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RHAM MANUAL

APPLICABLE TO RIVERS ONLY.

PROVIDES GUIDANCE ON HOW TO COLLECT, STORE, AND ANALYSE HABITAT DATA ONLY.

DOES NOT PROVIDE INFORMATION ON HOW YOU RELATE THE QUANTIFIED HABITAT INFORMATION TO INSTREAM HABITAT AND INSTREAM BIOTA TPCs.

THE FOCUS IS ON WADEABLE RIVERS. SOME INFORMATION IS PROVIDED FOR SEMI- AND NON-WADEABLE RIVERS.

POTENTIALLY, THE RHAM APPROACH NEEDS TO BE EXTENDED TO INCLUDE THE RIPARIAN ZONE. HOWEVER, THIS WILL BE A NEXT PHASE IN THE DEVELOPMENT OF THE RHAM.

THE FOCUS ON THIS MANUAL IS ON SETTING UP THE BASELINE FOR MONITORING AND HOW TO STORE ALL THE DATA SO THAT IT IS IN A FORMAT THAT CAN BE USED WHEN UNDERTAKING FOLLOW-ON MONITORING

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LIST OF ABBREVIATIONS AND ACRONYMS

Be	Bedrock
Bo	Boulder
Co	Cobble
DSS	Decision Support System
DWAF	Department of Water Affairs and Forestry
ERM	Ecological Reserve Monitoring
EWR	Ecological Water Requirements
EWRM	Ecological Water Resources Monitoring
EXCL	Excluding
F	Fast
FD	Fast/Deep
FI	Fast/Intermediate depth
Fi	Fines
FRAI	Fish Response Assessment Index
FROC	Fish Frequency of Occurrence
FS	Fast/Shallow
FVS	Fast/Very Shallow
GHU	Geomorphic Habitat Unit
Gr	Gravel
IHI	Index of Habitat Integrity
Inf	Infinity
LB	Left Bank
MRU	Management Resource Unit
NA	Not Applicable
NRU	Natural Resource Unit
Quat	Quaternary
RAU	Reserve Assessment Unit
RB	Right Bank
RHAM	Rapid Habitat Assessment Method
RHP	River Health Programme
RQS	Resource Quality Services
RU	Resource Unit
S	Slow
Sa	Sand
SD	Slow/Deep
SS	Slow/Shallow
SVS	Slow/Very shallow
TVHR	Transparent Velocity Head Rod
VD	Velocity Depth
VF	Very Fast
VS	Very Slow
WE	Water's edge
WRAU	Ecological Water Resources Assessment Unit

CONTENTS

13 SEMI- AND NON-WADEABLE RIVERS 11-1
13.1 WHEN IS A RIVER NON-WADEABLE?.. 11-1
13.2 NON-WADEABLE RIVERS APPROACH.. 11-2
13.3 SEMI-WADEABLE RIVERS APPROACH.. 11-2
14 SUMMARY OF STEP BY STEP CHECKLIST TO SET UP BASELINE for rham 12-1
14.1 BASELINE MONITORING 12-1
15 SUMMARY OF STEP BY STEP GUIDELINE TO UNDERTAKE FOLLOW-ON MONITORING 13-1
15.1 FOLLOW-ON MONITORING 13-1
16 REFERENCES 14-1

LIST OF TABLES

Table 2.1 Description of the rationale for the delineation of the National Resource Unit for the Fig 2.1.. 2-4
Table 2.2 Description of the rationale for the delineation of the Management Resource Unit according to Figure 2.2 2-7
Table 3.1 LOCAL DISTURBANCES TABLE 3-4
Table 4.1 Illustrations of benchmarks 4-8
Table 4.2 Positioning the upstream and downstream GHU borders.......................... 4-11
Table 6.1 Illustrations of substrate types.. 6-4
Table 6.2 Illustrations of cover features 6-5
Table 8.1 An example of a range of photographs that should be taken of a EWRM site 8-4
Table 9.1 Velocity-area procedure for determining stream discharge 9-2
Table 1.1 Flow class and substrate class definitions in the *FlowClassDefinitions* Sheet .... **Error! Bookmark not defined.**
Table 1.2 Discharge data and computations in the *DischargeData* Sheet............. **Error! Bookmark not defined.**
Table 1.3 Marginal zone and bank measurements in the *MarginalData* Sheet....... **Error! Bookmark not defined.**
Table 1.4 Instream cross-section point measurements in the *InstreamData* Sheet**Error! Bookmark not defined.**

LIST OF FIGURES

Figure 1.1 Sequential steps of the application of the RHAM for the baseline 1-2
Figure 2.1 Delineation of National Resource Units..2-4
Figure 2.2 Delineation of Management Resource Units 2-6
Figure 3.1 Selection of valley shapes (Parsons 2002)..3-2
Figure 3.2 Channel shape..3-2
Figure 3.3 Longitudinal connectivity under low flows (Parsons 2002)...........................3-2
Figure 3.4 Types of bars present (Parsons 2002) 3-3
Figure 3.5 Bank shape and bank slope (Parsons 2002)...3-3
Figure 3.6 Bed compaction and sediment matrix 3-4
Figure 4.1 Site delineation 4-2
Figure 4.2 Example of GHUs within an EWRM site..4-4
Figure 4.3 Example of a combined GHU...4-4
Figure 4.4 Example of the selection of GHUs on a pool riffle system 4-4
Figure 4.5 Example of the selection of GHUs on a pool riffle system 4-5
Figure 4.6 Example of the selection of GHUs on a seasonal alluvial system with permanent pools 4-5
Figure 4.7 Example of the selection of GHUs on a seasonal alluvial system with pools that are not necessarily perennial and not stable 4-6
Figure 4.8 Example of selection of GHUs on a mixed alluvial bedrock system.............4-6
Figure 5.1 Typical river profile from a cross-sectional measurement............................5-2
Figure 5.2 EWRM cross-section (blue line) with cross-section points (red markers) illustrating habitat assessed at each cross-section point. 5-3
Figure 5.3 Cross-sections and cross-section points in GHUs.......................................5-8
Figure 5.4 Cross-sections and cross-section points in GHUs.......................................5-8
Figure 6.1 Using the Velocity Rod at a cross-section point 6-2
Figure 6.2 Velocity Rod showing how the head is measured 6-2
Figure 7.1 Submerged portions of reeds...7-2
Figure 7.2 Illustration of length, width and depth of inundation of emergent vegetation (sketch by A Deacon)...7-3
Figure 8.1 Photos sequence linked to the steps above (illustration and photos by A Deacon) 8-3
Figure 13.1 Letaba River – Two Pool GHUs with hippos and crocodiles, i.e. non-wadeable 11-1
Figure 13.2 RHAM surveys in a Semi-wadeable river 11-3

1 INTRODUCTION

WHAT IS THE RAPID HABITAT ASSESSMENT METHOD (RHAM)?

The RHAM is a process to collate relevant habitat information in a cost-effective manner for Ecological Water Requirement Monitoring (EWRM) monitoring.

This document serves as a technical manual for the RHAM which includes the following:

- What is the purpose of the RHAM

Baseline monitoring

- How to select the sites.
- How to delineate the sites.
- How to undertake the measurements.

Follow-on monitoring

- What do the different levels of monitoring require in terms of the RHAM?

This document is a stand-alone manual which should be read with other documentation on the monitoring when it becomes available. The way that the results are used in terms of habitat and biota criteria as well as EcoSpecs and TPCs for instream biota will be described in separate documentation to come available at a later stage from RQS. This document must therefore only be seen as a 'how to' manual and concentrates on the methods used to collect habitat data consistently.

The application of the RHAM consists of a range of sequential steps which are described in a flow diagram (Fig 1.2). These steps provide the structure for this manual.

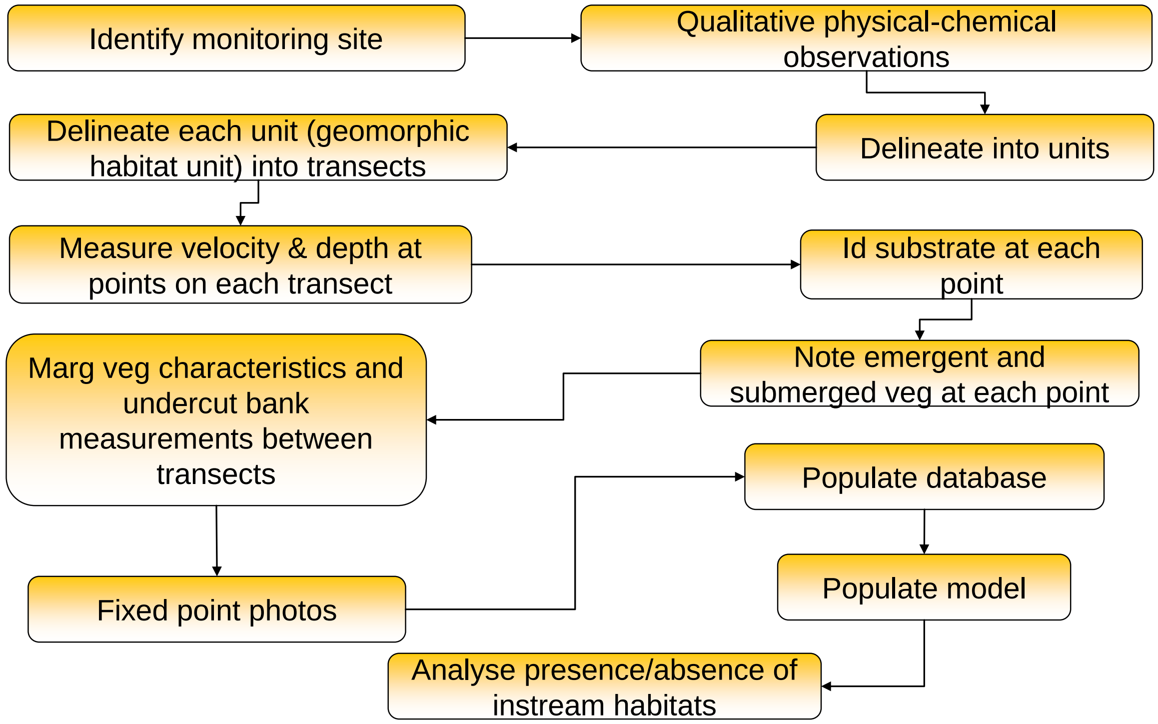


Figure 1.1 Sequential steps of the application of the RHAM for the baseline

The manual provides information in a structured way according to the flow diagram in Fig 1.1.

2 HOW TO SELECT A SITE

Management Resource Unit (MRU): A stretch of river of homogenous nature and distinct boundaries (usually but not necessarily of anthropogenic origin). The MRU can be any length depending and considering constraints of assessment. The MRU will normally represent a river stretch of the length of more than one km.

Ecological Water Resource Assessment Unit (WRAU): For Ecological Water Requirements (EWR) referred to as the Reserve Assessment Unit (RAU). Situated within a MRU and used to demarcate and describe a reach of river within the MRU with the most critical habitat.

Ecological Water Resources Monitoring (EWRM) Site: "Site" refers to "features of a place related to the immediate environment on which the place is located (e.g. terrain, soil, subsurface, geology, groundwater). (www.geographic.org/glossary.html)".

For the purpose of EWRM, 'site' refers to a stretch/length of river within the MRU which includes various geomorphic habitat units (eg riffles, pools, runs). These are characterised based on cross-section point data and biological data. The length of the reach will vary depending on:

- The purpose for which the site is selected.
- The complexity/diversity of the physical template of the river.
- Access and safety.

The process for selection of a site is a hierarchical process as follows:

- Delineate river into MRUs
- Select an EWRM Site within the MRUs
- Delineate the EWRM site into Geomorphic Habitat Units (GHUs) (Chapter 4)
- Delineate the GHUs into cross-sections (Chapter 5)

The delineation of the river into MRUs is described in 2.1 and modified from Kleynhans and Louw, 2008. The delineation of the river into MRUs is the same for the Ecological

Water Requirements (EWR) and the RHP (River Health Programme) applications.

The selection of the Monitoring Site is described in 2.2. The monitoring site is situated within this MRU and the considerations will differ for EWR and RHP applications. The differences will be discussed. For selection of EWR sites see Louw *et al*, 1999. For selection of RHP sites see DWAF, 2008.

2.1 DELINEATION OF THE RIVER INTO MRUS

2.1.1 Rationale

This section defines and describes the different units according to which a river should be investigated and studied for the purpose of EWR determination, RHP application and EWRM. The objective is to demarcate and delineate river reaches[1] following a hierarchical approach according to the following considerations:

- **Broad natural physical** reaches that constitute the river from its source downstream. These reaches are the result of the various drivers of the system under reference conditions, *viz*. Hydrology, Geomorphology and Physico-chemical attributes. It follows that the biota responded and adapted to these reference conditions (i.e., the broad natural habitat template) in a dynamic way depending on natural climatic variation. The boundaries between different broad natural reaches are not necessarily crisp and clear. However, where marked and rapid changes occur due to geology (e.g. geomorphology and physico-chemical changes) and hydrology (e.g. large tributaries or a change in climate) these boundaries may be easy to identify.
- **Smaller natural reaches** may be distinguished within these large reaches. Depending on the characteristics of the biological group and taxa considered, the distribution of biota will broadly coincide with the demarcation of the natural reaches. However, depending on the attributes (e.g. preferences and intolerances) of the biota they may be limited to smaller natural reaches within the broad natural physical reaches. These will result in so-called biological habitat segments (e.g. fish habitat segments, Kleynhans 1999). Depending on the life-history requirements of the biota and the dynamic nature of the ecosystems, the boundaries of the habitat segments can vary temporally and spatially. Some biota may be limited to particular smaller reaches within the broad natural reach; others may be present throughout the broad natural reach while others may be present across two or more broad natural reaches. This must be considered when defining the reference biological assemblage for a particular river reach.

