



Western Cape
Government

Department of Environmental Affairs and
Development Planning

EADP 1382

**Developing Practical Methods to Measure
Improved Water Quantity and Quality Post
Alien Invasive Clearing.**

Monitoring Guidelines

26 November 2023

Document Information

Project Title:	Monitoring Guidelines: Developing Practical Methods to Measure Improved Water Quantity and Quality Post Invasive Alien Plant Clearing
Prepared by:	<u>Apex Conservation Services:</u> Bruce Taplin, Dr Donovan Kotze, Rachel Putzier, and Stefan le Roux.
Contact Person(s):	<u>Bruce Taplin</u> (Project Lead) Mobile: +27 (0)727547656 Email: taplincms@outlook.com
Contact Details:	10 Louw Wepener, The Island, Sedgefield, 6573
Prepared for:	Western Cape Government Department of Environmental Affairs and Development Planning (DEA&DP)
Contact Person(s):	<u>John Wilson</u> (Project Manager DEA&DP) Mobile: +27 (0)21 483 4114 / +27 (0)67 102 4651 Email: John.Wilson@westerncape.gov.za

Acknowledgements: The Authors of this document would like to acknowledge and give a special thanks to John Wilson, Lynn Jacobs, Cikizwa Mbolambi and Ndanduleni Malwela from the Western Cape DEA&DP. We also thank the Keurbooms Ecological Infrastructure Investment Working Group (KEI IWG), notably Keith Spencer (CapeNature), and Robin Petersen (SANParks), for their support and expert input during the course of this project. We would also like to thank the landowners for accompanying us at Jackals Kraal, where these methods were tested their active participation and engagement was highly valuable. We thank in particular to Daniel Rogers for his insights and willingness to assist. We thank all stakeholders and surrounding landowners who contributed to the development of these methods, including the following individuals: Anje Taljaard (Bitou Municipality), Bianca Currie (Garden Route Biosphere Reserve), Rhian Berning (Eden to Addo Corridor Initiative), and Pamela Booth (Knysna Municipality: Environmental Planning). An additional thanks to Yaaseen Bodhanya for his GIS work on this project.

Contents

Preface	11
Legislation Considerations	12
Part A: Monitoring Guidelines	13
1. Introduction	13
2. Approach to developing guidelines	14
3. Objectives and outcomes	14
4. Stakeholders and networks	15
5. Spatial context	17
6. Water Quantity: Methods	22
6.1 Indirect methods.....	22
6.1.1 SAEON Application.....	22
6.1.1.1 Details of the method	26
6.1.1.2 Equipment required.....	27
6.1.1.3 Method	27
6.1.1.4 Advantages and limitations	28
6.2 Direct methods.....	29
6.2.1. Measuring streamflow: 90° V-notch weir method	29
6.2.1.1 Details of the method	32
6.2.1.2 Equipment	32
6.2.1.3 Method	33
6.2.1.4 Advantages and limitations	34
6.2.2 Measuring streamflow: Float method	35
6.2.2.1 Details of the method	37
6.2.2.2 Equipment required.....	37
6.2.2.3 Method	37
6.2.2.3 Advantages and limitations	40
6.2.3. Measuring streamflow: End depth culvert method.....	40
6.2.3.1 Details of the method	41
6.2.3.2 Equipment required.....	41
6.2.3.3 Method	41
6.2.3.5 Advantages and limitations	43

6.2.4. Measuring spring discharge: Container Fill Method	44
6.2.4.1 Details of the method	45
6.2.4.2 Equipment required.....	45
6.2.4.3 Method	46
6.2.4.4 Advantages and limitations	47
6.2.5. Measuring spring discharge: Water Level Recovery Method	47
6.2.5.1 Details of the method	48
6.2.5.2 Equipment required.....	48
6.2.5.3 Method	49
6.2.5.4 Advantages and limitations	50
6.2.6 Measuring borehole water: Water Level Meter	51
6.2.2.1 Details of the method	52
6.2.2.2 Equipment required.....	53
6.2.2.3 Method	53
6.2.2.3 Advantages and limitations	59
7. Water Quality: Methods.....	59
7.1. miniSASS	60
7.1.1 Details of the method	62
7.1.2 Equipment required.....	62
7.1.3 Method	62
7.1.4 Advantages and limitations	65
7.2 Water Clarity Tube	66
7.2.1 Details of the method	68
7.2.2 Equipment required.....	68
7.2.3 Method	68
7.2.4 Advantages and limitations	69
7.3 Water Clarity Colour Chart	70
7.2.1 Details of the method	71
7.2.2 Equipment required.....	71
7.2.3 Method	72
7.2.4 Advantages and limitations	72
7.4 Diatom sampling.....	73
7.3.1 Details of the method	75
7.3.2 Equipment required.....	75
7.3.3 Method	75
7.3.4 Advantages and limitations	78
8. Ecological Baseline Assessment: Methods	78

8.1 miniSASS	78
8.2 Riparian Health Audit	78
8.2.1 Details of the method	82
8.2.2 Equipment required.....	82
8.2.3 Method	82
8.2.4 Advantages and limitations	85
8.3 Fixed Point Photography.....	85
8.3.1 Details of the method	86
8.3.2 Equipment required.....	87
8.3.3 Method	87
8.3.4 Advantages and limitations	89
9. Data storage, management, and interpretation	89
10. How to choose an appropriate method.....	89
11. Conclusion.....	94
12. References and Bibliography	95
13. Appendices A	100
Appendix A.1 - Field Sheet Templates	100
A.1.1 Water loss estimation - SAEON Application	100
A.1.2 Streamflow - 90° V-notch Weir Method.....	101
A.1.3 Streamflow - Float Method	102
A.1.4 Streamflow - End Depth Culvert Method	103
A.1.5 Spring Discharge - Container Fill Method.....	104
A.1.6 Spring Discharge - Water Level Recovery Method.....	105
A.1.7 Borehole Water Level - Dipmeter Method	106
A.1.8 Biomonitoring - miniSASS Method	107
A.1.9 Turbidity - Water Clarity Tube	108
A.1.10 Turbidity - Water Clarity Colour Chart.....	109
A.1.11 Biomonitoring - Diatom Sampling	110
A.1.12 Ecological Health - Riparian Health Audit	111
A.1.13 Observational Monitoring - Fixed Point Photography	112
Appendix A.2 - miniSASS - Dichotomous Key and Identification of Macroinvertebrate Groups.....	113
Appendix A.3 - Riparian Health Audit - Photographic and illustrative Guide to Impacts ...	115
A.3.1 Exotic Vegetation	115
A.3.2 Rubbish Dumping	116
A.3.3 Bank Erosion	117

A.3.4 Inundation	118
A.3.5 Flow Modification	119
A.3.6 Channel Modification	120
A.3.7 Evidence of Decreased Water Quality	121
A.3.8 Vegetation Removal	122
Part B: Application of monitoring methods to the identified study site.....	124
1. Introduction	124
2. Study area	126
3. Site selection	127
4. Stakeholders.....	129
5. Field-testing methods	129
6. Ecological baseline assessment	134
6.1 Mapping and establishing attribute data of AIPs	134
6.2 Riparian Health Assessment.....	140
6.3 Fixed point photography	142
6.4 Ecological Baseline Summary	145
7. Conclusion.....	145
8. References and bibliography.....	147
9. Appendices B.....	148
Appendix B.1 - Field Testing Methods Recorded	148
B.1.1 Spring Discharge - Container Fill Method	148
B.1.2 Streamflow - Float Method	149
B.1.3 Streamflow - 90° V-notch Weir Method	150
Appendix B.2 - Ecological Baseline Assessment Field Sheets	151
B.2.1 Riparian Health Audit - Site 1	151
B.2.2 Riparian Health Audit - Site 2	152
B.2.3 Riparian Health Audit - Site 3.....	153
B.2.4 Fixed Point Photography.....	154

List of figures

Figure 1: (A) Map of South Africa's SWSAs showing Water Management Area boundaries; (B) Boundary of Outeniqua SWSA, where the Keurbooms Catchment is found (Images: Statistics South Africa, 2023).....	18
Figure 2: Location of the properties making up the Middle Section Group Farm within Keurbooms catchment.	20
Figure 3: Provides an example of how the Keurbooms study site was mapped into MU and assigned unique numbers.	23
Figure 4: Estimated water loss caused by AIPs per year per hectare (KL/yr/ha) within each of the MU's.	25
Figure 5: Illustrates the typical AIP infestations across the identified study site within the Keurbooms catchment. (1) Adult <i>Pinus</i> spp. at low density; (2) <i>A. mearnsii</i> at high density in the drainage line with lower density <i>Pinus</i> spp. higher on the slope; (3) a dense stand of young <i>H. sericea</i> at high density; (4) high density of young <i>A. mearnsii</i> next to a road.	26
Figure 6: Inserting key input data and results for the SAEON application: (1) Selecting AIP species; (2) Selecting the mean age, density (canopy cover), and size of the infestation; (3) Inserting the GPS location; (4) estimated range of water loss due to AIPs provided by application.	28
Figure 7: Size of streams for which the V-notch weir method is ideal (Image: ACS, 2023).	30
Figure 8: Components of the V-notch weir (People's Science Institute, n.d.).....	31
Figure 9: Steps of using the 90° V-notch weir method to calculate streamflow: (1) Inserting weir in the stream and wait until steady stream is observed over notch; (2) Measuring the head; (3) Using the conversion table to determine streamflow (Images: ACS, 2023; Terasmaa et al., n.d.).....	34
Figure 10: Size of stream that the float method should work well for (Image: ACS, 2023).	36
Figure 11: Dividing a stream into different segments for larger streams for the float method (Image: Brikowski, 2007).....	37
Figure 12: Summary of the float method: (1) Measuring and marking the reach, (2 & 3) measuring width and depth and calculate average area, (4) floating object downstream, and (5) calculating velocity and streamflow (Images: Irrigation Engineering, n.d.; USGS, n.d.; Brikowski, 2007).....	39
Figure 13: Sketches with relevant measurements and symbols for the end depth culvert method (Images: ACS, 2023).	41
Figure 14: The first two steps of the end depth culvert method: (1) Measuring the diameter of the culvert and (2) measuring the depth of water at the end point of the culvert (Images: FSL ORST, n.d.; Deziel, 2018).	42
Figure 15: A sump, which collects all the water of a spring, drained by an outflow pipe; the type of structure which can be utilized for the container fill method.	45
Figure 16: Collecting spring discharge from a single output in a container for the container fill method (Images: ACS, 2023).	46
Figure 17: Examples of ponds formed from water that has seeped to the surface where the water recovery method can be applied.....	48
Figure 18: The spring discharge water recovery method: (1) the water level in the depression is measured and marked on a guiding stick; and (2) a container of	

known volume is then used to remove water, and the time taken for the spring to refill the depression to the previously measured water level is recorded..... 50

Figure 19: Example of a borehole being used to extract water (Image: Wika, 2023).52

Figure 20: Summary of the Borehole Water Level Dipmeter method: (1) measuring the height of the borehole above ground, (2) a water level dipmeter, (3) taking the water level measurement in the borehole, and (5) ensuring that the dipmeter is measured at the same point consistently. (Images: Solinst, 2013.; Petersen and Strydom, n.d.)..... 55

Figure 21: Summary of the homemade water level meter method: (1) attaching a plastic bottle to measure the water level, (2) attaching a sinker to measure the borehole depth, (3) slowly lowering the string into the borehole with the float and sink devices. 58

Figure 22: (1) miniSASS can be applied to rocky areas (preferable) or sandy areas (miniSASS.org, n.d.). (2) implementing miniSASS in a flowing, rocky river which provides an example of a good study site (Image: MCF, 2014). 61

Figure 23: Summary of miniSASS: (1) Disturbing the water and collecting organisms, (2) Emptying collected invertebrates onto trays, (3) Identifying organisms collected, (4) Marking off collected organisms and calculating sensitivity, (5) Determining the Ecological Condition and Category based on sensitivity score and river category (Photos: GroundTruth, n.d.; MCF, 2017; MCG, 2015; miniSASS.org, n.d.). 64

Figure 24: Water being collected in a clarity tube within a stream. 66

Figure 25: The (1) water clarity tube with its different components: (2) base through which the target is viewed; (3) the magnets which are shifted to move the target; (4) and the stopper sealing the bottom of the tube (Images: Nzaee, n.d.; Ground Truth, n.d.)..... 67

Figure 26: (1) Collecting water in the water clarity tube; and (2) determining the disappearance and reappearance depths..... 69

Figure 27: Water for the water colour chart method can be collected from any water system (Image: UZH, 2016). 71

Figure 28: Five classifications for water clarity, from clear (1) to murky (5)..... 72

Figure 29: Examples of substrata from which diatoms can be collected: (1) and (2) Diatoms on rocks; (3) diatoms on sediment and pebbles; (4) diatoms on submerged tree branches; (5) diatoms on collected branches; (6) diatoms in sediment..... 74

Figure 30: Summary of using the diatom method: (1) Collect substratum; (2) rinse rocks and place in tray; (3) collect diatoms from substratum; (4) deposit diatoms to sample bottle; and (5) preserve and store samples (Images: Kelly, 2015; National Geographic, n.d.; Franchini, 2013; Kelly and Yallop, n.d.; Kelly, 2022)..... 77

Figure 31: Representation of the riparian zone in which the RHA should take place (Desai, 2016)..... 79

Figure 32: The eight impacts assessed with the RHA (Image: ACS, 2023; LWDD, 2019; iStock.com/Alexmia, 2017). 80

Figure 33: Summary of the RHA Method: (1) Riparian and Terrestrial zones. (2) Illustrative guideline to aid rating of impacts. (3) Description of impacts and corresponding percentage change and ratings. (4) Explanation of Ecological Conditions based on percentage change of the riparian zone. (Image: Desai, 2016). 84

Figure 34: Stream bank wherein Fixed Point Photographs should be taken to represent the stream (not flowing in this figure), banks, and surrounding vegetation. 86

Figure 35: Summary of the Fixed-point photography: (1) Record location, dropping a pin. (2) Use a compass or compass application to find each direction (North, South, East, West). (3) Take a photograph at breast height. Take a photograph in each direction (N- North; S- South; E- East; and W- West) (4) (Images: ACS, 2023; phonearena, 2023; active, 2013). 88

Figure 36: A decision tree to assist in deciding what method is appropriate for assessing the effects of clearing AIPs on water quantity. 92

Figure 37: A decision tree to assist in deciding what method is appropriate for assessing the effects of clearing AIPs on water quality. 93

Figure 38: Overview of a sub-catchment in the Keurbooms Catchment which was used as the study area. 125

Figure 39: Container fill method tested out in the field at Spring 1. 130

Figure 40: Testing out the float method at Site 3. 131

Figure 41: The portable weir method: (1) the weir was constructed in the field; (2) the weir headboard ready for implementations; (3) and the weir being tested in the field. 132

Figure 42: Temporary weir plate compromised after heavy rainfall in the Keurbooms Catchment (Image: Daniel Rogers, 2023). 133

Figure 43: Newly established AIP Management Units on Jackals Kraal Farm. 135

Figure 44: Illustrates the distribution of dominant AIPs by density class. 136

Figure 45: Estimated water loss caused by AIPs per year per hectare (KL/yr/ha) within each of the MU's. 137

Figure 46: Representations of AIPs in the study area: (1) High density stand of adult *A. mearnsii*; (2) High density adult *A. mearnsii* in the riparian area and lower density adult *Pinus* spp. higher on the slope; (3) Medium density young *H. sericea*; and (4) High density *Pinus* spp. 138

Figure 47: Points of interest in the study area. 140

Figure 48: Fixed point photography at Site 1: N - North view; E - East view; S - South view; and W - West view. 143

Figure 49: Fixed point photograph of the water flow at the spring. 144

List of tables

Table 1: Stakeholders for users to include when implementing water monitoring methods, and value these stakeholders may add. 15

Table 2: An example of the attribute data collected for the Keurbooms study site for two dominant AIPs. 24

Table 3: Advantages and limitations of using the SAEON application. 29

Table 4: Description of v-notch weir components. 31

Table 5: Standard notch sizes for 90o V-notch weirs (Roctest, n.d.) 32

Table 6: Advantages and limitations of the V-notch weir method. 35

Table 7: Advantages and limitations of the float method. 40

Table 8: Advantages and limitations of the end depth culvert method. 44

Table 9: Advantages and limitations of the container fill method. 47
 Table 10: Advantages and limitations of the water level recovery method. 51
 Table 11: Advantages and limitations of the (1) dipmeter and (2) homemade water level meter methods. 59
 Table 12: Advantages and limitations of the miniSASS biomonitoring method. 65
 Table 13: Advantages and limitations of the clarity tube method. 70
 Table 14: Advantages and limitations of the water clarity colour chart method. 73
 Table 15: Advantages and limitations of diatom sampling. 78
 Table 16: Examples of how AIPs affect the impacts described in the RHA. 82
 Table 17: Advantages and limitations of the Riparian Health Audit method. 85
 Table 18: Advantages and limitations of the Fixed Point Photography method. 89
 Table 19: Key factors to consider in deciding where to monitor water quantity and quality changes resulting from AIP clearing. 90
 Table 20: Attribute data established mapping of AIPs within the area. Columns are hidden in the dataset: the zone, sectors, dominant terrain, and coordinates. 139

List of acronyms and abbreviations

AIP	Alien Invasive Plant
ACS	Apex Conservation Services
Avg	Average
cm	Centimetre
cm²	Square Centimetre
cm/s	Centimetre per Second
DEA&DP	Department of Environmental Affairs and Development Planning
EC	Ecological Condition
FPP	Fixed-point photography
g	Gram
GF	Group Farm
GPS	Global Positioning System
ha	Hectare
kL/ha/yr	Kilolitre per Hectare per Year
kL	Kilolitre

L	Litre
L/min	Litre per Minute
L/s	Litre per Second
ml	Millilitre
mm	Millimetre
m	Metre
m²	Square Metre
m³	Cubic Metre
m/s	Metre per Second
m³/s	Cubic Metres per Second
MU	Management Unit
MUCPs	Management Unit Control Plans
NPO	Non-Profit Organisation
RHA	Riparian Health Audit
s	Seconds
SAEON	South African Environmental Observation Network
SANParks	South African National Parks
SASS	South African Scoring System
SWSA	Strategic Water Source Area

Preface

This document comprises of two sections, namely:

Part A - Monitoring Guide and;

Part B - Application of monitoring methods to the identified study site

Part A sets out the approach taken to develop this monitoring guide. The objectives and desired outcomes of the monitoring guide are described here. Users are able to use Part A to inform the selection of appropriate stakeholders, sites, and methods, as well as how to store and manage data they collect. The key stakeholders and institutional arrangements are highlighted to guide users on who should be included to form representative stakeholder networks. Further, Part A sets out criteria that can direct users on how to identify a suitable site within their own sub-catchment. The proposed methods for measuring water quantity, quality and ecological baselines are explained and step by step processes are outlined to guide users on their implementation.

Part B provides context for the monitoring guide set up in Part A. It is a proof of concept and demonstrates the results of the method testing and ecological baseline assessment undertaken within the Keurbooms Catchment. This section consists of an introduction providing background to the project, a description of the stakeholders and the study area, as well as the results of our method field testing and ecological baseline assessment.

Legislation Considerations

Before implementing the methods outlined within the monitoring guideline it is the responsibility of the users to ensure they are familiar with the relevant legislation, regulations and specific environmental management acts that govern activities within sensitive areas such as springs, wetlands, watercourses, and riverine habitats.

The following legislation is most relevant to the implementation of the monitoring guidelines:

1. National Environmental Management Act, 1998 (Act No.107 of 1998) ("NEMA")
2. Environmental Impact Assessment Regulations Listing Notice 1 of 2014("EIA")
3. Specific Environmental Management Act(s) ("SEMA") (e.g. National Water Act 36 of 1998)

During the implementation of the monitoring methods identified within the monitoring guideline care should be taken to avoid triggering any listed environmental activities as identified under NEMA. Activities most likely to be encountered during the implementation of the guidelines are documented in Table (i) and would constitute water use, thereby requiring authorization in terms of Section 21 of the National Water Act 36 of 1998.

Table (i): Lists activities that constitute water uses and require authorization in terms of Section 21 of the National Water Act.

ACTIVITY	EXAMPLE
Section 21 (c) Impeding or diverting the flow of water in a watercourse.	Construction of structures/facilities within surface water resources, e.g. weirs, bridges, pipelines, etc.
Section 21 (i) Altering the bed, banks, courses or characteristics of a watercourse.	Construction of structures/facilities within surface water resources, e.g. weirs, bridges, pipelines, etc. Introduction of unnatural characteristic to the resource.
Section 21 (j) Removing, discharging or disposing of water found underground if it is necessary of the efficient continuation of an activity or for the safety of the people.	Extraction of water from underground workings for safe continuation of activities.

Users should ensure that obstructions to watercourses are avoided. Obstructions to watercourses may include actions such as altering, diverting, or impeding the instream flow. Care must be taken to prevent negative changes to the breeding, nesting, or feeding patterns of aquatic biota, including migratory species; as well as to ensure that the movement of these organisms' up- and down-stream is not impeded. Further, when implementing these methods, the user must ensure that measures are taken to minimise the duration of disturbance and the footprint of the disturbance of the beds and banks of the watercourse.

Part A: Monitoring Guidelines

1. Introduction

Alien invasive plants (AIPs) are non-native plants brought to South Africa from other countries (Huang and Asner, 2009). These AIPs have no natural enemies (Allendorf and Lundquist, 2003; Kirichenko et al., 2013) and they reproduce rapidly, competing with indigenous plants for resources. AIPs are a major source of concern as a result of the threats that they pose to water security and biodiversity (Le Maitre et al., 1996). AIPs cause an increase in transpiration and evaporation rates and generally consume more water than indigenous plants. This results in decreased water quantity - reducing streamflow, runoff and underground water resources within these infested ecosystems (Le Maitre et al., 2020; Rebelo et al., 2022). As water availability declines, AIPs may also cause the water quality to deteriorate. This decreased water quality may result from the AIPs impacts on fire regimes, soil erosion, plant biomass and litter production, and nutrient cycling processes (Chamier et al., 2012).

These monitoring guidelines describe the criteria necessary for site selection, provide examples of useful stakeholders to engage with, and describe a data storage and management plan for collected information. A decision tree is included to inform users on which methods would be most appropriate for use on their own land. This guide provides methods that users can use to measure water quantity, water quality and assess ecological baselines. Each monitoring method will include a step-by-step guide describing how each method should be implemented. Each method will also include the following: the frequency of monitoring, skills required, equipment needed, as well as the advantages and limitations of each monitoring method.

These monitoring guidelines provide both direct and indirect methods that users may use to measure water quantity. The indirect method provided estimates the impact of AIPs on water flow by mapping the vegetation in an area and using an application developed by the South African Environmental Observation Network (SAEON). The monitoring guidelines also provide direct methods that users can use to monitor changes to streamflow and spring discharge. Streamflow can be used to measure the amount of water in a stream moving past a point over a certain time period. Streamflow monitoring methods provided include a 90° V-notch weir method, a float method, and end depth culvert method. Spring discharge can be used to measure the amount of water discharged from a spring over a certain time period. Spring discharge can be measured using the container fill method.

Water Quality methods outlined in these guidelines include miniSASS, water clarity tube, and diatom sampling. miniSASS is a biomonitoring method which helps measure the health of a river and therefore provides insight into the quality of the water. Water clarity tubes can be used to test turbidity, as suspended solids in turbid water affect water chemistry and microbiology- impacting water quality. Diatom sampling is a form of biomonitoring, where diatoms are bioindicators of water quality status.

Methods to measure the Ecological Baseline conditions are provided in the monitoring guide. This includes the Riparian Health Audit which can be used to determine the Ecological Condition (EC) which indicates the river's health. The miniSASS method can be used to assess the organisms present, which provides insight into the water quality, river health and ecological conditions of the surrounding environment. The final ecological baseline method described in

this guide is Fixed Point Photography, which provides a tool for observational monitoring of changes in the habitat, river flow conditions, bank destabilization, and vegetation invasions.

These monitoring guidelines have been developed to provide practical methods and give a step-by-step guide for users to measure changes to water quantity, quality, and ecological baselines. These methods can be applied by landowners or users before and after AIP clearing to quantify the alterations to water and ecosystems within these sites. Understanding and demonstrating the impact that these AIPs have on water quantity and quality, as well as the ecological condition of surrounding ecosystems is important, as it can help motivate the allocation of funds to clearing efforts, especially within strategic water source areas where water and ecosystem services are vulnerable.

Resources for more background information can be found [here](#).

2. Approach to developing guidelines

The approach taken to developing these guidelines included undertaking a literature review on the known impacts of AIPs. In this literature review a broad overview of methods to monitor water quality and quantity were investigated and reported. Stakeholders and landowners were engaged to inform which of these identified methods would be appropriate, easy to use and accessible. These proposed methods were field tested in the Keurbooms Catchment as a proof of concept and methods. This pilot project was used as a benchmark for testing out these methods and was used to inform this monitoring guide in terms of how best to implement methods, and potential advantages and limitations different methods offer. These monitoring guidelines therefore outline and describe these tested methods to measure water quantity and quality gains resulting from clearing AIPs. Practical, step by step instructions are provided for users, enabling them to implement the proposed methods and establish ecological baselines on their own land. Each section on each method also includes a description of the method and where to use it, the frequency at which to take measurements, skills required to use the method, cost of the method, an equipment list with links provided for specialized equipment, as well as advantages and limitations.

3. Objectives and outcomes

The objectives of the monitoring guidelines are to provide methods to:

- Measure the change in water quantity of a water system after clearing AIPs
- Measure how water quality within a system is altered after AIPs removal
- Conduct an ecological baseline assessment to monitor changes to the ecological condition of the system before and after AIP clearing

The desired outcomes of the monitoring guidelines are to:

- Quantify the impact of clearing AIPs on the water quantity available within water system, as well as the water quality
- Contribute to our understanding of the effects that AIPs have on water and ecosystems in which they are present

- Demonstrate the importance of removing AIPs for water security and maintaining ecosystem services - especially within strategic water source areas
- Indicate how AIPs contribute to degraded ecological health and conditions
- Illustrate to landowners, land users, stakeholders, funders and authorities the positive impacts that clearing AIPs may provide to help ensure future funding and investments to clear AIPs are maintained

4. Stakeholders and networks

When introducing a project or implementing monitoring methods, it is important to involve the correct stakeholders and relevant interested and affected parties. These key role-players will differ across landscapes and which individuals and organisations to include will depend on the institutional arrangements in place, as well as on the user implementing these methods and their needs. For example, a Biosphere Reserve may derive great value from involving landowners; however, if a landowner is implementing the methods, it may be useful for them to include specialist stakeholders, such as a representative from their local catchment authority. Each user will require their own specific set of stakeholders to help provide information, and support them.

There are a great deal of benefits that involving these role players may provide, and each stakeholder will be able to offer unique insights and experiences which may be useful. Table 1 outlines stakeholders who may be useful to include when deciding to monitor changes to water quantity and quality resulting from AIP clearing. These stakeholders may be involved for a variety of reasons and may each add value in different ways. Stakeholders should therefore be selected based on each user's context and needs.

Table 1: Stakeholders for users to include when implementing water monitoring methods, and value these stakeholders may add.

STAKEHOLDER	REASON FOR INVOLVEMENT
Landowners (farmers, landowners and users)	Landowners are important stakeholders as a result of the risks that AIPs pose to their land, and their legal obligations to control AIPs on their properties. Landowners can provide important context and local knowledge on the AIPs and the systems to be monitored - adding valuable insights and recommendations on which methods to use and where to implement them.
Neighbouring landowners or users	Neighbouring landowners should be involved given the impact that clearing AIPs and implementing methods may have on their surrounding land and downstream catchments. They may also be able to provide helpful information.
National and Provincial Government departments	Government Departments may be able to provide users with existing information (historical and present) on water quantity and quality from monitoring stations in the area which may be useful to inform methods selected and their implementation. These departments might also have a responsibility to manage water resources and be able to apply valuable input on opportunities and constraints in the area. National Government Departments may include the Department of Water and Sanitation; the Department of Agriculture, Land Reform and Rural Development; and the Department of Forestry, Fisheries and Environment. Relevant Provincial Government Departments to involve will comprise the Department of Agriculture, as well as the Department of Environmental Affairs and

	Development Planning.
District and local authorities (municipalities)	District and local authorities should be invited as they are responsible for the management of natural resources, AIPs, and for water supply to the local population. They may be able to provide important insights relating to that area such as informing users of existing institutional arrangement, as well as information on the selected monitoring sites and water courses in their jurisdiction.
Catchment authorities	Catchment authorities are responsible for management of catchments and could help highlight strategic areas, such as SWSAs or sub-catchments, which could be targeted for both clearing AIPs and water monitoring. In the Western Cape, examples of such catchment authorities that can possibly be approached are the Breede Olifants Catchment Management Agency and the Breede-Gouritz Catchment Management Agency.
Protected Areas and Environments	The management bodies of national, provincial and local Protected Areas and Environments, as well as stewardship-based Protected Areas and Environments should be approached if the methods are to be undertaken within their demarcated areas, domains and or buffer areas. This could allow the user and these methods to form part of AIP clearing and water monitoring programs these organisations might already have in place. PAs can help specify where and how the methods should be applied.
Biosphere Reserves	Biospheres Reserves may be able to provide information on AIPs and water sources in the area and possibly assist in implementing methods if they are to be undertaken within their domain.
Non-profit organisations	NPOs may also be able to provide a greater insight into the methods or study site. Their organisation may be able to get involved or support in the implementation of these methods.
Scientific community members and local citizen scientists	The local scientific community and citizen scientists can be approached for input on the study area as well as which methods would be most appropriate within that area.
Collaborations with other mandated/ interested organisations or individuals	Include any other stakeholders who may be able to provide information, insights or support.

A snowball approach can be adopted to develop a suitable network through engaging with stakeholders to identify other key informants or interested parties who would add value. This snowball method will also allow users to engage with stakeholders who they may not have considered or would not have been able to contact.

5. Spatial context

These methods described in this monitoring guide were developed and tested within the Keurbooms Catchment; however, they are designed to be applicable throughout the Western Cape. There are a variety of reasons which made this area a suitable study area. One of the reasons we selected this catchment was that it forms part of the Outeniqua Strategic Water Source Area (SWSA), as shown in Figure 1. SWSAs are crucial in contributing to South Africa's surface and groundwater supply (Le Maitre et al., 2018), supplying large amounts of water per unit area. SWSAs provide ecosystem services such as resilience to drought and climate change, clean water production, flood moderation, and prevention of erosion (Department of Forestry, Fisheries and the Environment, 2023). Increasing demands for freshwater, compounded upon by the effects of AIPs may result in reduced water availability in these SWSA in the future (Le Maitre et al., 2018). These threats to water will have the ability to cause major negative impacts on water security, which may be of great concern to the local communities who rely on this water source. It is therefore important to monitor the effect of removing AIPs on water quantity and quality within SWSAs. SWSA's such as the Keurbooms Catchment should be priority areas for the implementation of these methods.

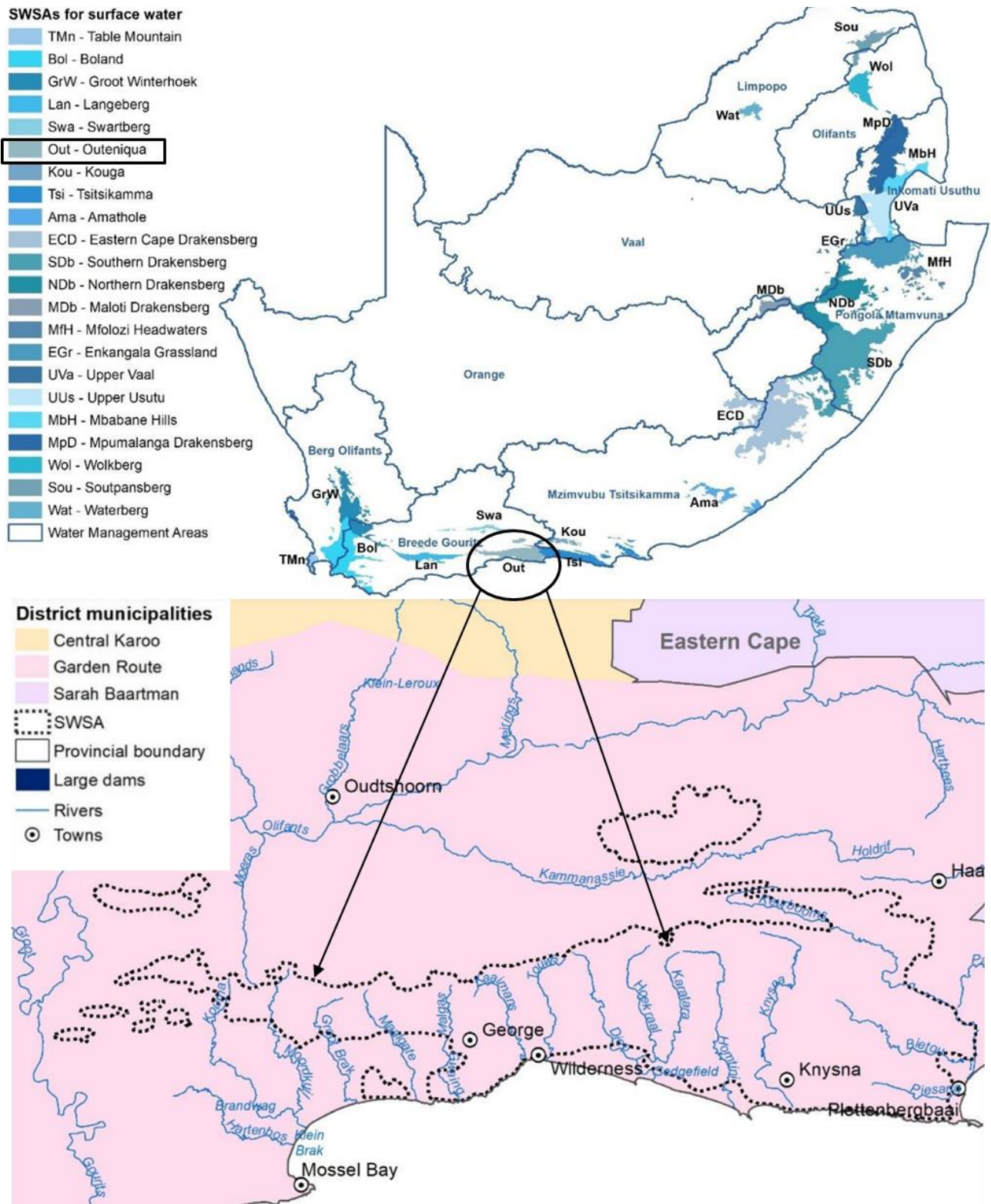


Figure 1: (A) Map of South Africa's SWSAs showing Water Management Area boundaries; (B) Boundary of Outeniqua SWSA, where the Keurbooms Catchment is found (Images: Statistics South Africa, 2023).

Although the Keurbooms Catchment provided a good study area, undertaking these methods across the entire catchment is too extensive to be feasible. Implementing these monitoring methods at a catchment scale would be too broad to determine changes in water quantity and quality given the great deal of confounding factors implementing these parameters besides for the AIP clearing.

Previous projects and research have been undertaken within the Keurbooms Catchment. In this previous work, Group Farm areas were established, with the goal of neighbouring landowners working together and potentially sharing resources, to maintain their ecological infrastructure. The Middle Section Group Farm (GF) in the Keurbooms Catchment was therefore selected as the study site. This area is shown in Figure 2 in relation to the Keurbooms Catchment area. Using the GF area narrowed down the area, providing a suitable site where methods could be implemented at a sub-catchment scale. Using a sub-catchment enables easier monitoring of changes to water quantity and quality post AIP removal, as well as allows for the results of this clearing to be isolated from other confounding factors.

This Middle Section GF provided a suitable study site, as it has a great density of important AIPs such as *Acacia mearnsii*, *Pinus* spp., and *Hakea sericea*. The previous work in this GF meant that there was prior knowledge and information of the sub catchment and these AIPs available. There were also prior relationships and networks which had been established with these landowners and stakeholders within the GF, and they had expressed interest in being involved.

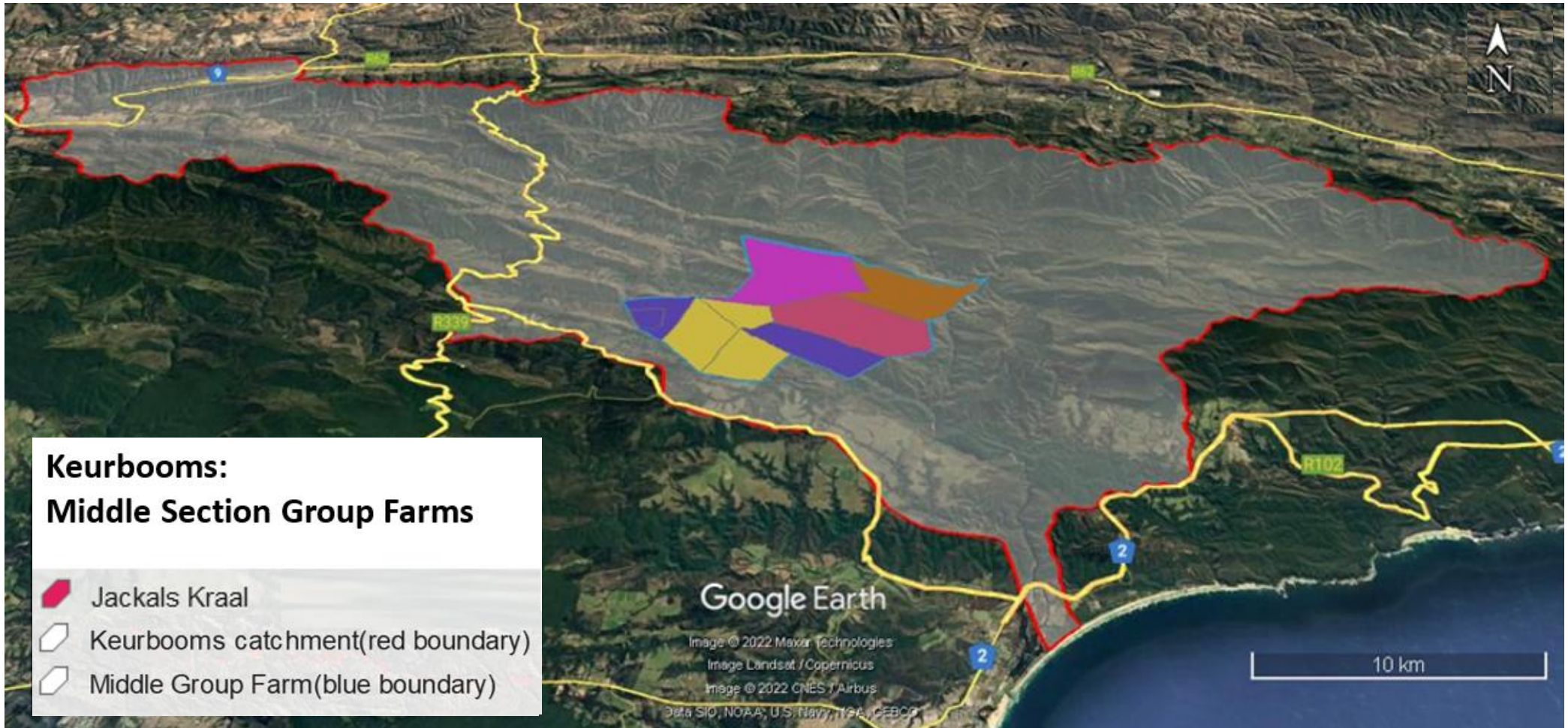


Figure 2: Location of the properties making up the Middle Section Group Farm within Keurbooms catchment.

