidae* (Backswimmers) | 3 | | | | |
| Pleidae* (Pygmy backswimmers) | 4 | | | | |
| Veliidae/M...veliidae* (Ripple bugs) | 5 | | | | |
| **MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)** | | | | | |
| Corydalidae (Fishflies & Dobsonflies) | 8 | | | | |
| Sialidae (Alderflies) | 6 | | | | |
| **TRICHOPTERA (Caddisflies)** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | | | | |
| Hydropsychidae 2 sp | 6 | | | | |
| Hydropsychidae > 2 sp | 12 | | | | |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocentronidae | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | | | | |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | | | | |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | 1 | B | A | B |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | A | | | A |
| **COLEOPTERA (Beetles)** | | | | | |
| Dytiscidae/Noteridae* (Diving beetles) | 5 | | | | |
| Elmidae/Dryopidae* (Riffle beetles) | 8 | | | | |
| Gyrinidae* (Whirligig beetles) | 5 | 1 | 1 | | A |
| Haliplidae* (Crawling water beetles) | 5 | | | | |
| Helodidae (Marsh beetles) | 12 | | | | |
| Hydraenidae* (Minute moss beetles) | 8 | | | | |
| Hydrophilidae* (Water scavenger beetles) | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae (Water Pennies) | 10 | | | | |

| Taxon | QV | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA (Flies)** | | | | | |
| Athericidae | 10 | 1 | | | 1 |
| Blephariceridae (Mountain midges) | 15 | | | | |
| Ceratopogonidae (Biting midges) | 5 | | | | |
| Chironomidae (Midges) | 2 | A | B | 1 | B |
| Culicidae* (Mosquitoes) | 1 | | A | | A |
| Dixidae* (Dixid midge) | 10 | | | | |
| Empididae (Dance flies) | 6 | | | | |
| Ephydridae (Shore flies) | 3 | | | | |
| Muscidae (House flies, Stable flies) | 1 | | | | |
| Psychodidae (Moth flies) | 1 | | | | |
| Simuliidae (Blackflies) | 5 | C | | | C |
| Syrphidae* (Rat tailed maggots) | 1 | | | | |
| Tabanidae (Horse flies) | 5 | | | | |
| Tipulidae (Crane flies) | 5 | | | | |
| **GASTROPODA (Snails)** | | | | | |
| Ancylidae (Limpets) | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* (Pond snails) | 3 | | | | |
| Physidae* (Pouch snails) | 3 | | | | |
| Planorbinae* (Orb snails) | 3 | | | | |
| Thiaridae* (=Melanidae) | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA (Bivalvies)** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae (Pills clams) | 3 | | | | |
| Unionidae (Perly mussels) | 6 | | | | |
| **SASS Score** | | | | | 101 |
| **No. of Taxa** | | | | | 17 |
| **ASPT** | | | | | 5.9 |