[1] For the purpose of this document, "reach" is broadly defined as "a specified segment of a stream's path" (www.wwnorton.com/college/geo/earth2/glossary/r.htm).

- Superimposed on these natural reaches are the changes brought about by anthropogenic activities. These activities may result in a homogenous impact throughout the length of a broad natural reach or their impact may be heterogeneous and result in smaller distinguishable sub-reaches. Physical driver changes as well as biological change agents (e.g. alien biota) may be involved.

Reference conditions (in terms of natural reaches, drivers and biota) need to be considered as these provide the natural evolutionary setting that indicates the resilience of the system to various forms of modification and stress. However, pragmatic considerations that come into the picture include anthropogenic changes to the system that are within the medium and long term not likely to change. These may include modifications to the system such as impoundments, agricultural, urbanization and forestry. Such modifications brings about changes in the natural reach characteristics in terms of the system drivers and biota and indicates changed reaches that needs particular consideration in order to manage them according *inter alia,* ecological importance and sensitivity, present ecological state, the recommended category and sustainability. This rationale also therefore enables the setting of resource quality objectives, ecological specifications and monitoring objectives and specifications.

Following this approach, the following classification of reaches is distinguished in terms of the setting of the ecological reserve for particular river reaches:

- Natural Resource Units (NRU)
- Management Resource Units (MRU)
- Ecological Water Resource Assessment Units (WRAU) (applicable for both EWRs and RHP
- Monitoring site which could be an EWR site or a RHP site. Generically these would be EWRM sites.

2.1.2 Natural Resource Unit (NRU)

The guiding principle is that if the hydrology, geomorphic characteristics (i.e. geomorphic zone), physico-chemical attributes and river size remains relatively similar, a NRU can be demarcated.

Two levels can be distinguished:

- Primary NRUs that are demarcated according to EcoRegions including relevant components of an EcoRegion that may contribute to the demarcation of NRUs, This will determine the broad ecological context (climate, geomorphology, hydrology and the broad physico-chemical profile) within which the river is situated

- Secondary NRUs can be indicated and if present, are nested within the Primary NRU and are defined according to a significant change in:
  - Geomorphic zones (slopes and geological attributes), which will determine the potential presence of certain habitats.
  - Hydrology which may be due to the flow contribution (in volume or seasonality) of tributaries or a change in ground water contribution.
  - Physico-chemical conditions which may be the result of a change in hydrology or geology. This will result in a specific meso-habitat that can influence the presence and abundance of species (e.g. biological habitat segments).

Figure 2.1 provides a hypothetical example to illustrate the described delineation. An explanation of the hypothetical delineation in table form (Table 2.1) is also provided.

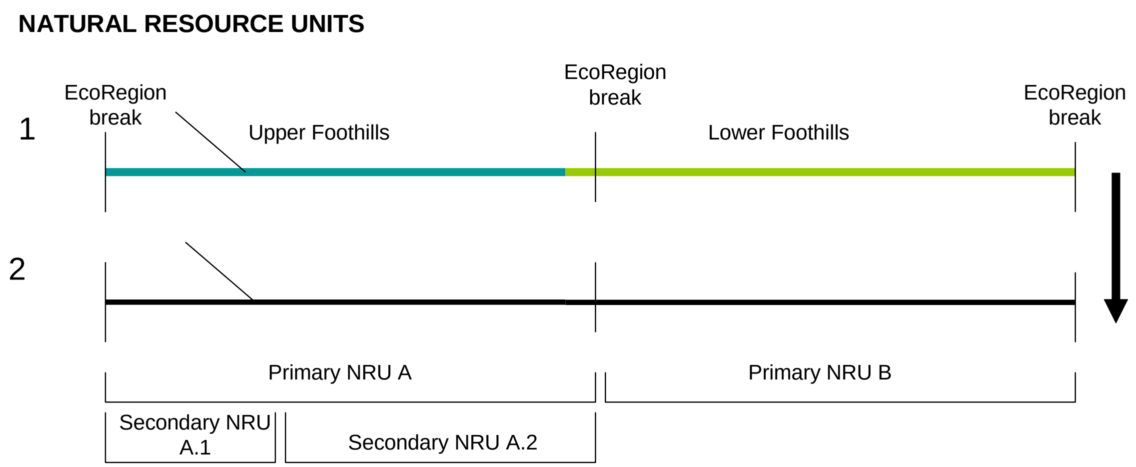


Figure 2.1 Delineation of National Resource Units

Table 2.1 Description of the rationale for the delineation of the National Resource Unit for the Fig 2.1.

UNIT	RATIONALE	DELINEATION
Primary NRU A	EcoRegions main determinant. As most of the EcoRegion also consists of one geomorphic zone, this provides additional motivation for the delineation	Start to end of EcoRegion
Secondary NRU A.1	The tributary provides sediment (alluvial) and different hydrology. This provides further delineation. The temperature is also different.	Start of EcoRegion to confluence of the tributary.
Secondary NRU A.2	Different hydrology and physico-chemical characteristics from the upstream section	Confluence of tributary to end of EcoRegion

2.1.3 Management Resource Unit (MRU)

The purpose of distinguishing MRUs is to identify a management unit within which the ecological water resource management can be implemented and managed based on one set of identified ecological water resource requirements.

The following provides the concept of Management Resource Units (MRUs):

- MRUs are based on the principle of homogeneity of impacts in the demarcated NRU.
- This may include the modification of flows in the system due to abstraction, regulation by impoundments and development along the NRU and upstream from the NRU which may influence the geomorphology and physico-chemical conditions.
- This can cause specific changes in the system drivers which will subdivide the NRU into MRUs.
- Modifications to a river reach may homogenize adjacent NRUs to the extent that they may constitute a single MRU.

MRUs are homogenous units which are sufficiently different from adjacent areas to warrant a separate assessment for ecological water resource management both in terms of EWRs and the RHP (Louw & Hughes, 2002). This means that results generated in the MRU, will be applicable for the whole MRU.

The following information is used to demarcate a MRU in relation to the NRU:

- Land cover or land use data (specifically within 500m of both sides of the river)
- Index of Habitat Integrity data if available
- System driver information as obtained from EcoStatus assessments. This may include information on hydrological changes in system operation

If there are no anthropogenic changes or modifications present along or upstream from a particular NRU, such a NRU will logically constitute a Management Resource Unit (MRU).

2.1.4 Ecological Water Resources Assessment Unit (WRAU)

Note, referred to in EWR studies as the Reserve Assessment Unit (RAU). The WRAU is situated within a MRU and it is used to demarcate and describe a reach of river within the MRU with the most critical habitat in the MRU. It has bearing upon the following:

- “Critical” refers to habitat being particularly responsive to changes in flow (and the associated physico-chemical and geomorphic conditions) and which can be related to critical phases in the life-cycle of biota.

- Additionally, if critical habitats are present in a particular reach, the EWR set to protect such habitat and its associated biota will also protect less critical habitat (and the associated biota).
- If habitat with the same level of "critical" are present over the whole of the MRU (i.e. in all reaches within the MRU), the reach selected as the RAU should preferably be the one that are in the best present ecological state.
- To provide for an eventual management monitoring context, the RAU can be defined in terms of biological habitat segments that represent the presence of a homogenous biological assemblage. This is important when reference conditions are formulated.
- The demarcation of the RAU is particularly important as it plays a decisive role of where EWR and RHP sites should be located.

Figure 2.2 provides a hypothetical example to illustrate the described delineation. An explanation of the hypothetical delineation in table form (Table 2.2) is also provided. The figure and table shows the delineation into MRU, WRAUs and also indicate where the EWR/RHP site (EWRM site) should be situated).

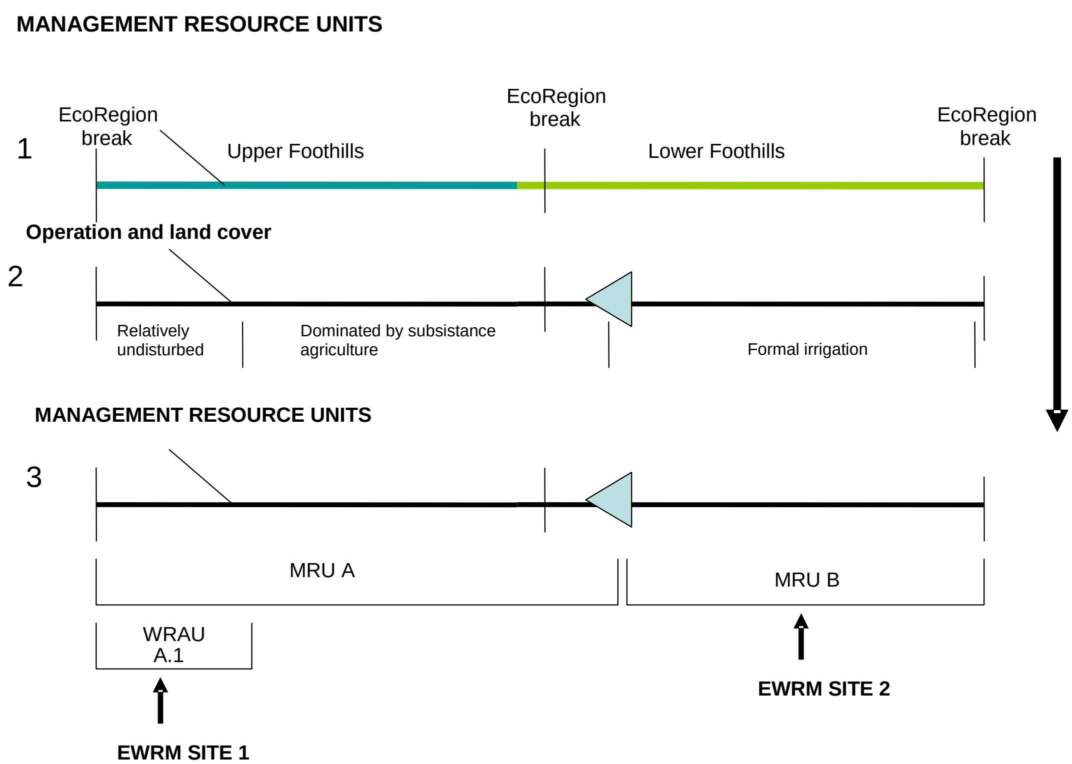


Figure 2.2 Delineation of Management Resource Units

Table 2.2 Description of the rationale for the delineation of the Management Resource Unit according to Figure 2.2

UNIT	RATIONALE	DECISION	DELINEATION
MRU A	Consists of mostly one EcoRegion Consists mostly one Geomorphic zone Land use dominated by subsistence agriculture Dam provides an operational break.	MRU larger than NRU to include short section to the dam.	Start of EcoRegion to Dam
WRAU A.1	WRAU provides critical habitat for species that prefer colder temperatures as the tributary brings in warmer water. As area is isolated, critical vegetation habitat such as marginal and overhanging vegetation present to provide cover. In area downstream from the tributary, this habitat has been removed by grazing and bush clearing.	Assessment of WRAU for EcoClassification and EWR assessment important as forms the critical section in the MRU	Start of EcoRegion to confluence of tributary (coincides with NRU A.1)
Recommendation: WRAU A.1: EcoClassification + EWR assessment therefore EWR site if possible to be situated within WRAU A.1 MRU A (excluding WRAU A.1): EcoClassification			
MRU B	Consists of one EcoRegion Consists one Geomorphic zone Land use dominated by formal irrigation End of EcoRegion provides logical break	MRU similar to NRU apart from the short section of NRU B which is above the dam.	Dam wall to end of EcoRegion
Recommendation: EcoClassification + EWR assessment As no WRAU identified within the MRU, the EWR site to be selected anywhere in the MRU. If there are any areas that are potentially in a better state than the rest of the MRU, it is recommended that the EWR be placed within that.			

2.2 EWRM SITE SELECTION

"Site" refers to "features of a place related to the immediate environment on which the place is located (e.g. terrain, soil, subsurface, geology, groundwater) (www.geographic.org/glossary.html)". Linked to this is the concept of "locality" which refers to the geographic area in which a collecting event occurs (porites.geology.uiowa.edu/entity.htm).

EWRM sites are usually either EWR or RHP sites.

2.2.1 EWR site

EWR sites are localities in a stream within the descending hierarchy of Primary NRU→Secondary NRU→MRU→RAU→EWR site. An EWR site is therefore a locality where measurements to determine the ecological water requirements of river will be done.