The factors which made the Keurbooms Catchment and the Middle Section GF a suitable study area and site were highlighted above. The approach and criteria used to guide our site selection within this area can be used to direct users in their own catchment and sub-catchment identification, and site selection. The following criteria are provided to help guide users on what factors to look for and what to avoid when identifying and selecting an appropriate study site to implement these monitoring methods:

- Suitability of geography and topology.
- Presence of key hydrological features to measure: sub-catchments, springs, streams, and culverts.
- Willingness of landowners to engage and assist in monitoring.
- Presence of AIPs in sufficient density and proximity to catchments.
- Ease and accessibility of site for implementing methods practically.
- Importance and need for clearing within that area – such as the presence of SWSA or for protection of ecosystem services.
- Limited confounding factors reducing the ability to link detected changes in water to AIP clearing.

If these factors above are present, the site may be suitable for the implementation of the methods outlined in these guidelines. If, however the identified site does not meet these criteria, it is unlikely that the site will be suitable for use in this context. If key features such as AIPs are absent, or are only present in low densities, it is unlikely that clearing them will provide a great enough impact on water quantity and quality that these monitoring methods will be able to distinguish changes. In addition to this, if catchments do not have the necessary hydrological features such as streams, springs or culverts, the methods outlined in this guide will not be able to be practically implemented. Users should therefore ensure that their sites are representative of all of these outlined criteria to ensure that monitoring is accurate and effective when implementing these methods on their own land.

The features and structures present on each site will be different based on the land use and purpose. The infrastructure and equipment available on these sites may be useful for informing changes in water quantity and quality resulting from AIP removal. Although these methods may not be accounted for within these monitoring guidelines, that is not to say that they will not add value as additional methods to consider, especially if they are already being implemented at that site. An example of such structures would be weirs, where data on the water quantity may be useful to consider as an addition to methods set out here. Methods such as this are often used to measure great quantities of water on a large scale. They have therefore not been included within this manual as stand-alone methods, as they are influenced by many factors which would obscure any effects AIP removal would have on water.

Other management actions present within a catchment, such as rehabilitation, dam decommissioning, erosion control, etc. may also result in improvements in water quantity and quality released from the catchment. Rehabilitation efforts, including planting indigenous species after AIP clearance, could reduce destabilization due to AIP removal and improve water quality by limiting sediment deposition in streams due to runoff.

There may also be equipment in place to measure climatic variables such as rain gauges, which may be useful to provide context and background for the site, however it is not the

focus of this monitoring guide, as it is not a measure of change in water quantity, quality or ecological baselines resulting from AIP clearing.

Whereas this section has provided broad scale criteria for selecting a study area, Section 10 will provide a more detailed approach to how to familiarize yourself with the situation on a property, where in a property to locate monitoring points, and which method/s to use based on the availability of certain hydrological and artificial features on a property.

6. Water Quantity: Methods

Methods to measure water quantity can be divided into direct and indirect methods. Direct methods use instruments to make physical measurements in the field at a study area. Indirect methods utilize models to make estimated measurements remotely.

Indirect methods can be considered in cases where direct measurements are not feasible. This might have to be the case for quantifying water gains on a large scale after clearing has taken place. Calculating streamflow requires frequent measurements over an extended period of time. Isolating the impact of the clearance from other factors influencing streamflow will also prove difficult. For this reason, indirect methods, such as estimating water gains from clearance with models, might have to be used for large areas.

Resources for the methods for measuring water quantity can be found [here](#).

6.1 Indirect methods

Models can be used as indirect methods to estimate the impact of AIPs on water quantity. These indirect methods can be used to quantify water loss of areas too large to be feasible.

6.1.1 SAEON Application

A great deal of research has been done on estimating the impacts of AIPs on water resources with flow reduction models (Le Maitre, 2000; Dzvikamanja et al., 2005; Le Maitre, 2016). Using these models, flow reductions are expressed as proportions of annual runoff and estimations are based on the species, age of vegetation, size of the infested area and species density. Based on this work, Glenn Moncrieff and the South African Environmental Observation Network (SAEON) developed an easy-to-use application to estimate the impact of AIPs on water flow (https://gmoncrieff.shinyapps.io/aliens_waterloss/).

Once a study site has been selected the area will need to be mapped to establish the distribution of AIPs within the study site (see Figure 4). AIP information such as dominant species, density and age class associated with the study site is then collected and assigned to the mapped area. This information is known as AIP attribute data. Depending on the size of the selected site, the area can be mapped into smaller management units (MUs) to enable a more accurate account of infestation. Figure 3 provides an example of how the Keurbooms study site were mapped into MUs and assigned unique numbers.

The area calculated for each MU, along with the AIP attribute data can then be imported into the application and used to estimate the water loss per management unit per annum. The information can be listed in a table (see Table 2) or illustrated in a map (see Figure 4).

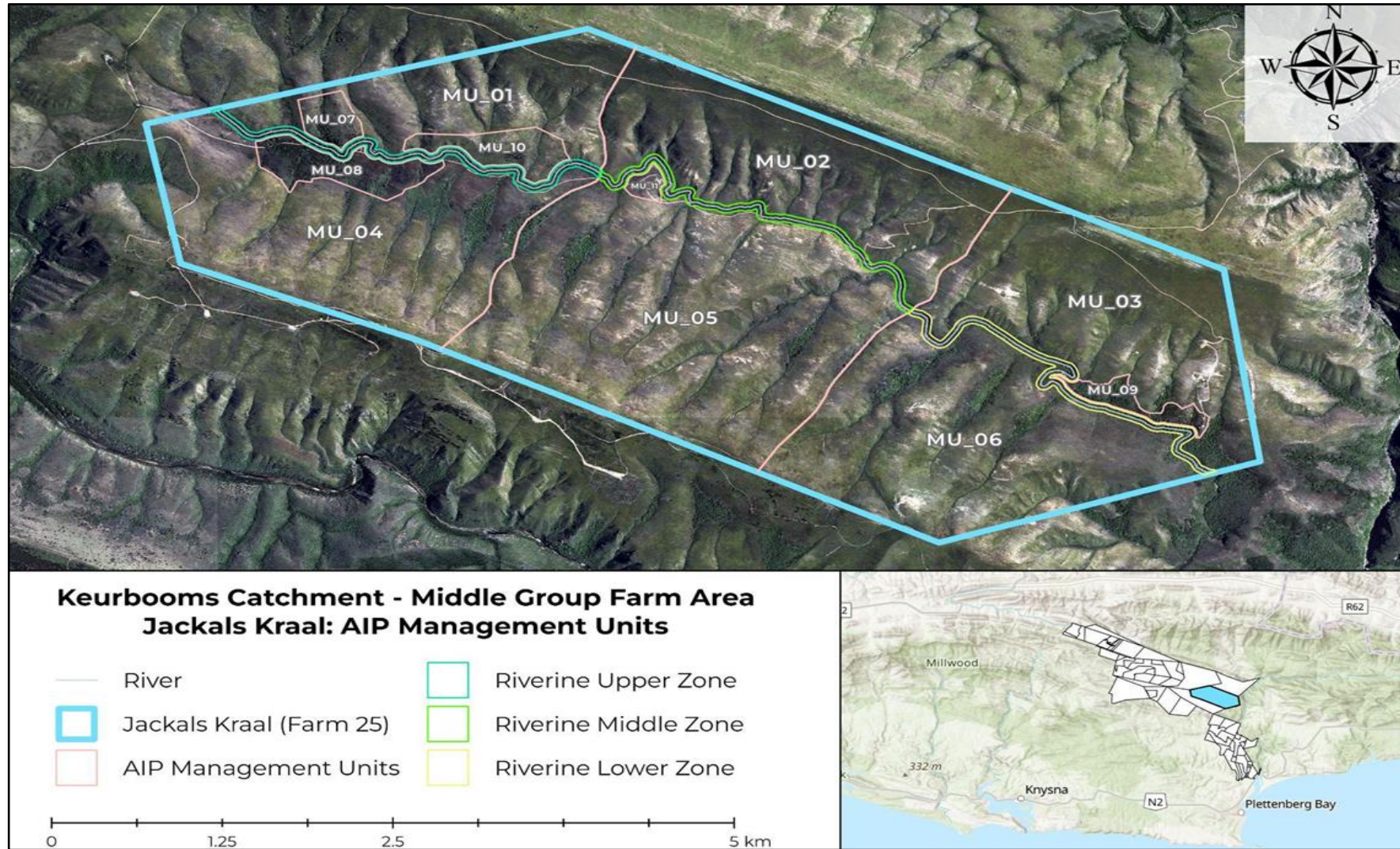


Figure 3: Provides an example of how the Keurbooms study site was mapped into MU and assigned unique numbers.

Table 2: An example of the attribute data collected for the Keurbooms study site for two dominant AIPs.

UID	Area (ha)	IAP Species #1	Age class of Species #1	% Density of Species #1	Estimated water loss caused by Species #1 per year (kL/yr)	IAP Species #2	Age class of Species #2	% Density of Species #2	Estimated water loss caused by Species #2 per year (kL/yr)
MU_01	107,58	P. pinaster/radiata	Mixed (Young)	30	6259,85	Hakea sericea	Young	20	652,79
MU_02	184,01	H. sericea	Young	35	28861,48	P. pinaster/radiata	Young	10	3976,50
MU_03	190,11	H. sericea	Young	35	31194,50	P. pinaster/radiata	Young	10	4735,61
MU_04	216,15	A. mearnsii	Young	7	9508,83	H. sericea	Young	3	3241,09
MU_05	336,84	H. sericea	Young	3	4725,69	P. pinaster/radiata	Young	2	1103,16
MU_06	233,24	H. sericea	Young	3	3578,40	P. pinaster/radiata	Young	2	178,15
MU_07	11,27	A. mearnsii	Mixed (Adult)	15	2252,70	P. pinaster/radiata	Adult	20	1483,11
MU_08	26,38	A. mearnsii	Mixed (Adult)	75	26735,07	P. pinaster/radiata	Adult	2	287,07
MU_09	12,27	A. mearnsii	Adult	20	3650,07				
MU_10	20,23	P. pinaster/radiata	Adult dominant	15	1729,84				
MU_11	4,34	H. sericea	Young	25	490,26	A. mearnsii	Young	5	122,91
RL	18,6	A. mearnsii	Young	35	3714,89				
RM	16,94	A. mearnsii	Young	45	4460,85				
RU	17,44	A. mearnsii	Mixed (Adult)	75	18551,99				
Total	1 395,40				145 714,41				15 780,39

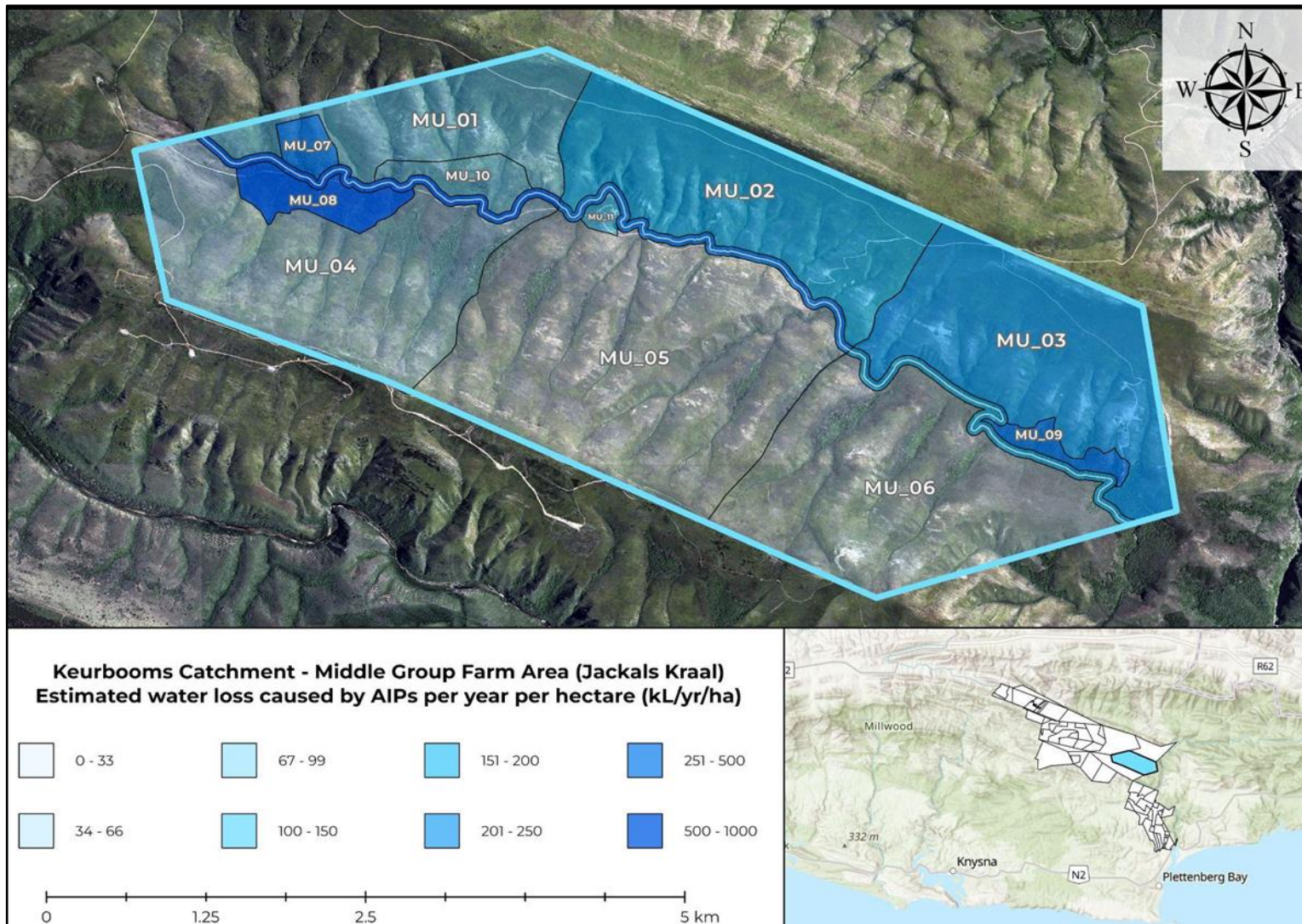


Figure 4: Estimated water loss caused by AIPs per year per hectare (KL/yr/ha) within each of the MU's.

The species, age and density of the AIP will determine the water loss in a given area. Different AIP species use different amounts of water and young infestations at low densities will use much less water than older, more closed stands. For this reason, attribute data is collected on the AIPs in the study area. It is important to note that *A. mearnsii*, one of the major AIP in the Western Cape, is not represented in the application. The developers of the application recommend a substitute AIP should be used and suggest *Acacia saligna*. Dominant species of similar density and age class should also be mapped together to ensure the information fed into the model is applicable to a specific MU and not the entire area otherwise the model will allocate water use information generically to the entire study site. In Figure 5 the typical infestations across the Keurbooms study site are shown as examples of different species at different ages and densities.

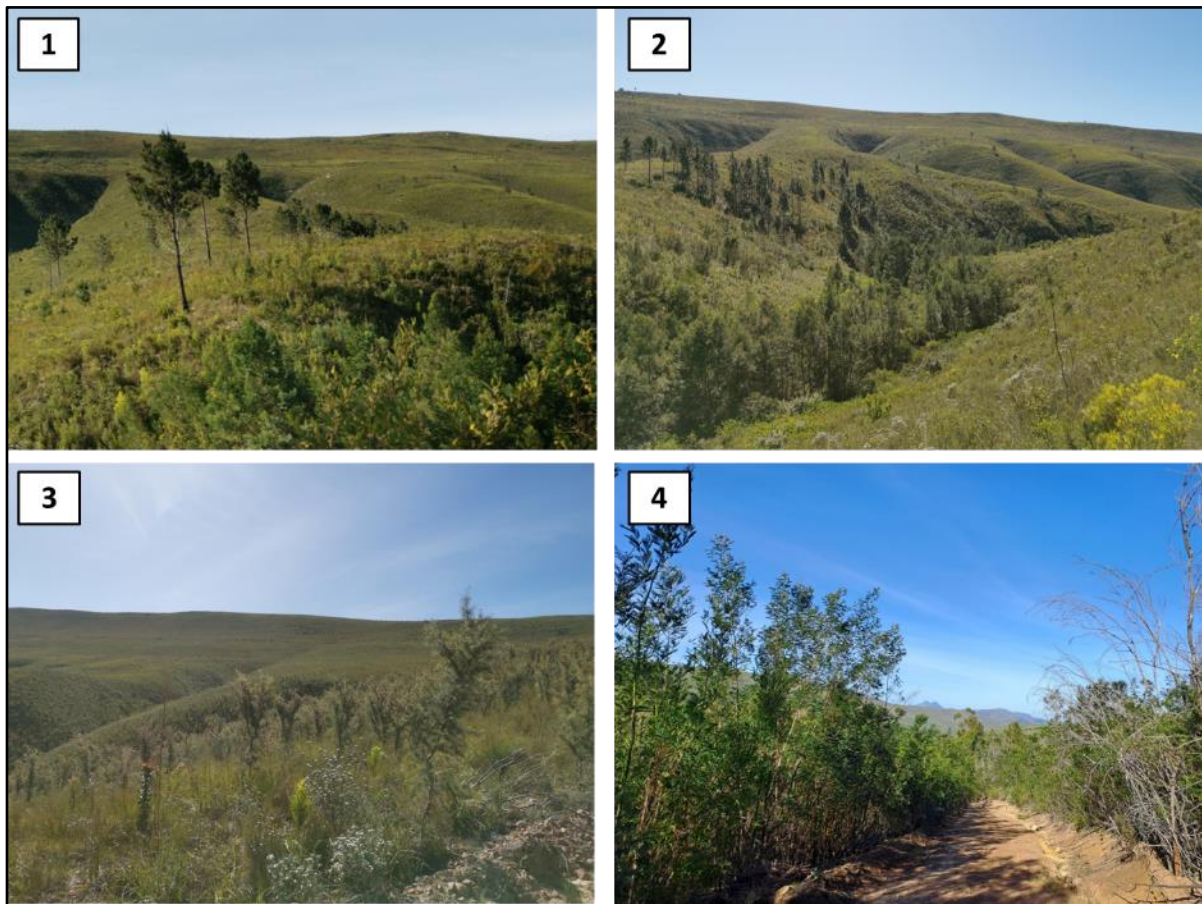


Figure 5: Illustrates the typical AIP infestations across the identified study site within the Keurbooms catchment. (1) Adult *Pinus* spp. at low density; (2) *A. mearnsii* at high density in the drainage line with lower density *Pinus* spp. higher on the slope; (3) a dense stand of young *H. sericea* at high density; (4) high density of young *A. mearnsii* next to a road.

6.1.1.1 Details of the method

Frequency: The application can be used once before clearing AIPs to estimate the water gains to expect after the removal of these plants. After the initial clearing, the need for follow up clearing can be determined annually by remapping AIPs in the areas and estimating water loss.

Skill requirement: Basic training is required for this method. Firstly, users will have to be trained in identifying AIPs and how to determine the age and density of the plants. Secondly, a knowledge of basic map reading and GIS mapping will be required. Google Earth or CapeFarm mapper are user friendly and freely available to use. Lastly, the user will need basic training on using the SAEON application.

Price: The method can be used for free if a GPS application is used on the user's cell phone and a GPS device does not have to be purchased. Two applications that can be used for capturing GPS points are Back Country Navigator and GAIA GPS. The SAEON application can be used for free.

Field sheet: [Click here](#)

Application available at: [Click here](#)

6.1.1.2 Equipment required

- Laptop/cell phone and access to the internet
- GPS device or GPS application on cell phone
- Mapping programs, such as Google Earth, ArcGIS, QGIS or CapeFarmMapper
- Water loss estimation Field Sheet - Appendix A.1.1

6.1.1.3 Method

Step 1

A field evaluation has to be done to collect data on the AIPs in the study area. First divide the study area into different MUs. These MUs should be marked on a physical map of the area which can later be used as a reference in Step 2 when the map is digitized. Also capture a GPS point at each MU.

Once the boundaries of each MU have been established, determine the species, age, and density for the three most dominant AIP species in each MU. Record this data on the field sheet (Appendix A1.1).

Step 2

Once the field evaluation has been completed, the areas should be mapped. Use a mapping program, such as Google Earth or ArcGIS, to digitize the boundaries of each MU. This can be done using both the GSP locations, and the boundaries drawn on the physical map. The attribute data of the AIPs should also be recorded in a table and can be loaded onto the digitized map using ArcGIS.

Use the digitized map to determine the area of each MU, which will be required for using the SAEON application.

Step 3

Finally, the SAEON application can be used to estimate the water loss due to AIPs for the study area. The water loss is determined for each of the dominant species in each of the MUs. Once

this has been done, water loss due to AIPs for the whole study area is calculated as the sum of water loss of each MU.

To estimate water loss, firstly select the species from the drop-down list (Figure 6.1). *A. mearnsii* is not available in the application, however, *Acacia saligna* can be used as a proxy. Next, select the mean age, density (canopy cover) and size of the area (Figure 6.2). Lastly, as seen in Figure 6.3, insert the location recorded at each MU. The application then provides the water loss due to the AIP as a range of water lost per year (Figure 6.4).

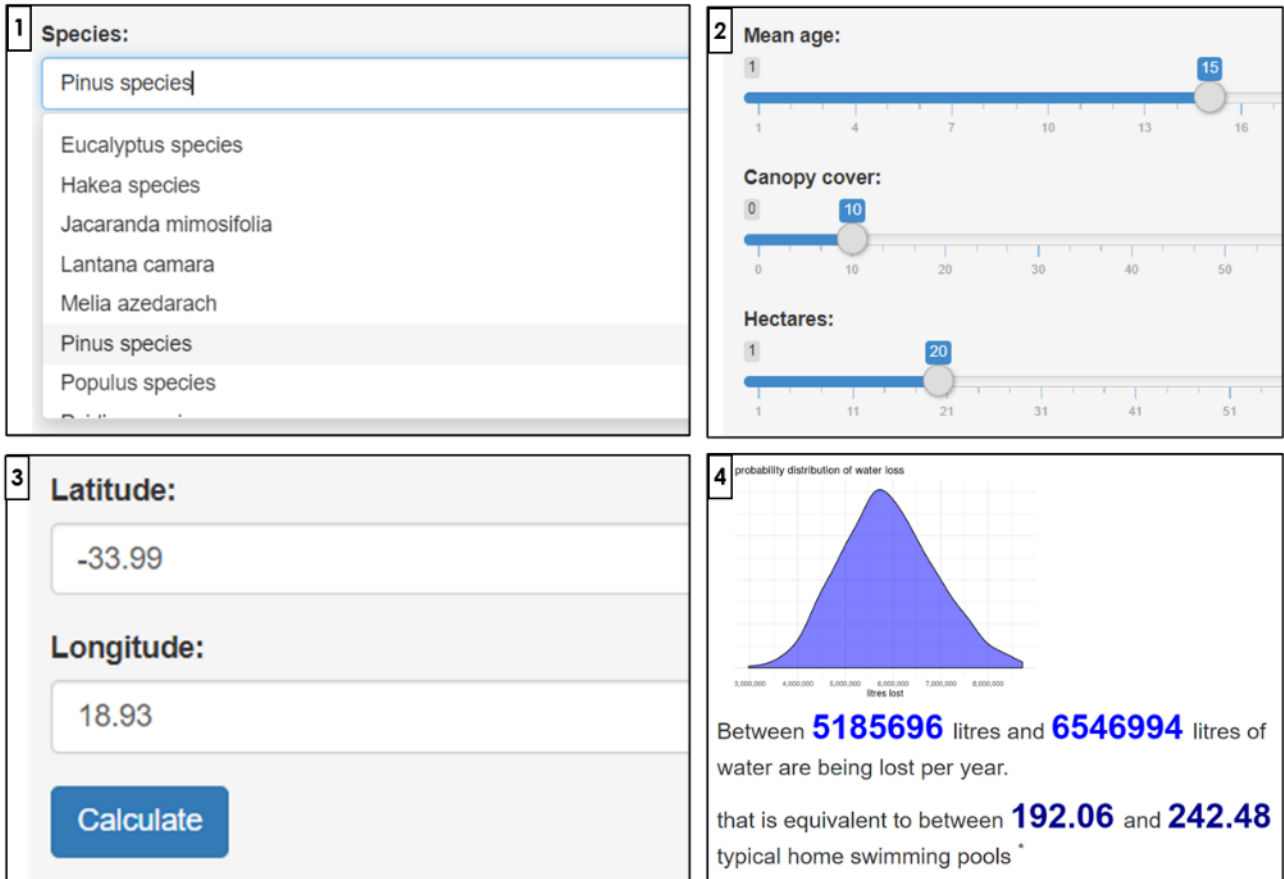


Figure 6: Inserting key input data and results for the SAEON application: (1) Selecting AIP species; (2) Selecting the mean age, density (canopy cover), and size of the infestation; (3) Inserting the GPS location; (4) estimated range of water loss due to AIPs provided by application.

6.1.1.4 Advantages and limitations

The advantages and limitations of using the SAEON application for estimating water loss due to AIP is provided in Table 3.

Table 3: Advantages and limitations of using the SAEON application.

ADVANTAGES	LIMITATIONS
Free	<i>A. mearnsii</i> not represented
Easy to use	Results of the application have not been validated
Can be used if limited resources do not allow for direct methods.	
Can be applied to estimate future savings of water that would result from preventing low infestations of IAPs developing into high infestations.	
Method can be applied quickly because it does not require repeated measures.	

6.2 Direct methods

Two parameters can potentially be measured using direct methods, namely streamflow and spring discharge. Streamflow can be used to measure the amount of water in a stream moving past a point over a certain period. Spring discharge can be used to measure water quantity by measuring the amount of water discharged from a spring over a certain period.

The direct methods included in this guideline are the 90° V-notch weir method, float method, and the end depth culvert method for measuring streamflow, and the container fill method to measure spring discharge.

6.2.1. Measuring streamflow: 90° V-notch weir method

V-notch weirs can be used to accurately measure water quantity. The weir is placed in the stream which dams the water and forces it over the notch of the weir, from which the necessary measurement is made (Dobriyal et al., 2017). The method can be particularly useful in water systems with low flow. Portable V-notch weirs can be constructed out of a wooden board with relative simplicity, making this an easy method to implement.

The v-notch weir should be used in streams such as the one demonstrated in Figure 7. Narrow streams are recommended for monitoring, as the weir plate must be wide enough to cover the entire cross-section of the stream (Dobriyal et al., 2017; People's Science Institute, n.d.). This method should also be used during low flows. Flooding and high flow events will not be representative of the area's flow and the weir board might wash away if the streamflow is too strong. Ensure that this weir installed does not block flow for longer than is necessary for taking an accurate reading. Riverbanks and streams should not be altered, and care should also be taken to avoid triggering any listed activities or EIA processes.



Figure 7: Size of streams for which the V-notch weir method is ideal (Image: ACS, 2023).

The components of the V-notch weir are described in Table 4 and illustrated in Figure 8. Each of these components are important to understand when constructing and using a portable 90° V-notch weir (People's Science Institute, n.d.; Terasmaa et al., n.d.). These measures should be used when making a weir out of wood.

Table 4: Description of v-notch weir components.

COMPONENT AND SYMBOL	DESCRIPTION
Head (H)	This is the depth of the water flowing over the crotch of the notch – it is measured in order to calculate streamflow. The head is measured upstream from the weir to prevent inaccuracies caused by the water level dropping as it flows over the notch.
Width (B)	The width of the weir should be wider than the stream being measured.
Height of the weir base (P)	This should be deeper than the downstream water level and at least twice as high as the measured head (H). The notch is inserted in the middle of the weir plate and the angle of the notch is 90°.

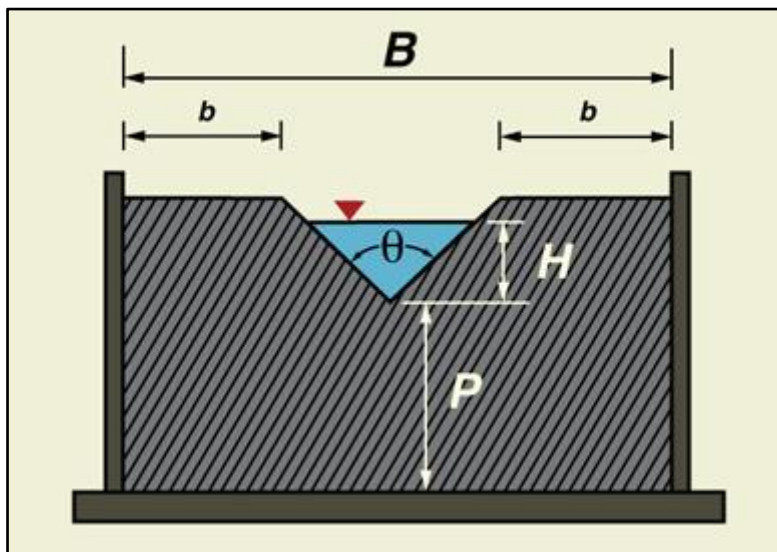


Figure 8: Components of the V-notch weir (People's Science Institute, n.d.).

In Table 5 standard sizes for V-notch weirs are summarised. The size of the notch cut into the wood will depend on the maximum flow the user is expecting. For a small, low flow stream (as shown in Figure 7), the first notch depth of 154mm should be sufficient.

Table 5: Standard notch sizes for 90o V-notch weirs (Roctest, n.d.).

MAXIMUM FLOW (L/S)	ANGLE OF NOTCH	NOTCH DEPTH (MM)
12	90°	154
67.8	90°	305
> 67.8	90°	455

A measuring staff should be placed on the upstream side of the weir, at a distance away from the weir of at least four times greater than the depth of the water flowing over the crotch (People's Science Institute, n.d.; Terasmaa et al., n.d.). A small staff level gauge can be used, however if this is not available, any measuring device such as a ruler will also suffice.

For the V-notch weir method an existing conversion table is used to determine the streamflow. Based on this predefined relationship, the conversion table converts the measured head (cm) to streamflow (L/s). The head and streamflow are directly proportional, which means the head will increase as the streamflow increases (People's Science Institute, n.d.; Terasmaa et al., n.d.).

Skill and effort will be required to install the weir and the staff gauge, and to ensure that no flow is lost beneath the weir plate. However, once this has been achieved only one, easy depth measurement needs to be taken to measure streamflow, making it a very rapid method to apply.

6.2.1.1 Details of the method

Frequency: Measurements can be taken monthly or more frequently when there is an opportunity for the user to take measurements.

Skill requirement: Basic training will be required on how to construct and install a portable V-notch weir, and how to determine streamflow by measuring the head.

Price: < R500

Field sheet: [Click here](#)

6.2.1.2 Equipment

- Wooden board for portable V-notch weir plate
- Level
- Staff level gauge or ruler
- Saw
- Protractor

6.2.1.3 Method

Step 1

Place the weir plate in the cross section of a stream (See Figure 9.1). The weir plate needs to be wide enough to cover the whole cross section of the stream because it is important that all the water in the stream flows through the notch. The user should also ensure that no water is flowing beneath the weir plate. If water is being lost, material should be placed at the base to prevent water flow beneath the plate (Dobriyal et al., 2017; People's Science Institute, n.d.; Terasmaa et al., n.d.).

Wait until a steady stream is observed flowing over the crotch (See Figure 9.1). Then place the measuring staff at a distance at least four times greater than the level of the water flowing over the crotch of the notch. So, for example, if the level of the water flowing over the crotch is 6cm, the measuring staff should be inserted at least 24cm from the weir (People's Science Institute, n.d.; Terasmaa et al., n.d.).

Step 2

Use a bubble level to determine the level of the crotch on the measuring staff (See Figure 9.2). To do so, place the level between the crotch of the V-notch weir and the measuring gauge. The bubble level should be horizontally level. Measure the difference between the height of the level against the staff gauge and the surface of the water. This measurement is called the head and is measured in cm (People's Science Institute, n.d.; Terasmaa et al., n.d.).

Step 3

Finally, use the conversion table to convert the head measurement (cm) to streamflow (L/s). The streamflow is simply read as the corresponding value of the measured head. For example, using the conversion table, a head measurement of 6cm will be converted to a streamflow of 1.2L/s (See Figure 9.3). The full conversion table is available in Appendix A.1.2. If the head is measured as a decimal number, it should be rounded to the nearest whole number to be used in the conversion table (Dobriyal et al., 2017; People's Science Institute, n.d.; Terasmaa et al., n.d.).

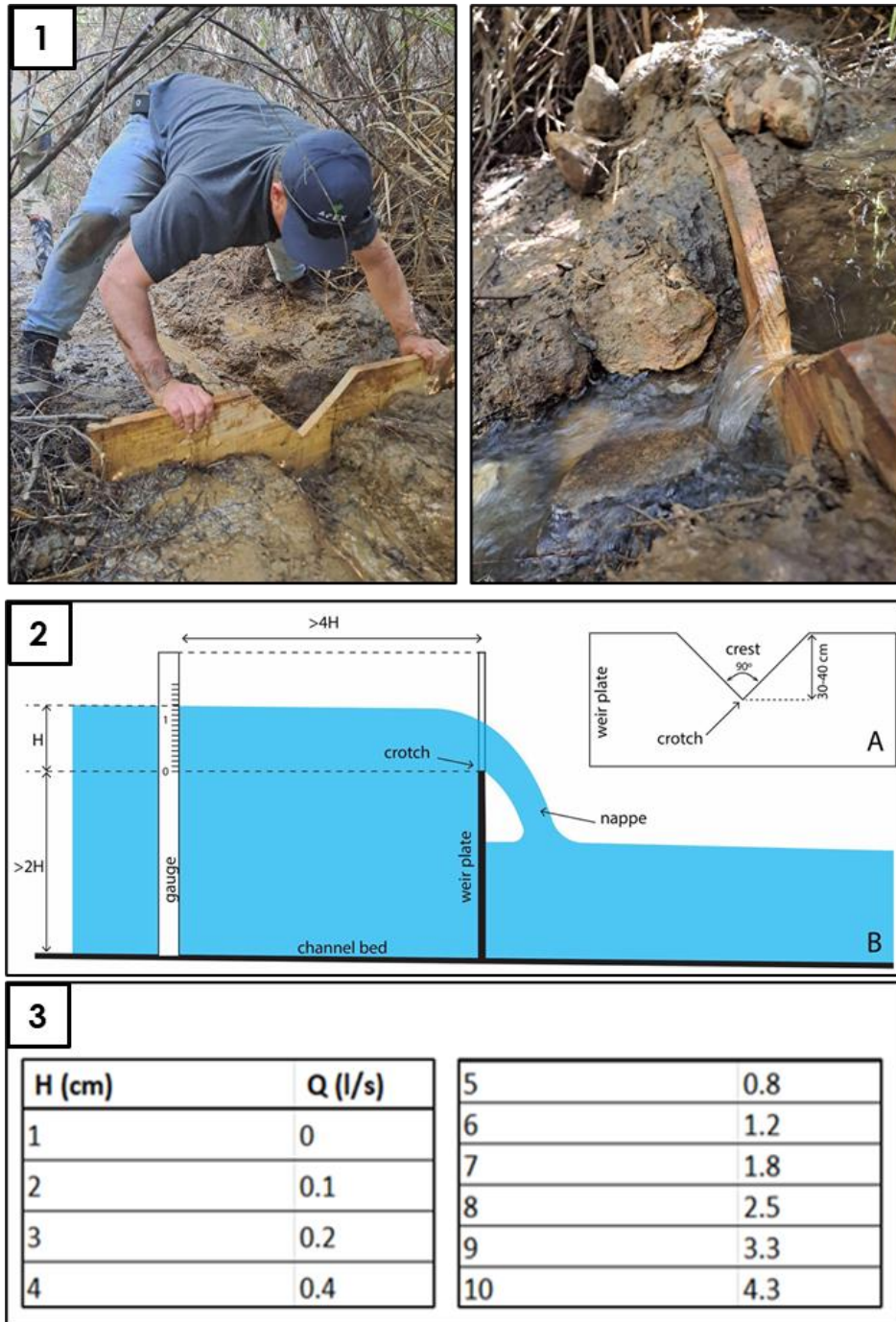


Figure 9: Steps of using the 90° V-notch weir method to calculate streamflow: (1) Inserting weir in the stream and wait until steady stream is observed over notch; (2) Measuring the head; (3) Using the conversion table to determine streamflow (Images: ACS, 2023; Terasmaa et al., n.d.).