**Other biota:**

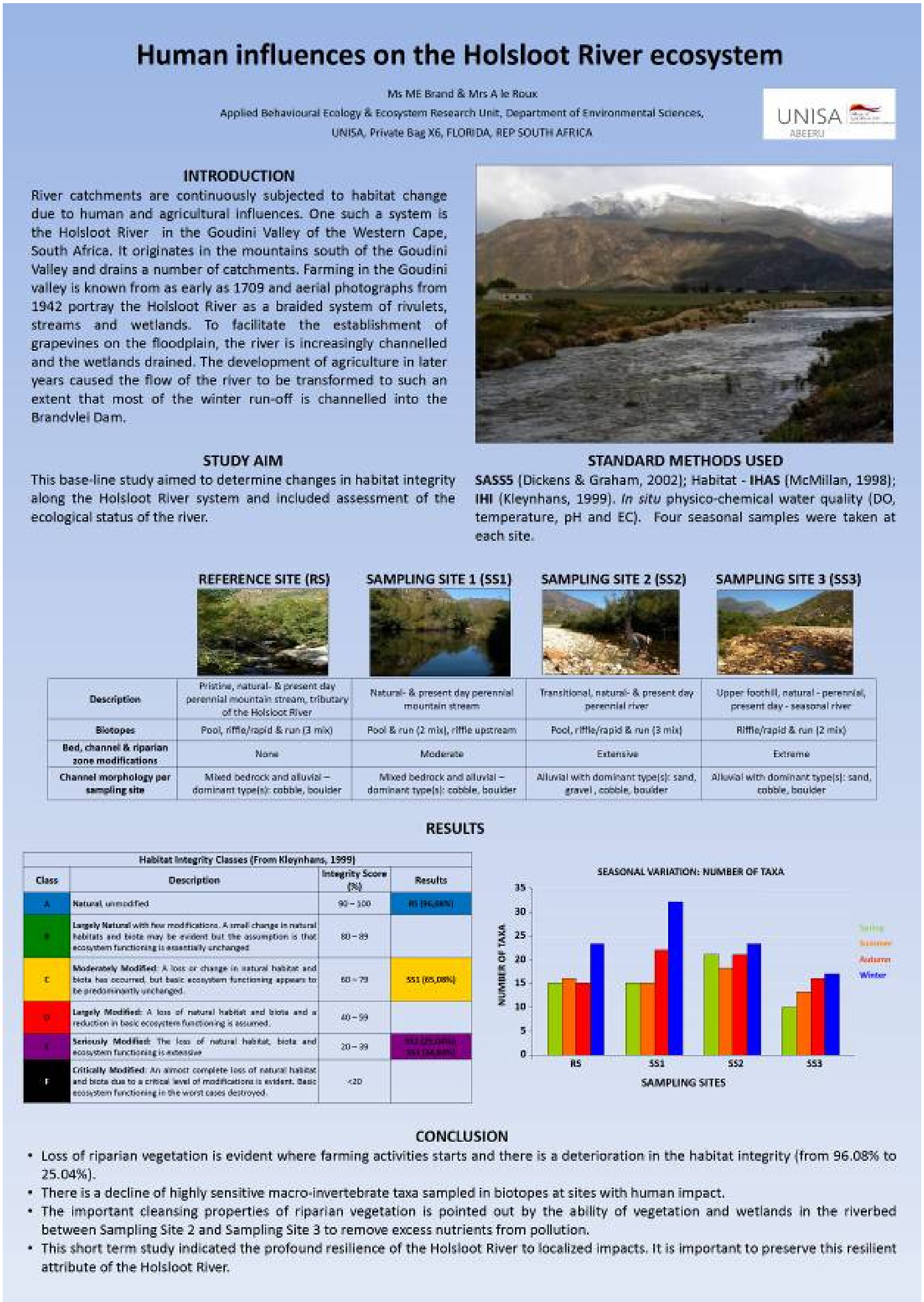
**Comments/Observations:**

Dead Algae = Cattle in the riverbed

**Procedure:**

Kick SIC & bedrock for 2 mins, max. 5 mins.   Kick SOOC & bedrock for 1 min.   Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m².   Stir & sweep gravel, sand, mud for 1 min total.   * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet).   Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000   S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud   SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Appendix 4 Results of the first study (2008-2009), presented at a conference of the International Water History association (IWHA) in July 2011, Mopani Rest Camp, Kruger National Park.



# Human influences on the Holsloot River ecosystem

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## INTRODUCTION

River catchments are continuously subjected to habitat change due to human and agricultural influences. One such a system is the Holsloot River in the Goudini Valley of the Western Cape, South Africa. It originates in the mountains south of the Goudini Valley and drains a number of catchments. Farming in the Goudini valley is known from as early as 1709 and aerial photographs from 1942 portray the Holsloot River as a braided system of rivulets, streams and wetlands. To facilitate the establishment of grapevines on the floodplain, the river is increasingly channelled and the wetlands drained. The development of agriculture in later years caused the flow of the river to be transformed to such an extent that most of the winter run-off is channelled into the Brandvlei Dam.

## STUDY AIM

This base-line study aimed to determine changes in habitat integrity along the Holsloot River system and included assessment of the ecological status of the river.

## STANDARD METHODS USED

**SASS5** (Dickens & Graham, 2002); Habitat - **IHAS** (McMillan, 1998); **IHI** (Kleynhans, 1999). *In situ* physico-chemical water quality (DO, temperature, pH and EC). Four seasonal samples were taken at each site.

| | REFERENCE SITE (RS) | SAMPLING SITE 1 (SS1) | SAMPLING SITE 2 (SS2) | SAMPLING SITE 3 (SS3) |
|---|---|---|---|---|
| **Description** | Pristine, natural- & present day perennial mountain stream, tributary of the Holsloot River | Natural- & present day perennial mountain stream | Transitional, natural- & present day perennial river | Upper foothill, natural - perennial, present day - seasonal river |
| **Biotopes** | Pool, riffle/rapid & run (3 mix) | Pool & run (2 mix), riffle upstream | Pool, riffle/rapid & run (3 mix) | Riffle/rapid & run (2 mix) |
| **Bed, channel & riparian zone modifications** | None | Moderate | Extensive | Extreme |
| **Channel morphology per sampling site** | Mixed bedrock and alluvial – dominant type(s): cobble, boulder | Mixed bedrock and alluvial – dominant type(s): cobble, boulder | Alluvial with dominant type(s): sand, gravel , cobble, boulder | Alluvial with dominant type(s): sand, cobble, boulder |

## RESULTS

Habitat Integrity Classes (From Kleynhans, 1999)

| Class | Description | Integrity Score (%) | Results |
|---|---|---|---|
| A | Natural, unmodified | 90 – 100 | RS (96,08%) |
| B | **Largely Natural** with few modifications. A small change in natural habitats and biota may be evident but the assumption is that ecosystem functioning is essentially unchanged | 80 – 89 | |
| C | **Moderately Modified**: A loss or change in natural habitat and biota has occurred, but basic ecosystem functioning appears to be predominantly unchanged. | 60 – 79 | SS1 (65,08%) |
| D | **Largely Modified**: A loss of natural habitat and biota and a reduction in basic ecosystem functioning is assumed. | 40 – 59 | |
| E | **Seriously Modified**: The loss of natural habitat, biota and ecosystem functioning is extensive | 20 – 39 | SS2 (25,04%)<br>SS3 (24,84%) |
| F | **Critically Modified**: An almost complete loss of natural habitat and biota due to a critical level of modifications is evident. Basic ecosystem functioning in the worst cases destroyed. | <20 | |

SEASONAL VARIATION: NUMBER OF TAXA

## CONCLUSION

- Loss of riparian vegetation is evident where farming activities starts and there is a deterioration in the habitat integrity (from 96.08% to 25.04%).
- There is a decline of highly sensitive macro-invertebrate taxa sampled in biotopes at sites with human impact.
- The important cleansing properties of riparian vegetation is pointed out by the ability of vegetation and wetlands in the riverbed between Sampling Site 2 and Sampling Site 3 to remove excess nutrients from pollution.
- This short term study indicated the profound resilience of the Holsloot River to localized impacts. It is important to preserve this resilient attribute of the Holsloot River.