The selection of EWR sites should consider the following physical attributes:

- Hydraulic cross-section(s) will be established here. The purpose of hydraulic measurements and the consequent modelling is to provide an interpretive link between flows at different stages and the resulting aquatic habitats at the site. In some cases a digital terrain model ("habitat model") will be developed to provide a more accurate and detail perspective of the response of various habitat features to changes in flow.
- Preferably the EWR site should be representative of the WRAU within which it is situated. "Representative" specifically refers to the hydraulics units at the site which should occur in similar proportions and with similar characteristics to that which occur at the majority of sites in the WRAU. Generally, however, the more complicated the site is in terms of hydraulic units (e.g. diversity of bed material and multiple channels), the more difficult hydraulic modelling of the site becomes. This detrimentally influences the accuracy of the hydraulic model and thus the prediction of habitat at various discharges. As a result, a compromise needs to be found between the representativeness of the EWR site and the accuracy of the hydraulics model.
- In addition to an ideal EWR site being representative of the RAU, it should also be sensitive in terms of its response to changes in water level (discharges). This will make the EWR site useful for future monitoring and the confidence in the interpretation of monitoring results.
- The ultimately ideal site would therefore be representative, practical and safe to measure and to model reasonably accurately, be accessible and be sensitive to changes in discharge to make it useful for habitat prediction.

Due to the importance of the accuracy of the hydraulic modelling, the EWR site cross-section is often not situated across the most habitat diverse areas. When delineating the RHAM reach and units, this could and should include the more diverse areas. It is however always important to select the EWR site used in Comprehensive or Intermediate EWR assessment as the EWRM site due to the detailed driver and response information collated.

2.2.2 RHP site

As hydraulic measurements will not play the overriding consideration, ecological diversity and sensitivity should play the key role. It must however always be considered whether an appropriate EWR site is at or in the near vicinity. This will ensure that the information collation for the RHP can be used for EWR assessment.

2.3 STEP BY STEP PROCEDURE

HOW TO DECIDE WHERE AN EWRM SITE SHOULD BE SELECTED

- Obtain maps of the river to be assessed.
- Plot the geomorphic zones on the maps.
- Plot the EcoRegions on the maps.
- Indicate any other information useful to determine the NRUs.
- Demarcate and name the NRUs.
- Provide the demarcation on maps and the reasoning on tables.
- Plot or indicate land cover on the maps.
- Plot the large tributaries on the maps.
- Plot the operational structures and/or indicate areas of abstractions, transfers, etc.
- View aerial videos or GoogleEarth the various river reaches.
- Derive the MRU borders and illustrate on maps.
- Provide reasoning on tables.
- Indicate whether any WRAUs exist, and if so, provide the required information on tables and figures.
- Indicate where preferably, EWRM sites should be selected.
- Identify potential sites on Google Earth and/or select sites during a reconnaissance site visit.
- Once the site has been selected, provide the GPS reading, directions to the site, arrangements for access and relevant telephone numbers.

Note that if an EWR study has been undertaken, all this information should be available and sites suitable for EWRM should have been selected.

3 BASELINE GENERIC DESCRIPTION OF THE SITE

3.1 GENERAL

- Assessor name(s)
- Organisation
- Date
- Weather conditions at the time of survey
- Weather conditions immediately before the survey (if information available)

3.2 LOGISTICS

- Description on how to reach site (supply map if necessary)
- Arrangements required to get to site (permit etc)
- Land owner's name and telephone number
- Type of vehicle required (normal car, high clearance (bakkie), 4x4)

3.3 LOCALITY OF THE SITE

- EWRM site name
- River
- Quat (http://www.dwaf.gov.za/iwqs/gis_data/RHPdata.asp)
- WMA
- Latitude and Longitude
- DWAF gauging station (http://www.dwaf.gov.za/hydrology/cgi-bin/his/cgihis.exe/station)

3.4 DESCRIPTION OF THE SITE

- EcoRegion (http://www.dwaf.gov.za/iwqs/gis_data/RHPdata.asp)
- Geomorphic zone (http://www.dwaf.gov.za/iwqs/gis_data/RHPdata.asp)
- GHU characterisation (i.e. pool/riffle, alluvial run etc) (see chapter 4)
- Hydrological type (natural)
- Hydrological type (present)
- Valley shape (Fig 3.1)
- Channel shape (Fig 3.2)
- Longitudinal connectivity at low flows (time of survey) (Fig 3.3)
- Types of bars present (Fig 3.4)
- Bank shape (Fig 3.5)
- Bank slope (Fig 3.5)
- Bed compaction (Fig 3.6)
- Sediment matrix (Fig 3.6)

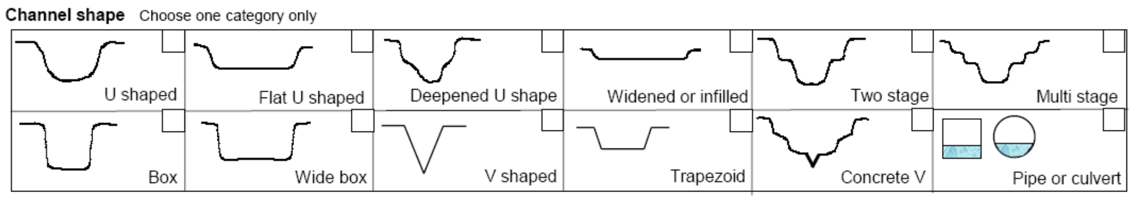


Figure 3.1 Selection of valley shapes (Parsons 2002)

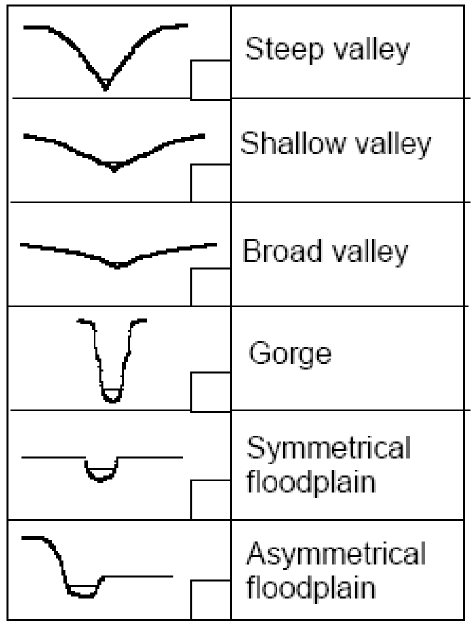


Figure 3.2 Channel shape

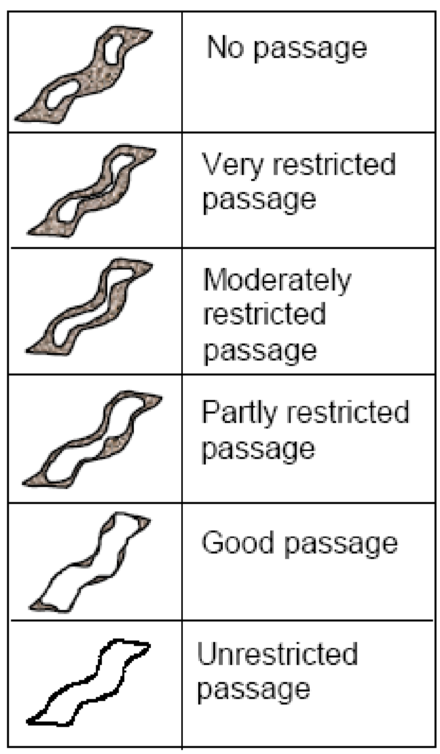


Figure 3.3 Longitudinal connectivity under low flows (Parsons 2002)

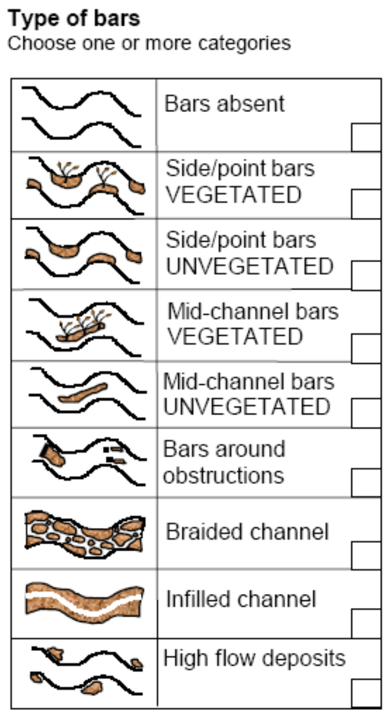


Figure 3.4 Types of bars present (Parsons 2002)

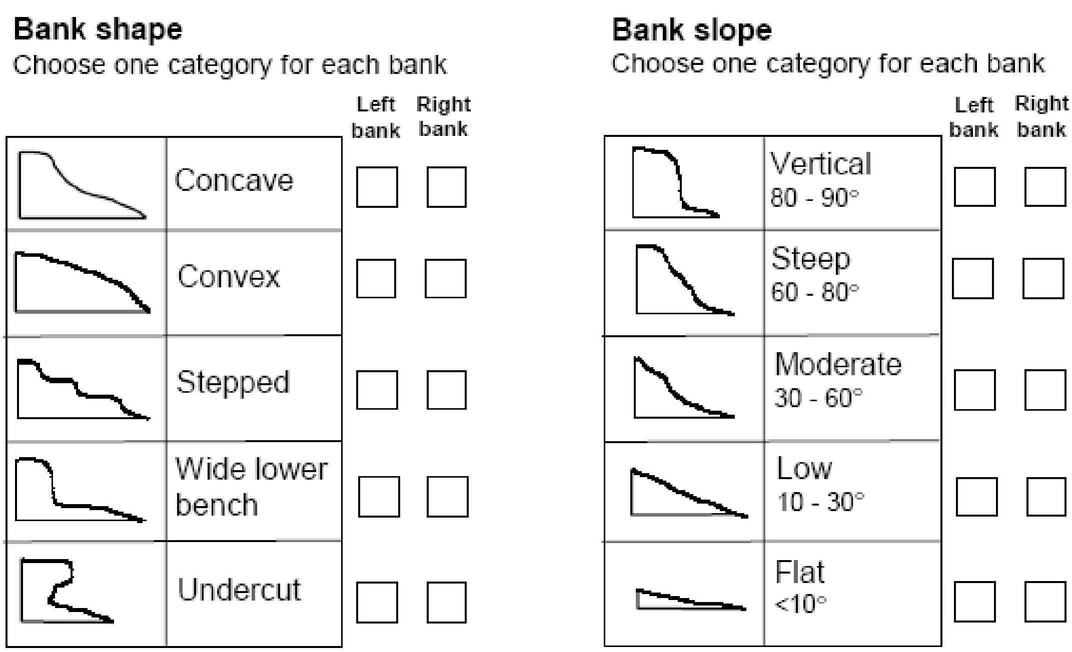


Figure 3.5 Bank shape and bank slope (Parsons 2002)

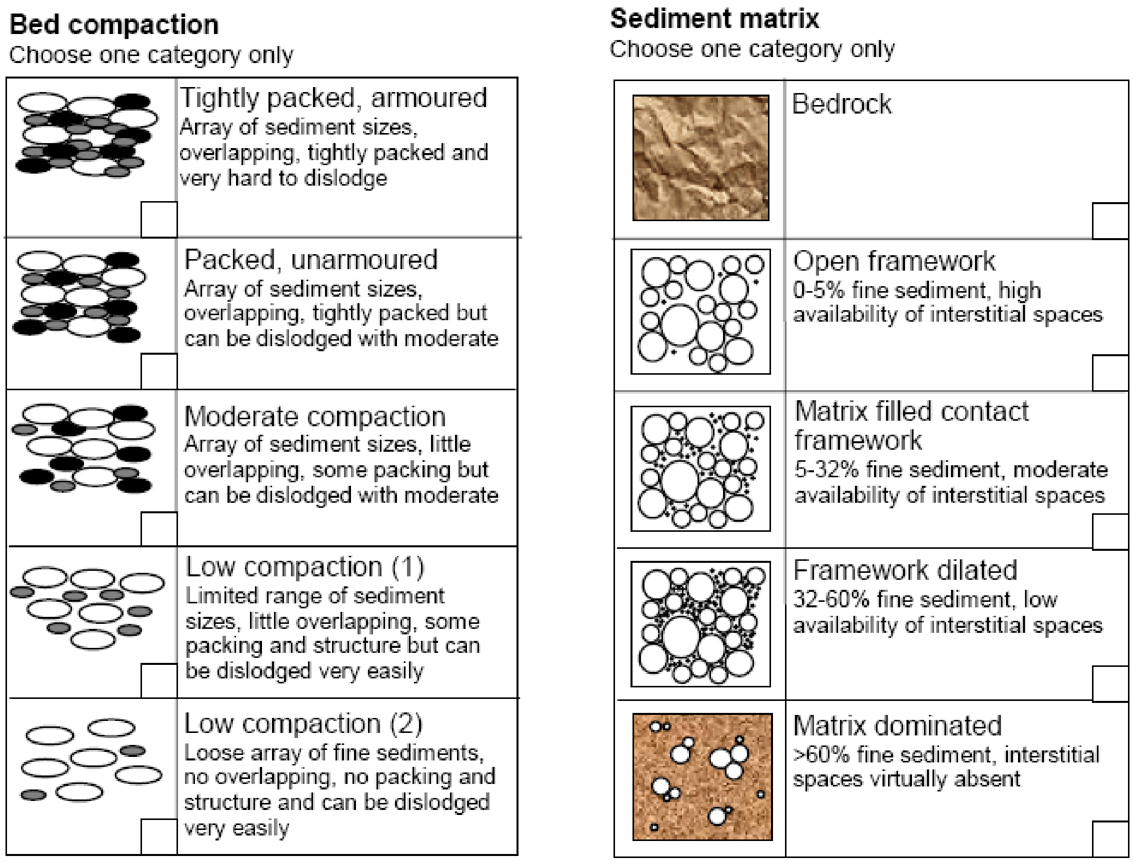


Figure 3.6 Bed compaction and sediment matrix

The preliminary field forms addressing these aspects are attached. (*cf* 17: Field forms)

3.5 LOCAL DISTURBANCES AT THE SITE

The information relates to the Index of Habitat Integrity (IHI) (Kleynhans *et al* 2008) information that is collated to derive the IHI ratings. However, the IHI evaluations of impacts are applicable to the MRU and not to the site per se. This information required here is applicable to the site and only serves as a record to identify any additional local disturbances or changes. The IHI for the MRU is a requirement as part of the baseline for EWRM and therefore does not have to be addressed here.