6.2.1.4 Advantages and limitations

In Table 6 the advantages and limitations of the 90° V-notch weir method are summarised.

Table 6: Advantages and limitations of the V-notch weir method.

ADVANTAGES	LIMITATIONS
Accurate	Can only be a temporary structure to avoid triggering a listed activity.
Easy to construct wooden weir	Susceptible to flood damage under high flow conditions.
Easy to take measurements once the weir and staff gauge has been installed.	May require maintenance.
	Effort and skill required to install weir and staff gauge and ensuring flow does not pass beneath the weir.

6.2.2 Measuring streamflow: Float method

The float method is used to calculate streamflow by measuring the time taken for an object to float over a known distance (Dobriyal et al., 2017). The float method requires minimal resources and equipment and is easy and quick to use, making it accessible to most users.

For this guideline the float method is intended for small streams (as seen in Figure 10). The method is better suited for narrow, calm streams as vertical turbulence of the float will influence its speed and reduce the accuracy of the measurements (Shope et al., 2013; Dobriyal et al., 2017).



Figure 10: Size of stream that the float method should work well for (Image: ACS, 2023).

If the method is however used in larger streams than shown above, the stream should be divided into segments (as illustrated in Figure 11) and streamflow calculated for each segment. The streamflow for the whole stream is then calculated as the average of the different segments (Dobryial et al., 2017; Othman, 2017; Hundt and Blasch, 2019).

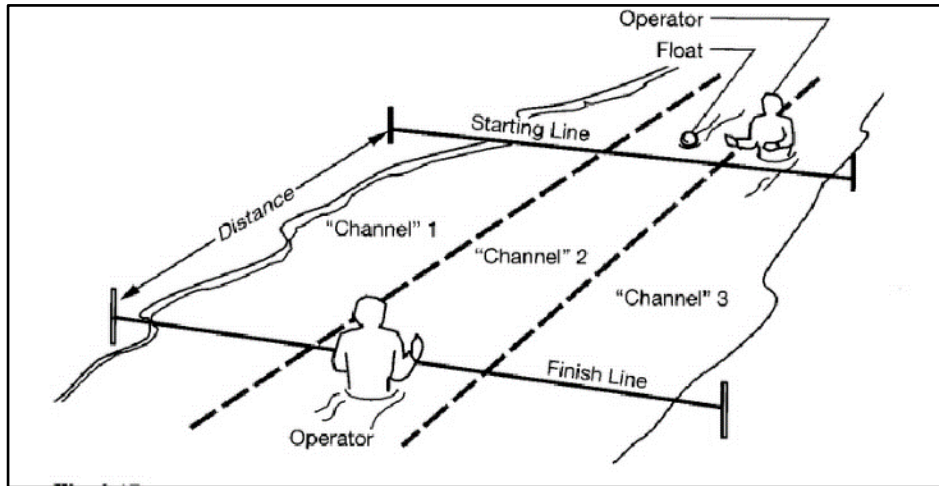


Figure 11: Dividing a stream into different segments for larger streams for the float method (Image: Brikowski, 2007).

The method uses the simple technique of recording the time it takes for a float to cross a known distance. This is used to determine the speed of the river. Using the width and depth of the stream its area can be calculated. The streamflow can then be calculated using the area and speed values, giving the user the amount of water (in m^3) that passes through the stream over a certain time period (per second). The float can be any object of low density, e.g., a piece of wood or a plastic bottle (Dobryial et al., 2017; Othman, 2017; Hundt and Blasch, 2019).

6.2.2.1 Details of the method

Frequency: Monthly, or more frequently when there is an opportunity to take measurements.

Skill requirement: No training is required for the float method. It is easy, and users should only need these guidelines and information in the resource library to be able to learn how to set up the float method and use it to calculate streamflow.

Price: < R100

Field sheet: [Click here](#)

6.2.2.2 Equipment required

- Stopwatch or timer
- Marker for start and finish line (can be any marker, such as a rope or pole, etc.)
- Measuring tape
- Floating device (any easily visible floating object, such as a stick or ping pong ball)
- Streamflow: Float Method Field Sheet - Appendix A.1.3

6.2.2.3 Method

Step 1

Measure and mark out a reach in the stream (see Figure 12.1). Record this distance. The part of the stream that is selected should be straight and have a relatively uniform cross section (Othman et al., 2017).

Step 2

Take a measurement of the depth and width of the stream at the beginning and endpoint of the reach. Record these measurements (Dobryial et al., 2017; Othman, 2017; Hundt and Blasch, 2019).

Step 3

Calculate the average depth and width of the stream using Formula (1) and (2) below. Following these calculations, calculate the average area of the stream using Formula (3) below.

(Dobryial et al., 2017; Othman, 2017; Hundt and Blasch, 2019).

Step 4

The float is then dropped slightly upstream from the beginning of the marked reach. Start the stopwatch as soon as the float crosses the first mark. As soon as the float reaches the downstream mark, stop the stopwatch. Record the time taken for the float to cross this distance. An example of the set up can be seen in Figure 12.4. (Dobryial et al., 2017; Othman, 2017; Hundt and Blasch, 2019).

Step 5

Calculate the velocity of the stream by dividing the distance of the reach by the time for the float to cross that distance using Formula (4) below.

Streamflow is then calculated using Formula (5). These five steps should be repeated five to ten times.

(Dobryial et al., 2017; Othman, 2017; Hundt and Blasch, 2019).

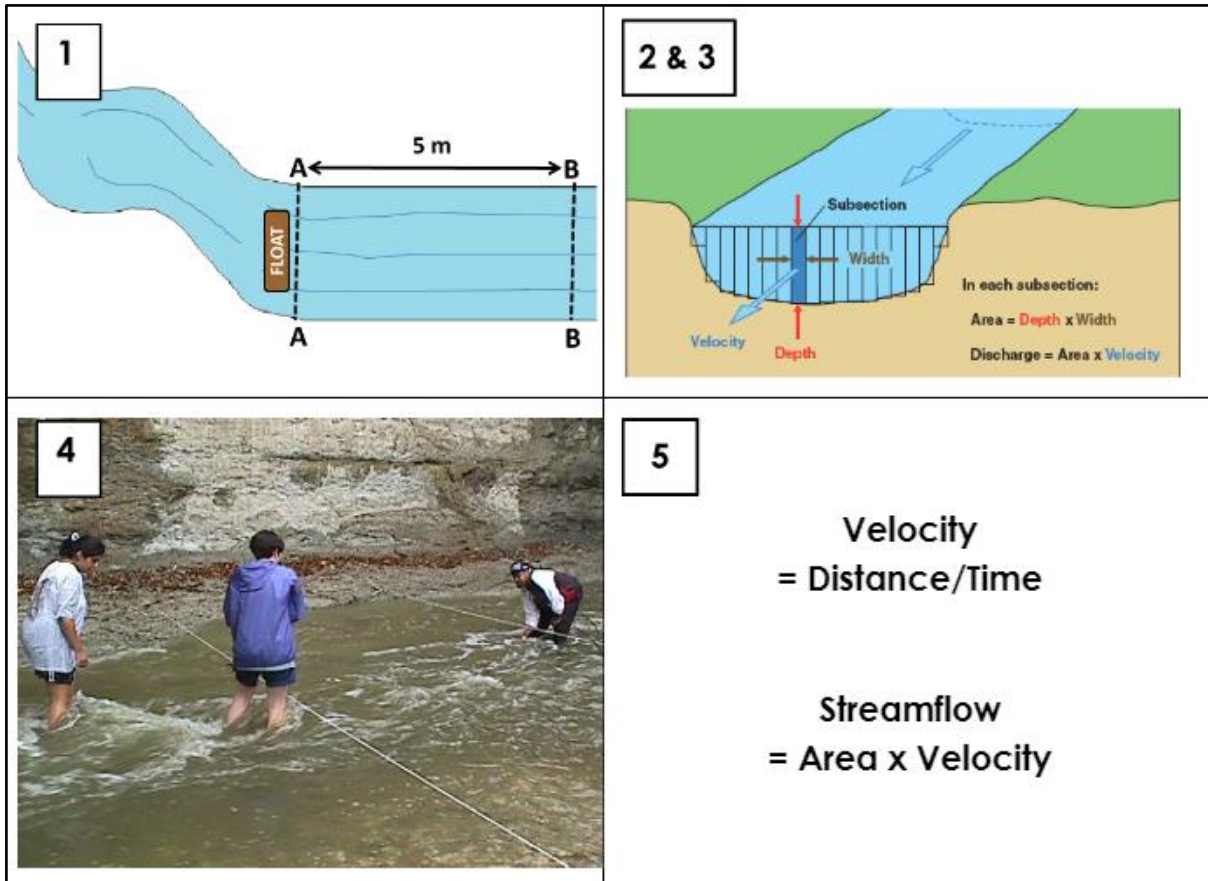


Figure 12: Summary of the float method: (1) Measuring and marking the reach, (2 & 3) measuring width and depth and calculate average area, (4) floating object downstream, and (5) calculating velocity and streamflow (Images: Irrigation Engineering, n.d.; USGS, n.d.; Brikowski, 2007).

In Box 1 the formulas required for the five steps of the float method are given.

$$\text{Depth}_{\text{Avg}} (\text{m}) = (\text{Depth}_{\text{Upstream}} - \text{Depth}_{\text{Downstream}}) \div 2$$

(1)

$$\text{Width}_{\text{Avg}} (\text{m}) = (\text{Width}_{\text{Upstream}} - \text{Width}_{\text{Downstream}}) \div 2$$

(2)

$$\text{Area}_{\text{Avg}} (\text{m}^2) = (\text{Depth}_{\text{Avg}} \times \text{Width}_{\text{Avg}})$$

(3)

$$\text{Velocity}_{\text{Float}} (\text{m/s}) = \text{Distance}_{\text{Reach}} (\text{m}) \div \text{Time} (\text{s})$$

(4)

$$\text{Streamflow} (\text{m}^3) = \text{Velocity}_{\text{Float}} (\text{m}) \times \text{Area}_{\text{Avg}} (\text{m}^2)$$

(5)

Box 1: Formulas required for Step 3 and 5 of the float method.

6.2.2.3 Advantages and limitations

In Table 7 the advantages and limitations of using the float method to calculate streamflow is provided.

Table 7: Advantages and limitations of the float method.

ADVANTAGES	LIMITATIONS
Easy to set up and to measure streamflow	Not accurate in larger, turbulent streams due to vertical turbulence.
Requires minimum resources and equipment	Time consuming - the reach length, as well as the depth and width of flow must be measured in addition to the replicated measurements of the float time. More time consuming than the V-notch weir method which only requires a single depth measurement.

6.2.3. Measuring streamflow: End depth culvert method

At study sites where culverts are present with waterflow with a drop off from the end of the culvert, the end depth culvert method is an easy and accurate method that can be utilized for measuring streamflow. The method requires minimal measurements, as only the diameter and depth of water have to be measured.

Figure 13 illustrates the important components of the end depth culvert method. The end view shows the end depth (H) and the diameter (D) that is measured. The end depth is the depth of the streamflow close to the end of the culvert where the water drops off. Figure 13 also illustrates some of the requirements that must be met for the method to be used. The length of the culvert has to be at least twenty times greater than the end depth ($L > 20h$). The drop off has to be greater than the end depth ($d > h$). Requirements, not illustrated below, should also be met. The culvert should be horizontal with a minimum slope, have smooth walls, and should not have an inlet or outlet control. The end depth should be greater than 5cm. Finally, the ratio of h/D should be between 0.095 and 0.5 (LMNO Engineering, 2014).

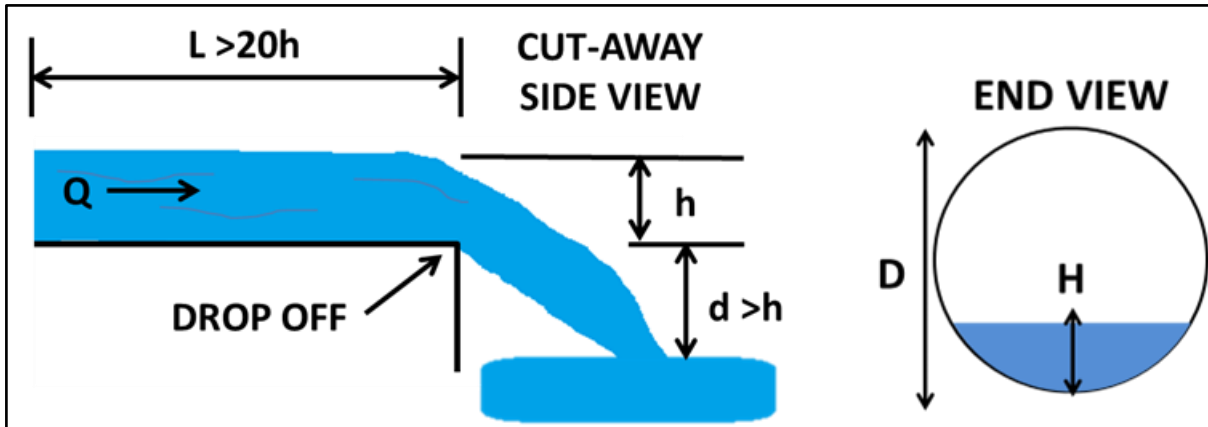


Figure 13: Sketches with relevant measurements and symbols for the end depth culvert method (Images: ACS, 2023).

The user has to take and record the diameter of the culvert only once. After this first measurement, all subsequent measurements will only require recording the end depth. After these measurements have been taken, two formulas are used to calculate streamflow in Litre per second. Given the complex calculations required for this method, these formulas have been added to the field sheet (link to field sheet in Section 6.2.3.1), which is an Excel document. In this spreadsheet, the user only has to add the diameter and end depth measurements and the streamflow will be automatically calculated.

6.2.3.1 Details of the method

Frequency: Monthly, or more frequently when there is an opportunity to take measurements.

Skill requirement: Basic training will be required on how to make necessary measurements and how to ensure the culvert in the study site meets all the necessary requirements.

Price: < R100

Field sheet: [Click here](#)

6.2.3.2 Equipment required

- Tape measure
- Streamflow: End Depth Culvert Method Field Sheet - Appendix A.1.4

6.2.3.3 Method

Step 1

Measure the diameter (see Figure 14) of the culvert with a tape measure and record the measurement. The diameter should be stored so that this step will not be required for subsequent measurements. Record the reading in centimetres (LMNO Engineering, 2014.).

Step 2

Use the tape measure to measure the end depth (see Figure 13) (LMNO Engineering, 2014).

Step 3

The last step is to use the formulas in Box 2 to calculate the streamflow (L/s). Formula 1 is first used to calculate the α value with the measured depth and diameter of the culvert. Formula 2 is then used to measure the streamflow in m^3/s and the value is multiplied by 1000 to convert it to L/s (LMNO Engineering, 2014.). The user can use the field sheet Excel document to avoid having to do the calculations themselves.

Figure 14 shows the first two steps of the end depth culvert method. Box 2 provides the formulas necessary to calculate streamflow using this method.

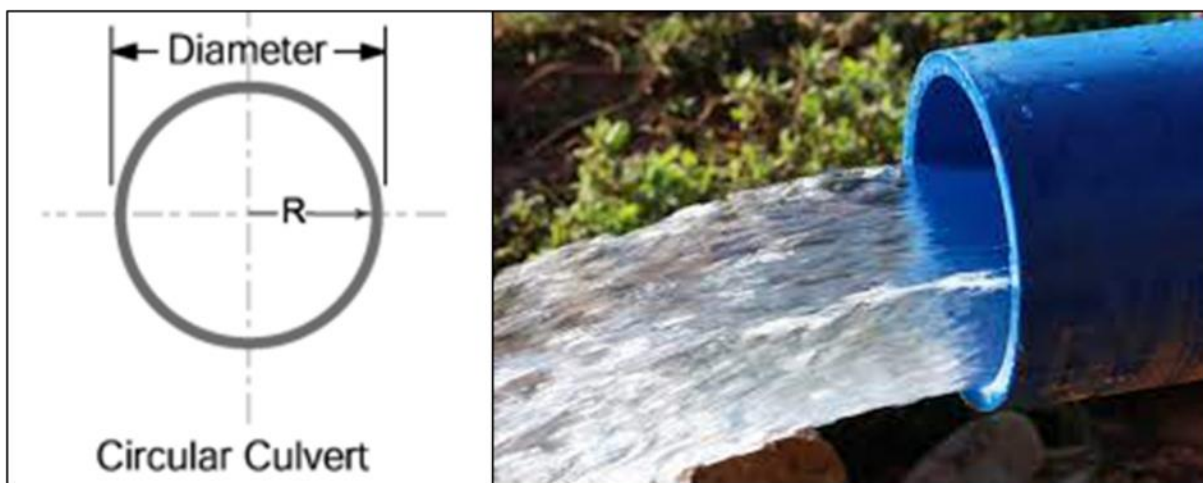


Figure 14: The first two steps of the end depth culvert method: (1) Measuring the diameter of the culvert and (2) measuring the depth of water at the end point of the culvert (Images: FSL ORST, n.d.; Deziel, 2018).

$$\alpha = \frac{h}{0.378 D} \quad (1)$$

Where,

h: depth of the water at the end of the culvert (m)

D: diameter of the culvert (m)

$$Q = \left(\frac{\sqrt{g} (0.5D)^{5/2}}{4(2\alpha - \alpha^2)^{1/4}} [2\cos^{-1}(1 - \alpha) - 2(1 - \alpha)\sqrt{2\alpha - \alpha^2}]^{3/2} \right) \times 1000 \quad (2)$$

Where,

Q: Streamflow (L/s)

g: 9.8066 m/s²

α : value calculated with formula 1

D: diameter of the culvert

Box 2: The formulas needed for calculating streamflow with the end depth culvert method (LMNO Engineering, 2014).

6.2.3.5 Advantages and limitations

In Table 8 the advantages and limitations of the end depth culvert method are presented.

Table 8: Advantages and limitations of the end depth culvert method.

ADVANTAGES	LIMITATIONS
Accurate	The method cannot be used if the requirements outlined above are not met.
Easy to take measurements	
Quick to take measurements as only one depth measure has to be taken every time flow is measured.	
Existing infrastructure can be used for the method	

6.2.4. Measuring spring discharge: Container Fill Method

The container fill method, also known as the timed volume or volumetric streamflow method, is based on the time it takes to fill a container of known volume to calculate the rate of discharge. The method is easy and requires minimal resources and technical knowledge (People's Science Institute, n.d.).

In order for the container fill method to be applicable to an area, an artificial structure that deviates all the water discharged from a spring through one output, such as a pipe (Dobriyal et al., 2017). In Figure 15 such a structure is shown. The structure is a sump drained by an outflow pipe. All the water discharged by the spring is collected by the sump, which makes it an ideal structure for the container fill method. If a similar structure is not present at a given monitoring site, it will either have to be built, or this method will not be applicable to the area.



Figure 15: A sump, which collects all the water of a spring, drained by an outflow pipe; the type of structure which can be utilized for the container fill method.

The only equipment necessary for this method is a container and a stopwatch, and the user to record the time it takes for the container to be filled. The only limitation is that it requires the artificial structure discussed above, which, if it is not present at the study site, will require more resources and time.

6.2.4.1 Details of the method

Frequency: Monthly, or more frequently when there is an opportunity to take measurements.

Skill requirement: No training is required. The step-by-step explanation in section 6.2.4.3 of these guidelines should provide all the support a user will require to use this method.

Price: < R100

Field sheet: [Click here](#)

6.2.4.2 Equipment required

- Bucket
- Stopwatch or cell phone with stopwatch
- Spring Discharge - Container Fill Method Field Sheet - Appendix A.1.5

6.2.4.3 Method

Step 1

Place a container of known volume so as to capture spring water flow from the main output. Make sure the container is not tilted (See Figure 16).

Step 2

Start the stopwatch immediately when the container begins to fill.

Step 3

As soon as the container is full, stop the stopwatch and record the time.

Step 4

Discharge is calculated by using Formula (1) below; dividing the volume collected by the time taken to fill the container.

(People's Science Institute, n.d.; Dobriyal et al.,2017).



Figure 16: Collecting spring discharge from a single output in a container for the container fill method (Images: ACS, 2023).

The formula required for using the container fill method is given in Box 3.

$$\text{Discharge (L/s)} = \text{Volume (L)} \div \text{Time (s)} \quad (1)$$

Box 3: The formula used for the container fill method.

6.2.4.4 Advantages and limitations

In Table 9 the advantages and limitations of the container fill method is presented.

Table 9: Advantages and limitations of the container fill method.

ADVANTAGES	LIMITATIONS
Easy to use	Will have to build a structure that collects all the spring water into one output if such a structure is not present in study area
Minimal resources and equipment required if an artificial structure is present that collects all the water discharged by spring.	

6.2.5. Measuring spring discharge: Water Level Recovery Method

The water level recovery method measures the rate of discharge from a spring seeping from below ground onto the surface (People's Science Institute, n.d.). The method is easy to apply, requiring minimal resources, and is a rapid method for monitoring water quantity from spring discharge.

Seeps are areas where groundwater has oozed through the soil surface. The method can be used where the discharged water has formed a pond (People's Science Institute, n.d.). Figure 17 shows examples of such ponds.

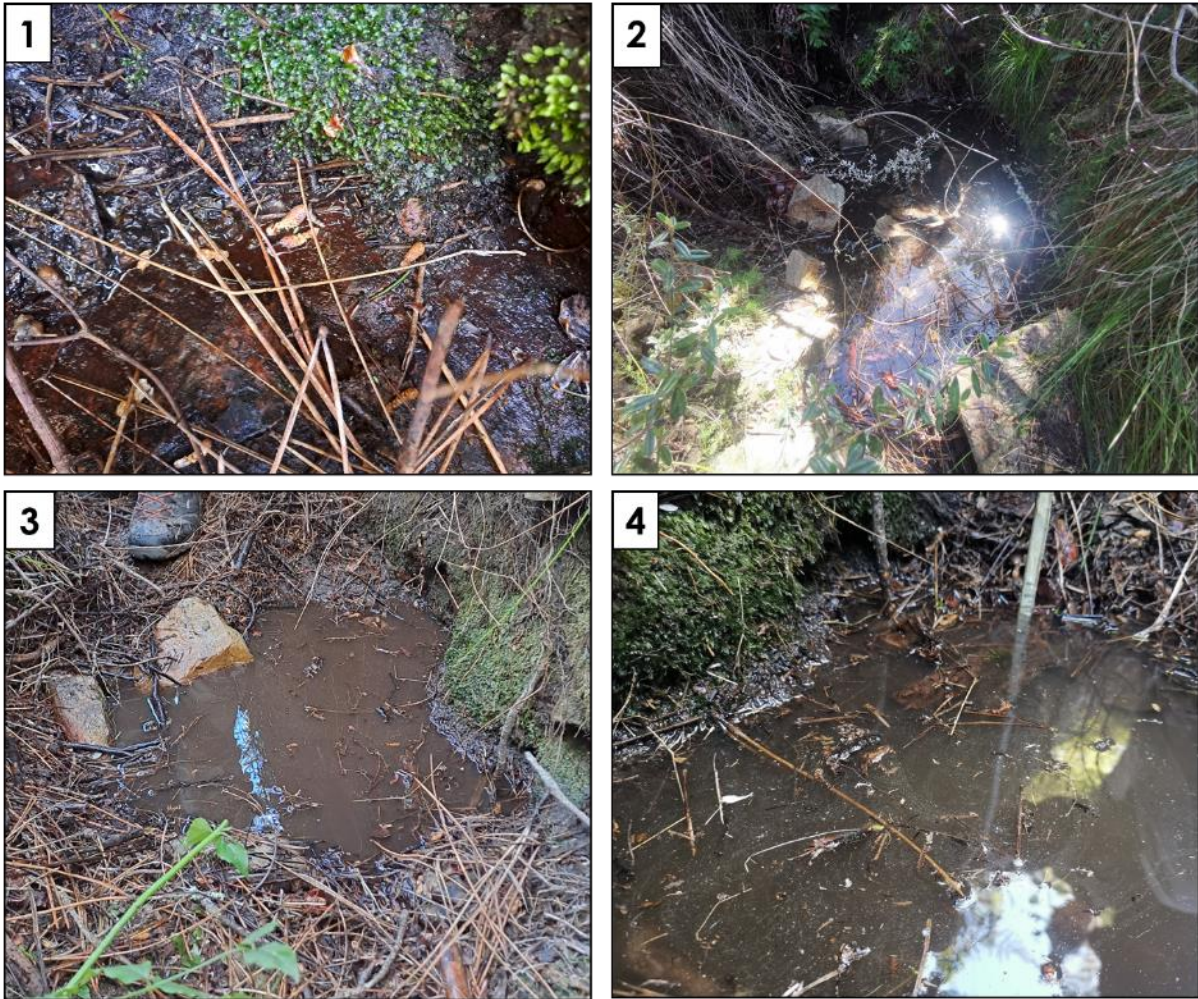


Figure 17: Examples of ponds formed from water that has seeped to the surface where the water recovery method can be applied.

A measuring gauge or stick is placed in the pond and the level of the water is recorded or marked. A known volume of water is removed with a container and the time for the water to refill to the original level is recorded. The volume of the container and time to refill is then used to calculate the discharge in Litres per second.

6.2.5.1 Details of the method

Frequency: Monthly, or more frequently when there is an opportunity to take measurements.

Skill requirement: Basic training might be required for users to identify springs seeping onto the surface. No training is however required for the method as users should be able to apply this method by following the steps in Section 6.2.4.3.

Price: < R100

Field sheet: [Click here](#)

6.2.5.2 Equipment required

- Measuring staff or stick

- Container of known volume
- Stopwatch or cell phone with stopwatch application
- Spring Discharge - Container Fill Method Field Sheet - Appendix A.1.6

6.2.5.3 Method

Step 1

Place a measuring gauge or stick at a fixed location in the depression and mark the water level on the stick (see Figure 18.1).

Step 2

Take a container of known volume and remove this volume of water from the depression (see Figure 18.2). Start the stopwatch as soon as the water is removed, which will cause the water level in the depression to drop down by a few centimetres.

Step 3

Keep watching the water level, and as soon as it comes up to the marked level, stop the watch and note the time.

Step 4

Discharge is calculated by dividing the volume collected by the time taken for the water to return to its original level (Formula 1 in Box 4).



Figure 18: The spring discharge water recovery method: (1) the water level in the depression is measured and marked on a guiding stick; and (2) a container of known volume is then used to remove water, and the time taken for the spring to refill the depression to the previously measured water level is recorded.

The formula required for using the water recovery method is given in Box 4.

$$\text{Discharge (L/s)} = \text{Volume of container (L)} \div \text{Time (s)} \quad (1)$$

Box 4: The formula used for the water recovery method.

6.2.5.4 Advantages and limitations

In Table 10 the advantages and limitations of the water recovery method are presented.

Table 10: Advantages and limitations of the water level recovery method.

ADVANTAGES	LIMITATIONS
Easy to use	If water refills slowly, it may be time-consuming and fine scale measurements will need to be made
Cost effective	Identifying appropriate seeps which refill without flowing may be difficult
Provides a method for measuring water when flowing streams are not available	

6.2.6 Measuring borehole water: Water Level Meter

Groundwater is stored below the earth's surface like an underground sponge filled with water (Ravenscroft and Murray, 2004). Groundwater is used up by AIPs. *Prosopis* (Fourie et al., 2007; Dzikiti et al., 2013; Ravhuhali et al., 2021) and *Acacia* (Maclear, and Kotze, 2000) species, for example, have been shown to deplete groundwater in drier regions. Clearing these AIPs may be useful for ensuring groundwater is saved.

Borehole monitoring provides a measurement of how far below the surface the water table starts (Wika, 2023). The water table is the uppermost level of the groundwater beneath the land surface (Ravenscroft and Murray, 2004). A water level meter can be used to measure the water level in a borehole (Ravenscroft and Murray, 2004; Solinst, 2013; Brumby Pumps, 2019; Petersen and Strydom, n.d.). The water level present within the borehole is measured by determining the depth of the borehole, as well as the depth of the water table within it. The water table depth is subtracted from the borehole depth to determine the water level present. These depths can be measured using the dipmeter Water Level Meter equipment which consists of stainless-steel probes attached to flat tape with measurements, fitted on a reel, which is lowered into the borehole (Solinst, 2013). A 9-volt battery is used to power the probes, and this alerts the user when contact is made with water and the water level is read off the tape at this point (Solinst, 2013). Alternatively, if equipment such as this is not accessible, a homemade water level meter can be used. Here the user can build their own meter using a string together with a floating device (to measure the water table) and sinking device (to measure the borehole depth). Both dipmeter and homemade water level meters are outlined within this monitoring guide.

This method requires the presence of a borehole. The area at which these boreholes are located will be different for each user. The borehole need not be at the site of the AIP clearing but should be in the same general area in order for effects of clearing to be detectable. Figure 19 shows an example of a borehole being used to extract water on a property.



Figure 19: Example of a borehole being used to extract water (Image: Wika, 2023).

Borehole water levels are influenced by a wide range of factors at a large scale, the groundwater present will be heavily influenced by rainfall, abstractions, and vegetation (indigenous and alien) for example. These impacts may obscure any changes resulting from AIP removal – it is therefore useful to use this method in conjunction with another water quantity measure outlined within this monitoring guideline.

6.2.2.1 Details of the method

Frequency: Measurements should be taken whenever the borehole is visited, or on a monthly basis at least. When water use is highest, more frequent measures may be useful.

Skill requirement: Basic training may be required to implement this method on existing boreholes, to ensure that accurate readings of the water level are made.

Price: > R10 000 for the dipmeter method

< R100 for the homemade water level method

Field sheet: [Click here](#)

6.2.2.2 Equipment required

Dipmeter:

- GPS device
- Size 10 Allen Key
- Handheld tape measure (e.g. 3m)
- Metal Filer (advantageous)
- Dipmeter, i.e. Water Level Meter. ([Click here](#) for website level measurement devices can be purchased).
- Spare 9v battery
- Borehole Water Level: Dipmeter Method Field Sheet - Appendix A.1.7
-

Homemade water level meter

- Rope or string such as fishing line
- Floating device (e.g. 1 L plastic bottle)
- Sinking device (e.g. a sinker)
- Tape or marker
- Tape measure
- GPS device
- Borehole Water Level: Dipmeter Method Field Sheet - Appendix A.1.7

6.2.2.3 Method

Dipmeter method

Based on methods set up by Petersen and Strydom (n.d.).

Step 1

Use the Borehole water level field sheet (Appendix A.1.7) to record the following information:

- The borehole name and site description
- The GPS coordinates and altitude of the borehole.
- Whether the borehole is “Active” or “Inactive”, indicating whether the borehole is currently in use and pumped for water supply.
- What the water is used for (e.g. water for game, drinking water).
- Whether the borehole is powered by an electrical pump, solar or diesel pump.

Step 2

Measure the height of the borehole casing (m) above the ground to measure the true depth of the water level below ground level (as shown in figure 20.1).

Step 3

Switch on the dipmeter (Figure 20.2) using the sensitivity dial and lower it slowly into the borehole until it begins to beep, which will indicate it has reached the water. Remove it, dry off excess water and lower it again until you get an accurate reading of the water table depth. Figure 20.3 depicts the water table depth measurement being taken using a dipmeter. Record this water table depth (m) on the field sheet. It is important to take the measurement at the same point on the borehole casing consistently, this is shown in Figure 20.4. A metal file or such equipment can be used to file a notch into the casing to mark the point at which the measurement is recorded.

Step 4

Drop the dipmeter probe and let it freefall to the bottom of the borehole. When it loses tension and you are sure you have reached the bottom, record the borehole depth (m) on the Borehole water level field sheet in Appendix A.1.7. If the borehole exceeds the length of your dipmeter, record it as being greater than the length of the dipmeter (e.g. >100m).

Step 5

Clean the probe with water and dry it if it is dirty before storage once measurements are taken.

Step 6

Subtract the casing height (m) from the borehole depth (m) and water table (m) measurements to ensure that the true depths below ground level are indicated.

Step 7

Subtract the water table depth (m) from the borehole depth (m) to find the water level (m) present within the borehole.

Step 8

Take a photo of the site with the borehole in the frame and part of the surrounding landscape and record the photo number. Record any additional notes or information using the Borehole water level field sheet in Appendix A.1.7.



Figure 20: Summary of the Borehole Water Level Dipmeter method: (1) measuring the height of the borehole above ground, (2) a water level dipmeter, (3) taking the water level measurement in the borehole, and (4) ensuring that the dipmeter is measured at the same point consistently. (Images: Solinst, 2013.; Petersen and Strydom, n.d.).

Homemade water level meter method

Based on methods set up in the video created by Brumby Pumps (2019):

<https://youtu.be/WXOWgXAOsA8?si=A2JIN0-say3eKkl>

Step 1

Use the Borehole water level field sheet (Appendix A.1.7) to record the following information:

- The borehole name, and site description
- The GPS coordinates and altitude of the borehole
- Whether the borehole is “Active” or “Inactive”, indicating whether the borehole is currently in use and pumped for water supply
- What the water is used for (e.g. water for game, drinking water)
- Whether the borehole is powered by an electrical pump, solar or diesel pump

Step 2

Cut a length of strong string such as a fishing line, at least 2 m longer than the known depth of the borehole. If the depth is unknown, it may be useful to have a length of between 80 to 120 m.

Step 3

Measure the diameter and height above ground of your borehole. Use this diameter as an indication of the dimensions needed to ensure that the water level meter you build is able to travel down the borehole easily, without getting stuck.

Step 4

Tie or attach a floating device (such as an empty bottle) onto this string, as shown in Figure 21.1. Ensure that this is very well secured, and check that this object is narrow enough to fit down the borehole.

Step 5

Slowly lower this string and float down the borehole, as shown in Figure 21.3. When the float hits the water, and the string is no longer being pulled down by gravity, you will have reached the water table. Make a marking point where on the length of rope the water table was reached. Also mark where on the borehole the measure was taken from, and ensure further measures are taken from the same point to ensure consistency.

Step 6

Remove the string with the float and measure the length of rope marked off using the tape measure - this will give you the water table depth (m).

Step 7

Attach a sinking device (such as a sinker) to the string securely, such as shown in Figure 21.2. Slowly lower the string into the borehole, as shown in Figure 21.3 - from the same marked off point as before. Let the string freefall to the bottom to measure the depth of the borehole (m). Record this point on the string with the marker/ tape and once again measure this length using the tape measure.

Step 8

Subtract the casing height (m) from the borehole depth (m) and water table (m) measurements to ensure that the true depths below ground level are indicated.

Step 9

Subtract the water table depth (m) from the borehole depth (m) to find the water level (m) present within the borehole.

Step 10

Take a photo of the site with the borehole in the frame and part of the surrounding landscape and record the photo number. Record any additional notes or information using the Borehole water level field sheet in Appendix A.1.7.

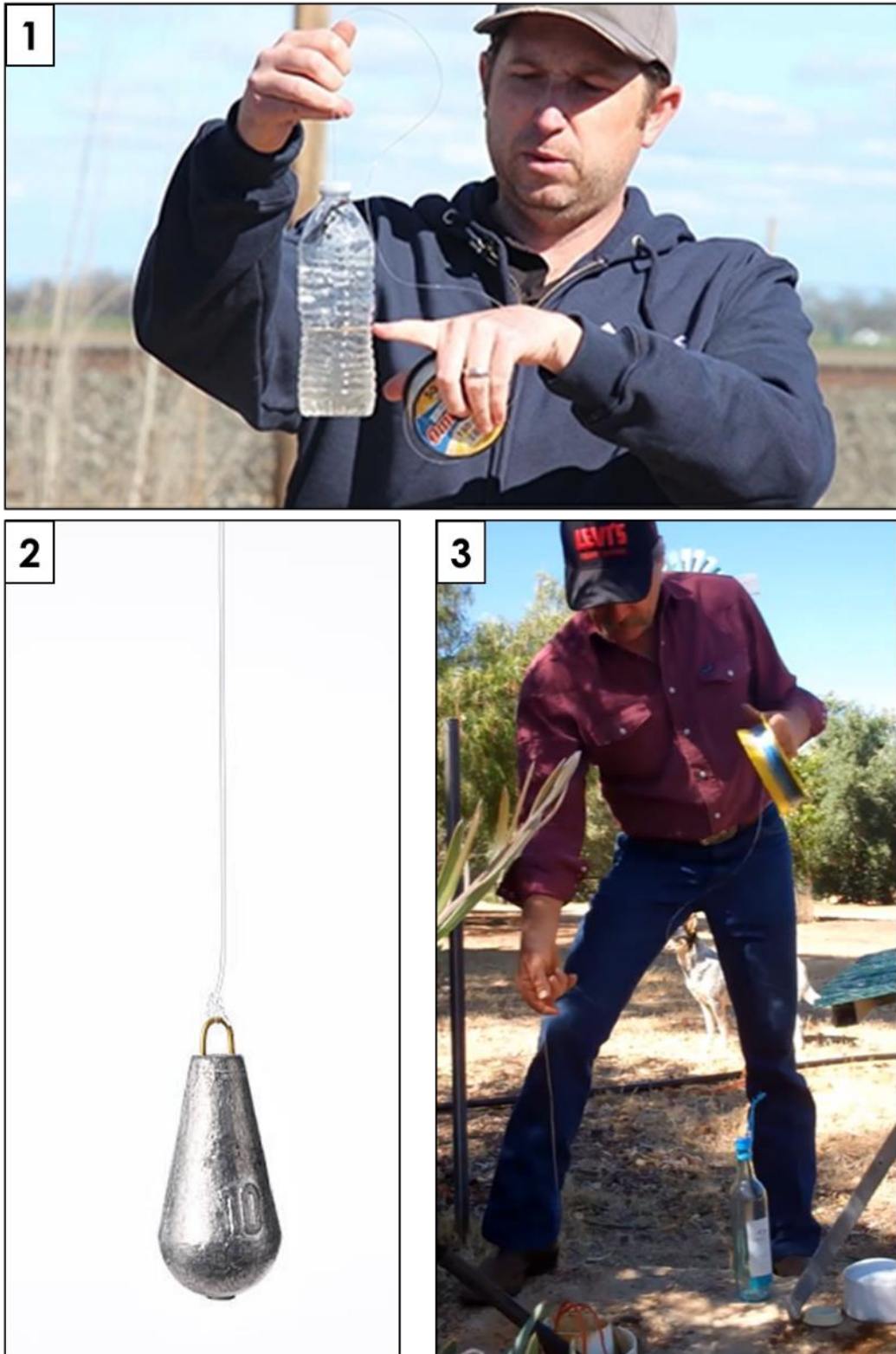


Figure 21: Summary of the homemade water level meter method: (1) attaching a plastic bottle to measure the water level, (2) attaching a sinker to measure the borehole depth, (3) slowly lowering the string into the borehole with the float and sink devices.

Any other existing methods in place:

If any other water level measuring methods are already established at a borehole, this equipment may also be used to make the measurements, and the results of these methods may also be recorded.

6.2.2.3 Advantages and limitations

In Table 11 the advantages and limitations of using the dipmeter method as well as the homemade water level meter method to measure borehole water levels are provided.

Table 11: Advantages and limitations of the (1) dipmeter and (2) homemade water level meter methods.

ADVANTAGES	LIMITATIONS
Dipmeter method	
Accurate	Very expensive if not already available
Well tested method	Effects of clearing AIPs may be minimal compared to other impacts at this scale.
Gives an indication of groundwater which AIPs impact heavily	Many confounding factors such as the effects of rainfall may obscure changes from clearing AIPs.
May already be in place and being measured	
Homemade water level meter method	
Cost effective	May be less accurate than the dipmeter method
Gives an indication of groundwater which AIPs impact heavily	Effects of clearing AIPs may be minimal compared to other impacts at this scale.
May already be in place and being measured	

7. Water Quality: Methods

Three methods are provided in this guideline to measure water quality. The miniSASS method can be used to determine river health, the water clarity tube method and the water clarity colour chart to measure water turbidity, and diatom sampling to track environmental changes in a water system.

River health indicates water quality by identifying the organisms that are able to survive in a system. The more sensitive an organism, the healthier the river and the better the water quality. Suspended solids in turbid water affect water chemistry and microbiology, which are of importance in terms of water quality. Diatoms are sensitive and respond to changes in physical and chemical parameters in a water system, providing an indication of environmental changes.

Resources for the methods for measuring water quality can be found [here](#).

7.1. miniSASS

miniSASS is a biomonitoring tool used to monitor the health of a water system by collecting and scoring aquatic invertebrates (Graham, 2012; Graham and Taylor, 2018). miniSASS is used to determine the health of a river or stream by assessing its biota. This provides insight into the ecological conditions of the river and surrounding habitat, and therefore may inform the user on the water quality and ecological state of its surrounding habitat.

The miniSASS method was developed as a simplified version of the previous, more technical SASS method (Taylor et al., 2022). Compared to the SASS method, the miniSASS is easier to use as it minimises the number of invertebrate families the user has to identify, yet it still provides scientifically robust results similar to the more comprehensive SASS methods (Graham et al., 2004).

To measure river health with the miniSASS, the researcher walks through the stream with a net and disturbs the stones, vegetation or sand in the area. The net is then emptied out onto a plastic tray. An identification guide is used to help identify the organisms collected. Each invertebrate group is given a sensitivity score, and the average score for the stream calculated. Based on the average score the stream can be classified as unmodified (natural condition), largely natural/few modifications (good condition), moderately modified (fair condition), largely modified (poor condition), or seriously/critically modified (very poor condition) (Graham, 2012).

The invertebrates for the miniSASS are collected while wading across a stream or river. The samples should be collected from systems with flowing water and not from stagnant water such as ponds and dams (miniSASS.org, n.d.). Sites are classified as rocky types or sandy types, and this distinction is shown in Figure 22.1. The best sites for collecting organisms are rocky types, which are areas with rocks and flowing water. The method can, however, still be applied to sandy areas (Graham and Taylor, 2018). Figure 22.2 shows a river which is flowing and rocky and would therefore provide good conditions for implementing this miniSASS method.

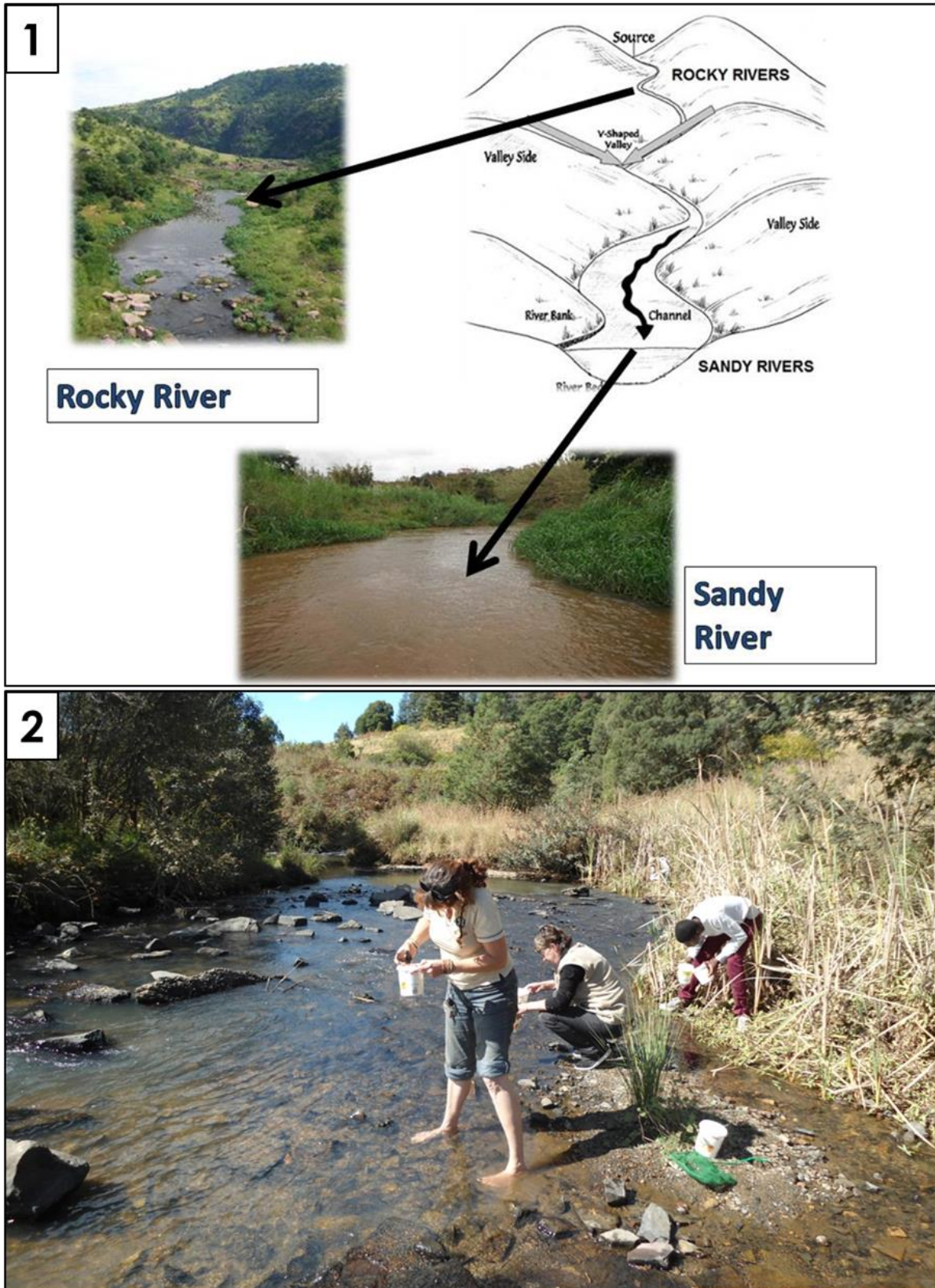


Figure 22: (1) miniSASS can be applied to rocky areas (preferable) or sandy areas (miniSASS.org, n.d.). (2) implementing miniSASS in a flowing, rocky river which provides an example of a good study site (Image: MCF, 2014).

7.1.1 Details of the method

Frequency: miniSASS monitoring should be done Bi-annually, however this may be done additionally whenever a situation arises which may cause important changes to the organisms present (such as after a flood).

Skill requirement: Intermediate training is required to implement this miniSASS method. This will involve training in how to sample the river for species, as well as how to identify species and score them based on their sensitivity.

Price: R 2070

Field sheet: [Click here](#)

7.1.2 Equipment required

- Dichotomous key, identification guide, site identification and scoring sheet - Appendix A.2
- Net
- Tray
- Magnifying glass
- Tweezers and pipette
- Sample bottles
- Biomonitoring - miniSASS Method Field Sheet - Appendix A.1.8

[Click here](#) for website where all required miniSASS equipment can be purchased.

7.1.3 Method

Step 1

Choose your monitoring site for implementing miniSASS - ensure that this site has flowing water. Preferably rocky sites should be selected, however sandy areas may also be selected.

Step 2

Hold the net in the water and disturb the rocks, vegetation, or sand with your feet to stir any organisms. While doing this walk across the whole stream for 5 minutes to collect the organisms. Invertebrates can also be picked off rocks (Graham and Taylor, 2018; miniSASS.org, n.d.).

Step 3

Rinse the net and deposit the collected contents to the tray so that organisms collected are visible (Graham and Taylor, 2018; miniSASS.org, n.d.).

Step 4

Identify the invertebrate group using the dichotomous key and identification guide provided in Appendix A.2 (miniSASS.org, n.d.).

Step 5

Mark the organisms that you have collected and identified off on the identification guide provided in Appendix A.2 (Graham & Taylor, 2018; miniSASS.org, n.d.).

Step 6

Check off the organisms which you identified, and fill in the site information on the field sheet (Appendix A.1.8) (miniSASS.org, n.d.).

Step 7

Add up the sensitivity scores of the identified organisms and calculate the average score on the field sheet (Appendix A.1.8) using the formula:

Total Score ÷ Number of groups identified

Step 8

Use the average score and the river category (rocky/ sandy) to find the associated ecological condition and ecological category of the stream. The interpretation guide for these scores in each river category and their corresponding ecological conditions and categories is provided in Appendix A.1.8.



5	ECOLOGICAL CONDITION	ECOLOGICAL CATEGORY	RIVER CATEGORY	
			Sandy Type	Rocky Type
	NATURAL CONDITION	Unchanged/untouched	> 6.9	> 7.2
	GOOD CONDITION	Few modifications	5.9 to 6.8	6.2 to 7.2
	FAIR CONDITION	Some modifications	5.4 to 5.8	5.7 to 6.1
	POOR CONDITION	Lots of modifications	4.8 to 5.3	5.3 to 5.6
	VERY POOR CONDITION	Critically modified	< 4.8	< 5.3

Figure 23: Summary of miniSASS: (1) Disturbing the water and collecting organisms, (2) Emptying collected invertebrates onto trays, (3) Identifying organisms collected, (4) Marking off collected organisms and calculating sensitivity, (5) Determining the Ecological Condition and Category based on sensitivity score and river category (Photos: GroundTruth, n.d.; MCF, 2017; MCG, 2015; miniSASS.org, n.d.).

7.1.4 Advantages and limitations

In Table 12 the advantages and limitations of the miniSASS method is summarised.

Table 12: Advantages and limitations of the miniSASS biomonitoring method.

ADVANTAGES	LIMITATIONS
Easy to use	Requires training
Scientifically robust	Cost of equipment
Determines short and long – term changes	Time consuming
Similar accuracy to SASS method, but simpler	Exclusion of taxa not accounted for on the scoring sheets
Gives an indication of water quality and provides information on ecological baseline	

7.2 Water Clarity Tube

The presence and removal of AIPs will have an effect on soil and erosion, as well as on the production of plant biomass which influence the turbidity of water. Water clarity is an indication of the total suspended solids in water. Suspended solids are material in water systems such as soil, planktonic organisms and organic matter. Too much suspended solids in water can have an impact on biomass production, aquatic biota, and habitats. The water clarity tube measures water clarity, which is a measurement of visual transparency of water (Graham and Taylor, 2018).

Water can be collected from any water system such as a stream, river, or dam, as shown in Figure 24. The samples should be collected from the centre of the system.



Figure 24: Water being collected in a clarity tube within a stream.

The water clarity tube, shown in Figure 25, is a 1m long, 50mm in diameter acrylic tube. The tube has a clear end through which the black target can be viewed. The target is moved by sliding the magnets up and down the tube. The tube is sealed at the bottom with a black seal.



Figure 25: The (1) water clarity tube with its different components: (2) base through which the target is viewed; (3) the magnets which are shifted to move the target; (4) and the stopper sealing the bottom of the tube (Images: Nzaae, n.d.; Ground Truth, n.d.).

The clarity tube is used to measure the turbidity of water by measuring the disappearance and reappearance depth of the viewing target. After the tube has been filled with water, the user's eye is placed close to the transparent base. The target is then slowly moved away until it is no longer visible. This distance recorded is the disappearance depth. The target is then moved towards the user until it is visible again. This is the reappearance depth. Water clarity is calculated as the average of the disappearance and reappearance depths.

7.2.1 Details of the method

Frequency: Monthly, or more frequently when there is an opportunity to take measurements.

Skill requirement: No training is required for using the clarity tube. These guidelines and the resource library should supply sufficient support for the user to understand and use the method.

Price: R1560

Field sheet: [Click here](#)

7.2.2 Equipment required

- Water clarity tube ([Click here](#) for website where water clarity tube can be purchased)
- Turbidity - Water Clarity Tube Method Field Sheet - Appendix A.1.9

7.2.3 Method

Step 1

Collect water from the centre of the stream with a bucket. Fill the clarity tube with the water. The water clarity tube can also be directly filled with water (as seen in Figure 26.1). Turn the water clarity up and down a few times to mix the water and hold the tube horizontally. The water clarity tube should be held perpendicular to sunlight (Killroy and Biggs, 2002; Graham and Taylor, 2018).

Step 2

Hold your eye close to the viewing window (as seen in Figure 26.2) and move the target away until it disappears using the magnets on the outside of the tube. The disappearance distance is recorded (Killroy and Biggs, 2002; Graham and Taylor, 2018).

Step 3

The viewer's eye is held close to the viewing window again and the target is moved closer using the magnets until it reappears. The reappearance distance is recorded (Killroy and Biggs, 2002; Graham and Taylor, 2018).

Step 4

Calculate visibility as the average distance of disappearance and reappearance, as seen in Formula (1) (Box 4).

These four steps should be repeated three times with the same sample. Before each reading the clarity tube should be shaken in order for the suspended solids in the water to be mixed (Kilroy and Biggs, 2002; Graham and Taylor, 2018). All sampling should be done by the same person to ensure consistency in readings.



Figure 26: (1) Collecting water in the water clarity tube; and (2) determining the disappearance and reappearance depths.

In Box 5 the formula needed for the water clarity tube is given.

$$\text{Water Clarity (cm)} = \frac{DD + RD}{2}$$

Where,

DD: Disappearance distance (cm)

RD: Reappearance distance (cm)

Box 5: The formula used in Step 4 of the clarity tube method.

7.2.4 Advantages and limitations

In Table 13 the advantages and limitations of the clarity tube method is presented.

Table 13: Advantages and limitations of the clarity tube method.

ADVANTAGES	LIMITATIONS
Easy to use	The method relies on subjective readings
An affordable water quality measuring method	Can break easily and need replacing
It is useful in shallow streams	

7.3 Water Clarity Colour Chart

The presence and removal of AIPs will have an effect on soil and in some cases may lead to erosion, Plant biomass may also be affected during the removal of AIP which may influence the turbidity of water. Water clarity is an indication of the total suspended solids in water. Suspended solids are material in water systems such as soil, planktonic organisms and organic matter. Too much suspended solids in water can have an impact on biomass production, aquatic biota, and habitats (Graham and Taylor, 2018).

Water can be collected from any water system such as a stream, river, or dam, as shown in Figure 27. The samples should be collected in sample bottles from the centre of the system.



Figure 27: Water for the water colour chart method can be collected from any water system (Image: UZH, 2016).

Compared to the water clarity tube, this method provides a cheaper, yet less accurate and sensitive, way of monitoring water clarity. To do so, firstly, water is collected from the centre of the water system. The water can be collected with any transparent bottles, as long as all the bottles are similar. Three samples should be collected from each system. Once collection has been done, the colour of the samples is compared to the colour chart in the field sheet (Figure 27 and Appendix A.1.10). The colour on the chart that most closely resembles each sample is recorded.

7.2.1 Details of the method

Frequency: Monthly, or more frequently when there is an opportunity to take measurements.

Skill requirement: No training is required for this method. These guidelines should supply sufficient support for the user to understand and use the method.

Price: <R100.

Field sheet: [Click here](#)

7.2.2 Equipment required

- Sample bottles (any transparent bottles)
- Turbidity - Water Clarity Colour Chart Field Sheet - Appendix A.1.10 (with colour chart included).
- Cell phone with camera

7.2.3 Method

Step 1

Collect water from the middle of the stream with the sample bottles. Any transparent bottles can be used as sample bottles. As soon as the samples have been collected, write the name of the site on the sample bottle. Collect three samples at different locations in the stream.

Step 2

Once the samples have been collected, shake the sample bottle and then compare the colour of the samples to the colour chart (see Figure 28 and Appendix A.1.10). Record the number of the colour on the colour chart that most closely resembles the colour of the collected sample. Do this for each sample at each site. Also take a photo of each of the collected samples for future reference.

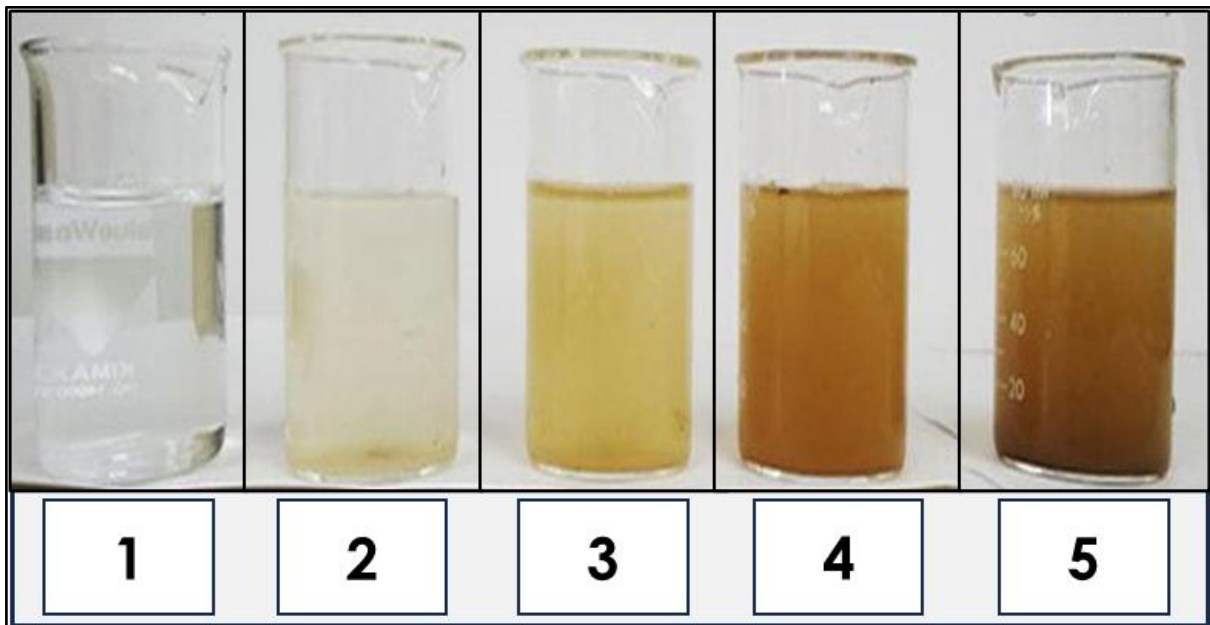


Figure 28: Five classifications for water clarity, from clear (1) to murky (5).

7.2.4 Advantages and limitations

In Table 14 the advantages and limitations of the water clarity colour chart method is presented.

Table 14: Advantages and limitations of the water clarity colour chart method.

ADVANTAGES	LIMITATIONS
Easy to use	The method relies on subjective readings
A method for measuring water clarity that is less expensive than the water clarity tube method	Less accurate measure of water clarity than clarity tube
Useful in any stream depth	Less sensitive for detecting a change in water clarity
Requires minimal resources	

7.4 Diatom sampling

Diatom sampling is a biomonitoring tool, which uses single-celled organisms to give an indication of water quality. Diatoms are small algae that contribute significantly to the productivity of ecosystems, forming the base of aquatic food chains (De la Rey, 2004). They are found in marine and freshwater habitats, as well as in moist terrestrial habitats (Serôdio and Lavaud, 2022).

Diatoms have been found to be useful ecological indicators and may be valuable to assess river health over time (Shikwambana et al., 2021). Diatoms are sensitive to change in nutrient concentrations and have a short lifespan and fast reproduction – they are therefore able to respond rapidly to changes in water quality (De la Rey, 2004; Shikwambana et al., 2021). There are many different diatom species, and they therefore are able to provide multiple, sensitive indicators of altered ecological conditions (EPA, 2023). Using diatoms as the biomonitoring organism is further useful, as diatoms can be studied year-round, as they are less dependent on seasons, flow, and habitat than other larger organisms (De la Rey, 2004; Shikwambana et al., 2021).

Diatom communities may be found on substrata by touch (they have a slimy feel), or they may be seen as a thin golden-brown film over the substrata they are attached to (Taylor et al., 2007). These diatoms should be collected from the substrata they are attached to. Rocks are an ideal substratum to collect from, as they are widely available throughout rivers year-round, and the ecology of diatoms growing on rocks is well understood. However, diatoms can also be collected from artificial structures, such as pieces of concrete or bridge supports, as well as emergent and submerged plants if necessary (see Figure 29 for examples of diatoms attached to substrata).

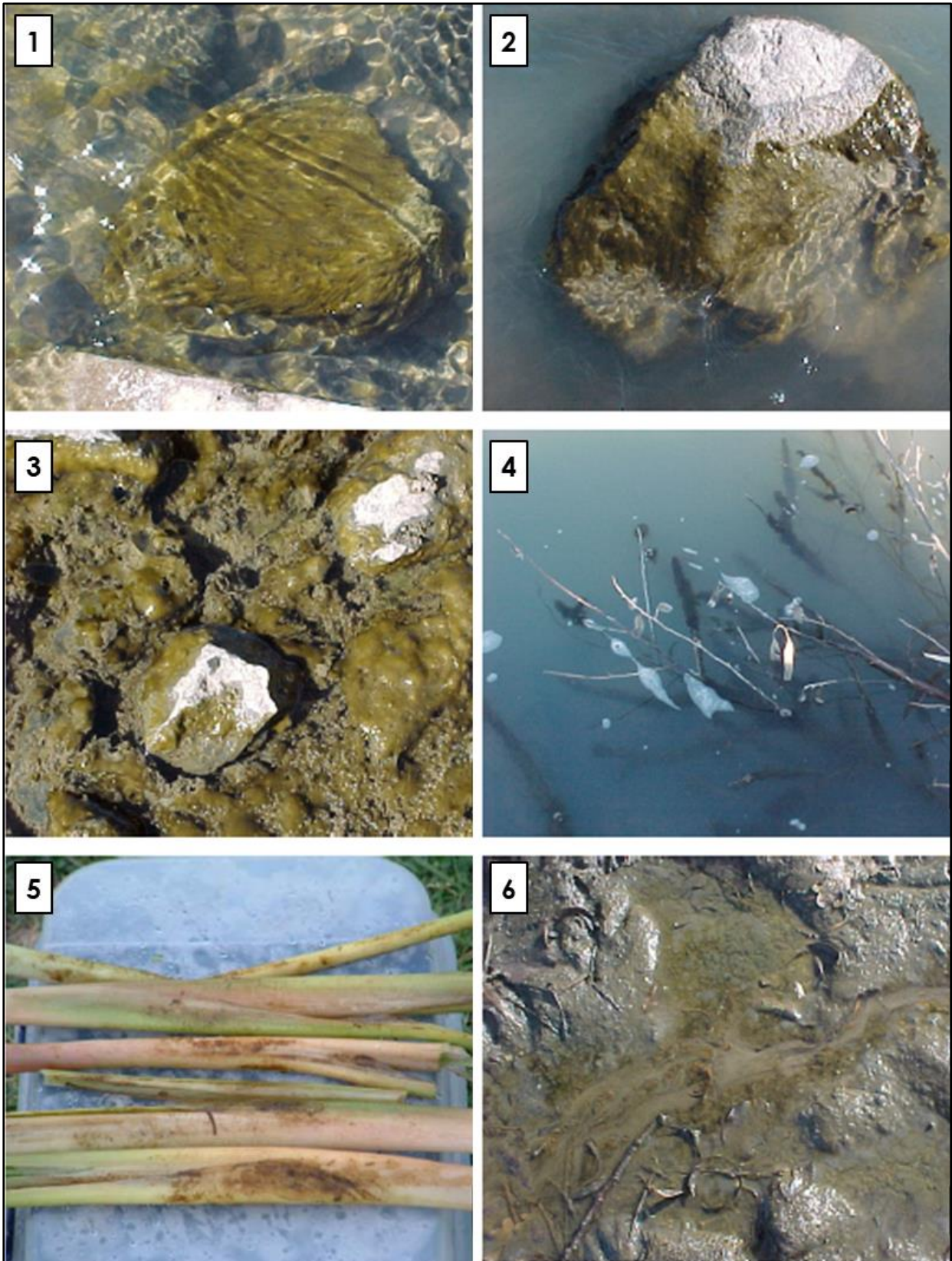


Figure 29: Examples of substrata from which diatoms can be collected: (1) and (2) Diatoms on rocks; (3) diatoms on sediment and pebbles; (4) diatoms on submerged tree branches; (5) diatoms on collected branches; (6) diatoms in sediment.

In order to collect diatom samples, the user firstly collects five to ten rocks (or other substrata). These are rinsed in the river and placed in a tray with river water. The diatoms are then brushed or scraped from the substrata and are collected in sample bottles. These samples are then either immediately placed in a refrigerator, if stored for less than 24 hours, or first preserved with Lugol's iodine or ethanol if storage is required for longer than 24 hours.

7.3.1 Details of the method

Frequency: Diatoms should be monitored on a monthly basis

Skill requirement: Basic training will be required on how to collect diatom sampling. Intermediate level training will be required on the preservation of samples.

Price: The cost of analysis is R1040 per sample.

Field sheet: [Click here](#)

7.3.2 Equipment required

- Tray
- Knife or toothbrush
- Sampling bottles
- Preserving solutions
- Biomonitoring - Diatom Sampling Method Field Sheets - Appendix A.1.11

7.3.3 Method

Part A: Sampling

The first part of this method is collecting substrata and sampling of diatoms within the stream.

Step 1

Collect five to ten rocks of the same size from a 10m reach in the stream. Rocks should not be collected within 1m from the riverbank as it might be within isolated waters or eddies and not be representative of the site. Rocks are the preferred substratum for sampling, but diatoms can also be collected from aquatic plants, as well as artificial structures such as concrete or bridge supports (Taylor et al., 2007; Shikwambana et al., 2021).

Step 2

Rinse the rocks in the stream and place them in a sampling tray with 50ml of water collected from the stream (Taylor et al., 2007).

Step 3

Use a toothbrush, knife or spoon to remove the diatoms from the rocks by scrubbing or scraping the side that faces up. Clean the scraping tool before and after collecting the diatom samples to avoid contaminating samples (Taylor et al., 2007).

Step 4

Place the collected diatom samples into a sample bottle. Label each sample bottle uniquely, using the site name (Taylor et al., 2007).

Part B: Storage

The second part of this method is the storage of the diatoms. Different measures are required based on the period for which the diatoms need to be stored. This storage time will depend on when the user can deliver the samples to an organisation that can analyse the diatoms (Taylor et al., 2007).

Short term storage: Less than 24 hours

If the diatom samples don't have to be stored for longer than 24 hours, simply store them in a refrigerator. Place the sample bottles with the diatoms in the refrigerator until the samples can be delivered for analysis (Taylor et al., 2007).

Long term storage: More than 24 hours

Storage for longer than 24 hours requires preservation measures.

Use Lugol's iodine as a preservation agent for short term preservation. To prepare Lugol's iodine, dissolve 2 g potassium iodide in 1 g iodine crystals in 300ml distilled water. Add the iodine for a final concentration of 1 % per volume (Taylor et al., 2007).

Use Ethanol for long term storage preservation and add this for a final concentration of 20 % by volume (Taylor et al., 2007).

After a solution has been added, store the sample bottles in a refrigerator until it is time to deliver it to a laboratory.

Part C: Analysis of samples

The samples have to be analysed in a laboratory. The samples will therefore have to be couriered to a facility that can do the analysis of diatom samples in order to monitor water quality. North West University has a laboratory where these samples can be analysed. The information provided will include an index score of the diatom samples, a community composition table, and a short report on the results of each site. The cost is R1040 per sample, plus the delivery cost.



Figure 30: Summary of using the diatom method: (1) Collect substratum; (2) rinse rocks and place in tray; (3) collect diatoms from substratum; (4) deposit diatoms to sample bottle; and (5) preserve and store samples (Images: Kelly, 2015; National Geographic, n.d.; Franchini, 2013; Kelly and Yallop, n.d.; Kelly, 2022).

7.3.4 Advantages and limitations

In Table 15 the advantages and limitations of the diatom sampling method are presented.

Table 15: Advantages and limitations of diatom sampling.

ADVANTAGES	LIMITATIONS
Accurate.	Preservation measures might be a challenge.
The results present both the present and past water quality in a water system.	Analysis of samples is expensive compared to other water quality methods.
Easy to collect samples.	
Collections can be made throughout the year regardless of season.	

8. Ecological Baseline Assessment: Methods

An Ecological Baseline Assessment must be done prior to removing the AIPs to establish the health, ecological conditions, and characteristics of the area in a state of invasion. This baseline summary will allow changes to the river and surrounding environment to be detected over time, once the AIPs are removed. We propose the use of three methods for conducting an ecological baseline: biomonitoring, fixed point photography, and a riparian zone audit. Biomonitoring is used to investigate river or stream health by identifying the biota present. Fixed point photography is a tool for observational monitoring of changes in river flow conditions, bank destabilization and erosion, vegetation invasions, and habitat changes. The Riparian zone audit is used to determine the Ecological Condition (EC), which describes the state of the system and is an indication of river health.

Resources for methods of conducting an ecological baseline assessment can be found [here](#).

8.1 miniSASS

Biomonitoring tools, such as the miniSASS, are used to determine the health of a river or stream by assessing its biota. This provides insight into the ecological conditions of the river and surrounding habitat.

Refer to Section 7.1 for the description of the miniSASS method and steps outlining its implementation.

8.2 Riparian Health Audit

The Riparian Health Audit (RHA) can be used to determine the health of riparian ecosystems. The RHA consists of identifying the riparian zone, identifying the effect that certain impacts have within the riparian zone, and how these impacts determine the condition and functionality of the riparian zone (Desai, 2016). The RHA should be conducted within the riparian zone of a sub-catchment, as demonstrated in Figure 31.

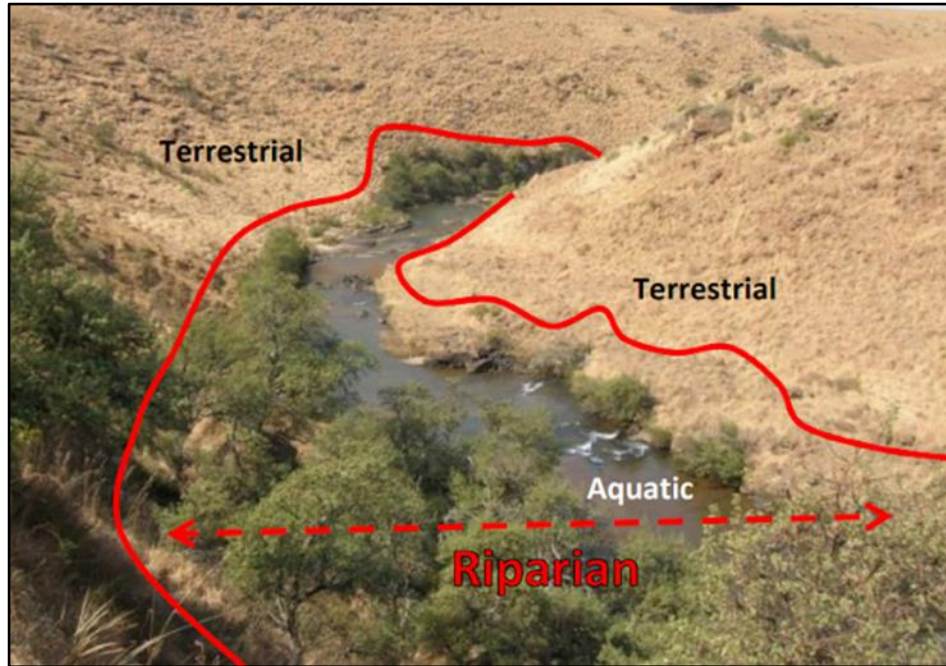


Figure 31: Representation of the riparian zone in which the RHA should take place (Desai, 2016).

Desai (2016) used literature reviews and research to identify eight impacts which were found to be the major negative influencers to the functioning and integrity of riparian ecosystems. These impacts include: (1) Exotic plants, (2) Rubbish dumping, (3) Bank Erosion, (4) Inundation, (5) Flow Modification, (6) Channel Modification, (7) Evidence of Decreased Water Quality, and (8) Exotic Vegetation Removal. Figure 32 summarises these eight impacts used studied when conducting the RHA.



Figure 32: The eight impacts assessed with the RHA (Image: ACS, 2023; LWDD, 2019; iStock.com/Alexmia, 2017).

Exotic plants are all those species not indigenous to the specific location including alien plants, invasive alien plants, commercial crops, gardens and hedgerows. Rubbish dumping includes the presence of waste due to dumping directly to the area, as well as transportation of waste from upstream sources. Bank erosion is the erosion of a bank of a stream due to runoff. For the purpose of the RHA the researcher should distinguish between natural and accelerated bank erosion. This accelerated or anthropogenic erosion may be driven by factors such as the destabilization of riverbanks due to digging/bulldozer activities, vegetation removal, exotic plant infestation, cattle access paths, or wastewater or stormwater causing an increase in water flow. Inundation is flooding in the riparian zone due to artificial obstructions, such as dams, slowing down water flow. Flow modification is the change of the natural flow of a stream due to structures such as pipes or water works increasing or decreasing the amount of water. Channel modification is caused by artificial structures such as causeways, road-alignments, culverts, gabions and canals and is defined as any change in the natural shape of the banks in the riparian zone. Changes in the water quality of a stream will lead to changes in the physical-chemical properties of the stream. Indicators of a decrease in water quality can include the presence of livestock, domestic use of the stream, presence of sewage or fertilizer, biological foam, or chemical agents such as factory dye. Vegetation removal is the decrease in indigenous vegetation due to activities such as livestock trampling, excessive harvesting, artificial structures, agriculture, and mining (Desai, 2016).

Desai (2016) designed the RHA to enable users to identify, rate and report on the impacts to local rivers and streams on a basic level. The RHA gives a score based on the extent to which the riparian zone being assessed has been degraded compared to that of natural conditions. Changes recorded are therefore the result of human influences and negative impacts. For these guidelines, this method has the specific aim of determining the impacts of AIPs. A greater focus is therefore placed on the role of these AIPs within rivers, streams, and riparian zones being assessed. AIPs are largely the result of human activities, and therefore any degradation they cause in the riparian zone will be compared to that of natural conditions. Examples of the manner in which AIPs may specifically influence these factors is shown in Table 16. A description of habitat and indigenous species was also added to the field sheet created by Desai (2016), as shown in Appendix A.1.12.

Table 16: Examples of how AIPs affect the impacts described in the RHA.

IMPACT IN RHA	EXAMPLE OF EFFECTS OF AIPS
1. Exotic Vegetation	This includes AIPs, as they are non-indigenous plants
2. Rubbish Dumping	N/A
3. Bank Erosion	AIPs are prone to falling over into rivers and destabilizing the banks - which does not generally happen with indigenous vegetation. This can create localised bank erosion.
4. Inundation	N/A
5. Flow Modification	AIPs such as <i>A. mearnsii</i> use up much greater quantities of water than indigenous vegetation and where present in the riparian area and upstream catchment, contribute to increased rates of transpiration and evaporation. This reduced water availability alters the flow regime and can contribute to flow ceasing - especially in dry seasons.
6. Channel Modification	Falling AIPs may destabilize the riverbanks, which can cause a change to the structure of channels.
7. Evidence of Decreased Water Quality	AIPs may reduce water availability, which decreases the dilution capacity of the water, affecting the quality. AIPs may also release chemicals or increased plant litter into the system which are not present naturally.
8. Indigenous vegetation Removal	Removal of indigenous vegetation occurs as a result of direct removal (e.g. as would occur before an area is planted to crops) as well as displacement when outcompeted by AIPs.

8.2.1 Details of the method

Frequency: The RHA may be implemented annually, and additionally after any noticed major changes within the riparian zone if the opportunity arises.

Skill requirement: Intermediate training is required to ensure that users are able to identify appropriate riparian zones for implementing this method. Training may also be useful to demonstrate how each impact can be identified and scored, and the ecological condition interpreted. Training on how to identify AIPs will be useful.

Price: No Cost

Field sheet: [Click here](#)

8.2.2 Equipment required

Ecological Health - Riparian Health Audit Method Field Sheets - Appendix A.1.102 RHA score guidance illustrations (Appendix A.3)

8.2.3 Method

Step 1

Before the RHA can be conducted, there are preliminary steps which must be taken:

- Divide the riparian zone into reaches, or sections, which can be monitored. This will be based on the proposed scale of implementation, the land use, property boundaries, or changes in the pattern of the channel and structure of the river.
- Envision the riparian zone as it would occur under natural conditions. This is what the RHA assessment and scoring of changes from the effects of the previously highlighted eight impacts will be based against.
- Create field work maps to guide directions within the field.