Table 3.1 must be used to identify the disturbance, to provide a comment regarding the disturbance, and to provide a rating (1 – 5). The rating is an evaluation of the extent and severity of the disturbance with 5 relating to a severe disturbance applicable to most of the site. The focus area is the channel condition and the riparian zone as well as any disturbances immediately outside of the riparian zone which impacts on the site.

Table 3.1 LOCAL DISTURBANCES TABLE

MODIFICATION	COMMENT	RATING
Abstraction (run of river)		

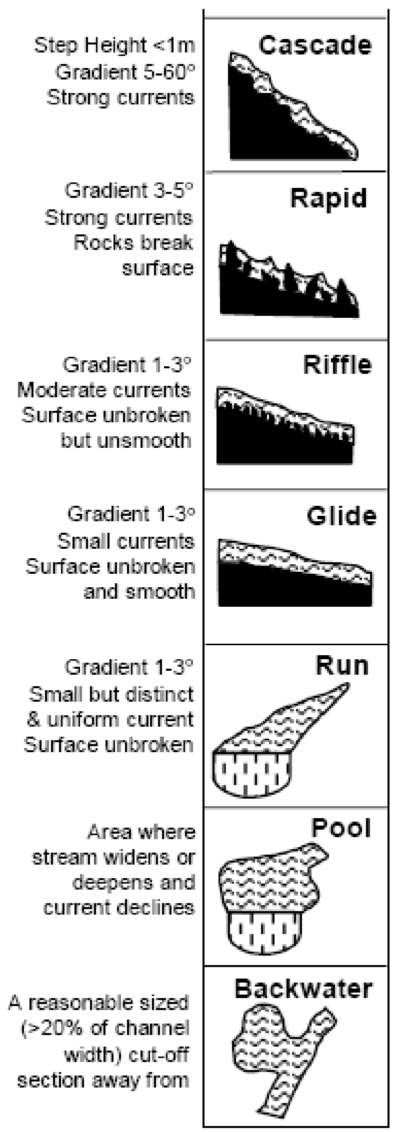
Animal farming		
Artificial covering		
Bed: material disturbance/removal		
Bed: stabilization (e.g. concrete)		
Buildings		
Channel Straightening		
Construction activities		
Crossings low water (immediately upstream or downstream)		
Dams (immediately upstream or downstream)		
Dry land farming		
Erosion		
Forestry		
Invasive alien vegetation		
Irrigation		
Mining		
Off-channel dams		
Recreation		
Riparian vegetation removal		
Roads		
Rubbish dumping		
Runoff/effluent:		
Trampling		
Weirs (immediately upstream or downstream)		

4 HOW TO SELECT AND DELINEATE THE GEOMORPHIC HABITAT UNITS WITHIN AN EWRM SITE

4.1 GEOMORPHIC HABITAT UNIT (GHU)

GHUs are relatively uniform sections in the site – uniform in terms of velocity, substrate, depth, width, gradient etc and must be of a practical length to assess, i.e. not individual elements (logs, rocks, gravel patches etc) that represent microhabitats.

Basically GHUs refer to hydraulic units, ie uniform patches of flow and substrate material. These GHUs are often described as pools, runs, riffles. Due to the conflicting definitions of the terms and the explanations there-of, the following (Parsons 2002) has been selected to define the GHUs.



- **Cascade (CA):** Water movement rapid and very turbulent over steep channel bottom. Most of the water surface is broken in short, irregular plunges, mostly whitewater. Sound: roaring. (FAST DEEP)
- **Rapid (RA):** Water movement rapid and turbulent, surface with intermittent whitewater with breaking waves. Sound: continuous rushing, but not as loud as cascade. (FAST DEEP AND FAST SHALLOW AND FAST VERY SHALLOW)
- **Riffle (RI):** Water moving, with small ripples, waves and eddies - waves not breaking, surface tension not broken. Sound: "babbling", "gurgling". (FAST VERY SHALLOW, FAST SHALLOW AND FAST DEEP)
- **Run (RN):** Water moving with a relatively smooth, unbroken surface. Low turbulence. (FAST SHALLOW AND OR FAST DEEP). Similar to a glide.
- **Pools**: Still water, low velocity, smooth, glassy surface, usually deep compared to other parts of the channel: (SLOW DEEP and SLOW SHALLOW). The following are different types of pools one can find.
  - → Plunge Pool (PP) Pool at base of plunging cascade or falls.
  - → Trench Pool (PT) Pool-like trench in the center of the stream
  - → Lateral Scour Pool (PL) Pool scoured along a bank.
  - → Impoundment Pool (PD) Pool formed upstream of a natural constriction (hydraulic control).
- **Backwater (BW):** A cut-off section away from the main river

Different GHUs represent different habitats and very specifically different velocity depth classes with substrate. GHUs therefore vary in importance based on the critical habitat or preference of the specific indicator guild at the site and in the MRU. These GHUs also react differently to anthropogenic changes – some GHUs are more stable than others. It therefore is logical that the most important GHUs (for the indicator species) and those likely to be sensitive to change might require more attention than other GHUs. GHUs therefore are evaluated and monitored separately.

4.2 DELINEATION OF THE SITE

The site is delineated by the upstream border of the upstream GHU and the downstream border of the most downstream GHU (Fig 4.1). I.e. the selection of GHUs is required before the site can be defined. Practical considerations will often guide the number of units to be selected.

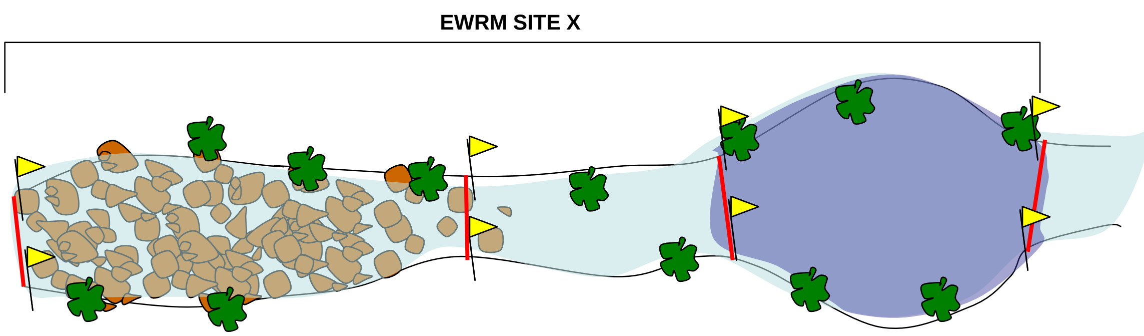


Figure 4.1 Site delineation

4.3 HOW TO SELECT GHUS

Ideally more than one GHU and very specifically the most critical GHU (in terms of the indicators and sensitivity to change) should be selected. Specific emphasis on the constraints in terms of resources must at all stages be considered and sometimes only the critical GHU can be selected (eg as for the RHP).

The following is provided as a guideline:

WHAT TO DO	HOW TO DO IT
Identify the indicator instream biota guilds for fish and invertebrates.	Source available literature. Use the FROC data base. Consult local experts.
Identify the most important GHU for these guilds.	Fish: Use the FRAI database to determine the habitat preferences for the indicator fish guild that occurs. This will provide information to derive the most important GHU.

	Invertebrates:
Identify the most sensitive GHU in terms of habitat.	This is mostly linked to geomorphological changes and type and size of substrate.
Determine the key GHU.	Use the above information and derive the most important GHU. In perennial pool riffle systems, this will often be the riffle. In non-perennial systems and alluvial systems, it will normally be the pools.
Document the reasons for selecting the key GHUs	
Select the additional GHUs	
Document the reasons for selecting the additional GHUs	

Considerations on number of GHUs that can be assessed:

- If the EWRM site is an EWR site, then all the different GHUs should be selected. (i.e. in a pool riffle run system – there should be three GHUs. (Fig 4.2))
- If the EWRM site is a RHP site, it is recommended that all the GHUs must be selected for baseline; however, it is likely that only the key GHU is monitored in detail and that the other GHUs could be subject to a visual and broad assessment only. If at all possible, all three GHUs should be surveyed in detail as part of the baseline – follow-on monitoring could then concentrate only on the key sites unless there is a specific need for assessing the other GHUs.

Other issues that play a role:

- The pool GHU in these wadeable rivers is often non-wadeable. The suggested process for non-wadeable rivers will then have to be applied (*cf* 13).
- Rivers with riffles that can potentially move easily: Some riffles – especially in predominantly alluvial system, has the tendency to move downstream in the system after flooding. In these systems, the riffle and the downstream run should have the same number of cross-sections (see Chapter 4). This is so that the available critical habitat (now in the run) is still measured during monitoring.
- Note that often a GHU and run could be present adjacent to each other (secondary channel, divided by an island or bedrock outcrop etc). In that case, a GHU can include two geomorphic GHUs, i.e. a combined GHU (example in Fig 4.3).

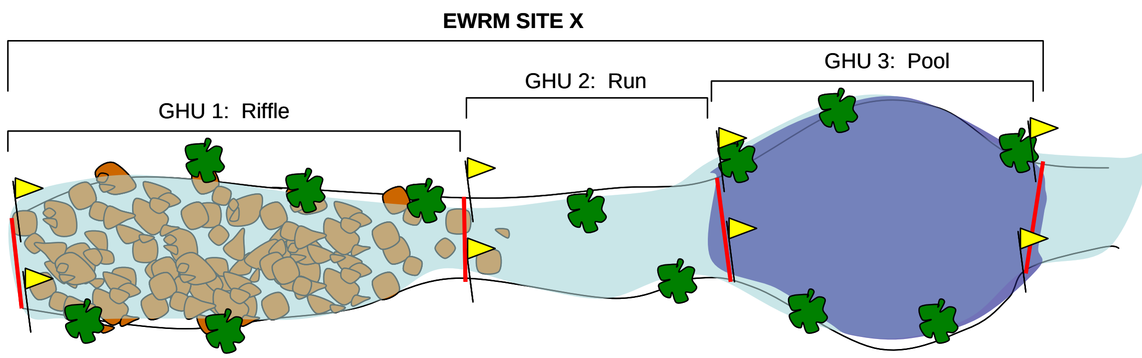


Figure 4.2 Example of GHUs within an EWRM site

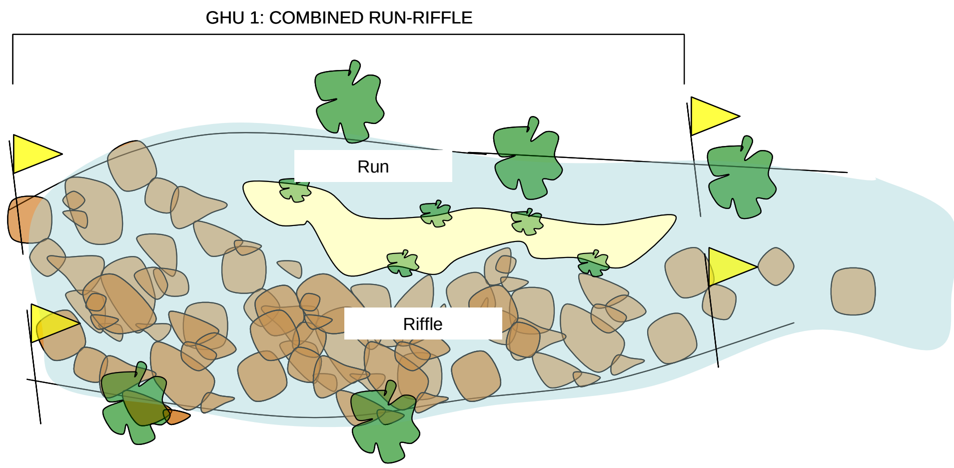


Figure 4.3 Example of a combined GHU

Google Earth images are provided in Figures 4.4 to 4.8 as examples of different EWRM sites delineated into GHUs and the reasons provided. Note that these are hypothetical examples.