Step 2

Identify the extent of the riparian zone. It might be wide or narrow depending on the gradient and size of the valley bottom (Figure 33.1). Observe where transitions between vegetation types occur as the indication of the boundary of the riparian zone.

Step 3

Rate the eight impacts on a scale from 0 to 5 based on the change that has occurred in the study area, compared to the natural condition. This rating is based on the intensity and extensiveness of the impact.

Figure 33.2 provides an example of the photographic and illustrative guideline to help rate each factor, the full illustrative guide by Desai (2016) can be found within Appendix A3.

Figure 33.3 provides a guideline to enable the rating of impacts.

Use the RHA field sheet in Appendix A.1.12 to record details of each sampling area and the rating of each impact.

Step 4

Finally, calculate the ecological condition of the site based on the ratings of each impact. Add the ratings for each impact together for a score calculated out of a total of 40. Calculate the Percentage Change by using: $\text{Score}/40 \times 100$. This score indicates the percentage of change that has occurred to the riparian system compared to the natural conditions. This value is used to find the corresponding ecological condition of the riparian zone, as shown in Figure 33.4.

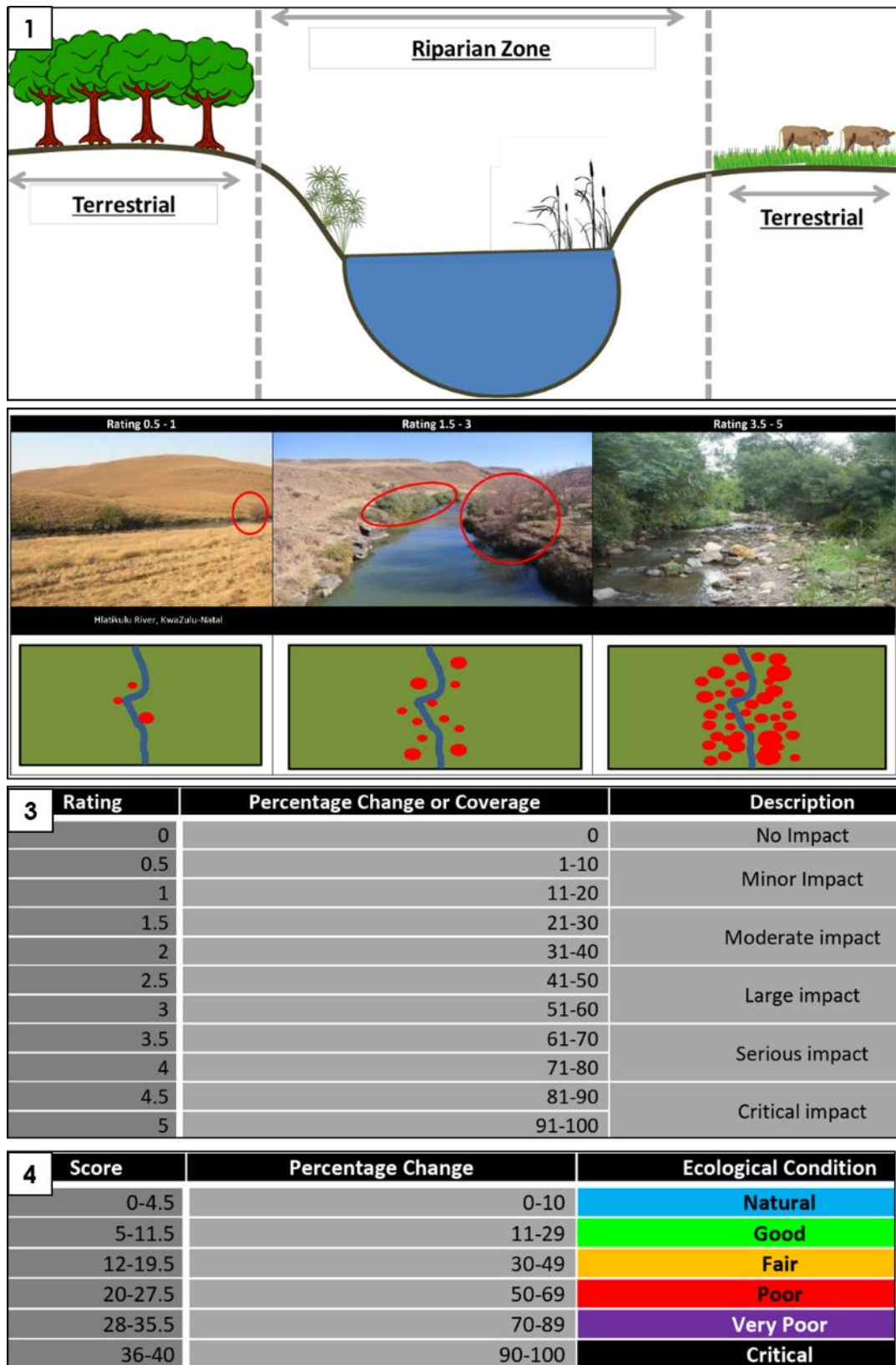


Figure 33: Summary of the RHA Method: (1) Riparian and Terrestrial zones. (2) Illustrative guideline to aid rating of impacts. (3) Description of impacts and corresponding percentage change and ratings. (4) Explanation of Ecological Conditions based on percentage change of the riparian zone. (Image: Desai, 2016).

8.2.4 Advantages and limitations

The advantages and limitations associated with using the RHA method are outlined in Table 17 to give users an indication of whether this will be an appropriate method for them to use.

Table 17: Advantages and limitations of the Riparian Health Audit method.

ADVANTAGES	LIMITATIONS
Easy to use	Requires training
Practical	Time consuming at the start
Indicates Ecological Health changes in the riparian zone	Subjective
Determines short and long – term changes	Does not specifically include an assessment of the buffer zone required to protect the riparian zone
Cost effective (no equipment required)	Not developed to detect changes based on AIP removal
The audit can be carried out by citizen scientists and qualified persons	

8.3 Fixed Point Photography

Fixed-point photography (FPP) involves taking a photograph of the exact same point, at recurring intervals for a period of time so that they can be compared and changes to that landscape can be identified and assessed (South Downs National Park, 2018). Repeat photography provides a more in-depth view into the history of an area and illustrates environmental changes which have taken place (Kull, 2005). Fixed-point photography has the potential to allow users to monitor changes in river flow conditions, bank destabilisation and erosion, vegetation invasions, and habitat changes. This method helps document evidence of destabilisation within the riparian zone resulting from the presence and removal of AIPs. AIPs such as black wattle have an impact on sedimentation and soil erosion within river systems which are important components to analyse when considering how their removal will affect water quality and ecological conditions (Rowntree, 1991; Job & Ellery, 2013). The visual nature of these photographs also makes this method a good monitoring option for producing results which can be used to engage with stakeholders and funders, as it illustrates the changes easily and impactfully.

Traditional fixed point photography has been modernized to ensure that it is up to date with current available technology so that monitoring is cost-effective and accessible (Hammond et al., 2020). The steps to implement the Fixed Point Photography (FPP) method in this monitoring guideline therefore include the use of smartphones with compass and GPS applications to record and locate photograph sites. These smartphones also have cameras which can be used to take these photographs.

These methods should be applied in stream banks to detect changes to the water, banks, and surrounding vegetation and habitat, as demonstrated in Figure 34. These photos, together with

field survey data such as vegetation and habitat surveys can be used to provide long-term information on species in the site, the vegetation growth forms and fluctuations, including the introduction and densification of AIPs (Hoffman et al., 2010; Masubelele et al., 2013). The field guide for FPP therefore includes a site, habitat, and vegetation description (Appendix A.1.13).



Figure 34: Stream bank wherein Fixed Point Photographs should be taken to represent the stream (not flowing in this figure), banks, and surrounding vegetation.

8.3.1 Details of the method

Frequency: Fixed Point Photographs should be taken annually, however if there are any major changes detected in the area, it is advised to take additional photos after these changes have occurred.

Skill requirement: Basic training will be required to demonstrate how to select a fixed point which represents the area appropriately. Basic training will also be helpful to demonstrate re-locating these areas, and how to take the photo in a standard manner, in all directions. Plant identification training may be useful to aid users in identifying both indigenous and AIP species, as well as training on identifying types of erosion.

Price: < R100

Field sheet: [Click here](#)

8.3.2 Equipment required

- Cell phone with camera, GPS and a compass application
- Optional: Fencing standards to mark locations
- Observational Monitoring - Fixed Point Photography Method Field Sheet - Appendix A.1.13

8.3.3 Method

Step 1

Choose a location for your fixed point photography. This point should be within a stream bank, the view should be unobstructed in all directions, and it must be representative of the study site's stream, vegetation and banks.

Step 2

Record this site for each photograph by locating it and recording its GPS location with a smartphone (or a handheld GPS device). Once the location has been recorded, it can also be marked by placing a fencing standard into the ground.

Step 3

Use a compass application on a smartphone (or compass) to determine each direction (North, South, East and West).

Step 4

Hold the smartphone (or camera) at breast height, at approximately 1.5 m, as shown in Figure 35.3. Take a photograph in each of the four directions, as is demonstrated in Figure 35.4. Ensure that lighting is good and that the image is clear.

Step 5

Fill out the field sheet for FPP as shown in Appendix A.1.13, recording the location, and a description of the site and habitat, the vegetation (indigenous and AIPs), and erosion at each site.



Figure 35: Summary of the Fixed-point photography: (1) Record location, dropping a pin. (2) Use a compass or compass application to find each direction (North, South, East, West). (3) Take a photograph at breast height. Take a photograph in each direction (N- North; S- South; E- East; and W- West) (4) (Images: ACS, 2023; phonearena, 2023; active, 2013).

8.3.4 Advantages and limitations

The advantages and limitations that the Fixed Point Photography method offers are outlined in Table 18 below.

Table 18: Advantages and limitations of the Fixed Point Photography method

ADVANTAGES	LIMITATIONS
Easy to use	Requires smartphone with GPS or a camera and GPS device
Cost effective	
Changes easy to determine and visually detect – non-technical interpretation	Does not provide quantitative data on change
Detects long term changes	

9. Data storage, management, and interpretation

Data collected by landowners and users can be easily collected using our template field sheets presented in Appendix A.1, as well as in the resource folder attached. If the field sheets are printed out, then information can be filled out directly onto the form, which can then be stored in a file or folder and kept as a hard copy. To save data as a soft copy, users can scan these completed field sheets using scanning software. Alternatively, they may enter the data they collected into the electronic spreadsheet file (Microsoft Excel document) which is attached as an additional resource to these monitoring guidelines. Care should be taken to ensure that no errors occur when re-entering the data. These soft copy versions of the collected data may be stored on the user's computer, on an external hard drive or any other storage device. These soft copy versions may also be uploaded online to cloud storage using websites which offer storage services such as OneDrive or Google Drive.

Once data has been collected, users should interpret the data to help them understand how water quantity, quality and ecological conditions are changing as a result of removing AIPs. The information generated from these monitoring techniques can help inform users on whether clearing is resulting in a measurable change, and may help determine which clearing methods, and which species clearing is most effective. If users need help interpreting the data, it may be useful to contact stakeholders who may be able to provide assistance or further insights. Further literature explaining these methods and providing guidance on their interpretation can be found in the resource folder or literature review.

10. How to choose an appropriate method

In Section 5 criteria were provided to help guide users on what factors to look for and what to avoid when identifying and selecting appropriate study sites to implement monitoring methods. Section 5 did however only provide guidance for site selection on a broad scale.

The current section will provide a finer scale approach to selecting monitoring sites on a property and on selecting the appropriate method to apply.

Before deciding on where on the property to monitor the effects of AIPs and their clearing on water quantity and quality and what methods to apply, it is important to familiarize yourself with the property. First, briefly describe the property in terms of its topography, underlying geology and streamflow, in particular identifying which are the most perennial streams on the property. In addition, based on local knowledge, identify some of the key factors which have been observed to affect streamflow and its quality, potentially including droughts, fires and changes in landcover. Second, at a broad scale, describe how AIP infestation and the particular species vary across the property, and what clearing was undertaken in the past and is planned for the future, being realistic about what might be achievable with available resources.

Once you have familiarized yourself with the situation on the property, you will be better informed to decide where in the property to locate monitoring points (Table 19) and which method/s to use (Figure 36 and 37).

Table 19: Key factors to consider in deciding where to monitor water quantity and quality changes resulting from AIP clearing.

KEY FACTORS TO CONSIDER	DESCRIPTION OF THE RATIONALE
Natural perenniality of flows	Springs and streams which have flows which are naturally sustained/perennial are preferable to ones which naturally flow for only a short duration, i.e. are ephemeral.
Size of the catchment area feeding the monitoring point	The larger catchment area feeding the monitoring point, the more difficult it is likely to be to find a site where water flows are not affected by other confounding factors, e.g., abstraction for irrigation. Therefore, small sub-catchments where AIPs likely represent the primary impact on water flows are generally best.
Degree of infestation and anticipated level of clearing.	The available citizen science methods included in this guideline are generally coarse, and therefore small changes are unlikely to be reliably detected. Therefore, if only a small proportion of a large infestation of a sub-catchment is to be cleared then its potential effects on water flows from the sub-catchment are unlikely to be detected using direct methods. Similarly, if the infestation is at a low level, even if it covers a large area of the sub-catchment and most of the infestation is cleared, it will again likely be unrealistic to expect any change in flows resulting to be reliably detected.
Opportunities for the inclusion of a control site.	In addition to AIPs, the discharge over time in a spring or stream is affected by multiple other factors, notably the naturally variable rainfall. This makes isolating the specific effect of the AIP clearing a challenge. It may be, for example, that shortly after the clearing there is a particularly wet period, which, if not accounted for, could result in the positive effect of AIP clearing to be over-estimated. Alternatively, if a dry period coincidentally following the clearing, is not accounted for then this could result in the effect of AIP clearing being underestimated. Thus, by including a comparable sub-catchment which is similar to the catchment to be cleared, but differs in that it is not cleared, then “background noise” effect of other factors can be better understood and therefore better accounted for.
Opportunities for before and after monitoring	Given the multiple influencing factors described above, the longer the period of monitoring before the clearing, the better you will be able to take account of these factors. This applies particularly to cases where a control (as described above) is not available/possible.

Opportunities for using natural or human-made focal points of water flow for the reliable flow measurement.	Natural or human-made focal points of water flow (e.g., a spring collection point or culvert) can potentially be used for the reliable measurement of flows without having to install a specific structure such as a V notch weir.
Accessibility of the site	Given that a site needs to be revisited on frequent occasions, it is preferable to select sites which are as accessible as possible.

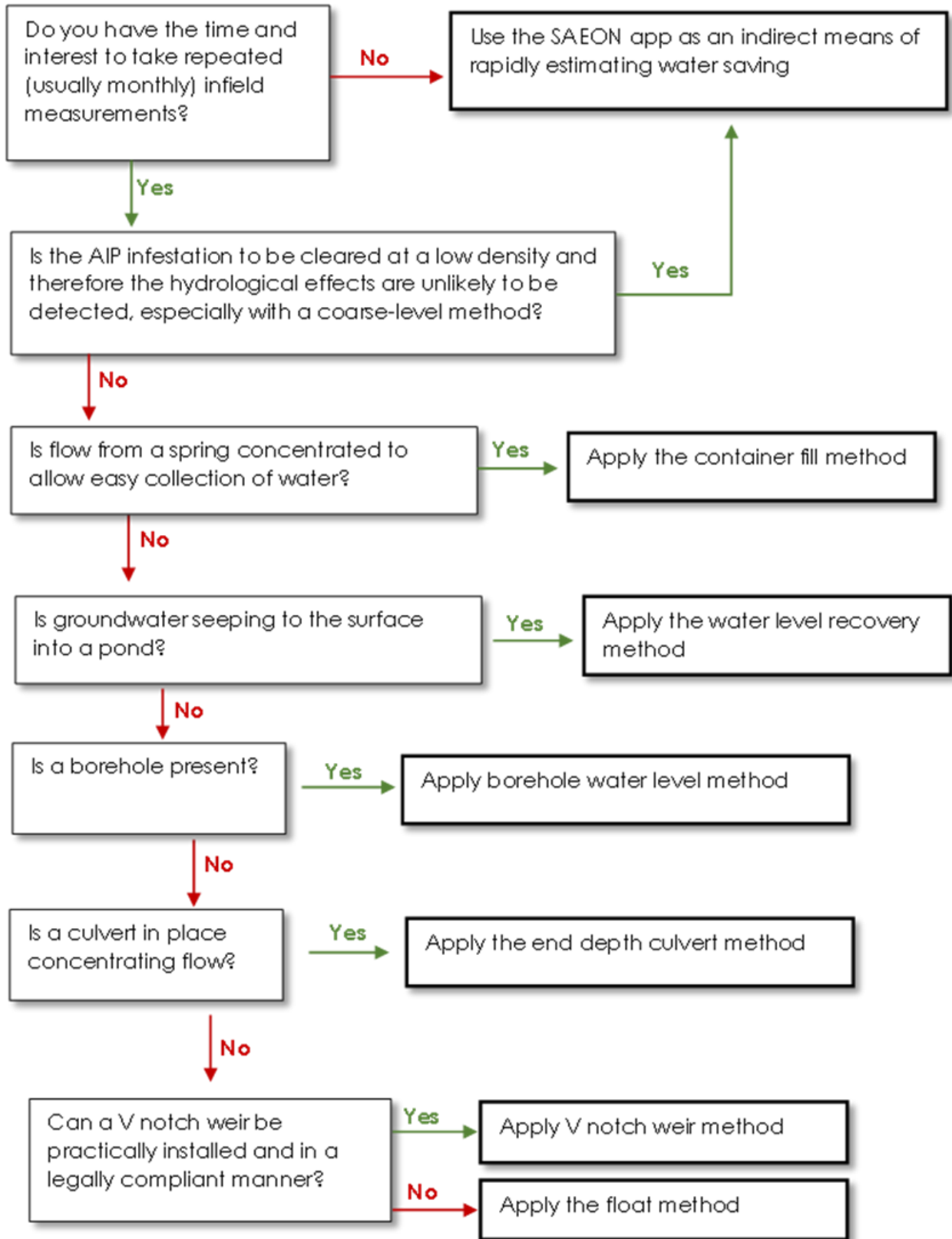


Figure 36: A decision tree to assist in deciding what method is appropriate for assessing the effects of clearing AIPs on water quantity.

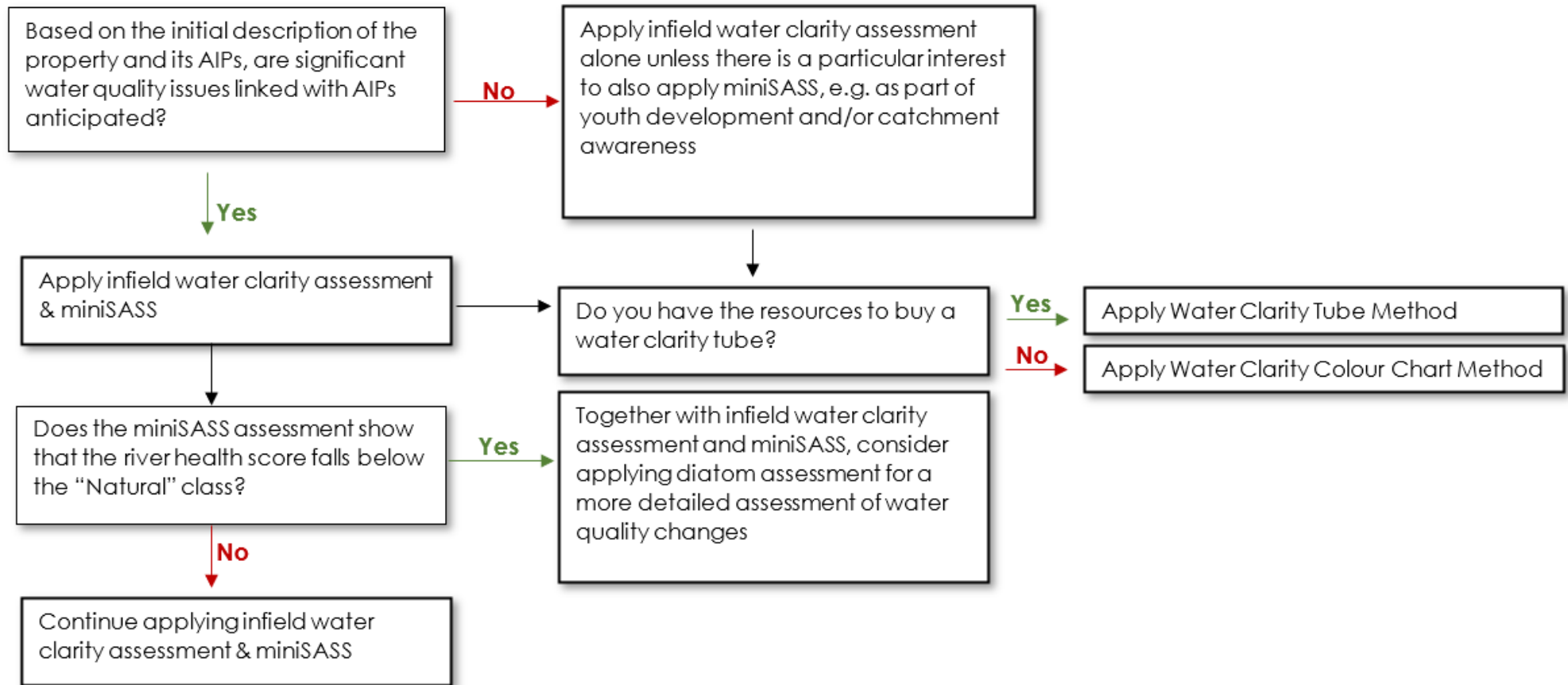


Figure 37: A decision tree to assist in deciding what method is appropriate for assessing the effects of clearing AIPs on water quality.

11. Conclusion

This project creates an opportunity for a variety of stakeholders to work together to monitor and highlight the threats that AIPs pose on our water resources. These monitoring guidelines provide step by step instructions for users on where and how to undertake water monitoring methods. These monitoring guidelines enable users to monitor the impact of clearing AIPs on water quantity and quality, as well as ecological baselines.

The proposed methods are designed to be easy to use, accessible, and appropriate for a wide range of landowners and users across a variety of catchments and sub-catchments throughout the Western Cape. The success of the roll out of these proposed methods, however, will depend on the suitability of sites. The methods are dependent on factors such as appropriate hydrological, geographical and topographical structures, the presence of AIPs, and the willingness of landowners.

Measures within these guidelines may act as useful tools to demonstrate how important clearing AIPs is - especially within SWSAs such as the Keurbooms Catchment. These methods allow landowners to quantify changes to water quantity and quality, as well as to ecological conditions arising as a result of AIP removal. If gains in water quantity and quality are quantified, this may provide evidence of the contribution that clearing AIPs can have on water availability. Coupling this clearing with rehabilitation and restoration efforts will further aid in increasing the water quality and help mitigate potential impacts following AIP clearing. Therefore, these methods may help persuade landowners, users, local authorities, and funders to acknowledge and support the continued need to prioritize AIP management and rehabilitation. Understanding the importance of removing AIPs and restoring these areas will help motivate further funding and resources to be directed towards clearing efforts.

12. References and Bibliography

- Active, 2013. Available at: <https://www.active.com/outdoors/articles/iphone-photography-apps-for-your-adventures>
- Allendorf, F.W. and Lundquist, L.L., 2003. Introduction: population biology, evolution, and control of invasive species. *Conservation Biology*, pp.24-30.
- Brikowski, T., 2007.
Available at:
https://personal.utdallas.edu/~brikowi/Teaching/Field_Methods/Gauging_Background.html
- Brumby Pumps, 2019. Available at: https://youtu.be/WXOWgXAOsA8?si=A2JIN0-say3eKkl_
- Chamier J., Schachtschneider K., le Maitre D.C., Ashton P.J. and van Wilgen B.W., 2012. Impacts of invasive alien plants on water quality, with particular emphasis on South Africa. *Water SA* 38: 345-356.
- De la Rey, P.A., Taylor, J.C., Laas, A., Van Rensburg, L. and Vosloo, A., 2004. Determining the possible application value of diatoms as indicators of general water quality: A comparison with SASS 5. *Water Sa*, 30(3), pp.325-332.
- Department of Forestry, Fisheries and the Environment, 2023. Natural Capital 3: Accounts for Strategic Water Source Areas, 1990 to 2020. Pretoria: Statistics South Africa.
- Desai, M., 2016. Riparian Health Audit. Water Research Commission, Pretoria.
- Dezial, C., 2018. Available at: <https://sciencing.com/flow-rate-vs-pipe-size-7270380.html>
- Dobriyal, P., Badola, R., Tuboi, C. and Hussain, S.A., 2017. A review of methods for monitoring streamflow for sustainable water resource management. *Appl Water Sci* 7: 2617–2628.
- Dzikiti, S., Schachtschneider, K., Naiken, V., Gush, M., Moses, G. and Le Maitre, D.C., 2013. Water relations and the effects of clearing invasive *Prosopis* trees on groundwater in an arid environment in the Northern Cape, South Africa. *Journal of Arid Environments*, 90, pp.103-113.
- Dzvukamanja, T.N., Görgens, A.H.M. and Jonker, V., 2005. *Streamflow reduction modelling in water resource analysis*. Pretoria: Water Research Commission.
- Environmental Protection Agency (EPA), 2023. Available at: <https://www.epa.gov/national-aquatic-resource-surveys/indicators-sediment-diatoms>.
- Forest Science Labs - Oregon State University (FSL ORST), n.d. Available:
https://www.fsl.orst.edu/geowater/FX3/help/FX3_Help.html#7_Culvert_Basics/Culvert_Shapes.htm
- Fourie, F., Mbatha, K., Verster, H. and Van Dyk, G., 2007, September. The effect of vegetation (*Prosopis* sp.) on groundwater levels in Rugseer River, Kenhardt, South Africa. In *Groundwater and Ecosystems, XXXV IAH Congress*. Poster paper presented at Groundwater and Ecosystems, XXXV IAH Congress (pp. 17-21).

Franchini, W., 2013. Available at: http://www.mccrone.com/wp-content/uploads/2015/01/Franchini_article107.pdf

Graham, M. and Taylor, J., 2018. Development of citizen science water resource monitoring tools and communities of practice for South Africa, Africa and the world. Water Research Commission.

Graham, P.M., 2012. Reassessment of the mini-sass biomonitoring tool as a resource for environmental education in the river health programme and cross-linking to with the national curriculum statement. *Water Research Commission. WRC Report No.*

Graham, P.M., Dickens, C.W. and Taylor, R.J., 2004. miniSASS—A novel technique for community participation in river health monitoring and management. *African Journal of Aquatic Science*, 29(1), pp.25-35.

GroundTruth, n.d.

Available at: <http://www.groundtruth.co.za/our-products>

Hammond, W.M., Stone, M.E. and Stone, P.A., 2020. Picture worth a thousand words: Updating repeat photography for 21st century ecologists. *Ecology and Evolution*, 10(24), pp.14113-14121.

Hoffman, M.T., Rohde, R.F., Duncan, J., Kaleme, P., Webb, R., Boyer, D. and Turner, R., 2010. Repeat photography, climate change, and the long-term population dynamics of tree aloes in southern Africa. *Repeat photography: methods and applications in the natural sciences*, 133, p.142.

Huang, C.Y. and Asner, G.P., 2009. Applications of remote sensing to alien invasive plant studies. *Sensors*, 9(6), pp.4869-4889.

Hundt, S. and Blasch, K., 2019. Laboratory assessment of alternative stream velocity measurement methods. *PloS one*, 14(9), p.e0222263.

Irrigation Engineering, n.d.

Available at: <http://ecoursesonline.iasri.res.in/mod/page/view.php?id=124800>

iStock.com/Alexmia, 2017. Available at: <https://eos.org/research-spotlights/when-income-goes-up-does-pollution-go-down>

Job N, and Ellery F, 2013. Policy brief: Halting degradation of Southern Cape peatlands in agricultural landscapes. *Policy Brief Rhodes Univ.* 8, 1–8.

Kelly, M., 2015.

Available at: <https://microscopesandmonsters.wordpress.com/2015/04/12/diatoms-and-dinosaurs/>

Kelly, m., 2022. Available at:

<https://microscopesandmonsters.wordpress.com/2022/05/28/whats-in-a-sample-2/>

Kelly, M., Yallop, M., n.d. Available at: <https://slideplayer.com/slide/3435566/>

Kilroy, C. and Biggs, B.J., 2002. Use of the SHMAK clarity tube for measuring water clarity: comparison with the black disk method. *New Zealand Journal of Marine and Freshwater Research*, 36(3), pp.519-527.

Kirichenko, N., Péré, C., Baranchikov, Y., Schaffner, U. and Kenis, M., 2013. Do alien plants escape from natural enemies of congeneric residents? Yes but not from all. *Biological Invasions*, 15, pp.2105-2113.

Lake Worth Drainage District (LWDD), 2019. Available at:
<https://www.lwdd.net/news/drainage-canals-are-not-dump-sites>

Le Maitre, D.C., Blignaut, J.N., Clulow, A., Dziki, S., Everson, C.S., Görgens, A.H. and Gush, M.B., 2020. Impacts of plant invasions on terrestrial water flows in South Africa. In *Biological Invasions in South Africa* (pp. 431-457). Cham: Springer International Publishing.

Le Maitre, D.C., Forsyth, G.G., Dziki, S. and Gush, M.B., 2016. Estimates of the impacts of invasive alien plants on water flows in South Africa. *Water Sa*, 42(4), pp.659-672.

Le Maitre, D.C., Seyler, H., Holland, M., Smith-Adao, L., Nel, J.L., Maherry, A. and Witthüser, K., 2018. Identification, Delineation and Importance of the Strategic Water Source Areas of South Africa, Lesotho and Swaziland for Surface Water and Groundwater. Report No (p. 4). TT 743/1/18, Water Research Commission, Pretoria.

Le Maitre, D.C., Van Wilgen, B.W., Chapman, R.A. and McKelly, D.H., 1996. Invasive plants and water resources in the Western Cape Province, South Africa: modelling the consequences of a lack of management. *Journal of applied ecology*, pp.161-172.

Le Maitre, D.C., Versfeld, D.B. and Chapman, R.A., 2000. Impact of invading alien plants on surface water resources in South Africa: A preliminary assessment.

LMNO Engineering, 2014. Circular culvert free-flow discharge calculation - Water free-flowing from end of pipe. End depth method. ISO 4371 [Online]. Available at:
<https://www.lmnoeng.com/Waterfall/CulvertDischarge.php>

Masubelele, M.L., Hoffman, M.T., Bond, W. and Burdett, P., 2013. Vegetation change (1988-2010) in Camdeboo National Park (South Africa), using fixed-point photo monitoring: The role of herbivory and climate. *Koedoe: African Protected Area Conservation and Science*, 55(1), pp.1-16.

Maclear, L.A. and Kotze, J., 2000. The effects of alien vegetation clearing on a coastal aquifer, Bushmans River Mouth, Eastern Cape. In *Groundwater: past achievements and future challenges* (pp. 215-220).

Midlands Conservancies Forum (MCF), 2014. Available at:
<https://midlandsconservanciesforum.files.wordpress.com/2014/06/mpofana-feet-wet.jpg>

Midlands Conservancies Forum (MCF), 2017. Available at:
<https://midlandsconservanciesforum.wordpress.com/page/2/>

miniSASS.org, n.d.
Available at: <https://minisass.org/en/downloads/>

miniSASS.org, n.d.

Available at: <https://minisass.org/en/how/are-you-ready/>

miniSASS.org, n.d.

Available at: <https://minisass.org/en/how/how-collect-minisass-sample/#:~:text=Halfway%20fill%20the%20tray%20with,we%20shall%20use%20as%20data>

Mpophomeni Conservation Group (MCG), 2015. Available at:

<https://mpophomeniconservationgroup.wordpress.com/tag/minisass/>

National Geographic, n.d. Available at:

<https://www.nationalgeographic.com/science/article/140311-rock-snot-rivers-freshwater-science-environment>

Nzaee, n.d. Available at: <https://www.nzaee.org.nz/providers/horizons-regional-council>

Othman, A., Mohd Khairudin, W., Othman, J., Abd Ghani, M. and Mohd Saudi, A.S., 2017. Water flow measuring methods in small hydropower for streams and rivers-A study. Int. J. Appl. Eng. Res, 12, pp.14484-14489.

People's Science Institute. Undated. 3.1 Spring discharge measurement in different flow settings. MCLLMP Virtual Training. Spring Initiative Partners, Dehradun, India.

Rebelo, A.J., Holden, P.B., Hallows, J., Eady, B., Cullis, J.D., Esler, K.J. and New, M.G., 2022. The hydrological impacts of restoration: A modelling study of alien tree clearing in four mountain catchments in South Africa. Journal of Hydrology, 610, p.127771.

Petersen and Strydom, n.d. Groundwater Monitoring Protocol: Hydrocensus.

Phonearena, 2023. Available at: https://www.phonearena.com/news/How-to-use-an-Android-phone-as-a-compass_id61926

Ravenscroft, P., and Murray, R., 2004. Groundwater Monitoring for Pump Operators. DWAF.

Ravhuhali, K.E., Mudau, H.S., Moyo, B., Hawu, O. and Msiza, N.H., 2021. Prosopis species—an invasive species and a potential source of browse for livestock in semi-arid areas of South Africa. Sustainability, 13(13), p.7369.

Roctest, n.d. V-notch - Triangular weir.

Available at: <https://roctest.com/wp-content/uploads/2018/06/V-NOTCH-E50106-180601-RTT.pdf>

Rowntree K, 1991. An assessment of the potential impact of alien invasive vegetation on the geomorphology of river channels in South Africa, *Southern African Journal of Aquatic Science*, 17, pp.28-43.

Serôdio, J. and Lavaud, J., 2022. Diatoms and their ecological importance. In Life Below Water (pp. 304-312). Cham: Springer International Publishing.

Shikwambana, P., Taylor, J.C., Govender, D. and Botha, J., 2021. Diatom responses to river water quality in the Kruger National Park, South Africa. *Bothalia-African Biodiversity & Conservation*, 51(1), pp.1-11.

Shope, C.L., Bartsch, S., Kim, K., Kim, B., Tenhunen, J., Peiffer, S., Park, J.H., Ok, Y.S., Fleckenstein, J. and Koellner, T., 2013. A weighted, multi-method approach for accurate basin-wide streamflow estimation in an ungauged watershed. *Journal of Hydrology*, 494, pp.72-82.

Solinst, 2013. Available at: <https://www.solinst.com/products/level-measurement-devices/101-water-level-meter/>

South Downs National Park, 2018. Fixed Point Photography- Case Study. Available at: https://www.southdowns.gov.uk/wp-content/uploads/2018/03/Fixed-Point-Photography_March_2018.pdf

Statistics South Africa (Stats SA), 2023. Natural Capital Series 3: Accounts for Strategic Water Source Areas, 1990 to 2020.

Taylor, J., Graham, M., Louw, A., Lepheana, A., Madikizela, B., Dickens, C., Chapman, D.V. and Warner, S., 2022. Social change innovations, citizen science, miniSASS and the SDGs. *Water Policy*, 24(5), pp.708-717.

Taylor, J.C., Harding, W.R. and Archibald, C.G.M., 2007. A methods manual for the collection, preparation and analysis of diatom samples. Version, 1, p.60.

Terasmaa, J., Vainu, M., Koit, O., Sisask, K., Abreldaal, P., Puusepp, L., n.d. Spring monitoring manual for volunteers. Available at: https://allikad.info/manuals/volunteer_monitoring_manual_ENG.pdf

USGS, n.d. Available at: <https://www.usgs.gov/media/images/a-century-usgs-measured-steam-discharge-using-current-meters>

University of Zurich (UZH), 2016. Available at: <https://www.labmanager.com/environmental-dna-uncovers-biodiversity-in-rivers-9035>

Wika, 2023. Available at: https://microsites.wika.com/newscontentgeneric_ms.WIKA?AxID=472

13. Appendices A

Appendix A.1 - Field Sheet Templates

A.1.1 Water loss estimation - SAEON Application

INDIRECT METHODS - SAEON APPLICATION - FIELD SHEET			
DATE:		LONGITUDE:	
PROJECT AND SITE:		LATITUDE:	
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description)			
MANAGEMENT UNIT ID:			
Dominant Species #1			
	SPECIES	MEAN AGE	DENSITY
Dominant Species #2			
	SPECIES	MEAN AGE	DENSITY
Dominant Species #3			
	SPECIES	MEAN AGE	DENSITY
NOTES:			
INDIRECT METHOD - SAEON APPLICATION - SITE AND METHOD:			

A.1.2 Streamflow - 90° V-notch Weir Method

SURFACE FLOW DISCHARGE: V NOTCH WEIR - FIELD SHEET					
DATE:			LONGITUDE:		
PROJECT AND SITE:			LATITUDE:		
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description)					
CROTCH HEIGHT (cm):					
DISTANCE FROM GAUGE TO WEIR (cm):					
ID		HEAD (cm)		DISCHARGE (L/s)	
DISCHARGE-HEAD RELATIONSHIP FOR A 90 ° V-NOTCH WEIR					
H (cm)	Q (l/s)	H (cm)	Q (l/s)	H (cm)	Q (l/s)
1	0	11	5,5	21	27,9
2	0,1	12	6,8	22	31,3
3	0,2	13	8,3	23	35
4	0,4	14	10	24	38,9
5	0,8	15	12	25	43,1
6	1,2	16	14	26	47,5
7	1,8	17	16	27	52,2
8	2,5	18	19	28	57,1
9	3,3	19	22	29	62,3
10	4,3	20	24	30	67,8
NOTES:					
V NOTCH WEIR SITE AND METHOD:					

A.1.3 Streamflow - Float Method

STREAM FLOW MEASUREMENTS: AREA-VELOCITY FLOAT METHOD - FIELD SHEET					
DATE:			LONGITUDE:		
PROJECT AND SITE:			LATITUDE:		
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description)					
DISTANCE (cm): 1		AVERAGE DEPTH (cm):		AVERAGE WIDTH (cm):	
ID	DISTANCE (d) (cm)	TIME (t) (s)	VELOCITY = (d) / (t) (cm/s)	AREA OF CROSS SECTION (A) = avg. depth x avg. width (cm ²)	STREAMFLOW Q= (60 x A x V) / 1000 (litre/min.)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
AVERAGE					
NOTES:					
FLOAT SITE AND METHOD:					

A.1.4 Streamflow - End Depth Culvert Method

STREAMFLOW: END DEPTH CULVERT METHOD - FIELD SHEET						
DATE:			LONGITUDE:			
PROJECT AND SITE:			LATITUDE:			
SITE DESCRIPTION AND CONDITIONS: (Weather, season, temperature, water flow description)						
ID	DIAMETER OF CULVERT PIPE (cm)	DIAMETER OF CULVERT PIPE (m)	DEPTH (cm)	DEPTH (m)	ALPHA	STREAMFLOW (L/s)
		0		0	#DIV/0!	#DIV/0!
*Insert measured values in yellow cells						
NOTES:						
END DEPTH CULVERT SITE AND METHOD:						

A.1.5 Spring Discharge - Container Fill Method

SPRING DISCHARGE: STOPWATCH - CONTAINER METHOD - FIELD SHEET			
DATE:		LONGITUDE:	
PROJECT AND SITE:		LATITUDE:	
SITE DESCRIPTION AND CONDITIONS: (Weather, season, temperature, water flow description)			
ID	VOLUME WATER (V) (litre)	TIME (t) (seconds)	DISCHARGE $Q = (V \times 60) / t$ (litre/min.)
1			
2			
3			
4			
5			
6			
AVERAGE			
NOTES:			
SPRING DISCHARGE SITE AND METHOD:			

A.1.6 Spring Discharge - Water Level Recovery Method

SPRING DISCHARGE: WATER LEVEL RECOVERY - FIELD SHEET			
DATE:		LONGITUDE:	
PROJECT AND SITE:		LATITUDE:	
SITE DESCRIPTION AND CONDITIONS: (Weather, season, temperature, water flow description)			
ID	VOLUME OF CONTAINER (V) (litre)	REFILL TIME (t) (seconds)	DISCHARGE $Q = (V \times 60) / t$ (litre/min.)
1			
NOTES:			
WATER LEVEL RECOVERY SITE AND METHOD:			

A.1.7 Borehole Water Level - Dipmeter Method

BOREHOLE WATER LEVEL: DIPMETER - FIELD SHEET			
DATE:	LONGITUDE:		
PROJECT AND SITE:	LATITUDE:		
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description)			
BOREHOLE NAME:	ALTITUDE:		
CASING HEIGHT (m):	CASING DIAMETER (m):		
ACTIVE / INACTIVE:	CASING DIAMETER (m):		
WATER USE:			
POWER SOURCE:			
ID	WATER TABLE DEPTH (m) (Buzzer / Float measurement)	BOREHOLE DEPTH (m) (Bottom of borehole/ sinker measure)	WATER LEVEL (m) (Borehole depth - Water table depth)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
AVERAGE			
NOTES:			
BOREHOLE WATER LEVEL: IMAGE			

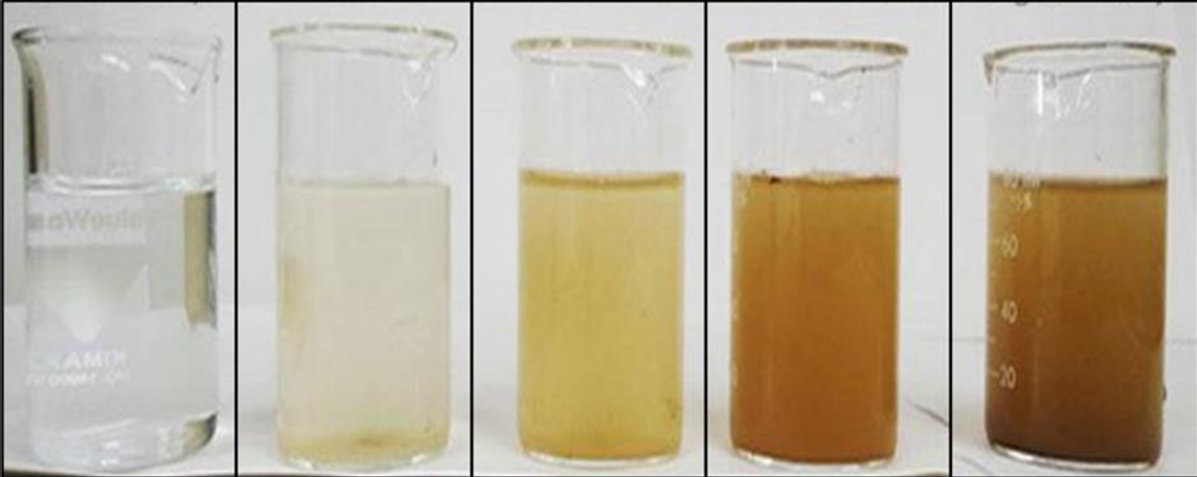
A.1.8 Biomonitoring - miniSASS Method

miniSASS: FIELD SHEET																																									
DATE:	LONGITUDE:																																								
PROJECT AND SITE:	LATITUDE:																																								
SITE DESCRIPTION AND CONDITIONS:																																									
<p style="text-align: center;">SCORING:</p> <p>1. On the table, circle the sensitivity scores of the identified organisms.</p> <p>2. Add up all of the sensitivity scores.</p> <p>3. Divide the total of the sensitivity scores by the number of groups identified.</p> <p>4. The result is the average score, which can be interpreted into an ecological category given below.</p> <p style="text-align: center;">INTERPRET MINISASS SCORE:</p> <p>Although an ideal sample site has rocky, sandy, and vegetation habitats, not all habitats are always present at a site. If your river had no rocky habitats that were sampled, use the sandy type category to interpret your scores.</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr style="background-color: #cccccc;"> <th style="text-align: left; padding: 2px;">GROUPS</th> <th style="text-align: right; padding: 2px;">SENSITIVITY SCORE</th> </tr> </thead> <tbody> <tr><td style="padding: 2px;">Flat worms</td><td style="text-align: right; padding: 2px;">3</td></tr> <tr><td style="padding: 2px;">Worms</td><td style="text-align: right; padding: 2px;">2</td></tr> <tr><td style="padding: 2px;">Leeches</td><td style="text-align: right; padding: 2px;">2</td></tr> <tr><td style="padding: 2px;">Crabs or shrimps</td><td style="text-align: right; padding: 2px;">6</td></tr> <tr><td style="padding: 2px;">Stoneflies</td><td style="text-align: right; padding: 2px;">17</td></tr> <tr><td style="padding: 2px;">Minnow mayflies</td><td style="text-align: right; padding: 2px;">5</td></tr> <tr><td style="padding: 2px;">Other mayflies</td><td style="text-align: right; padding: 2px;">11</td></tr> <tr><td style="padding: 2px;">Damselflies</td><td style="text-align: right; padding: 2px;">4</td></tr> <tr><td style="padding: 2px;">Dragonflies</td><td style="text-align: right; padding: 2px;">6</td></tr> <tr><td style="padding: 2px;">Bugs or beetles</td><td style="text-align: right; padding: 2px;">5</td></tr> <tr><td style="padding: 2px;">Caddisflies (cased & uncased)</td><td style="text-align: right; padding: 2px;">9</td></tr> <tr><td style="padding: 2px;">True flies</td><td style="text-align: right; padding: 2px;">2</td></tr> <tr><td style="padding: 2px;">Snails</td><td style="text-align: right; padding: 2px;">4</td></tr> <tr><td style="padding: 2px;">TOTAL SCORE</td><td style="text-align: right; padding: 2px;"></td></tr> <tr><td style="padding: 2px;">NUMBER OF GROUPS</td><td style="text-align: right; padding: 2px;"></td></tr> <tr><td style="padding: 2px;">AVERAGE SCORE (miniSASS Score)</td><td style="text-align: right; padding: 2px;"></td></tr> <tr><td style="padding: 2px;">Average Score =</td><td style="text-align: right; padding: 2px;"></td></tr> <tr><td style="padding: 2px;">Total Score ÷ Number of groups</td><td style="text-align: right; padding: 2px;"></td></tr> </tbody> </table>	GROUPS	SENSITIVITY SCORE	Flat worms	3	Worms	2	Leeches	2	Crabs or shrimps	6	Stoneflies	17	Minnow mayflies	5	Other mayflies	11	Damselflies	4	Dragonflies	6	Bugs or beetles	5	Caddisflies (cased & uncased)	9	True flies	2	Snails	4	TOTAL SCORE		NUMBER OF GROUPS		AVERAGE SCORE (miniSASS Score)		Average Score =		Total Score ÷ Number of groups			
GROUPS	SENSITIVITY SCORE																																								
Flat worms	3																																								
Worms	2																																								
Leeches	2																																								
Crabs or shrimps	6																																								
Stoneflies	17																																								
Minnow mayflies	5																																								
Other mayflies	11																																								
Damselflies	4																																								
Dragonflies	6																																								
Bugs or beetles	5																																								
Caddisflies (cased & uncased)	9																																								
True flies	2																																								
Snails	4																																								
TOTAL SCORE																																									
NUMBER OF GROUPS																																									
AVERAGE SCORE (miniSASS Score)																																									
Average Score =																																									
Total Score ÷ Number of groups																																									
ECOLOGICAL CONDITION	ECOLOGICAL CATEGORY	RIVER CATEGORY																																							
		Sandy Type	Rocky Type																																						
NATURAL CONDITION	Unchanged/untouched	> 6.9	> 7.2																																						
GOOD CONDITION	Few modifications	5.9 to 6.8	6.2 to 7.2																																						
FAIR CONDITION	Some modifications	5.4 to 5.8	5.7 to 6.1																																						
POOR CONDITION	Lots of modifications	4.8 to 5.3	5.3 to 5.6																																						
VERY POOR CONDITION	Critically modified	< 4.8	< 5.3																																						
NOTES:																																									
SITE AND METHOD:																																									

A.1.9 Turbidity - Water Clarity Tube

WATER TURBIDITY: CLARITY TUBE - FIELD SHEET			
DATE:		LONGITUDE:	
PROJECT AND SITE:		LATITUDE:	
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description)			
ID	APPEARANCE DEPTH (CM)	DISAPPEARANCE DEPTH (CM)	AVERAGE DEPTH (CM)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
AVERAGE			
NOTES:			
FLOAT SITE AND METHOD:			

A.1.10 Turbidity - Water Clarity Colour Chart

WATER TURBIDITY: WATER CLARITY COLOUR CHART - FIELD SHEET				
DATE:	LONGITUDE:			
PROJECT AND SITE:	LATITUDE:			
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description)				
ID	CLARITY SCORE			
1				
2				
3				
				
1	2	3	4	5
NOTES:				
WATER CLARITY COLOUR CHART SITE AND METHOD:				

A.1.11 Biomonitoring - Diatom Sampling

DIATOM SAMLING - FIELD SHEET			
DATE:		LONGITUDE:	
PROJECT AND SITE:		LATITUDE:	
SAMPLE NAME:			
SITE DESCRIPTION AND CONDITIONS: (Weather, season, temperature, water flow description)			
NOTES:			
DIATOM SAMPLING SITE AND METHOD:			

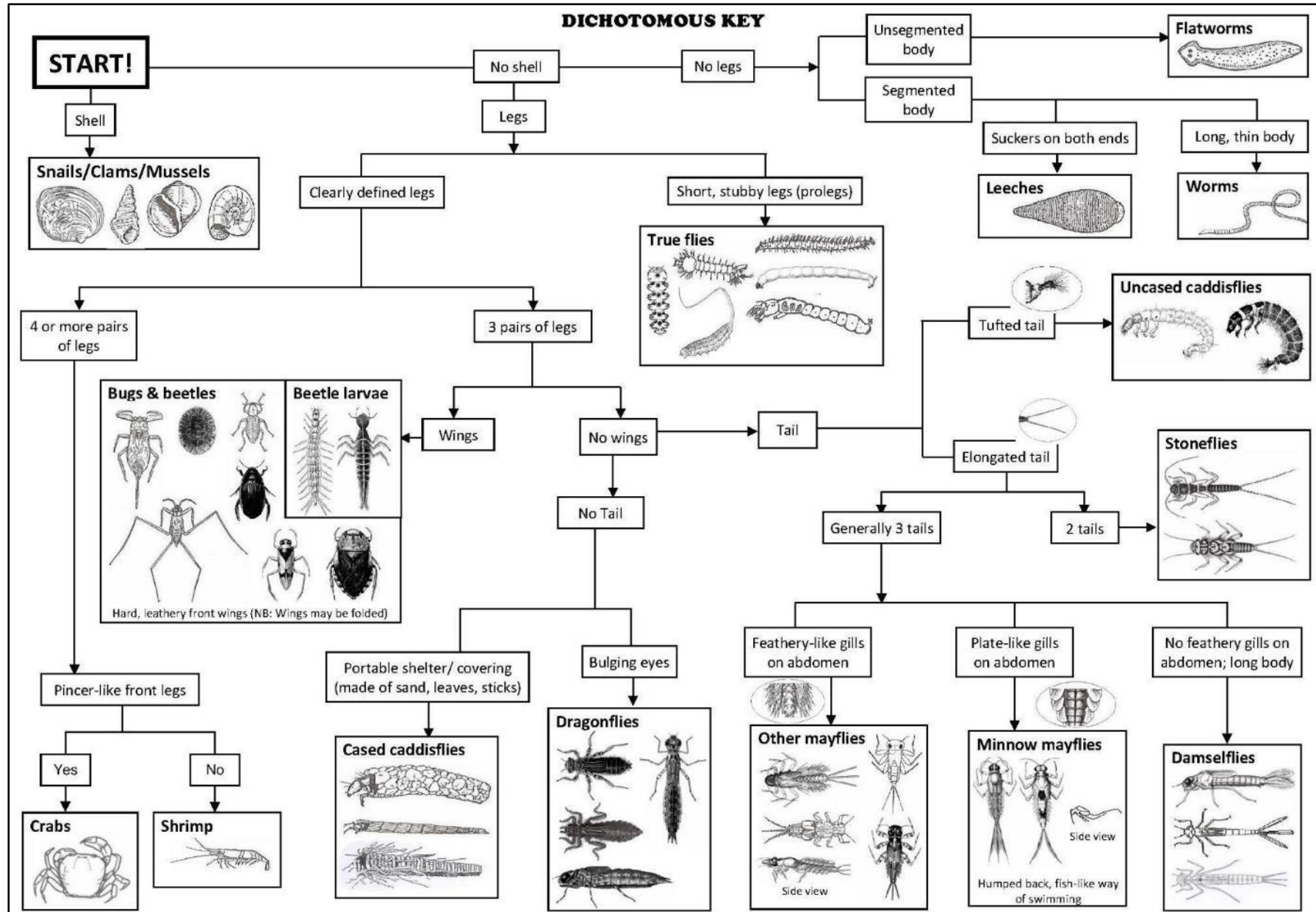
A.1.12 Ecological Health - Riparian Health Audit

RIPARIAN HEALTH AUDIT: FIELD SHEET										
DATE:			UPSTREAM LONGITUDE:				DOWNSTREAM LONGITUDE:			
PROJECT AND SITE:			UPSTREAM LATITUDE:				DOWNSTREAM LATITUDE:			
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description)										
RATE EACH IMPACT FROM 0-5										
SITE	1 EXOTIC VEGETATION	2 RUBBISH DUMPING	3 BANK EROSION	4 INUNDATION	5 FLOW MODIFICATION	6 CHANNEL MODIFICATION	7 EVIDENCE OF DECREASED WATER QUALITY	8 VEGETATION REMOVAL	TOTAL SCORE	PERCENTAGE (TS/ 40 X 100)
ECOLOGICAL HEALTH SCORE:						STUDY SITE:				
SCORE	PERCENTAGE CHANGE	ECOLOGICAL CONDITION								
0 - 4.5	0 - 10	Natural								
5 - 11.5	11 - 29	Good								
12 - 19.5	30 - 49	Fair								
20 - 27.5	50 - 69	Poor								
28 - 35.5	70 - 89	Very Poor								
36 - 40	90 - 100	Critical								
NOTES:										

A.1.13 Observational Monitoring - Fixed Point Photography

FIXED POINT PHOTOGRAPHY: FIELD SHEET							
DATE:				LONGITUDE:			
PROJECT AND SITE:				LATITUDE:			
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description)							
SURVEYOR:							
POINT DESCRIPTION: (How to find the marker)							
HABITAT DESCRIPTION:							
INDIGENOUS SPECIES:							
INVASIVE ALIEN PLANTS:							
DOMINANT SPECIES:		EXTENT:		DENSITY:		AGE:	
		Isolated		Occasional		Seedling	
		Moderate		Very Scattered		Young	
		Extensive		Scattered		Adult	
				Moderate		Mixed	
				Dense			
				Closed up			
SOIL EROSION:				UTILIZATION:		VEG CONDITION SCORE:	
TYPE:		EXTENT:		EXTENT:		SCORE:	
Sheet		Very extensive		Light		0 - 25%	
Rill		Wide spread		Moderate		25% - 50%	
Gully		Fragmented		Heavy		50% - 75%	
Donga		Localised		Severe		75% - 100%	
Head cut				Other			
Channelling				Game			
Riverbank							
ORGANIC LITTER:							
MATERIAL COMPOSITION:				SOIL SURFACE COVER:			
Fine				Absent			
Medium				Sparse			
Coarse				Moderate			
				Dense			
NOTES:				SITE:			

Appendix A.2 - miniSASS - Dichotomous Key and Identification of Macroinvertebrate Groups



Flat worms



Flat worms are characterised by their flattened shape and soft bodied, worm-like form. They have an arrow-shaped head with two dorsal eyespots and are generally mottled or dark grey in colour. Flatworms move with a gliding action and are generally scavengers or carnivores.

Leeches



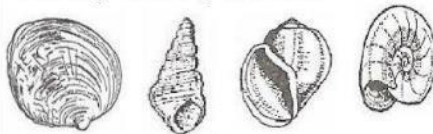
Leeches are segmented organisms that have very flexible bodies. When moving they expand to become long and thin, and then contract to become short and stubby. They have suckers on both ends of the body used for feeding and locomotion. Leeches are variable in colour, from grey, to red-brown and black. They swim with a fast, snaking movement and are found under stones, vegetation and debris.

Worms



Worms are long and segmented, with a cylindrical shape much like small earthworms. Their colouring is usually pink to brown. They are usually seen writhing around in debris, digesting the substrate they fed on.

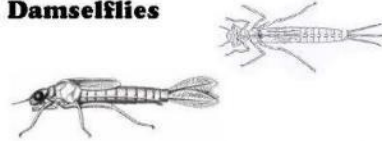
Snails / Clams / Mussels



Snails are molluscs with hard shells that vary in size, shape and colour. Habitats vary, with some snails, such as limpets, clinging to rocks, whereas clams and mussels are found in sand. The more common snails move over stones and vegetation. Some snails are host to bilharzia, a serious health hazard for humans.

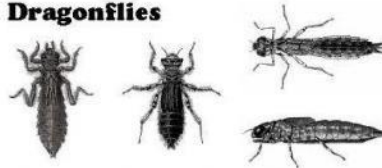
Images not to scale

Damselflies



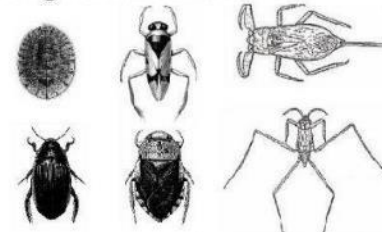
Damselflies have elongated bodies generally with three broad tails/gills on the tip of the abdomen. Damselflies are carnivorous and have a 'mask' over the lower part of the face, which hinges out to reveal a pair of pincers used to catch their prey. They are often found in vegetation growing on the edges of rivers.

Dragonflies



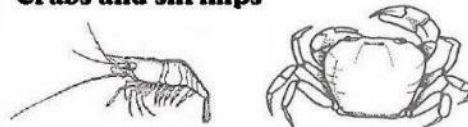
Dragonflies are robust creatures that are stout and have a large head and protruding eyes. Some have short legs whilst others have long legs. They do not have tails, but swim using 'jet propulsion' by forcefully ejecting water from the abdomen. Dragonfly nymphs are usually the largest organisms found in a sample and are the most powerful invertebrate predators in the water.

Bugs and Beetles



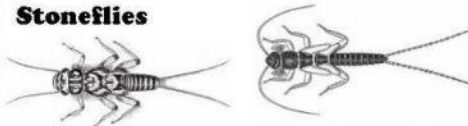
Bugs can be defined as having a piercing and sucking beak for mouthparts, and two pairs of membranous wings. Beetles on the other hand have 'jaws' and outer wings that are hardened to protect the inner wings. Some bugs and beetles are well adapted to swimming, such as water boatmen, backswimmers, pond skaters and water striders. Most bugs and beetles are carnivorous, but some feed on algae.

Crabs and shrimps



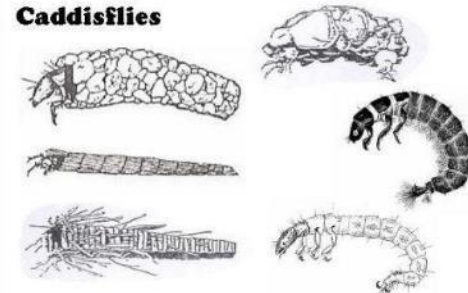
Crabs and shrimp form part of the order Decapoda (ten legs) and have bodies and legs hardened to form a tough shell. They have four or five pairs of legs. Their eyes that are carried on stalks and are movable. Crabs are scavengers that feed mainly on leaf litter but will feed on animals when given the chance. Shrimps are mostly scavengers or deposit feeders.

Stoneflies



The nymphs of adult stoneflies usually have two long tails and three pairs of legs, each having two claws at the tip. A characteristic feature of stonefly nymphs are the tufts of gills on the side of the body as well as gills between the two tails. Wing pads on the thorax are often dark and obvious. Some species run across the substrate very efficiently and are potent invertebrate predators. Other species are smaller and feed on plant material. Most live in well-oxygenated, clean water.

Caddisflies



The aquatic larvae of adult caddisflies have a hard head with three pairs of legs attached to an elongated, soft body. Finger-like gills on the abdomen and anal appendages can be seen with the naked eye. Some caddisflies construct portable shelters from sand grains, bits of vegetation and/or silk that are glued together to form a characteristic case shape. Most case-building types cannot swim whereas the caseless types swim freely across the substrate. Some feed on algae and detritus whereas others are predators.

Mayflies

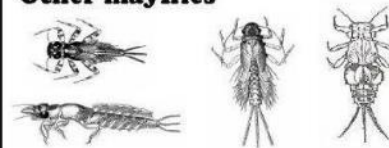
Mayfly nymphs vary greatly in shape and size and can survive for months in the water. However, the adults only live for a day or two. In this time, adults never feed, only mating and lay eggs in the water.

Minnow mayflies



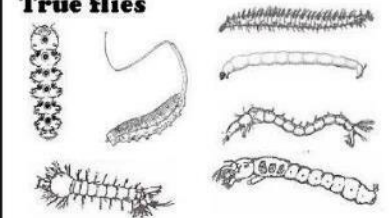
These mayflies have a narrow head and a small, slender, but not flattened body. They have leaf shaped gills on both sides of the abdomen and two but more commonly three tails, depending on the species.

Other mayflies



Other mayflies are characterised by an elongated body, large head, well-developed mouthparts and stout legs. They live in a variety of habitats, including burrowing in mud, crawling amongst decaying leaves, and scurrying over stones in fast flowing water.

True flies



Most fly larvae have a fairly indistinct head but elaborate tail ends. They often have small, soft legs (prolegs), segmented bodies and have the appearance of maggots. Some have bristles/spines and antennae. True flies live in a variety of habitats including sand, mud and stones in fast flowing water. They can either be carnivorous or filter feeders.

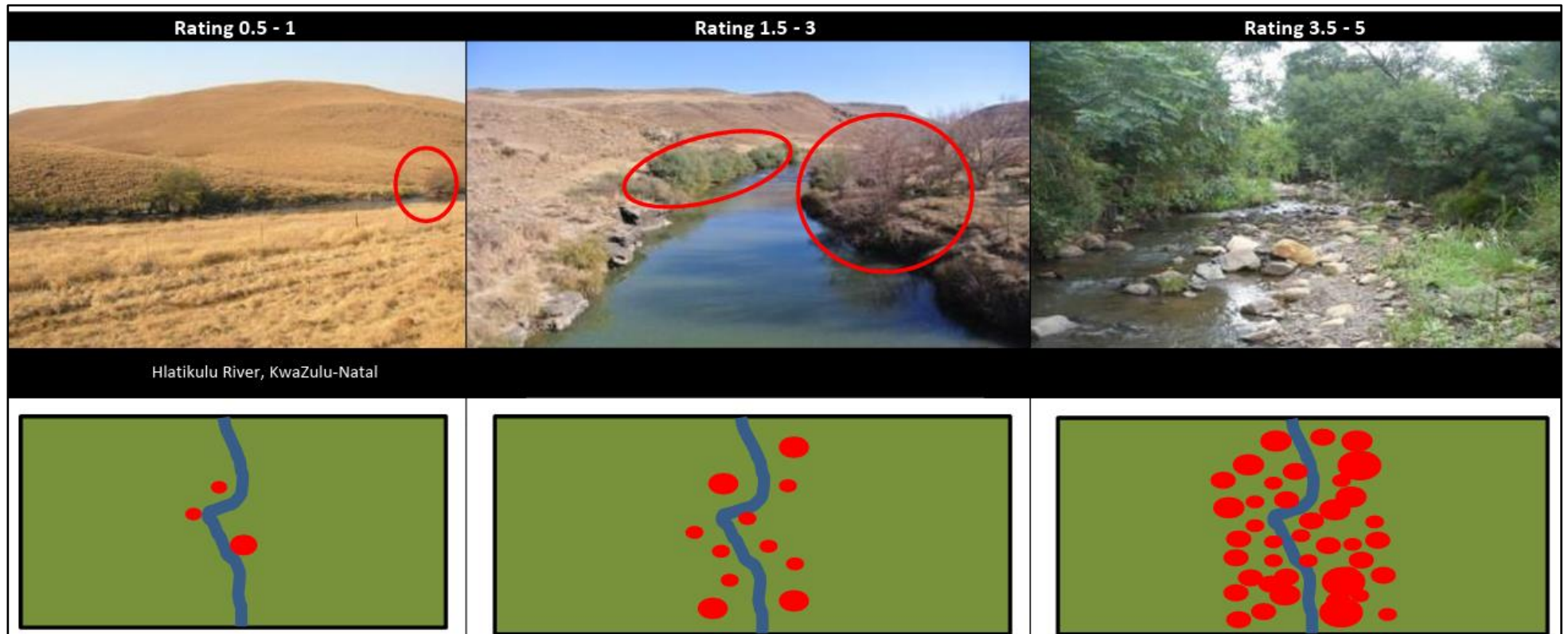
Images not to scale

Appendix A.3 - Riparian Health Audit - Photographic and illustrative Guide to Impacts

(Extracted from Desai, 2016)

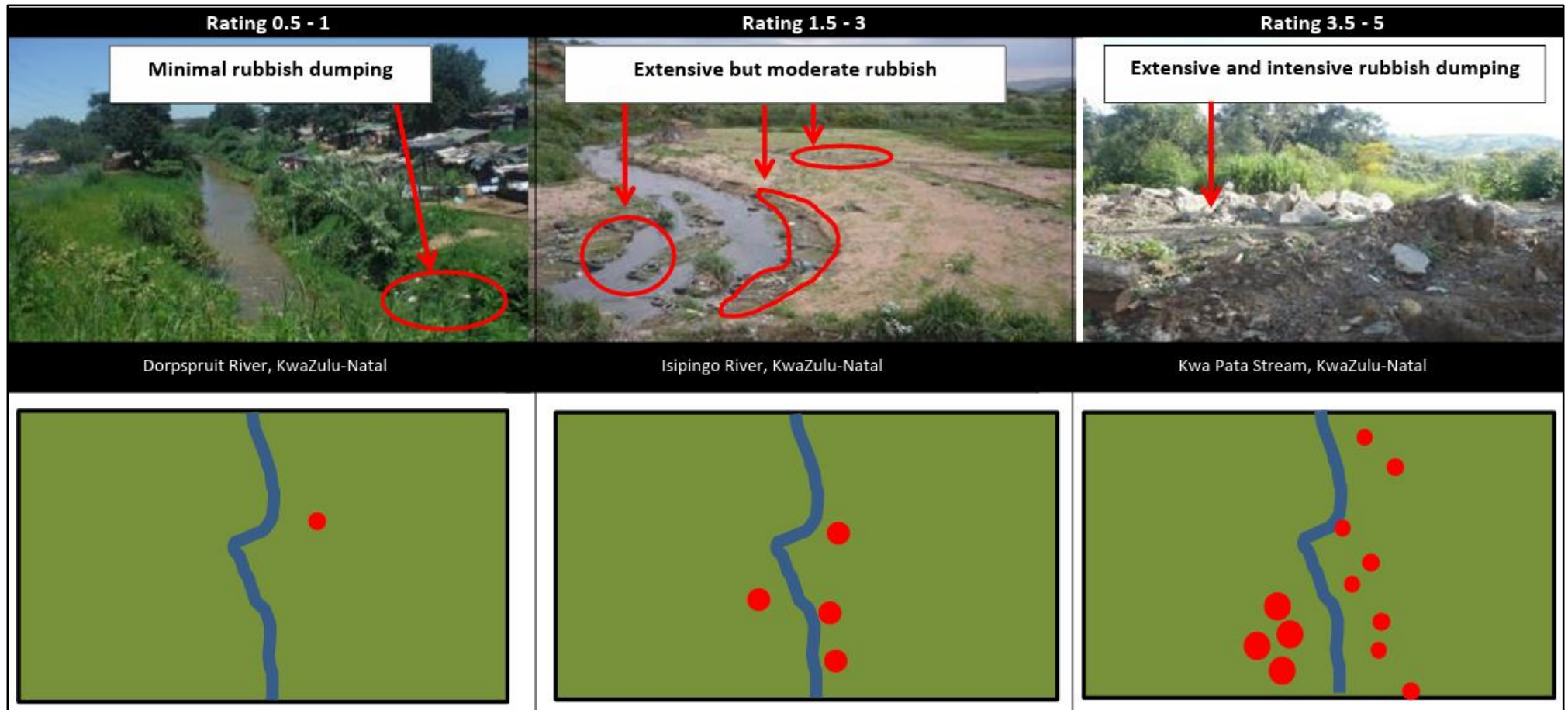
A.3.1 Exotic Vegetation

Exotic vegetation should be rated according to their abundance within the riparian zone. Remember, this includes AIPs, gardens, crops & hedgerows.



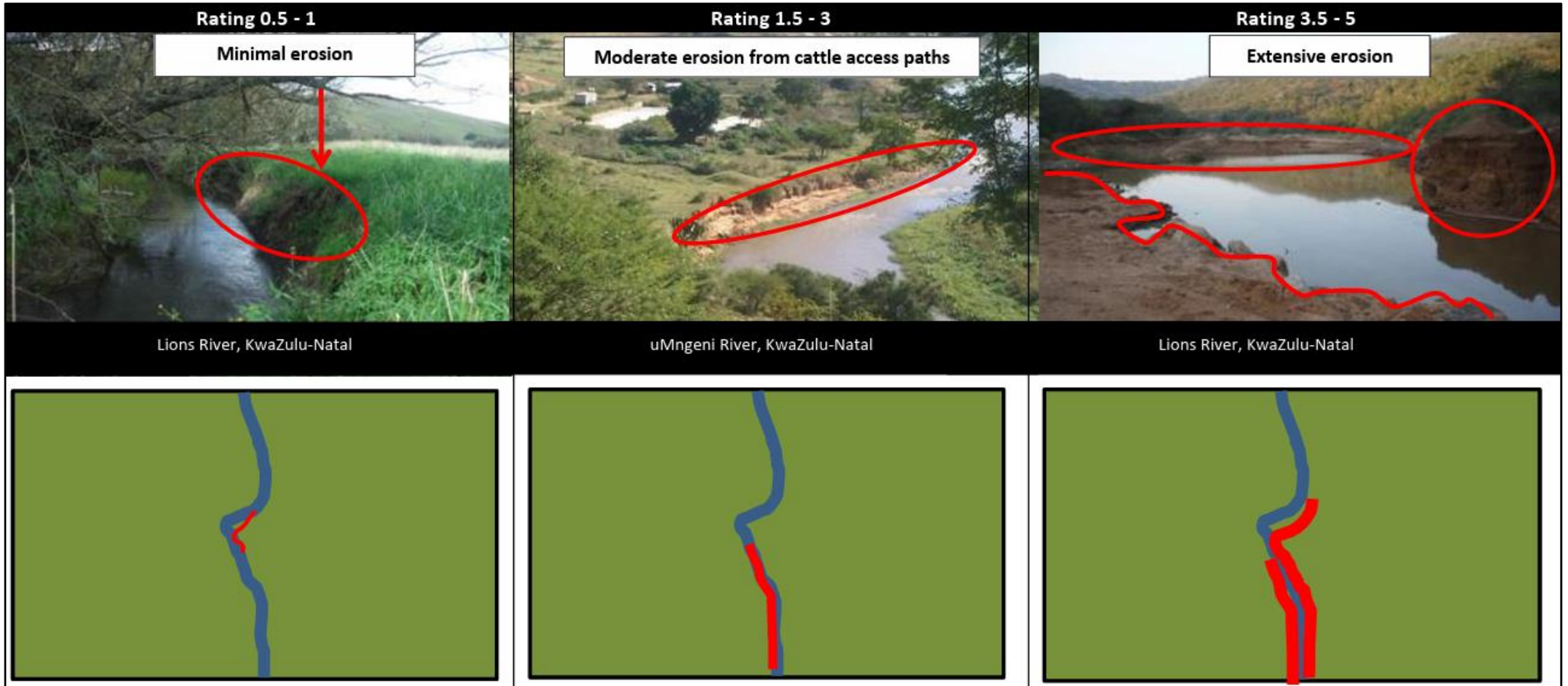
A.3.2 Rubbish Dumping

Rubbish dumping should be rated on the intensity and extent of coverage (percentage of cover) within the riparian zone and the local effects on ecological health.



A.3.3 Bank Erosion

Bank erosion should be rated when it is caused by unnatural circumstances and should be based on the extent of coverage.




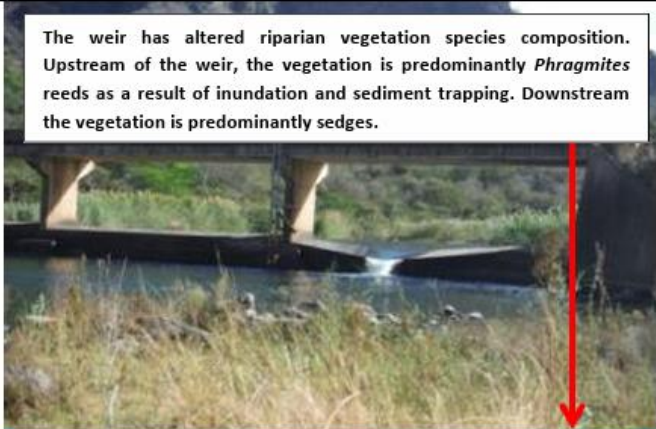



A.3.4 Inundation

Inundation is the flooding of the riparian zone through the construction of impoundments to impede water flow and typically results in an alteration of habitat characteristics. The riparian system is transformed into an aquatic system with a resultant change in geochemical processes and biota.



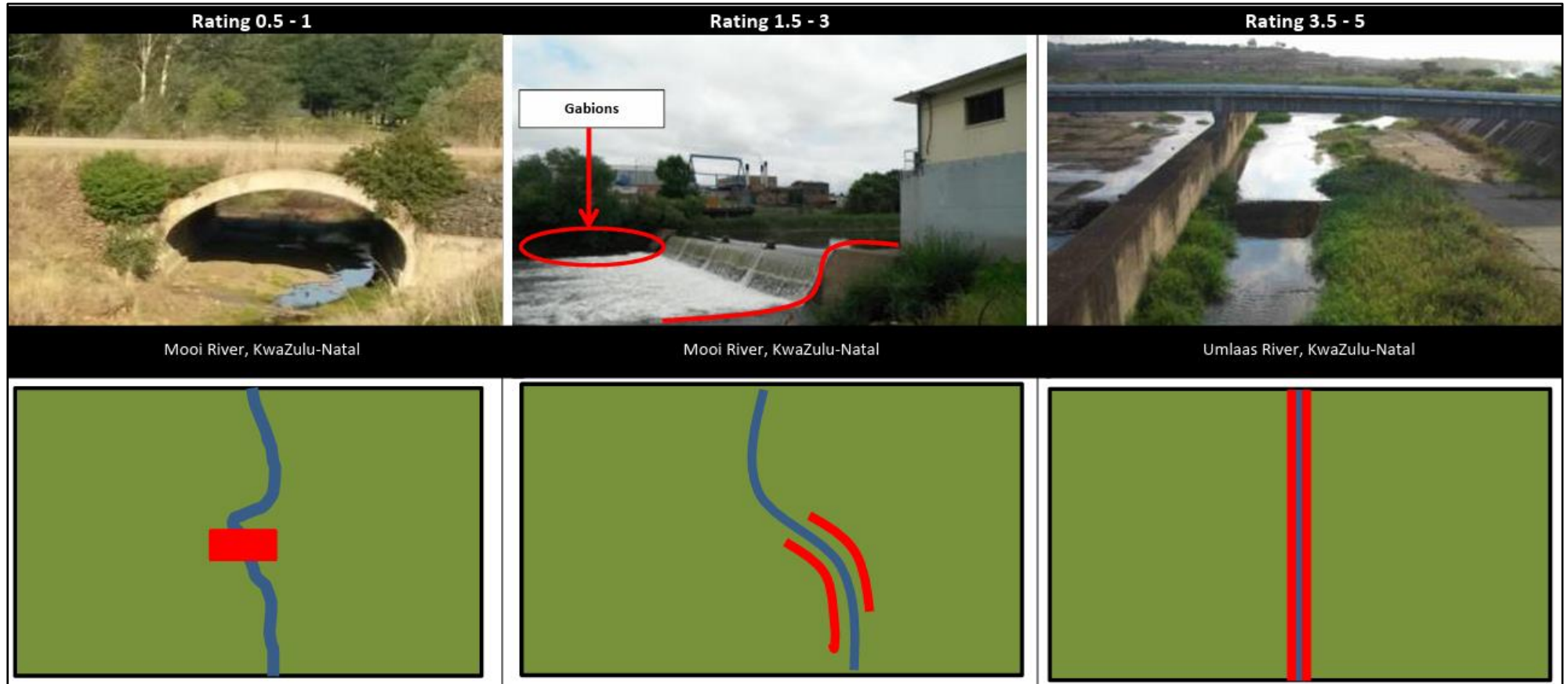
A.3.5 Flow Modification

Flow modifications can be either an increase or decrease in flow, or a change in the natural seasonal flow.