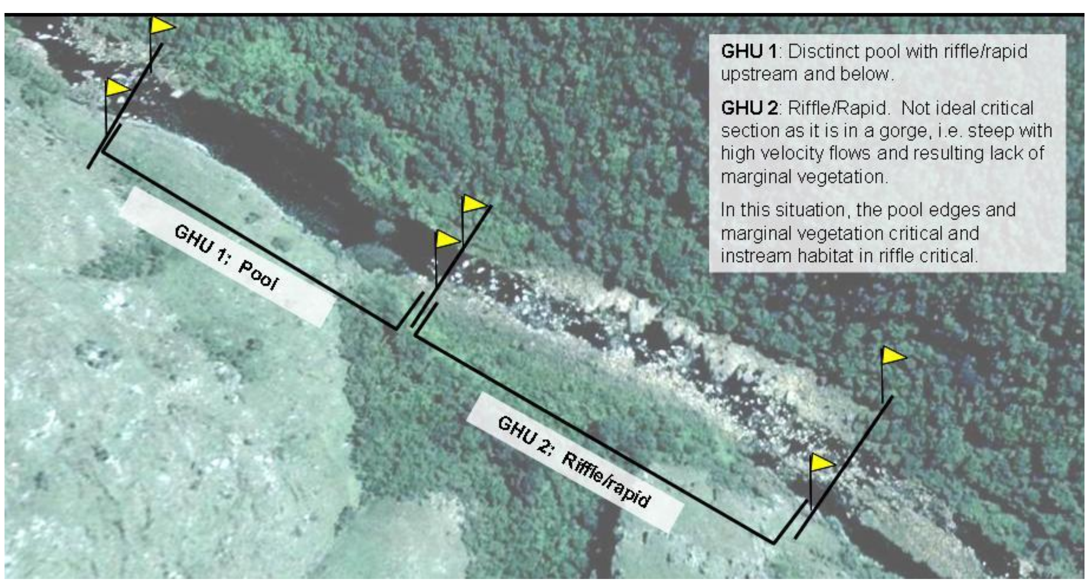


Figure 4.4 Example of the selection of GHUs on a pool riffle system

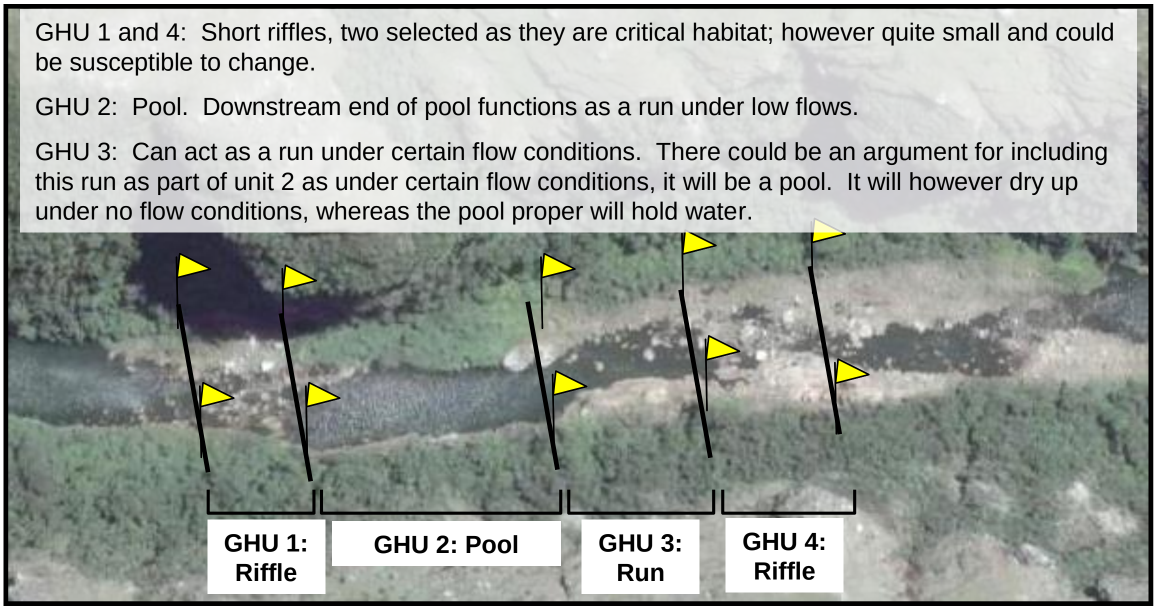


Figure 4.5 Example of the selection of GHUs on a pool riffle system

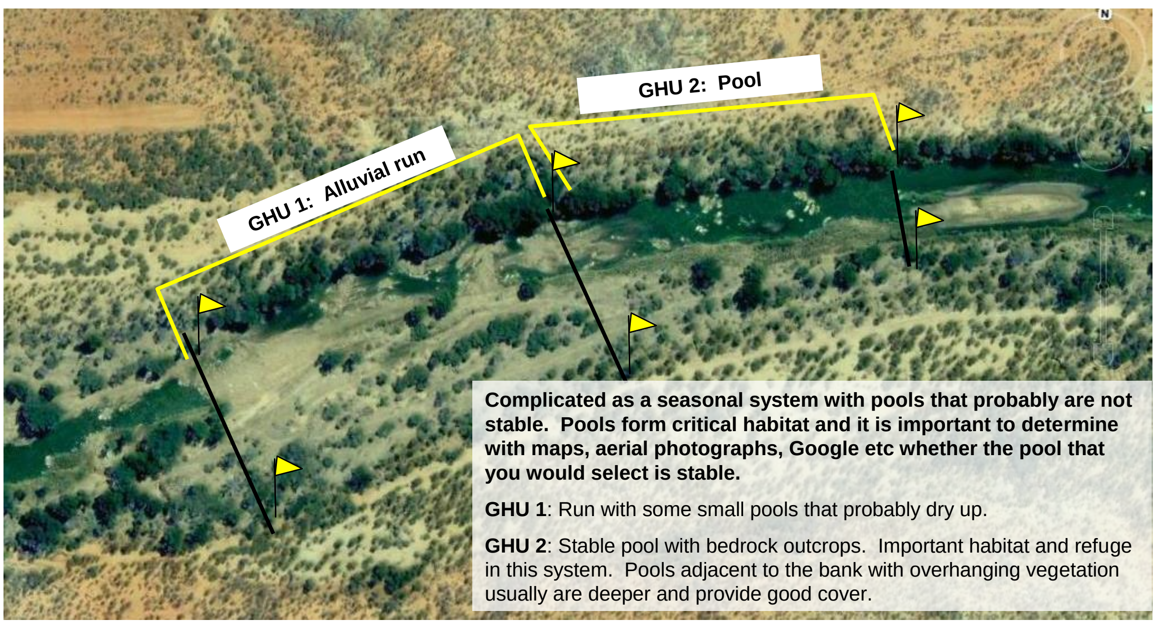


Figure 4.6 Example of the selection of GHUs on a seasonal alluvial system with permanent pools

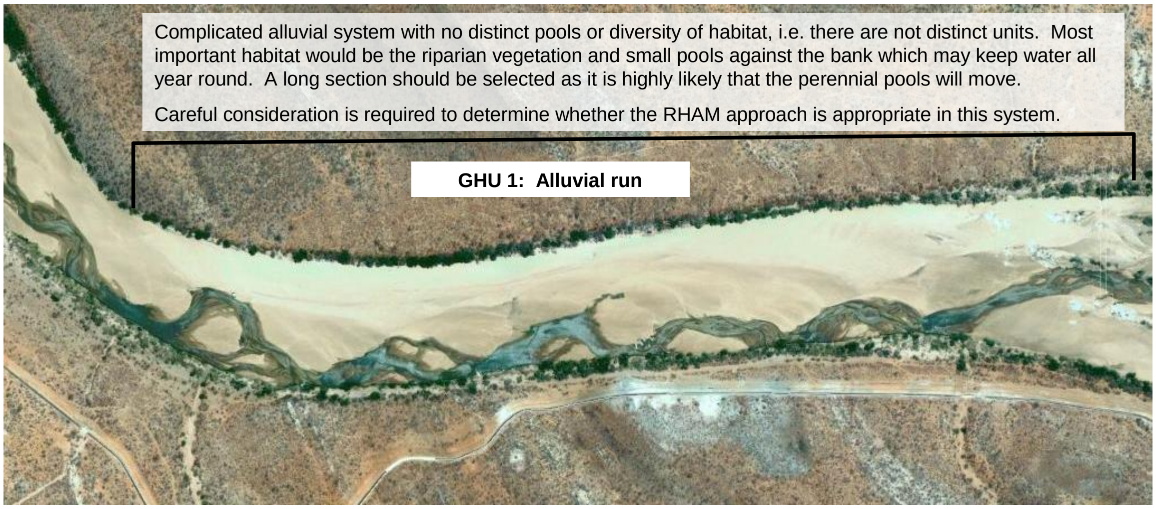


Figure 4.7 Example of the selection of GHUs on a seasonal alluvial system with pools that are not necessarily perennial and not stable

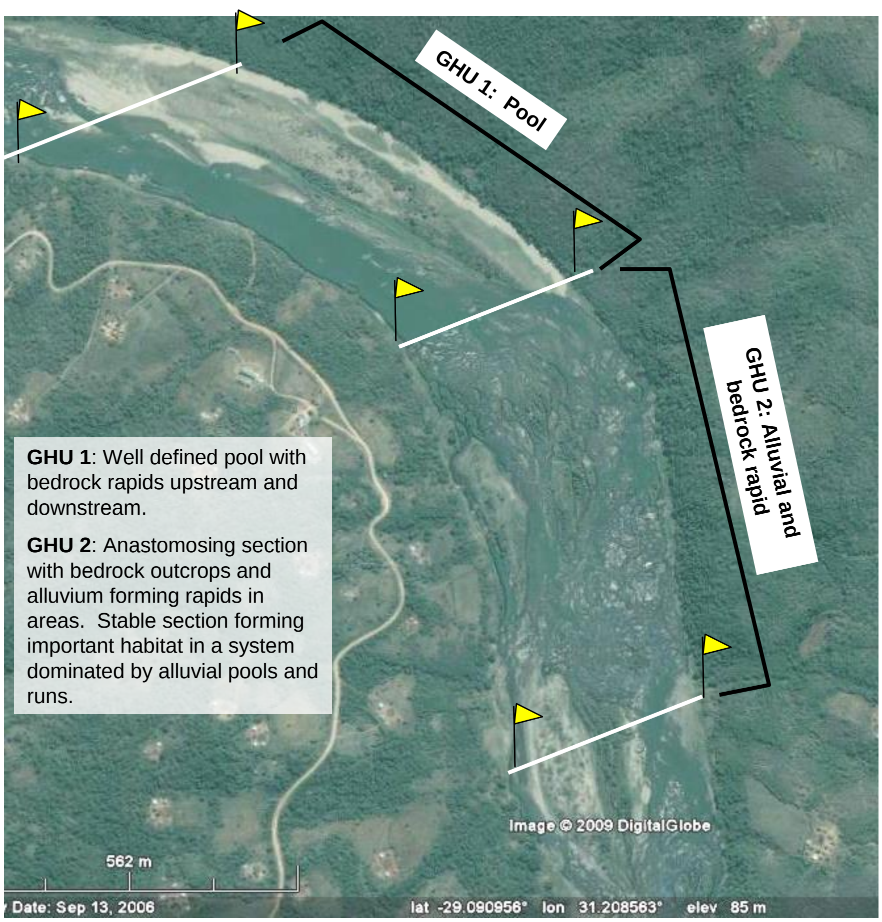


Figure 4.8 Example of selection of GHUs on a mixed alluvial bedrock system

4.4 HOW TO FIX THE GHU BOUNDARIES

During the baseline assessment, the GHUs will be selected and benchmarked. The upstream border of the GHU must be marked so that it is possible to find the same border during follow-on monitoring. This is essential as follow-on monitoring needs to provide data which is comparable to the baseline data.

4.4.1 Benchmarks

There are various ways of benchmarking the sites and the appropriate way must be selected considering the visual and environmental impact of the benchmarking, as well as the time and material available.

There are 4 ways of benchmarking (Table 4.1):

- Steel peg in concrete
- Bedrock or boulder
- Any distinctive object that is unlikely to move (fence post, bridge pillar, marker on road, large tree, etc).
- Photographs and GPS (stand alone or in combination with the above)

When selecting the way to benchmark the site, the following must be considered:

- The steel peg in concrete must be used as a last resort due to the following:
    - → Can (and often is) removed by people.
    - → Can be removed by wild animals (elephant, warthog, etc)
    - → Can be moved and or removed by floods
    - → If covered (to prevent it being removed by people), is often difficult to find.
    - → Requires cement, pegs.
- The bedrock or boulder is the most ideal due to the following:
    - → It is unlikely to move.
    - → It is the least trouble to mark.
    - → It is the easiest to find again.
    - → It has no visual/aesthetic impact.
- Other distinctive objects (preferable to peg in concrete option):
    - → It is unlikely to move
    - → It is easy to find again.
    - → It is however seldom present at the upstream boundary of the GHU and then one has to use additional ways of finding the upstream border.
- Photographs and GPS readings are applicable as aids for benchmarking irrespective of the methods selected. In certain situations, they can be used without other aids where there are no rocks or other distinctive objects. Although not as accurate as used in combination with the other options, it can be used successfully if the character of the river is distinct at the boundary (i.e. recognisable features in the river at the upstream border).