Rating 0.5 - 1	Rating 1.5 - 3	Rating 3.5 - 5
	<p data-bbox="853 368 1462 488">The weir has altered riparian vegetation species composition. Upstream of the weir, the vegetation is predominantly <i>Phragmites</i> reeds as a result of inundation and sediment trapping. Downstream the vegetation is predominantly sedges.</p>  	<p data-bbox="1525 368 2134 456">Dam has largely transformed riparian characteristics downstream via reducing lateral extent of riparian zone and altering vegetation types and species.</p>  
Bush stream, KwaZulu-Natal	uMngeni River, KwaZulu-Natal	Mpushini River, KwaZulu-Natal

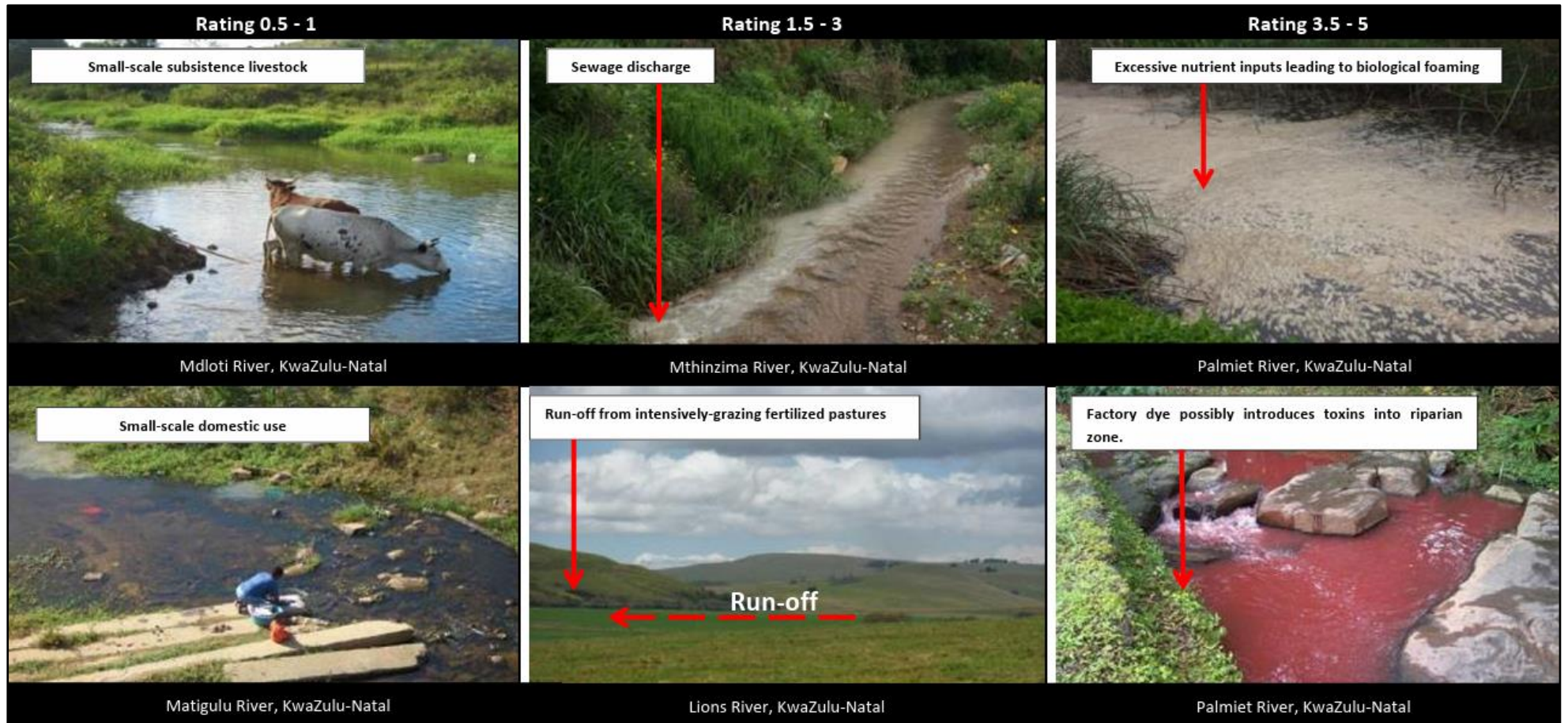
A.3.6 Channel Modification

The rating should be based on the longitudinal extensiveness (how far along the bank) of the modification within the reach being assessed.



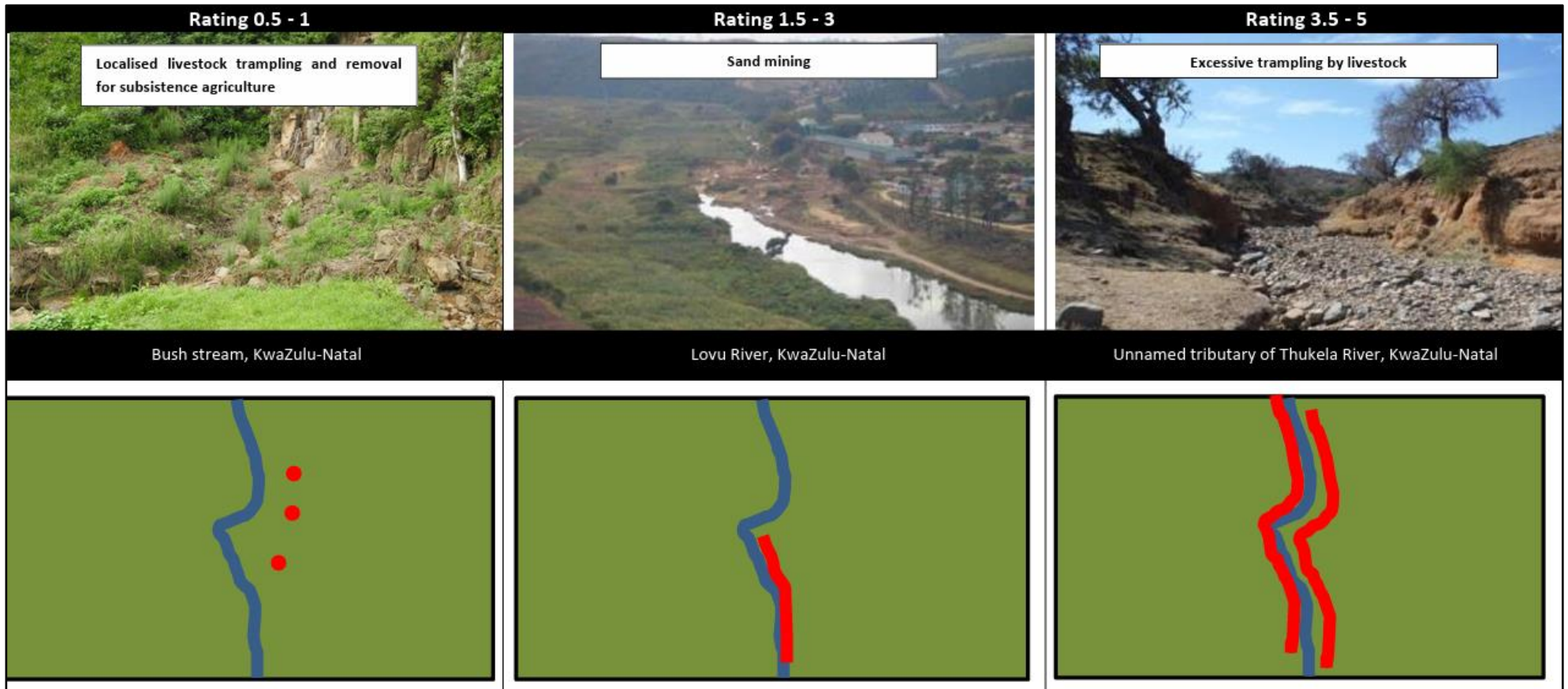
A.3.7 Evidence of Decreased Water Quality

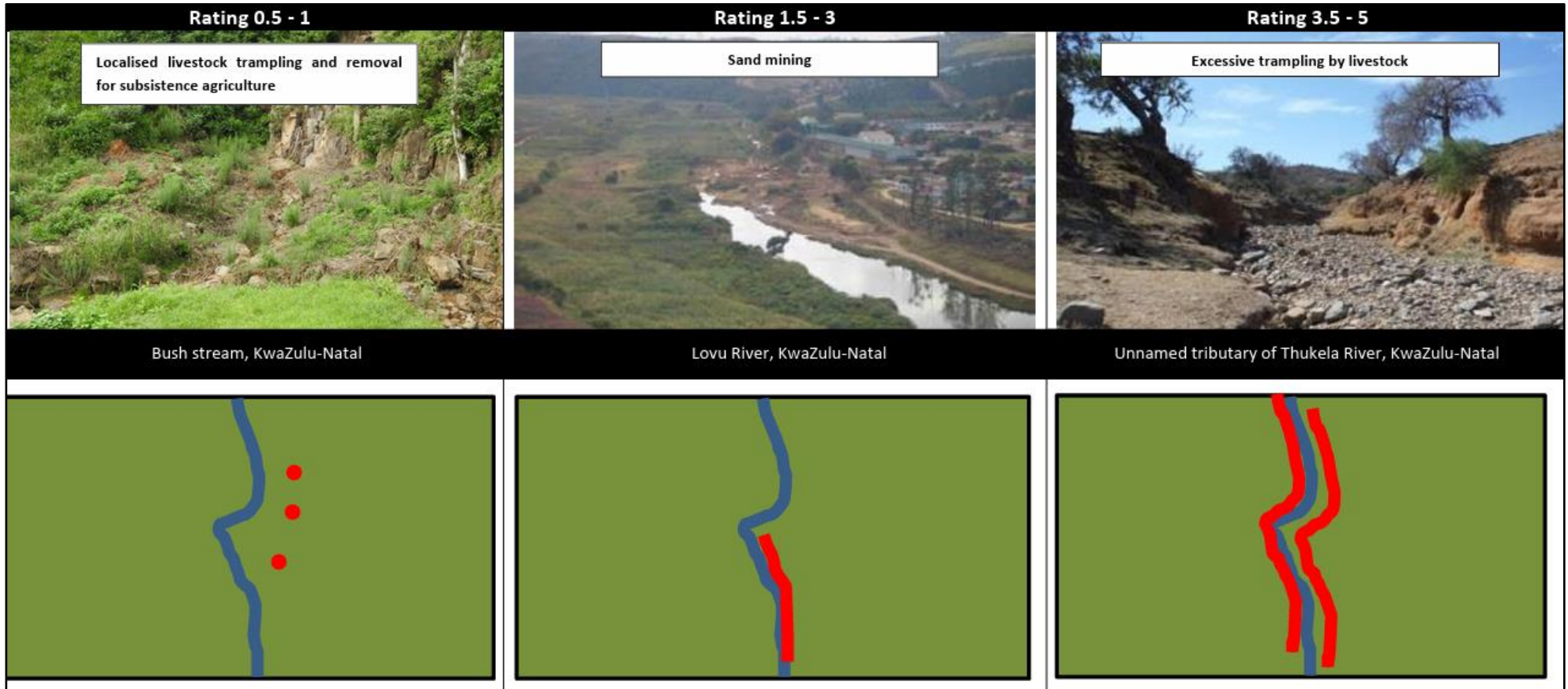
The impact rating is based on the extent of the impact and the overall effect on riparian systems.



A.3.8 Vegetation Removal

The impact rating should be based on the extent of removal.





Part B: Application of monitoring methods to the identified study site

1. Introduction

Alien invasive plants have been a source of major concern due to their negative effects on ecological infrastructure. The Ecological Infrastructure Investment Framework (EIIIF), 2021 was developed under the Western Cape Provincial Biodiversity Strategy and Action Plan to help guide decision-makers from both the private and public sector in where and how to invest to promote the resilience of the province's ecological infrastructure.

As part of EIIIF focus, Management Unit Control Plans (MUCPs) have been developed by the DEA&DP for the Holsloot, Karatara, and Keurbooms Catchments located in the Western Cape of South Africa. These MUCPs provide greater insights into both the threats that AIPs pose, as well as the needs of the stakeholders within these areas. Due to the considerable insights established for these catchments, together with the willingness of landowners to participate, it was decided that one of these catchments would make a suitable study site to test the selected monitoring methods. An overview of this area is shown in Figure 38 below.

In addition to insights gained through the development of the MUCPs, focused work was undertaken within the Keurbooms Catchment during the development of the Group Farm Concept Plans. It therefore made good sense to focus efforts on testing the monitoring methods in the Keurbooms catchment as a continuation of this work.

Due to the expansive nature (85 896 ha) of the Keurbooms catchment it was decided to focus the efforts of the study in a sub-catchment within the Keurbooms broader catchment which spatially aligned with the Middle Group Farm Concept Area. This was done to test the viability and suitability of the proposed methods, as well as to review their applicability and ease of use within the context of the project.



Figure 38: Overview of a sub-catchment in the Keurbooms Catchment which was used as the study area.

Some of the methods which were identified during the literature review were tested, and the monitoring guidelines in Part A provide step by step instructions to enable users to implement them. These monitoring guidelines develop and set out methods that landowners and users can use to measure water quantity and quality gains resulting from clearing AIPs - providing evidence of the contribution that clearing AIPs can have on water availability. It further provides guidance to landowners and land users regarding establishing baselines for the relevant watercourses. These methods are designed to be appropriate in terms of the degree of confidence required, easy so that landowners can undertake the methods, and financially accessible. A number of these methods were tested out within the Keurbooms Catchment; however, they are designed to be rolled in other similar catchment areas.

Part B outlines the proof-of-concept project, providing context for the monitoring guidelines in Part A. This section will provide a description of the study area, as well as how specific sites within this area were selected for testing the methods and undertaking the ecological baseline study. It will include stakeholders that were involved and how these stakeholders have contributed to the project thus far. This part will also include a description of the methods that were tested in the

study area, the results found, and the practicality of these methods for monitoring water quantity and quality. Finally, the ecological baseline assessment for the study area includes mapping of AIP and the associated attribute data collected, with the estimated water loss due to these AIPs; results of three River Health Assessments undertaken; and fixed point photographs taken at two sites. Part B demonstrates the extent of AIP infestations on Jackals Kraal, as well as opportunities for monitoring the impacts of these infestations on water quantity and quality.

2. Study area

Given the large spatial extent of the Middle Group Farm (GF) area and the difficulty of the terrain needing to be covered, together with the limited time, which was available for field testing of the methods, it was decided to focus the testing on a single property. The following criteria were applied for selecting this property:

- Landowner interest in monitoring water flows and quality
- A range of AIP infestations on the property
- Accessibility to a range of potential monitoring sites on the property

Based on the above criteria, the property selected was Jackals Kraal, Farm Nr 25 (area: 1395 ha) located in the Middle Section of the Middle GF. The eastern-most sections of the property were, however, very inaccessible, leaving approximately 900 ha to be used in the testing of the methods. This 900 ha area includes 4 by 4 tracks traversing most of its area.

The selected Jackals Kraal property makes up the upper portion of the catchment drained by the last major tributary of the Keurbooms River before its confluence with the Palmietrivier. The entire portion of the catchment is underlain by Table Mountain Sandstone Group, Nardouw subgroup. This catchment portion runs in a west to east direction and includes two main aspects: north-facing and south-facing. The south-facing slopes extend to higher altitudes than the north-facing slopes (596m compared with 516 m) and are more steeply sloped (25-45% slopes compared with 15-20% slopes). The tributary streams from the south-facing slopes appear to have flows which are inherently more sustained than those of the north-facing slopes (Rogers D, 2023. Pers comm, Jackals Kraal, Knysna Region). This is likely owing to differences between the respective slopes in terms of factors such as aspect, elevation and slope steepness, and possibly also hydrogeology. The most perennial of the south-facing tributaries, which is fed by the highest elevation areas in the property, is used as the primary water supply point for the property. This continued to flow during the several years of consecutive below average rainfall encountered from 2016 onwards, but eventually ceased to flow shortly before the drought broke in 2022 (Rogers D, 2023. pers. comm., Jackals Kraal, Knysna Region).

At least seven of the south-facing tributaries have what Daniel Rogers (2023, Pers. comm., Jackals Kraal, Knysna Region) describe as springs, which he has verified. It is important to note that these are not springs in the strict sense of being sites where water flowing below the ground discharges onto the surface at a localized site, usually upslope of a stream or at the head of a stream channel. Instead, these springs lie within the stream channel well downstream of the channel head and result from the discharge of subsurface water which is not confined to a localized site.

The main stream draining the catchment portion is largely perennial, and since being observed by Daniel Rogers (2023. Pers. comm., Jackals Kraal, Knysna Region) from 2015, it was only in 2020 that it stopped flowing. Interestingly, this drying up of flows was despite the fact that some of the key tributaries continued to flow at least for another year (Rogers D, 2023. pers. comm., Jackals Kraal, Knysna Region). The dense growth of black wattle which had grown up in the main stream a few years after the 2015 fire is likely to have played a key role in hastening the drying up of its flows. Also influencing flows was the 2016 fire which burnt most of the 900 ha area. As to be expected, despite being below average rainfall years, water flows were relatively high for the first year or so following the fire given that the vegetation growth and associated transpiration were still relatively low, but the level of transpirative loss would have gradually increased over time with vegetation regrowth, particularly of black wattle.

Direct human use of water in the 900 ha is minimal and confined largely to water for domestic use and household gardens for seven individuals. Thus, overall, the primary human impacts to water flow are through the increased water use associated with AIPs in the catchment.

Within the 900 ha area, AIP infestations are greatest in the riparian area associated with the main channel. However, this infestation varies greatly down the length of this area, including a large approximately 40 ha dense infestation in its upper reaches, smaller patches in the mid-reaches and scattered trees in the lower reaches. Outside of the riparian area of the main stream, infestation (mainly of pines and hakea) is greatest in the catchments of the first three tributaries in the south-facing slopes, and somewhat less in the catchments of the remaining south-facing tributaries and all of the north-facing tributaries.

3. Site selection

The following factors were considered when deciding where to locate the monitoring sites within the overall selected 900 ha area.

- Natural features of the selected area and relative infestation levels of AIPs, described in the previous section.
- Opportunities for the inclusion of a control site.
- Opportunities for using natural or human-made focal points of water flow to facilitate the reliable measurement of flows.
- Accessibility of the site

Springs are immediately affected by the AIPs growing in what is usually a relatively small upslope area, for which the likelihood of there being other confounding factors affecting water quantity is much lower than for a site lower in the catchment. Thus, springs were seen as representing one of the best opportunities for demonstrating direct causal links between AIP clearing and increased water flow. In terms of tributaries, the south-facing tributaries were prioritized given their greater flows compared with the north-facing tributaries, as described in the previous section.

The first three of the south-facing tributaries have catchments with some of the highest AIP infestation levels in the 900 ha area and appear fairly comparable. Thus, they appeared to potentially represent the best opportunity for a paired catchment approach, whereby two

comparable catchments, one cleared of AIPs and the other not cleared (the negative control) are compared so as to reliably isolate the specific effect of AIPs on catchment water yield. Had the springs in these three catchments been located at the stream heads they would have been easy to access given that the 4 by 4 track runs close to the stream heads. However, they are located >200m downstream on an extremely steep slope with dense vegetation difficult to walk through. A further difficulty is that, as described earlier, water discharge is not at a localized site which can be easily collected, thus requiring the introduction of a human-constructed method to facilitate measurement of flow. For these reasons, they were judged to be less suitable than initially had been anticipated.

Given the challenge described above of springs not being localized, the spring used as the main water source on the property provides a good opportunity for collecting water as it has a specially constructed sump drained by an outflow pipe which was designed for the collection of water for human use. In addition, the landowner has a particular interest in monitoring this spring as it is their primary water source. Furthermore, this site is relatively accessible and the tributary immediately to the east could potentially serve as a control site (although it would likely require the introduction of a human-constructed method to facilitate measuring of flow). The main disadvantage of the water source site is that AIP infestations in its catchment are not high, making it potentially difficult to detect changes in flows as a result of clearing of the AIPs in the catchment of this tributary.

An opportunity exists for measuring the outflow from the overall 900 ha area, which could potentially be cleared of AIPs enough to result in a detectable contribution to waterflows, particularly if the focus of the clearing was on the upstream wattles in the riparian area. In addition, near the outflow of the 900 ha area, water flow is focussed through four culvert pipes, which provide a potentially promising opportunity for measuring flows. Prior to the major flows of 2022/23, the outflow of the culverts was above ground level, readily facilitating the measurement of flow out of the culvert/s. However, owing to recent sediment deposition, the current ground level now lies above the bottom lip of the culverts, thereby negating this potential measurement opportunity. Thus, for the purposes of field testing, a temporary V-notch weir was installed to measure flow. Nevertheless, it should be noted that if the recently deposited sediment immediately below the culvert was cleared at the culvert outflow then in the future the culvert itself could potentially be used to assist in measuring stream discharge. A potential reference site for this monitoring at the outflow of the 900 ha area would be in a comparable similar catchment immediately north, which also has a tributary of the Keurbooms flowing in west to east direction, but under different ownership. There was inadequate time during the field visit to verify the suitability of this catchment.

4. Stakeholders

We involved a variety of landowners, stakeholders, and interested and affected NPO's, institutions and authorities. Landowners and farmers within the Middle GF and South Group Farms (GF) were invited to participate in a meeting to inform the development of methods which would be suitable, easy and appropriate for use on their land. Landowners were also given the opportunity to join for a site visit to provide insight into where on their farms these methods could be implemented and tested. Local authorities included representatives from the Knysna and Bitou Municipality; Department of Water and Sanitation. The Breede-Gouritz Catchment Management Agency was included to provide representation of a Catchment Authority. Representatives from Protected Areas such as SANParks and CapeNature were invited to participate, as well as the Garden Route Biosphere Reserve. Other interested and affected organisations in the area such as the Eden to Addo Corridor Initiative, the Keurbooms Ecological Infrastructural Investment and Outeniqua to Tsitsikamma Water Working Groups were also included. These stakeholders were invited to join a meeting to provide valuable insight into the areas and to provide input on methods that might be appropriate for the guidelines. Further, they were invited to visit the study site to determine if these proposed methods would be effective, and to engage further on how these methods could best be applied. These stakeholders were also given the opportunity to suggest any other stakeholders in their networks who would be able to provide valuable insight into this project.

5. Field-testing methods

The Apex Conservation Services (ACS) team, including Bruce Taplin, Dr Donovan Kotze, Rachel Putzier, and Stefan le Roux, visited the study area on 6 and 7 September 2023, with stakeholders joining them on 8 September 2023. One of the purposes of the field visits was to evaluate some of the methods found during the literature review in order to determine the practicality of applying these methods for the scope of this project. Four methods were field-tested: (1) Container fill method; (2) float method; (3); 90° V-notch weir method; and (4) the water clarity tube method.

The container fill method was tested at Spring 1, which is the only water source for the landowner. The method was tested at a constructed sump drained by an outflow pipe which was designed for the collection of water for human use. Figure 39 illustrates how the method was applied by utilizing the outflow pipe.



Figure 39: Container fill method tested out in the field at Spring 1.

In order to measure the spring discharge at the site, the time to fill a 1.75L water bottle was recorded. The method was repeated six times (see field sheet in Appendix B.1.1). The average discharge at Spring 1 was calculated as 1.94L/min. The container fill method was very easy to use and, only using a water bottle, required minimal resources. The method will, however, require more time and resources if a structure such as the sump with the outflow pipe is not present at a given study site, and has to be built in order to collect all discharged water.

The float method was tested at Site 3. In order to do so, a small temporary channel was created. The distance marked out for the method was 100cm. First, to measure the speed of the stream, a small piece of wood (about 5cm) was allowed to float the 100cm distance. The time was recorded. This procedure was repeated 10 times. The width and depth of the stream was measured at three areas in the channel. The average width and depth were 13.83cm and 4.5cm, respectively. The average area was calculated as 62.24cm². The average area and speed (48.95m/s) were used to calculate the average streamflow at Site 3. The result, measured with the float method, was 182.81L/s (See Appendix B.1.2 for field sheet). Figure 40 shows the float method tested out during the field visit. The float method is easy to use. The only equipment required were the spade to dig the channel and a tape measure to measure length of the floating distance, depth and width. Although digging the channel took some time, using the method itself only took 5 - 10 minutes.



Figure 40: Testing out the float method at Site 3.

A 90° V-notch weir was made during the field visit (Figure 41.1) and installed at Site 3. The weir was made out of wood, as shown in Figure 41.2. A chainsaw and handsaw were used to cut the notch. The notch height cut into the plank was 154mm. The weir can be seen in Figure 41.3.



Figure 41: The portable weir method: (1) the weir was constructed in the field; (2) the weir headboard ready for implementations; (3) and the weir being tested in the field.

The weir was installed into the channel dug for the float method and stabilized with rocks on either side of the weir base. A stick was used as a measuring gauge and was placed 24cm from the weir. The head measured was 6cm. A conversion table was used, and the measured head was converted to a streamflow of 1.2L/s. The field sheet can be seen in Appendix B.1.3. The construction and installation of the weir took about two hours. Once this has been done, however, the process will be much faster as it took less than five minutes to take the measurement and to determine streamflow with the conversion table. However, the temporary nature of this structure may be a limitation if there are heavy rains or floods, as an increase in water flow may compromise the weir plate. Figure 42 demonstrates the weir plate which we implemented in the Keurbooms Catchment which was slightly displaced after heavy rains within the area. Encouragingly, the landowner has already reinstalled the weir plate which demonstrates interest and commitment to the project.



Figure 42: Temporary weir plate compromised after heavy rainfall in the Keurbooms Catchment (Image: Daniel Rogers, 2023).

The water clarity tube was also tested. It was found that some difference in the results were found between different observers. The same person should therefore do all the measurements with the water clarity tube. There was also some fluctuation between taking readings in direct sunlight compared to taking readings in the shade. The readings should be taken with the clarity tube held

perpendicularly to the sunlight. No results of the water clarity tube were however recorded. The water clarity tube is easy to use and is a time-effective method for measuring water quality.

6. Ecological baseline assessment

The ACS team undertook a rapid ecological baseline assessment on Jackals Kraal, Farm Nr 25, in the Keurbooms River Catchment on 6 to 8 September 2023. The assessment consisted of three key components, namely: (1) Remapping of AIPs and establishment of attribute data, (2) Riparian Health Assessments (RHAs), and (3) Fixed point photography (FPP).

6.1 Mapping and establishing attribute data of AIPs

Broad scale mapping was undertaken during the development of the Middle GF Concept Plan however, for the purpose of the current task we required mapping at a finer scale. During the reassessment of the area there was an opportunity to collect additional AIP information and remap the study site at a finer scale (see Figure 43 which illustrates the revised AIP Management Units).

The revised AIP data was used to estimate the amount of water loss within the area as a result of the AIP infestations by using the application developed by Glenn Moncrieff and SAEON. The application allows the user to model the estimates based on key input data of AIPs, namely: mean age, canopy cover, size of the infested area, and the GPS location.

In order to estimate the amount of water loss due to AIPs in each management unit (MU), as well as the total water loss within the area, the extent of the AIPs had to be determined. Figure 44 shows the dominant AIPs and density of infestation in each MU.

The SAEON application was used to estimate the water loss as a result of AIPs for each MU. Figure 45 shows the estimated water loss for each MU per annum.

The results of modelled AIP attribute data are listed in Table 20. Estimated water loss per hectare per year was the highest for the Upper Riverine area (1063.76 kL/ha/yr) and MU 08 (1013.46 kL/ha/yr), due to the high density of *A. mearnsii* in these areas.

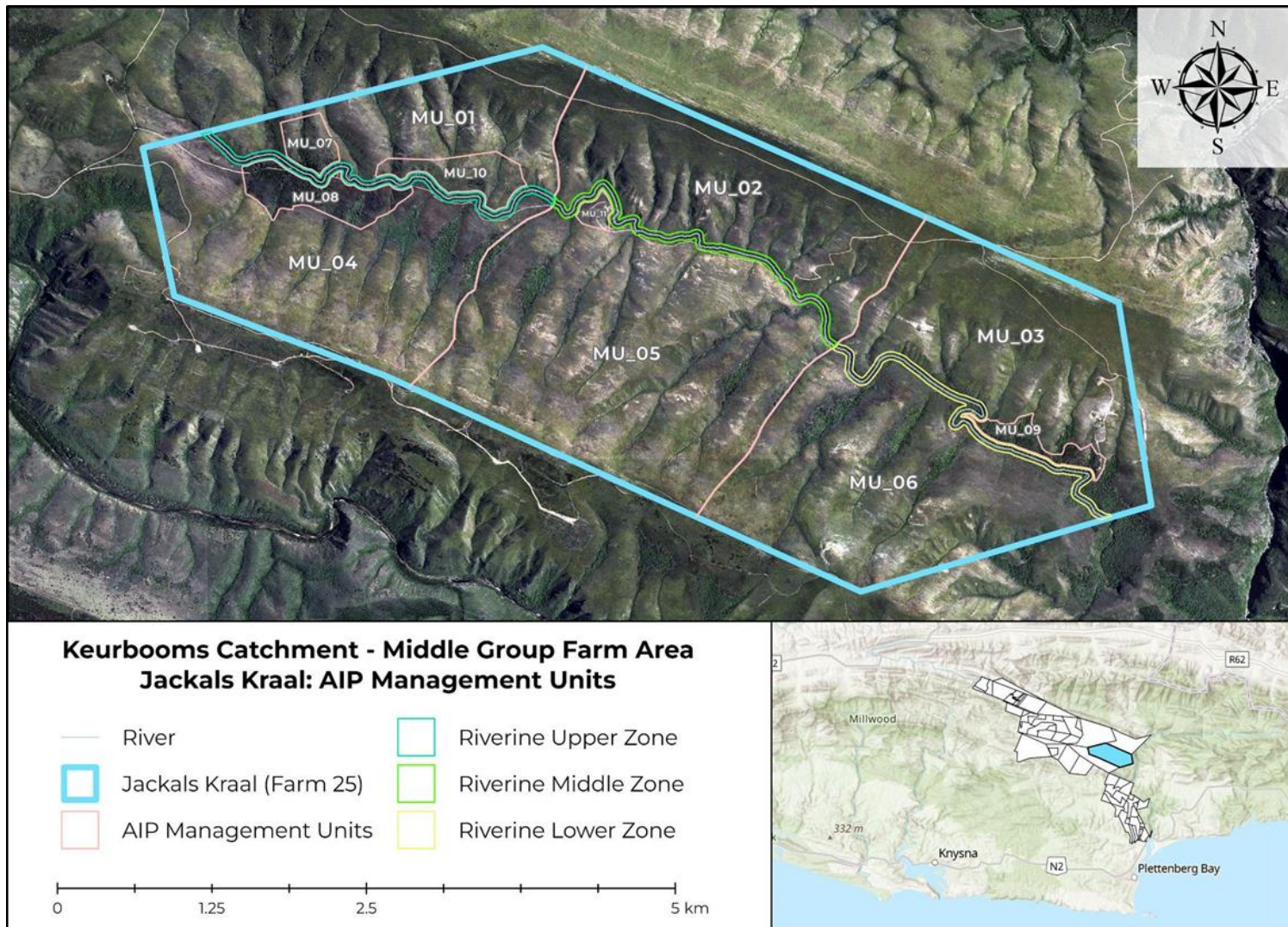


Figure 43: Newly established AIP Management Units on Jackals Kraal Farm.

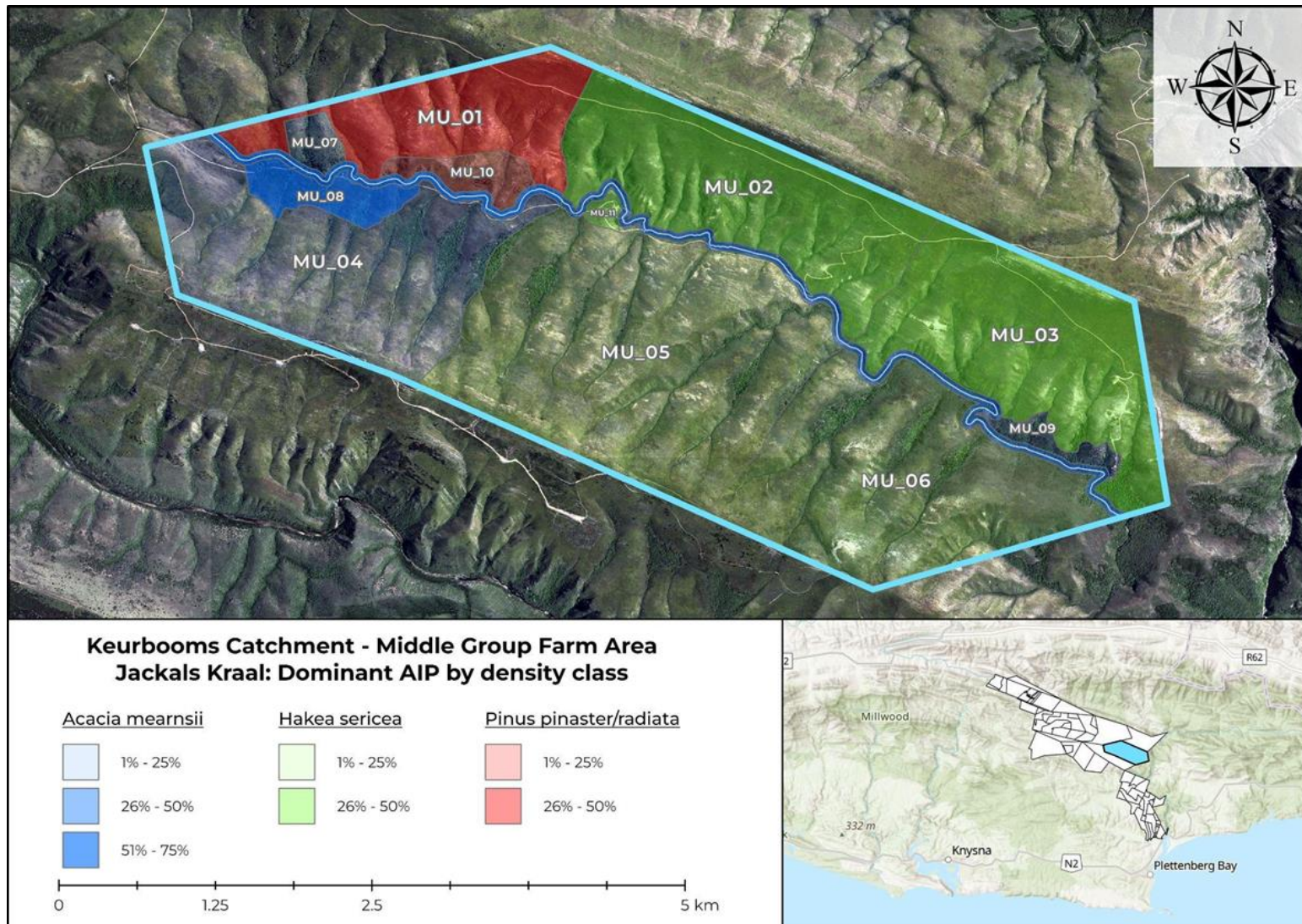


Figure 44: Illustrates the distribution of dominant AIPs by density class.