Table 4.1 Illustrations of benchmarks

<table>
<tr><th colspan="2">Peg in concrete</th></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Note that the peg is not essential and is more applicable for hydraulic cross-sections. The concrete on its own would suffice.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">These pictures show the difficulties in finding the benchmark a year after establishing it.</td></tr>
<tr><th colspan="2">Bedrock/boulder benchmark</th></tr>
<tr><td></td><td></td></tr>
</table>


Other distinctive objects




<table>
<tr><th colspan="2">Photographs</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Distinctive rock on LB as upstream border. Also good indication of flow at which monitoring should be undertaken (i.e., low flows and similar to photograph).</td><td>Distinctive rock in the stream as indicator of upstream border. Also good indication of flow at which monitoring should be undertaken (i.e., low flows and similar to photograph).</td></tr>
</table>

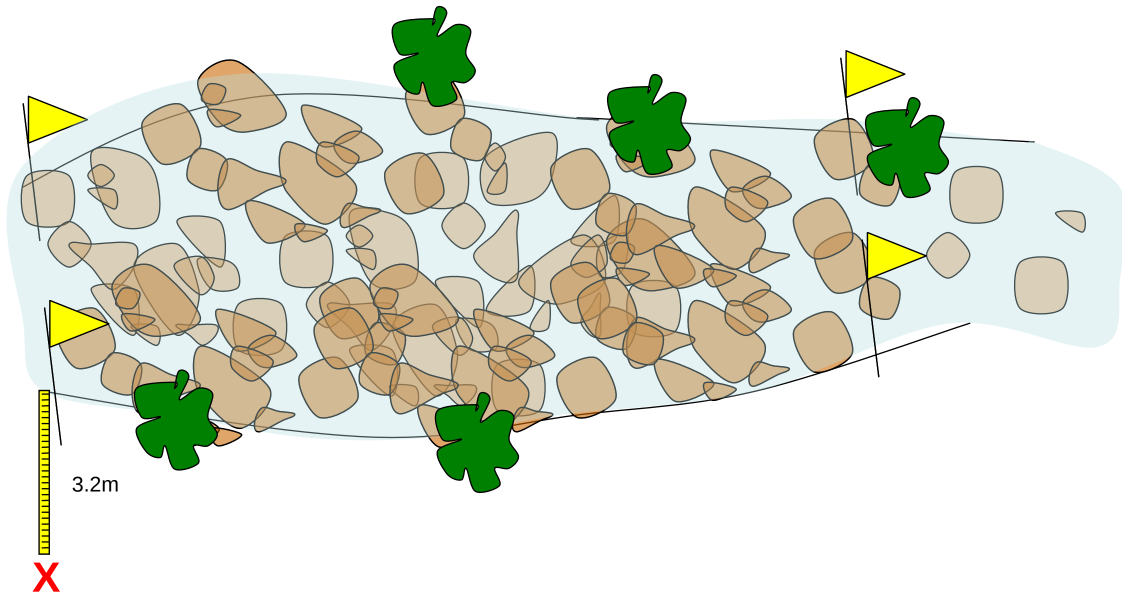
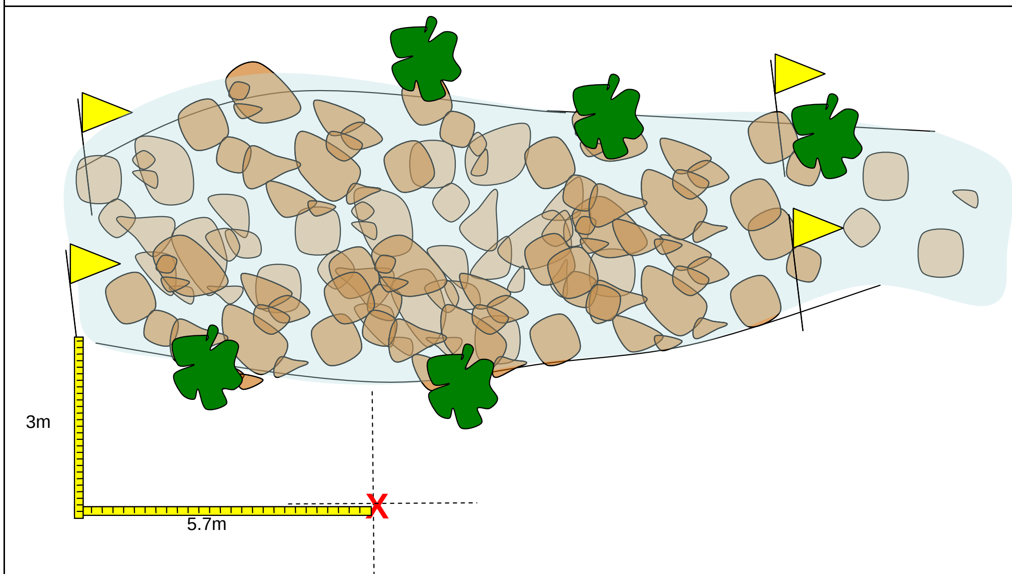
4.4.2 Positioning the upstream and downstream GHU borders

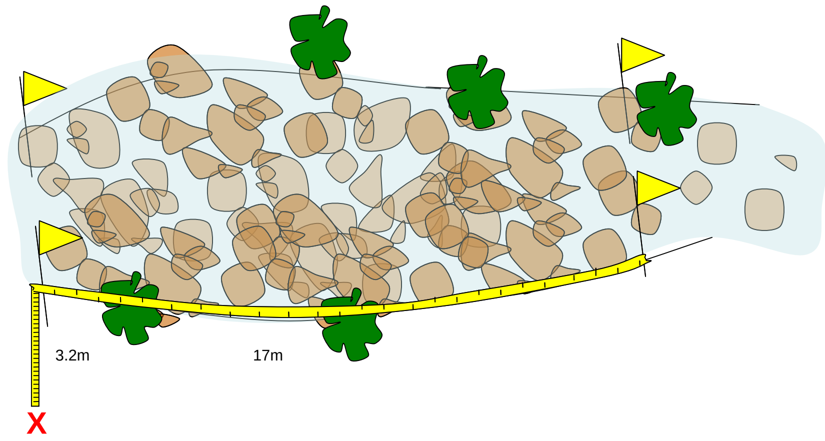
A benchmark will be selected as close as possible to the upstream border bank. However, benchmarks are usually not conveniently situated at the point where your upstream border is, and you therefore have to use the benchmark to guide you to the upstream border. A tape measure and or GPS provide the necessary guidance. The illustrations in Table 4.4 give an indication.

Note that this will not be necessary if you have a benchmark, and a distinctive rock or marker in the channel as illustrated above which then provides you an accurate indication of the upstream border.

The downstream border can be marked in exactly the way as described for the upstream border, or, it can be taped from the upstream border. NOTE: The downstream border must only be fixed once you have finalised the number of cross-sections (*cf* chapter 5).

Table 4.2 Positioning the upstream and downstream GHU borders

UPSTREAM BORDER FROM BENCHMARK (X)

Benchmark depicted by **X**. The distance on a straight line to the edge of the river representing the right bank upstream border point is 3.2m.

Benchmark depicted by **X**. The tape measure is positioned on the ground in a straight line towards the US border parallel to the river. Then one walks towards the river in a straight line.

DOWNSTREAM BORDER MEASURED FROM UPSTREAM BORDER

The tape is put down all along the river bank to the point where the downstream border should be. When measuring your downstream border consider the number of cross-sections you want to put in (*cf* chapter 5). It is therefore not a separate action as described here.

4.4.3 GPS and Photographs

Use your GPS to obtain the coordinates of each benchmark and the upstream and downstream border of the GHU. It is recommended that you check the accuracy of your GPS at each point and if necessary, wait until sufficient satellites are connected so that the accuracy is less than 5 meters. (Photographic guideline in Chapter 8).

4.5 STEP BY STEP PROCEDURE TO SELECT GHUS AND RECORD INFORMATION.

- Identify the indicator instream biota guilds for fish and invertebrates
- Identify the most important GHU for these guilds
- Identify the most sensitive GHU in terms of habitat.
- Determine the key GHU.
- Document the reasons for selecting the key GHUs
- Select the additional GHUs
- Document the reasons for selecting the additional GHUs.
- Identify the benchmarks for the GHUs.
- Mark/establish the benchmarks
- Document where they are in relation to the upstream or downstream border of the GHU.
- Mark the upstream and downstream borders with flag markers.
- Document where the upstream border flags are compared to the benchmarks.

- Document where the downstream border flags are compared either to a benchmark, or to the upstream benchmark.
- Take a GPS reading at each benchmark and at the upstream and downstream border of the GHU.
- Take photographs and ensure all photographs are either labelled or information written down.

5 HOW TO SELECT CROSS-SECTIONS IN GHUS

NOTE:

THE CROSS-SECTION APPROACH IS APPLICABLE FOR **WADEABLE** RIVERS ONLY.
A river or GHU is considered wadeable when one can practically and safely work in the river under normal base/low flow conditions.

Cross-sections are measured within each GHU. Some terminology confusion can arise between cross-sections and transects. A transect is one-dimensional whereas a cross-section is two-dimensional.

TRANSECT
A transect is a line perpendicular to the flow of water from one bank to the other, along which samples are taken or measurements are made. (Simonson *et al*, 1993)

CROSS-SECTION
The area of the channel in vertical cross-section, perpendicular to flow, within the banks. Cross-sectional area is computed as the channel width times the mean channel depth (Simonson *et al*, 1993)

5.1 WHY CROSS-SECTIONS (TRANSECTS)?

The transect line intercept is a line determined by two points on opposite streambanks and is useful as the location reference for the measurement of habitat conditions. This line intercept allows for repeated measurements at exactly the same location at different times and yet allows the randomness in site selection needed to meet statistical requirements (Platts *et al*, 1983). The transect line intercept method has been used successfully in many studies that have documented aquatic conditions over space and time (Herringtong and Dunham 1967); Platts 1974; Platts and Megahan 1975; cooper 1976; Duff and Cooper 1978; Megahan and others 1980).

Habitat data must be collected within the basic framework of the transect method (Platts *et al.* 1983). Various channel, stream bottom, or bank characteristics are measured or visually estimated along each transects. These transect assessments are repeated many times within a station (GHU) to provide an overall picture of habitat (Simonson *et al*, 1993). Stream habitat characteristics are measured at positions along the transect-line (transect-point estimates) (Simonson 1993). Simonson recommends the transect-point scale as it is usually faster, easier, and less subjective to estimate habitat variables within smaller transect-reach or transect point areas versus larger transect-reach areas. (Simonson, unpublished data).

The RHAM therefore consists of various cross-sections within a GHU with cross-section points on the cross-sections where habitat measurements are taken. Cross-sections, if properly marked, allow follow up monitoring to be undertaken at the same place as before and in some ways cater for observer error and subjectivity when random sampling is undertaken. Furthermore, it allows technicians with no specialist knowledge to undertake follow-up monitoring.

5.2 WHAT IS A CROSS-SECTION?

A channel cross-section is essentially a "slice" through the channel, made at right angles to the flow (Gordon et al., 1992). Data collected at a cross-section provides information on linear and aerial channel dimensions. Aspects of channel dimension are related to discharge character and sediment transport, and can also be used to examine changes that occur in the channel profile as a result of anthropogenic or natural events. (Parsons *et al* 2002).

Cross-sections are used in EWR studies for hydraulic modelling and for those purposes, require measurements using survey equipment. Considering the constraints in terms of resources and capacity, equipment is kept to a minimum during EWRM and the cross-sections are measured using a depth rod and a measuring tape. Regardless of the equipment used, the procedure for measuring cross-sections involves taking vertical measurements at several points across a horizontal transect-line. At each point, both the horizontal distance across the channel and the vertical distance to the streambed are recorded. A typical cross-section is shown in Fig 5.1.

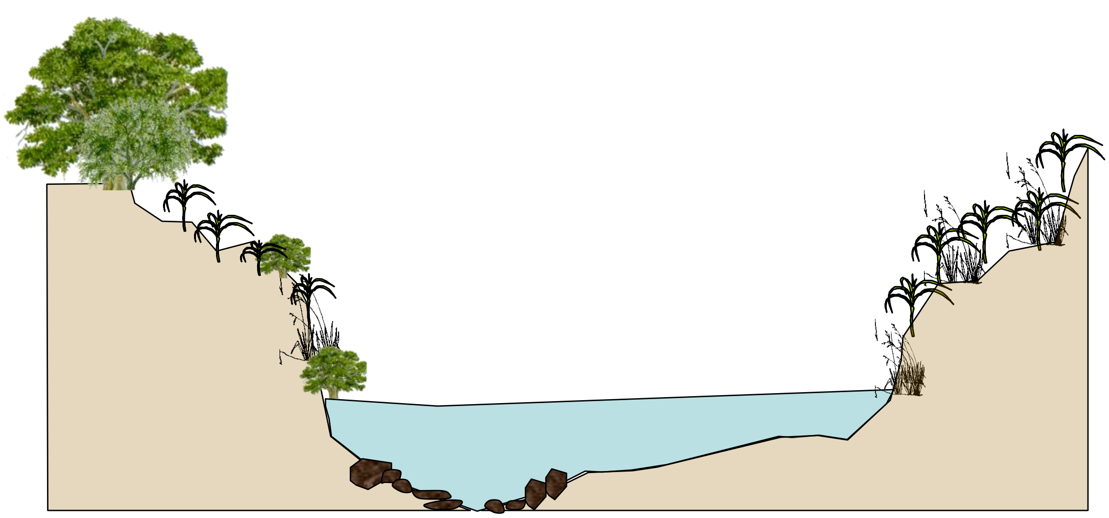


Figure 5.1 Typical river profile from a cross-sectional measurement

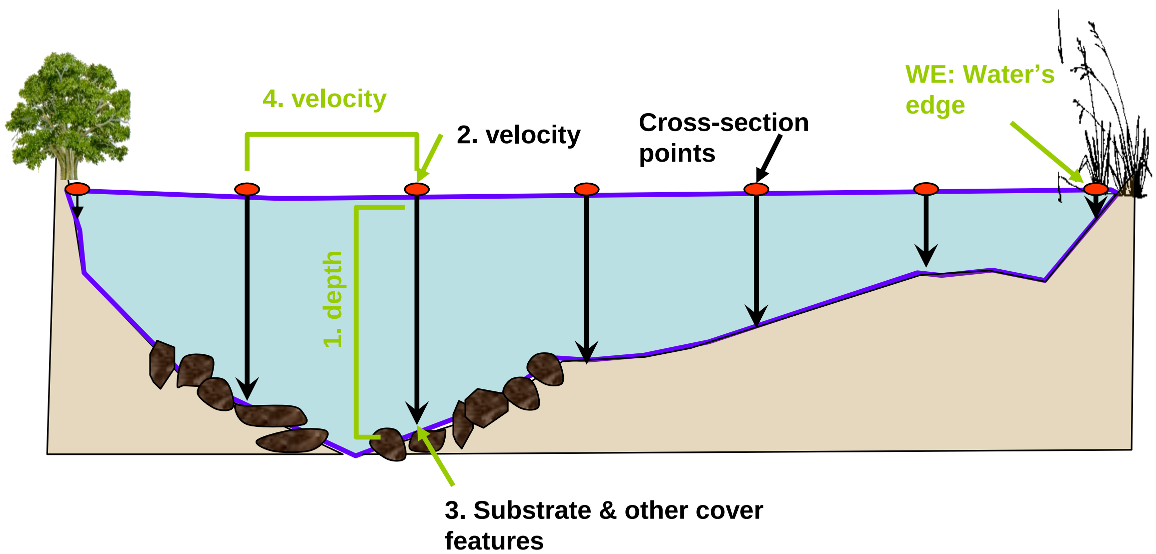
5.3 WHAT DATA IS COLLATED ON A CROSS-SECTION?

Habitat data must be collected at the cross-sections. Essential habitat for instream biota requires the following to be measured:

- Depth
- Velocity
- Substrate
- Cover

Normal cross-section measurements include depth measurements at the cross-section points (*cf* 5.2). Velocity and substrate must be measured as well as any instream cover features (Fig 5.2). Velocity would require a flow meter which is an expensive instrument. To ensure that the monitoring can be undertaken cost-effectively, a Transparent Velocity Head Rod (Fonstad, *et al* 2005) is used. This is referred to further in this document as the Velocity Rod. Equipment required to measure cross-section-habitat is:

- Velocity Rod or flow meter.
- Depth rod (can use the Velocity Rod to measure depth)



- Tape measure

Figure 5.2 EWRM cross-section (blue line) with cross-section points (red markers) illustrating habitat assessed at each cross-section point.

Note, cover features such as algal growth etc is also measured at each point and the marginal cover is measured longitudinally along the GHU. More of this is explained in chapter 6.

5.4 HOW MANY CROSS-SECTIONS AND CROSS-SECTION POINTS?

The recommendations regarding the number of cross-section and points per GHU are numerous (Platts 1985, Simonson 1993, Parsons 2002, Peck 2006), but not necessarily applicable to EWRM. The constraints in terms of resources and capacity dictate that the follow-on monitoring must be quick. A trade-off therefore exists between the time that can be spent monitoring and the quality and amount of data that can be collected.

Considering the trade-off, preliminary recommendations are made based on experience gained developing and testing RHAM on approximately 30 sites. It must however be noted that this testing was not geared for establishing guidelines for number of cross-sections and points. Once sufficient data has therefore been collated, these preliminary recommendations will be reviewed. It must further be noted that expert judgement must be used when selecting the cross-sections and points as the

- homogeneity of the GHUs will play a role in the detail required;
- the detail at one site could differ for the various GHUs (key GHU more detail than the other GHUs).

Guidelines on where the cross-sections and points must be are provided in 4.5. It must be noted that the relationship between width and the number of cross-sections, are relevant for the key GHU.

These, as well as various examples on how many cross-sections to select on different river GHUs are illustrated on Google Earth images.

PRELIMINARY GUIDELINES: NUMBER OF CROSS-SECTIONS AND NUMBER OF CROSS-SECTION POINTS ON KEY GHUs

- Average GHU width < 2m:
  - → Minimum of 3 cross-sections and maximum of 10 cross-sections
  - → Suggested points: Every 0.5m (excluding 2 water's edge (WE) points). If the river is very small, change this to every 0.2m.
- Average GHU width 2 – 10m:
  - → Minimum of 3 cross-sections. Maximum of 10 cross-sections.
  - → Suggested points: Every 1m (excluding WE points).
- Average GHU width > 10m:
  - → Minimum of 3 cross-sections. Maximum of 10 cross-sections.
  - → Suggested points: Every 2m (excluding WE points) to a maximum of 10 points. I.e., if the river is 30 m wide, points will be situated every 3 m.

The following must be considered when deciding on the number of cross-sections and cross-sections points:

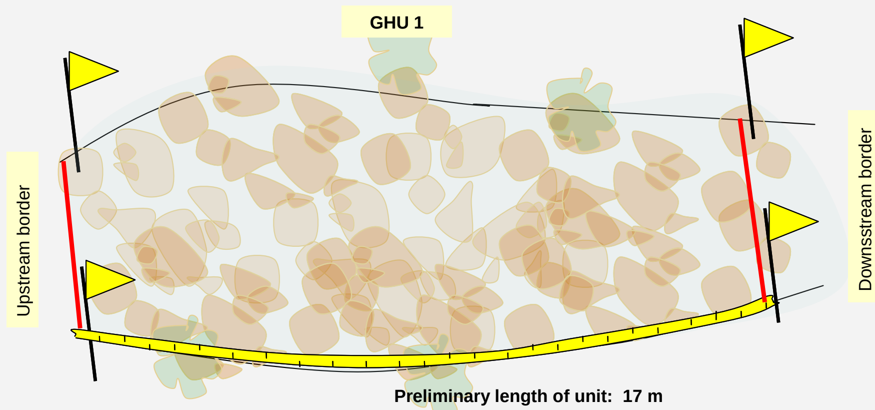
- EWR sites can often warrant more cross-sections than RHP sites.
- During baseline, more cross-sections can be taken than would necessarily be monitored during follow-on monitoring.
- The critical GHU should have more cross-sections than the other GHUs.
- Time and resources will be the most important factor when determining the number of cross-sections.
- Do as many cross-sections as your resources allow during baseline.

5.5 WHERE DO YOU PLACE THE CROSS-SECTIONS?

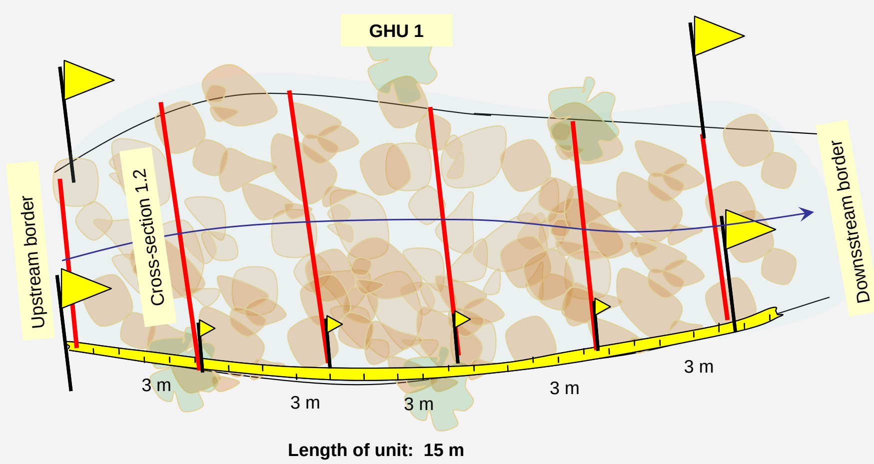
Once you have decided the number of cross-sections, per GHU, you have to space them between the GHU borders. The following steps must be taken:

WHERE TO PLACE CROSS-SECTIONS IN A GHU

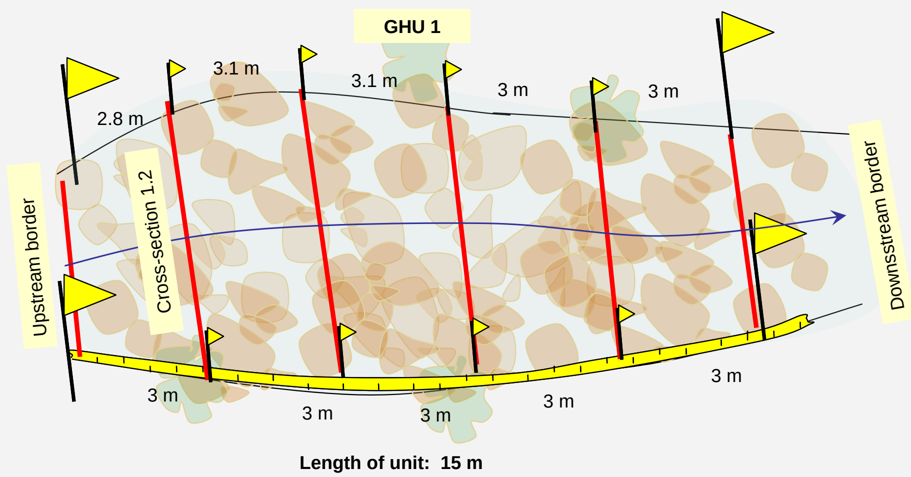
- Measure the length of the GHU ALONG THE BANK from the upstream to the downstream border (red dotted line) as marked by the border flags.



- Determine the number of cross-sections based on the width of the river and the preliminary guidelines provided, as well as considering the homogeneity of the GHU (the more homogenous, the less cross-sections required).
- In the example below, the preliminary GHU length was put down as 17. Now however, considering the guidelines to set cross-sections based on length of river, you determine that you require 6 cross-sections. Rounding your intervals off to 3 m, you would then have a final length of 15 m. (I.e., this is why the downstream border cannot be determined in isolation of this process – *cf* Table 4.2). Place flags on the right bank (RB) (the bank with the tape measure).

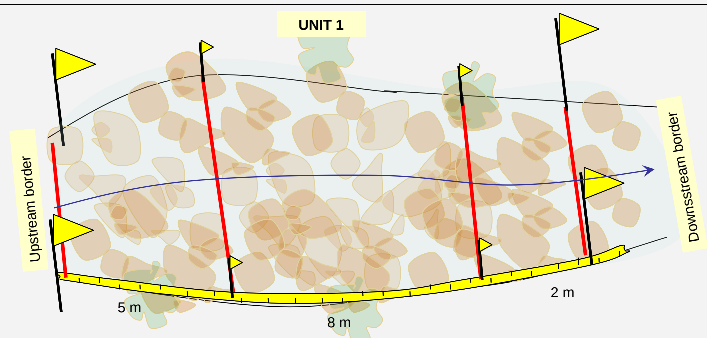


- Place border flags on the left bank (LB) to mark the other end of the cross-sections (solid red lines). Note that the cross-sections should always be (90 degrees) to the flow, therefore distances between the cross-sections on the LB might not be the same as on the RB. These distances must also be recorded during the survey.



- Note: The distances between the cross-sections do not HAVE to be equal. (see below). If time constraints are such that you can only monitor a limited number of cross-sections, then you must place them where they would be most usefull.

ALWAYS MAKE SURE YOU INCLUDE THE WIDEST SECTION OF THE GHU.
IF AN EWR SITE, TRY AND INCLUDE THE HYDRAULIC CROSS-SECTION AS ONE OF YOUR CROSS-SECTIONS.



- Photograph each cross-section when flag markers have been positioned.
- Document where each cross-section is and the width between (field forms, *Cf* 17)

5.6 WHERE DO YOU PLACE THE CROSS-SECTION POINTS?

Once you have decided the number of cross-section points per cross-section, you have to space them equally on the cross-section line according to the guidelines provided in chapter 5. Note that as a fixed length between points according to the average width of the river is being used, the distance between the last point and the WE point will normally be different. The following must be considered:

- The first and the last point must be at the waters edge.
- These points are EXCLUDED when you decide on number of points. The reason for this is that if you are only putting in 3 points, and two of them are at the water's edges, you will have only one point representing instream habitat.
- Use the estimated average width and decide on the length between the points

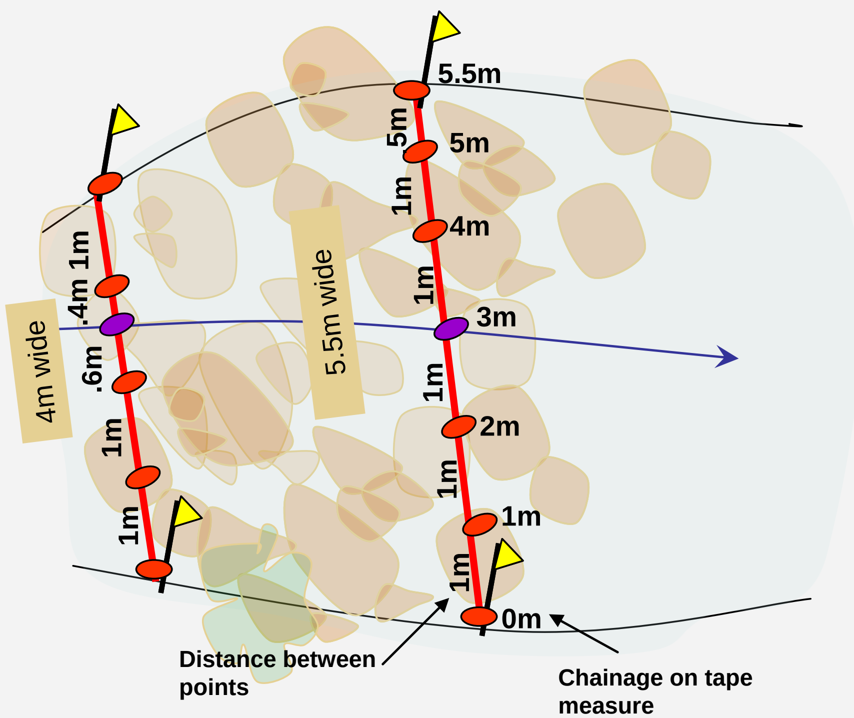
according to the guideline. As the river width is an average, some cross-sections will have more points than others.