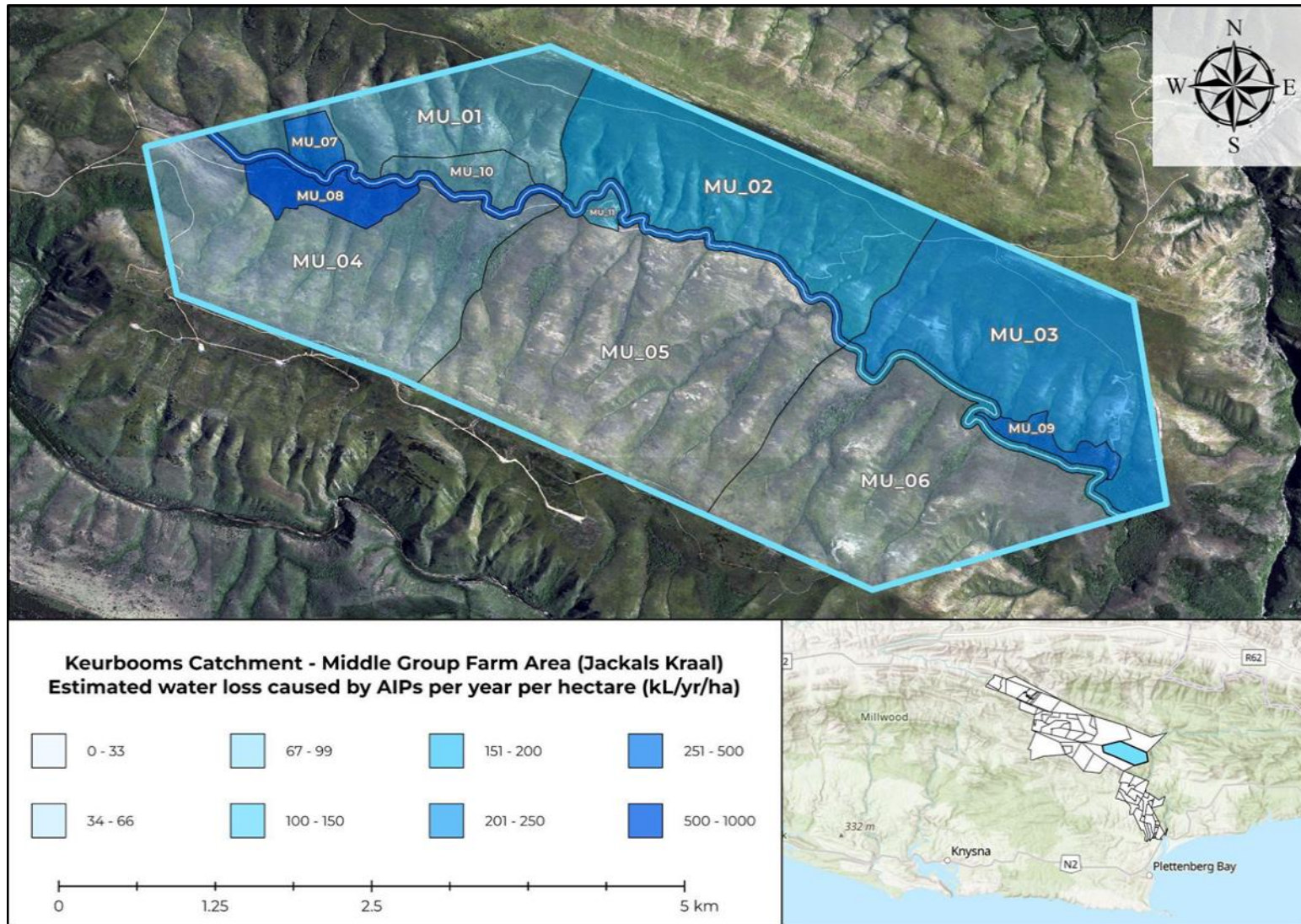


Figure 45: Estimated water loss caused by AIPs per year per hectare (KL/yr/ha) within each of the MU's.

Within each of these MUs, different AIP species occur at a variety of ages and density classes. In Figure 46 photos of some of the main AIPs infestations in the area are presented.

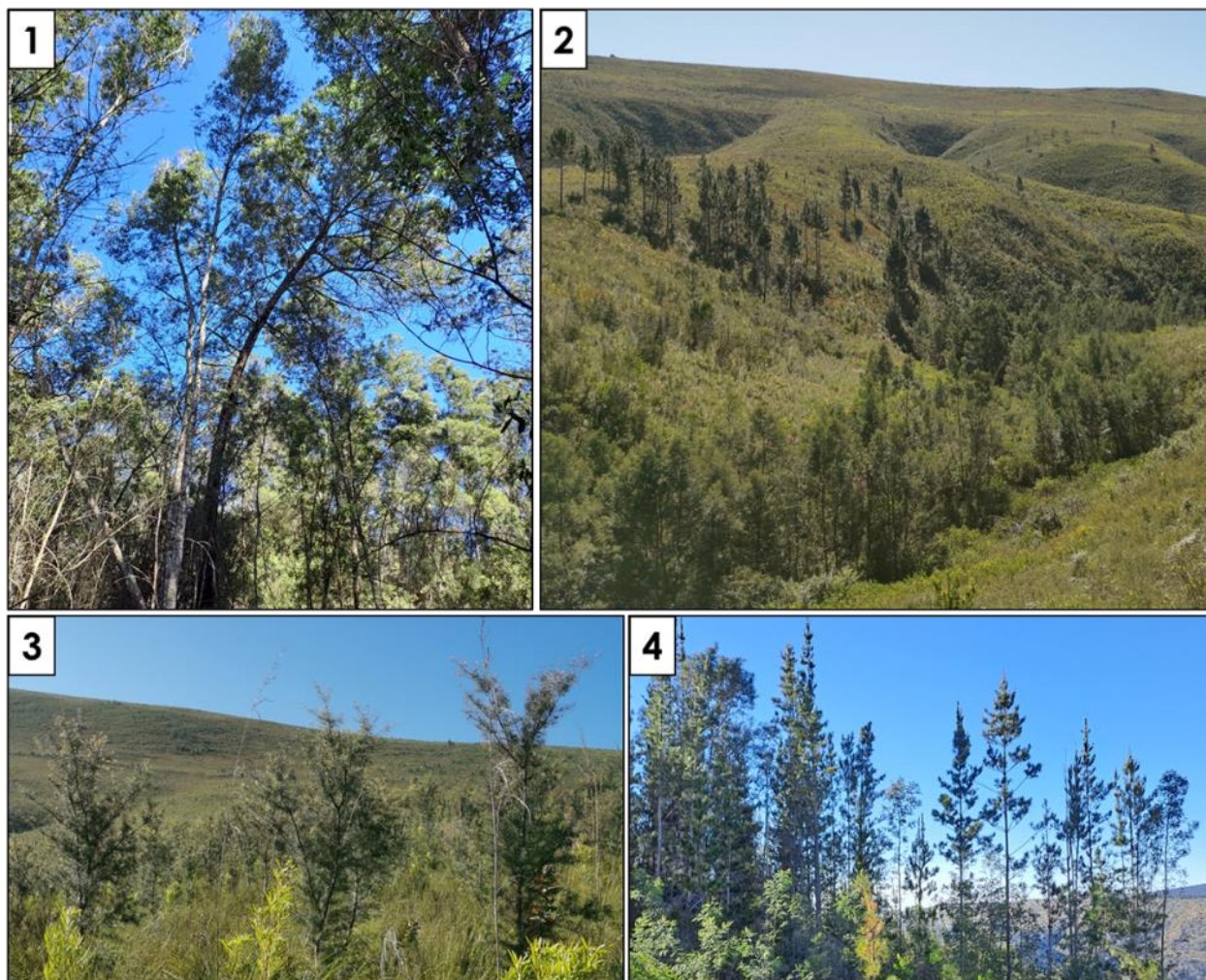


Figure 46: Representations of AIPs in the study area: (1) High density stand of adult *A. mearnsii*.; (2) High density adult *A. mearnsii* in the riparian area and lower density adult *Pinus* spp. higher on the slope; (3) Medium density young *H. sericea*; and (4) High density *Pinus* spp.

In Table 20, the attribute data established for the area is displayed. The table provides data on the dominant species within the area, including the water loss per area due to AIPs, estimated with the SAEON application. Estimated water loss per hectare per year was the highest for the Upper Riverine area (1063.76 kL/ha/yr) and MU 08 (1013.46 kL/ha/yr), due to the high density of *A. mearnsii* in these areas. The estimated annual water loss for the area were 125.70 kL/ha, with a total estimated annual water loss of 175 401.36 kL for the whole property.

Table 20: Attribute data established mapping of AIPs within the area. Columns are hidden in the dataset: the zone, sectors, dominant terrain, and coordinates.

UID	Area (ha)	IAP Species #1	Age class of Species #1	% Density of Species #1	Estimated water loss caused by Species #1 per year (kL/yr)	IAP Species #2	Age class of Species #2	% Density of Species #2	Estimated water loss caused by Species #2 per year (kL/yr)	IAP Species #3	Age class of Species #3	% Density of Species #3	Estimated water loss caused by Species #3 per year (kL/yr)	Combined estimated water loss per year (kL/yr)	Normalised estimated water loss (kL/yr/ha)
MU_01	107,58	P. pinaster/radiata	Mixed (Young)	30	6259,85	Hakea sericea	Young	20	652,79	A. mearnsii	Mixed	5	2469,13	9381,77	87
MU_02	184,01	H. sericea	Young	35	28861,48	P. pinaster/radiata	Young	10	3976,50	A. mearnsii	Young	3	3245,15	36083,12	196
MU_03	190,11	H. sericea	Young	35	31194,50	P. pinaster/radiata	Young	10	4735,61	A. mearnsii	Young	3	3438,79	39368,90	207
MU_04	216,15	A. mearnsii	Young	7	9508,83	H. sericea	Young	3	3241,09	P. pinaster/radiata	Young	2	1141,98	13891,91	64
MU_05	336,84	H. sericea	Young	3	4725,69	P. pinaster/radiata	Young	2	1103,16	A. mearnsii	Young	1	2012,05	7840,89	23
MU_06	233,24	H. sericea	Young	3	3578,40	P. pinaster/radiata	Young	2	178,15	A. mearnsii	Young	1	1579,02	5335,57	23
MU_07	11,27	A. mearnsii	Mixed (Adult)	15	2252,70	P. pinaster/radiata	Adult	20	1483,11					3735,80	331
MU_08	26,38	A. mearnsii	Mixed (Adult)	75	26735,07	P. pinaster/radiata	Adult	2	287,07					27022,14	1024
MU_09	12,27	A. mearnsii	Adult	20	3650,07									3650,07	297
MU_10	20,23	P. pinaster/radiata	Adult dominant	15	1729,84									1729,84	86
MU_11	4,34	H. sericea	Young	25	490,26	A. mearnsii	Young	5	122,91	P. pinaster/radiata	Mixed (Young)	2	20,44	633,61	146
RL	18,6	A. mearnsii	Young	35	3714,89									3714,89	200
RM	16,94	A. mearnsii	Young	45	4460,85									4460,85	263
RU	17,44	A. mearnsii	Mixed (Adult)	75	18551,99									18551,99	1064
Total	1 395,40				145 714,41				15 780,39				13 906,56	175 401,36	

6.2 Riparian Health Assessment

A Riparian Health Audit (RHA) was conducted at three different sites in the study area. The RHA is used to evaluate a river's habitat integrity through analysing the conditions of a portion of the river margins (the riparian reach). For the RHA, eight impacts that have potential negative effects on the functioning and integrity of riparian ecosystems are identified and scored out of five. The eight impacts are exotic vegetation, rubbish dumping, bank erosion, inundation, flow modification, evidence of decreased water quality, removal of indigenous plants (including vegetation displacement) and channel modification.

In Figure 47 the points of interest in the study area are displayed. RHAs were undertaken at Site 1, Site 2, and Site 3.

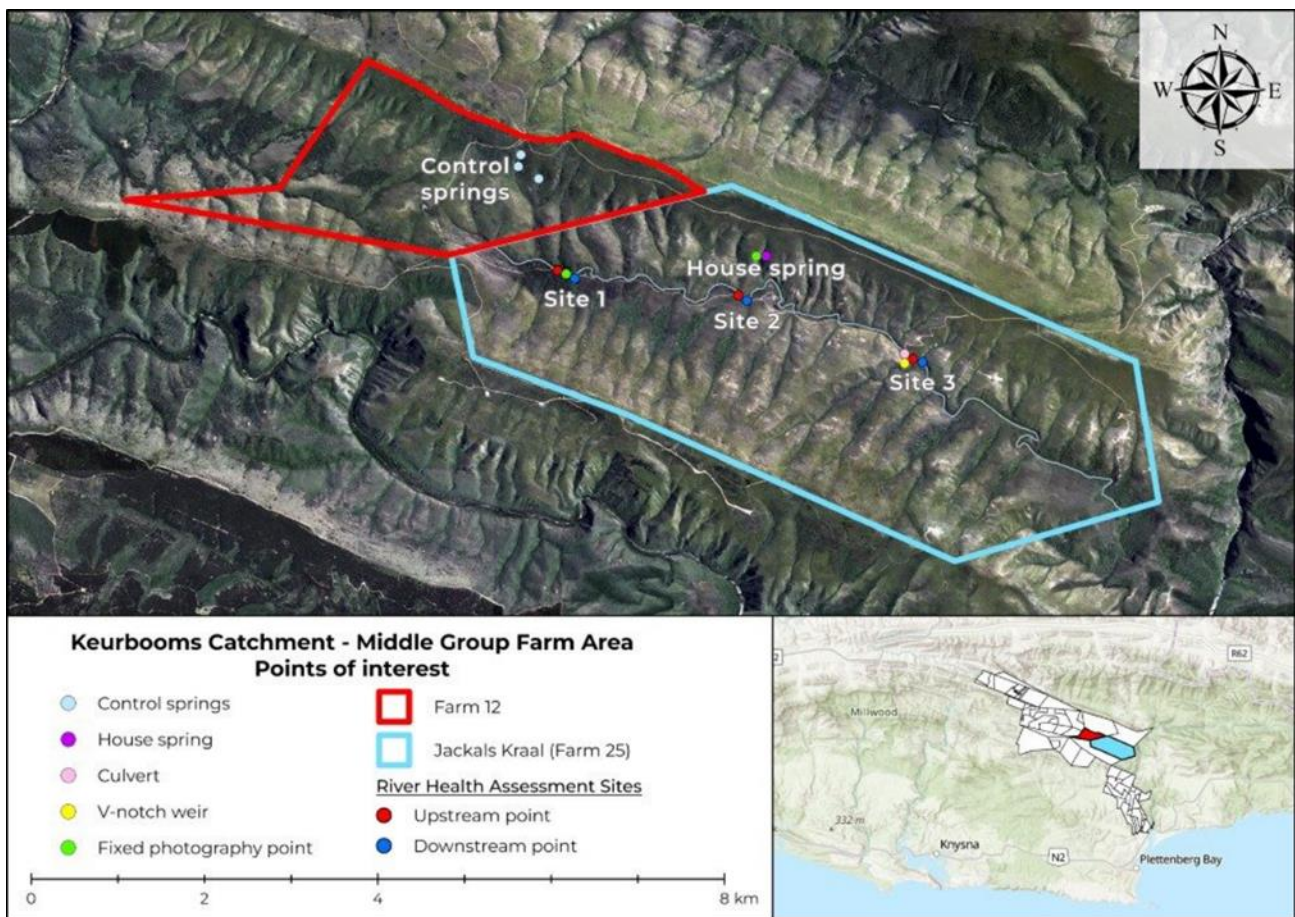


Figure 47: Points of interest in the study area.

Appendix B.2.1 lists the results of the RHA undertaken at Site 1 which had a fair ecological condition, with a percentage change of 42.5%. The greatest impact on the area was AIPs and Vegetation Removal (displacement due to AIPs), scoring a 4 out of 5 for both.

Site 1 was a highly transformed riverine habitat. There was a closed stand of mixed aged *Acacia mearnsii*. The density of the AIPs was 75%. Bank destabilization was also observed, most likely due to the extensive *A. mearnsii* infestation. According to the RHA, the site was in a fair ecological condition, with a percentage change of 42.5%.

Due to the extensive infestation of *A. mearnsii* along this river and the number of *Pinus pinaster* adults, Site 1 was given an exotic vegetation rating of 4.5. No rubbish dumping or inundation is present. Limited bank erosion (score of 2) was observed where some of the AIPs present have fallen into the river and destabilized the bank, however this is localised. The key factor altering the flow regime was *A. mearnsii* - this was scored a 3 based on the adult AIP stands which use up water – and there was no river water flowing at this site likely because of this effect. Falling AIPs change the riverbanks and destabilize them which may cause a change to channels, giving it a score of 2. There was no flowing stream on which to base the water quality score – this score (1.5) was therefore based partially on our knowledge of the system and the effects of AIPs on water quality and partly on the stagnant water remaining in the system. Indigenous vegetation at the site was displaced and outcompeted by AIPs which caused a “removal” of native plants, which is why the high score of 4.5 was given for the site.

Indigenous species present at Site 1 are: *Dietes iridioides*, *Pittosporum viridiflorum*, *Helichrysum petiolare*, *Diospyros dichrophylla*, *Gymnosporia buxifolia*, *Panicum deustum*, *Halleria lucida*, *Rapanea melanophloeos*.

In Appendix B.2.2 the results of the RHA undertaken at Site 2 are displayed. The greatest impact on the area was the AIPs, scoring a 3 out of 5. The area had a percentage change of 23.75%, which is good ecological condition.

Site 2 is a marginally transformed river stream. *A. mearnsii* is present at 5 – 10 % density infestation causing the bulk of the ecological challenges. There is a moderate representation of indigenous vegetation still present. In certain areas *A. mearnsii* has fallen and changed river flow conditions. According to the RHA, the site was in a good ecological condition, with a percentage change of 23.75%.

At Site 2, exotic vegetation scored a 3. *A. mearnsii* is the most dominant and is in the process of replacing the indigenous vegetation. *Rubus fruticosus* (Bramble) is also present. No rubbish dumping or inundation was present at the site. Bank erosion scored a 1 for the slight bank erosion caused by falling *A. mearnsii*. Most bank erosion is however natural. There is a score of 2 for flow modification here, as *A. mearnsii* and other AIPs use up more water than indigenous vegetation, reducing the amount of water available to flow through the system. There is however a lower presence of wattles here. There is a slight alteration (rating: 1) in the channel structure caused by AIPs with a drop off in the middle area which is steeper than one would expect naturally. Evidence of decreased water quality was limited (score of 1), with a low-density AIP stand present that could decrease the water quantity and affect the dilution capacity. The vegetation removal scored a 1.5. There are indigenous species present, however *A. mearnsii* is moving into and increasing in that area which will pose a threat of indigenous plant removal.

The indigenous species present at Site 2 are *Osteospermum moniliferum*, *Virgilia oroboides*, *Helichrysum petiolare*, *Polygala fruticosa*, *Searsia pyroides*.

In Appendix B.2.3 the results of the RHA undertaken at Site 3 are displayed. The site was in the best condition of the studied areas, with most impacts having zero or low scores. The site had a percentage change of 10%, classifying it with a natural ecological condition.

The RHA was done down the river from the culvert. Site 3 had an extensive infestation of scattered AIPs including *A. mearnsii*. This is a marginally transformed river stream with a good representation of indigenous vegetation still present. There is however a threat of AIPs moving into the area. According to the RHA, the site was in a natural ecological condition, with a percentage change of only 10%.

The site scored a 1 for exotic vegetation because of the presence of isolated stands of young *A. mearnsii* trees, as well as *R. fruticosus* which is prominent along most of the middle and eastern riverine areas. No rubbish dumping, artificial bank erosion, or inundation was present at the site. Given the low density of AIPs within the area compared to Site 1 and 2, the impact on flow is limited, scoring a 2. Channel modification was scored a 0.5 because the road has caused some sedimentation within the upper stream. This is however not replicated downstream. There was not strong evidence of any factors which would decrease the quality of water – however there may be slight effects of sediment runoff, household wastewater, and AIPs, and it is safer to give a low score so land users are cautious and aware that this can change. Due to the low density of AIPs within the area, the score for vegetation removal was also low.

Indigenous species present at Site one are *Passerina rigida*, *Erica canaliculata*, *Pelargonium cordifolium*, *Pelargonium peltatum*, *Virgilia oroboides*, *Polygala fruticosa*, *Chrysanthemoides monilifera*, *Carpha glomerata*, *Pteridium aquilinum*, *Cliffortia odorata*, *Restio tetragonus*, *Paspalum urvillei*.

6.3 Fixed point photography

FPP involves taking a photograph at the same point, over a period of time to demonstrate changes occurring within the landscape. Photographs were taken at two sites in the study area. This method illustrates changes that take place within an ecosystem over time and will serve as a visual representation of the impact of clearing AIPs on the ecological baseline. FPP allows land users to document evidence of bank destabilisation, erosion, and sedimentation in the riparian zone resulting from AIPs.

The first FPP was taken at Site 1 (the same site as in the RHA). Here we located a point where the view of the surrounding riparian zone and land was not obstructed. We used a GPS device to take the point location and placed a metal pin in the ground. We used a smartphone and compass to take photos at breast height in each direction. Figure 48 shows the photographs representing Site 1 from the North, South, East, and West directions.



Figure 48: Fixed point photography at Site 1: N - North view; E - East view; S - South view; and W - West view.

The second FPP was taken at the Spring, where we also measured the spring discharge. Here we took the location of the photograph point, and a photograph depicting the spring flow and conditions. Figure 49 demonstrates the FPP illustrating the spring's ecological baseline condition and flow.



Figure 49: Fixed point photograph of the water flow at the spring.

In Appendix B.2.4 the site and description location which form a part of the Fixed Point Photography are displayed. This information provides an overview of the ecological conditions, describing the habitat, classifying soil erosion and its extent, and summarising the indigenous and alien vegetation present, as well as the utilization and vegetation condition score and organic litter. This field sheet acts to supplement and enhance the value of the photos taken at these points.

For Site 1, the fixed point photographs illustrate the extensive, dense invasion of *A. mearnsii* and *P. pinaster* of mixed ages within the riparian zone. The habitat and vegetation have been largely transformed in this site. There is no flowing water, and localised riverbank soil erosion is present. Utilization is moderate by game, and the vegetation condition was given a score of 0 to 25 % indicating that it was highly degraded. The soil is largely open, with only sparse surface cover and a predominantly coarse organic litter composition.

6.4 Ecological Baseline Summary

Our findings suggest that AIPs pose a major threat to the water sources within this system, as well as the health and ecological condition of the terrestrial land and riparian zones. Dominant AIPs include *A. mearnsii*, *H. sericea*, and *Pinus* spp. These were found in varying densities and age classes around the study site. Site 1 on the farm displayed extensive and dense invasions of adult *A. mearnsii* and *P. pinaster* which caused a degradation of the riparian zone and natural vegetation within the area. Threats largely resulted from the presence of AIPs here, and few human impacts were found contributing to the degradation of the site. Therefore, we found Site 1 to have a fair ecological condition. Site 2 had a lower density infestation, with *A. mearnsii* and *R. fruticosus* as the dominant AIP species. Indigenous vegetation was still present within this area, and we determined the ecological condition to be good. Site 3 was the least invaded site and displayed scattered AIPs including *A. mearnsii*. The river stream was only marginally transformed and indigenous vegetation was still intact. The site was therefore determined to be in a natural ecological condition. This site however may be threatened by spreading AIPs in the future.

7. Conclusion

The Keurbooms river is the main water supply for the town of Plettenberg bay and the neighbouring areas in Bitou Municipality, and the Keurbooms catchment forms part of the Outeniqua Strategic Water Source Area. Infestations of AIPs occur within this catchment, with species such as *A. mearnsii*, *Pinus* spp., *Eucalyptus* spp., and *H. sericea* dominating the vegetation and decreasing the water quantity and quality within this system.

As part of developing the monitoring guidelines presented in Part A, a field visit was undertaken at Jackals Kraal, a farm in the Middle Section Group Farm. A small portion of the property was not easily accessible, however around 900ha of the property was still available for testing the proposed methods. The property was selected due to the landowner's interest in monitoring water flows and quality, the presence of a range of AIP infestation levels, and the presence of a number of accessible and suitable hydrological structures to monitor.

The reasons for the visit were to engage with the landowner and other relevant stakeholders, to identify potential monitoring sites, to field-test some of the methods proposed in Part A, and to conduct an ecological baseline assessment. It was important to test out the ease of use of the methods and engage with stakeholders while doing so to receive input on these methods. The ecological baseline assessment included re-mapping AIPs in the area, conducting Riparian Health Audits, and taking fixed point photographs. This information can be used to highlight those areas most in need of management of AIPs.

Given the large scale of the study area, direct methods for measuring the impact of AIPs on water quantity and quality is unfeasible for the entire property; it would be too difficult to isolate the impact of AIPs from other confounding factors. To avoid this issue, springs provide one of the best opportunities to demonstrate the link between AIP clearing and water quantity and quality.

Springs are good monitoring sites, as AIPs have an immediate impact on the water. These springs can be measured in small upslope areas which will reduce the likelihood of there being other confounding factors affecting water quantity compared to that of a site lower in the catchment.

The spring used as the main water supply for the property was identified as a potential monitoring site as it already has a sump that collects water of the spring and is drained by an outflow pipe, it is accessible, and a tributary close-by can potentially be used as a control site. The container fill method was tested out at this site and proved to be an easy method for measuring water quantity.

There was also an area close to the outflow of the available 900ha area where water flow is focused through culvert pipes. The 90° V-notch weir method was successfully tested at the culvert pipes. The culvert method can be another viable option at the outflow if the sediment deposition currently present at the culvert pipes are removed. There is also a comparable catchment north of the outflow that could potentially be used as a reference site.

The main impact on water flow in Jackals Kraal is the effect of AIPs. Jackals Kraal has a variety of AIP infestations at varying densities. Quantifying the impacts of AIPs on water quantity and quality can provide evidence to prove the severity of the problem and serve as a motivation for the management of AIPs and investment of funds towards their removal. The identified monitoring sites can be used to measure these impacts with easy to use methods, requiring minimal resources, and the results could help display the need for clearing AIPs.



8. References and bibliography

Rogers, D., 2023. Personal communication, Jackals Kraal, Knysna Region.


9. Appendices B

Appendix B.1 - Field Testing Methods Recorded


B.1.1 Spring Discharge - Container Fill Method

SPRING DISCHARGE: STOPWATCH - CONTAINER METHOD - FIELD SHEET			
DATE: 06/09/2023		LONGITUDE: 23°19'45.54"E	
PROJECT AND SITE: WCG EILF Project - Spring 1		LATITUDE: 33°52'58.86"S	
SITE DESCRIPTION AND CONDITIONS: (Weather, season, temperature, water flow description) Warm, sunny, wind present - Early Spring - Water treacle down the rock and flowing out of "spring"			
ID	VOLUME WATER (V) (litre)	TIME (t) (seconds)	DISCHARGE $Q = (V \times 60) / t$ (litre/min.)
1	1.75	53.55	1.960784314
2	1.75	54.41	1.929792318
3	1.75	52.91	1.984501985
4	1.75	54.17	1.938342256
5	1.75	54.07	1.941927131
6	1.75	55.11	1.905280348
AVERAGE			1.94
NOTES:			
SPRING DISCHARGE SITE AND METHOD:			
			

B.1.2 Streamflow - Float Method

STREAM FLOW MEASUREMENTS: AREA-VELOCITY FLOAT METHOD - FIELD SHEET					
DATE: 06/09/2023			LONGITUDE: 23°20'39.62"E		
PROJECT AND SITE: WCG EIF Project - Site 3			LATITUDE: 33°53'30.19"S		
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description) Warm, sunny, wind present - Early Spring - Water flowing					
DISTANCE (cm): 1	100	AVERAGE DEPTH (cm):	4.5	AVERAGE WIDTH (cm):	13.833
ID	DISTANCE (d) (cm)	TIME (t) (s)	VELOCITY = (d) / (t) (cm/s)	AREA OF CROSS SECTION (A) = avg. depth x avg. width (cm ²)	STREAMFLOW Q= (60 x A x V) / 1000 (litre/min.)
1	100	1.92	52.08333333	62.2485	194.5265625
2	100	2.25	44.44444444	62.2485	165.996
3	100	2.22	45.04504505	62.2485	168.2391892
4	100	2.12	47.16981132	62.2485	176.175
5	100	1.89	52.91005291	62.2485	197.6142857
6	100	1.91	52.35602094	62.2485	195.5450262
7	100	2.13	46.94835681	62.2485	175.3478873
8	100	1.84	54.34782609	62.2485	202.9842391
9	100	2.24	44.64285714	62.2485	166.7370536
10	100	2.02	49.5049505	62.2485	184.8965347
AVERAGE					182.81
NOTES:					
FLOAT SITE AND METHOD:					
					

B.1.3 Streamflow - 90° V-notch Weir Method

SURFACE FLOW DISCHARGE: V NOTCH WEIR - FIELD SHEET					
DATE: 07/09/2023			LONGITUDE: 23°20'39.62"E		
PROJECT AND SITE: WCG EILF Project - Site 3			LATITUDE: 33°53'30.19"S		
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description) Warm, sunny, wind present - Early Spring - Water flowing					
CROTCH HEIGHT (cm):			15.4		
ID	DISTANCE FROM GAUGE TO WEIR	HEAD (cm)			
1	24	6			
DISCHARGE-HEAD RELATIONSHIP FOR A 90 ° V-NOTCH WEIR					
H (cm)	Q (l/s)	H (cm)	Q (l/s)	H (cm)	Q (l/s)
1	0	11	5.5	21	27.9
2	0.1	12	6.8	22	31.3
3	0.2	13	8.3	23	35
4	0.4	14	10	24	38.9
5	0.8	15	12	25	43.1
6	1.2	16	14	26	47.5
7	1.8	17	16	27	52.2
8	2.5	18	19	28	57.1
9	3.3	19	22	29	62.3
10	4.3	20	24	30	67.8
NOTES:					
V NOTCH WEIR SITE AND METHOD:					
					


Appendix B.2 - Ecological Baseline Assessment Field Sheets

B.2.1 Riparian Health Audit - Site 1


RIPARIAN HEALTH AUDIT: FIELD SHEET										
DATE: 07/09/2023		UPSTREAM LONGITUDE: 23°18'32.76"E				DOWNSTREAM LONGITUDE: 23°18'33.95"E				
PROJECT AND SITE: WCG- Ellif - Site 1		UPSTREAM LATITUDE: 33°53'4.06"S				DOWNSTREAM LATITUDE: 33°53'4.65"S				
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description) Daniel Rogers - Site 1 - Wattle Stand Warm, sunny, wind present - Early Spring - No water flow (stagnant water downstream)										
RATE EACH IMPACT FROM 0-5										
SITE	1 EXOTIC VEGETATION	2 RUBBISH DUMPING	3 BANK EROSION	4 INUNDATION	5 FLOW MODIFICATION	6 CHANNEL MODIFICATION	7 EVIDENCE OF DECREASED WATER QUALITY	8 VEGETATION REMOVAL	TOTAL SCORE	PERCENTAGE (TS/ 40 X 100)
Site 1	4.5	0	2	0	3	2	1.5	4	17	42.5
ECOLOGICAL HEALTH SCORE:						STUDY SITE:				
SCORE	PERCENTAGE CHANGE		ECOLOGICAL CONDITION							
0 - 4.5	0 - 10		Natural							
5 - 11.5	11 - 29		Good							
12 - 19.5	30 - 49		Fair							
20 - 27.5	50 - 69		Poor							
28 - 35.5	70 - 89		Very Poor							
36 - 40	90 - 100		Critical							
NOTES:										




B.2.2 Riparian Health Audit - Site 2

RIPARIAN HEALTH AUDIT: FIELD SHEET											
DATE: 07/09/2023			UPSTREAM LONGITUDE: 23°19'39.31"E				DOWNSTREAM LONGITUDE: 23°19'40.43"E				
PROJECT AND SITE: WCG- EIFF - Site 2			UPSTREAM LATITUDE: 33°53'12.31"S				DOWNSTREAM LATITUDE: 33°53'12.48"S				
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description) Daniel Rogers - Site 2 - Middle Reaches Ecological Baseline Assessment Warm, sunny, wind present - Early Spring - No water flow											
RATE EACH IMPACT FROM 0-5											
SITE	1 EXOTIC VEGETATION	2 RUBBISH DUMPING	3 BANK EROSION	4 INUNDATION	5 FLOW MODIFICATION	6 CHANNEL MODIFICATION	7 EVIDENCE OF DECREASED WATER QUALITY	8 VEGETATION REMOVAL	TOTAL SCORE	PERCENTAGE (TS / 40 X 100)	
Site 2	3	0	1	0	2	1	1	1.5	9.5	23.75	
ECOLOGICAL HEALTH SCORE:						STUDY SITE:					
SCORE	PERCENTAGE CHANGE		ECOLOGICAL CONDITION								
0 - 4.5	0 - 10		Natural								
5 - 11.5	11 - 29		Good								
12 - 19.5	30 - 49		Fair								
20 - 27.5	50 - 69		Poor								
28 - 35.5	70 - 89		Very Poor								
36 - 40	90 - 100		Critical								
NOTES:											
											

B.2.3 Riparian Health Audit - Site 3

RIPARIAN HEALTH AUDIT: FIELD SHEET																																											
DATE: 08/09/2023		UPSTREAM LONGITUDE: 23°20'39.62"E			DOWNSTREAM LONGITUDE: 23°20'39.94"E																																						
PROJECT AND SITE: WCG- EIIF - Site 3		UPSTREAM LATITUDE: 33°53'30.19"S			DOWNSTREAM LATITUDE: 33°53'30.60"S																																						
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description) Observations made by Apex team and Stakeholders collectively Warm to hot, sunny, wind present - Early Spring - Water flowing																																											
RATE EACH IMPACT FROM 0-5																																											
SITE	1 EXOTIC VEGETATION	2 RUBBISH DUMPING	3 BANK EROSION	4 INUNDATION	5 FLOW MODIFICATION	6 CHANNEL MODIFICATION	7 EVIDENCE OF DECREASED WATER QUALITY	8 VEGETATION REMOVAL	TOTAL SCORE	PERCENTAGE (TS/ 40 X 100)																																	
Site 3	1	0	0	0	2	0.5	0.5	0	4	10																																	
ECOLOGICAL HEALTH SCORE:						STUDY SITE:																																					
SCORE	PERCENTAGE CHANGE	ECOLOGICAL CONDITION																																									
0 - 4.5	0 - 10	Natural																																									
5 - 11.5	11 - 29	Good																																									
12 - 19.5	30 - 49	Fair																																									
20 - 27.5	50 - 69	Poor																																									
28 - 35.5	70 - 89	Very Poor																																									
36 - 40	90 - 100	Critical																																									
NOTES:																																											
																																											

B.2.4 Fixed Point Photography

FIXED POINT PHOTOGRAPHY: FIELD SHEET																																										
DATE: 07/09/2023				LONGITUDE: 23°18'33.26"E																																						
PROJECT AND SITE: WCG EIIIF Project - Site 1				LATITUDE: 33°53'4.36"S																																						
SITE DESCRIPTION AND CONDITIONS: (Weather, temperature, season, water flow description) Warm, sunny weather, wind present - Early Spring - No water flow (stagnant water downstream)																																										
SURVEYOR: Bruce Taplin																																										
POINT DESCRIPTION: (How to find the marker) 30 m North of the road at the wattle stand, situated on island in the river																																										
HABITAT DESCRIPTION: Transformed riverine habitat and vegetation, now dense AIPs, with a mixed age <i>Acacia mearnsii</i> stand of a density of 75% Evidence of bank destabilization																																										
INDIGENOUS SPECIES: Understorey <i>Panicum deustum</i> and <i>Dietses iridioides</i>																																										
INVASIVE ALIEN PLANTS: <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <thead> <tr> <th style="width: 35%;">DOMINANT SPECIES:</th> <th style="width: 20%;">EXTENT:</th> <th style="width: 15%;">DENSITY:</th> <th style="width: 15%;">AGE:</th> <th style="width: 15%;"></th> </tr> </thead> <tbody> <tr> <td><i>Acacia mearnsii</i></td> <td>Isolated</td> <td>Occasional</td> <td>Seedling</td> <td></td> </tr> <tr> <td><i>Pinus pinaster</i></td> <td>Moderate</td> <td>Very Scattered</td> <td>Young</td> <td></td> </tr> <tr> <td></td> <td>Extensive</td> <td>X Scattered</td> <td>Adult</td> <td></td> </tr> <tr> <td></td> <td></td> <td>Moderate</td> <td>Mixed</td> <td>X</td> </tr> <tr> <td></td> <td></td> <td>Dense</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td>Closed up</td> <td>X</td> <td></td> </tr> </tbody> </table>								DOMINANT SPECIES:	EXTENT:	DENSITY:	AGE:		<i>Acacia mearnsii</i>	Isolated	Occasional	Seedling		<i>Pinus pinaster</i>	Moderate	Very Scattered	Young			Extensive	X Scattered	Adult				Moderate	Mixed	X			Dense					Closed up	X	
DOMINANT SPECIES:	EXTENT:	DENSITY:	AGE:																																							
<i>Acacia mearnsii</i>	Isolated	Occasional	Seedling																																							
<i>Pinus pinaster</i>	Moderate	Very Scattered	Young																																							
	Extensive	X Scattered	Adult																																							
		Moderate	Mixed	X																																						
		Dense																																								
		Closed up	X																																							
SOIL EROSION:		UTILIZATION:		VEG CONDITION SCORE:																																						
TYPE:	EXTENT:	EXTENT:		SCORE:																																						
Sheet	Very extensive	Light		0 - 25%		X																																				
Rill	Wide spread	Moderate	X	25% - 50%																																						
Gully	Fragmented	Heavy		50% - 75%																																						
Donga	Localised	X Severe		75% - 100%																																						
Head cut		Other																																								
Channelling		Game																																								
Riverbank	X																																									
ORGANIC LITTER: <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <thead> <tr> <th style="width: 30%;">MATERIAL COMPOSITION:</th> <th style="width: 30%;">SOIL SURFACE COVER:</th> <th style="width: 40%;"></th> </tr> </thead> <tbody> <tr> <td>Fine</td> <td>Absent</td> <td rowspan="4" style="text-align: center;">Open Soil Surface</td> </tr> <tr> <td>Medium</td> <td>Sparse</td> </tr> <tr> <td>Coarse</td> <td>X Moderate</td> </tr> <tr> <td></td> <td>Dense</td> </tr> </tbody> </table>								MATERIAL COMPOSITION:	SOIL SURFACE COVER:		Fine	Absent	Open Soil Surface	Medium	Sparse	Coarse	X Moderate		Dense																							
MATERIAL COMPOSITION:	SOIL SURFACE COVER:																																									
Fine	Absent	Open Soil Surface																																								
Medium	Sparse																																									
Coarse	X Moderate																																									
	Dense																																									
NOTES:				SITE:																																						
																																										

Monitoring Guidelines Compiled by Apex Conservation Services

From left: Rachel Putzier; Stefan le Roux; Bruce Taplin; and Dr Donovan Kotze



Email: John.Wilson@westerncape.gov.za

Tel: +27 21 483 4114 Fax: +27 21 483 4651

Department of Environmental Affairs and Development Planning

Chief Directorate: Environmental Sustainability

Directorate: Biodiversity & Coastal Management

www.westerncape.gov.za

Department of Environmental Affairs and Development Planning: General Enquiries

Email: enquiries.eadp@westerncape.gov.za

Tel: +27 21 483 4091 Fax: +27 21 483 3016



**Western Cape
Government**