- A point should always fall in the deepest section of the river (thalweg: deepest part of a stream's channel. www.wwnorton.com/college/geo/earth2/glossary/t.htm). If the points according to the measured distance do not fall on the deepest point, an additional point must be included and the distances away from the other points documented (this is further explained below).

The following steps must be taken:

WHERE TO PLACE CROSS-SECTION POINTS ON A CROSS-SECTION

- Decide on the number of points considering width of river. If the river is on average 5 m wide, then points are 1m from each other. These numbers of points exclude the two WE points.
- An illustration is provided of the spacing of the points on the cross-sections, specifically on ones which are not exactly 5 m wide. The two example cross-sections were 5.5 and 4m wide. The approach is as follows:



- 4m wide: 1m from the bank would only give 5 points. None of these points go through the thalweg (represented by the blue arrow-line). An extra point is therefore included (blue circle).
- 5.5m wide: As the thalweg point falls on the 1m distance, no additional thalweg point is required.
- Document where each point is in relation to the WE and provide the chainage or distance between the points on the field forms (*cf* 17, Fieldforms)

Google Earth river images (Fig 5.3 and 5.4) are used to illustrate the number of cross-sections and cross-section points to select. Reasons are provided. Note that these are hypothetical examples.

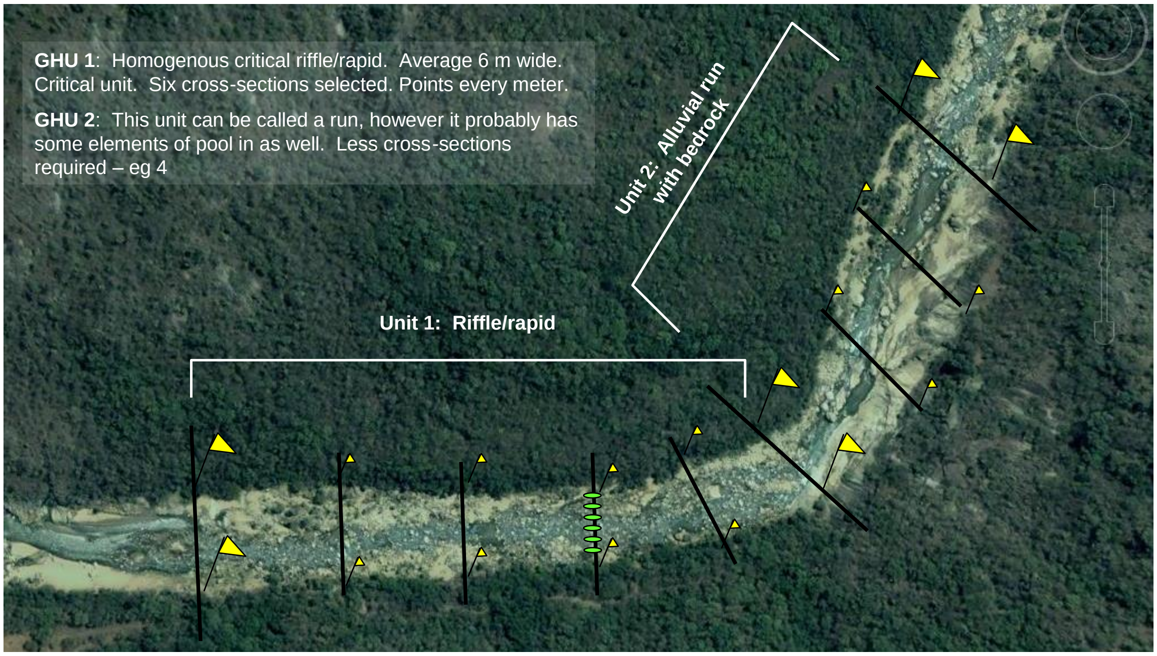


Figure 5.3 Cross-sections and cross-section points in GHUs

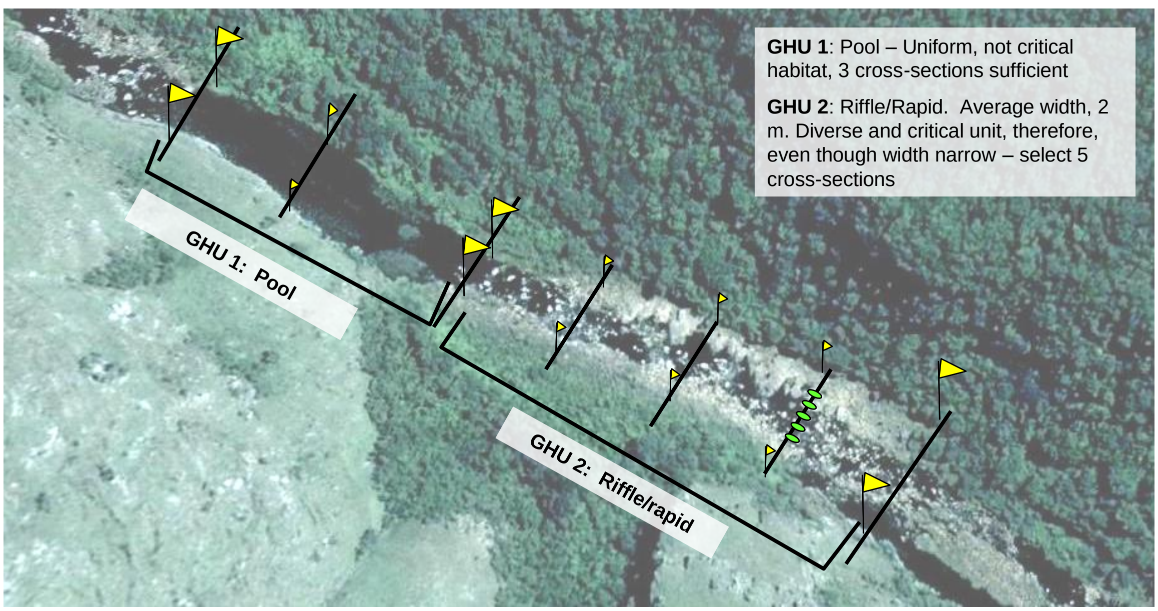


Figure 5.4 Cross-sections and cross-section points in GHUs

6 WHAT AND HOW DO YOU MEASURE AT EACH CROSS-SECTION AND CROSS-SECTION POINT

6.1 WHERE, HOW AND WITH WHAT DO YOU MEASURE VELOCITY?

WHERE?

At each cross-section point.

HOW AND WITH WHAT?

- **Current meter (flow meter):** Use the current meter at each point and measure velocity at 50% of the depth. (It is assumed that if you have access to a current meter, you know how to use it or can follow the suppliers instructions).
- **Velocity Rod**: Use the Velocity Rod (Fonstad, 2005) according to the information supplied below. Note that there are other versions of these velocity rods as well that can be used. Due to the ease of using it and the cheap costs, the Transparent Velocity Rod is recommended.

6.1.1 Use of the Velocity Rod

The Velocity Rod must be constructed according to the specifications in Fonstad, 2005.

At each point, the velocity rod (Fig 6.1) is used as follows:

- Stand in the river at the cross-section point, facing upstream.
- Put the Velocity Rod in the stream with the broad side facing you, and the stream flow coming towards you.
- The flat surface of the Velocity Rod must be at the back of the velocity rod, with the side with the ‘rulers’ on facing you.
- Measure the difference in head (Fig 6.2). Round this off as the resolution is such that you do not require this in exact details.
- Note: If the flow is very low, no head will be indicated. Do not complete zero in the data sheets if you can see that there is some flow. Just record a low velocity (or small head – i.e. 1 mm) so that it is recorded that velocity is present, but that it falls in the SLOW class (i.e. less than .3m/s).

Figure 6.1 Using the Velocity Rod at a cross-section point

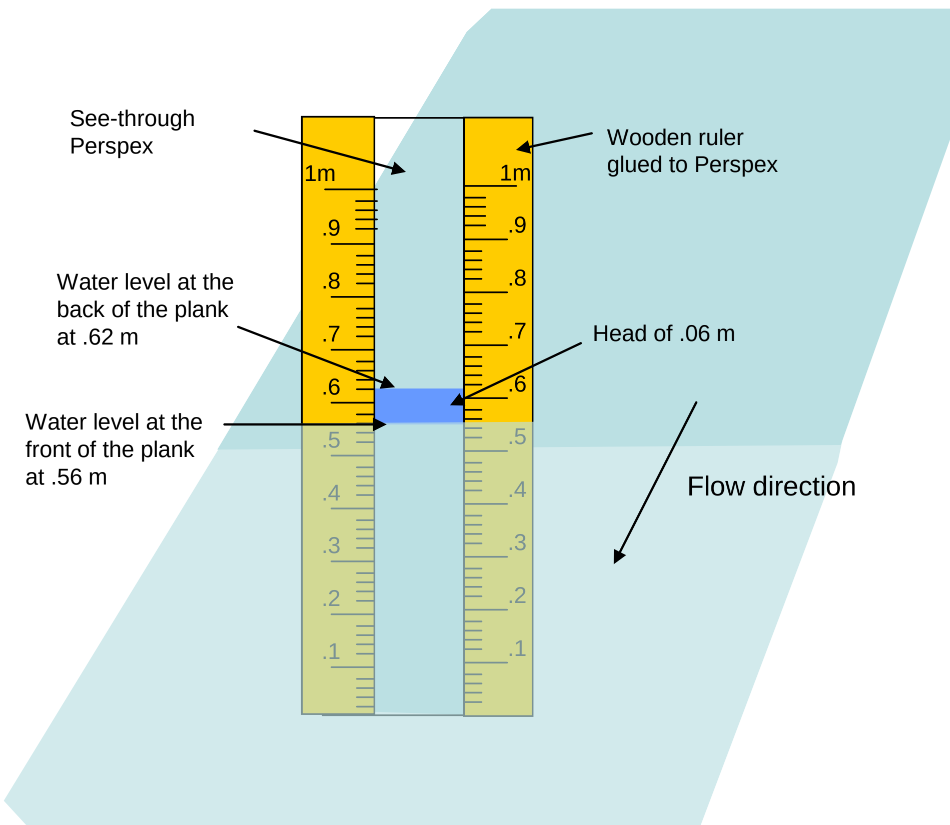


Figure 6.2 Velocity Rod showing how the head is measured

6.1.2 Recording of data

The data must be stored in the field sheets at the appropriate places. (*cf* 17, Fieldforms)

6.2 WHERE AND HOW DO YOU MEASURE DEPTH?

WHERE?

At each cross-section point

HOW AND WITH WHAT?

- **Depth rod:** Use a calibrated current meter pole, or broomstick with sewing tape fixed to it, or any other calibrated pole.
- **Velocity Rod**: The velocity rod can be used by turning it SIDEWAYS and reading off the depth. Do NOT use the velocity rod in the same position as when you measure the head, as that does not provide a realistic depth (it is drawn down below the depth in front). The position of least resistance against the current will therefore provide the most accurate depth.

6.3 WHERE AND HOW DO YOU MEASURE SUBSTRATE?

WHERE?

At each cross-section point.

HOW AND WITH WHAT?

With the depth rod or Velocity Rod. The substrate on the point where the rod touches are documented. A 30 cm radius (estimated) around the point represents the substrate. If more than one type of substrate occurs, indicate which two either by indicating presence absence (1 for each substrate that occurs), or provide the proportion, eg .4 for one substrate and .6 for the other (40 and 60 %).

The different types of substrates (illustrated in Table 6.1) and abbreviations are:

Substrate	Abbreviation	Size (mm)
Roots*	-	n/a
Fines	Fi	0 – 0.2
Sand	Sa	0.2 – 6
Gravel	Gr	6 – 60
Cobbles	Co	60 – 250
Boulder	Bo	>250
Bedrock	Be	n/a

*Roots: Refer to root wads forming substrate with no flow in and around it

Table 6.1 Illustrations of substrate types

Roots	Fines
Sand	**Gravel**
Cobbles	**Boulder**
Bedrock	

6.4 WHERE AND HOW DO YOU MEASURE OTHER INSTREAM COVER FEATURES?

WHERE?

At each cross-section point.

HOW AND WITH WHAT?

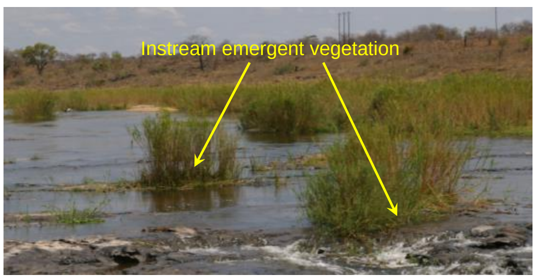
With the depth rod or Velocity Rod. The other cover features on the point where the rod touches are documented. A 30 cm radius (estimated) around the point represents the substrate. Note: This is marked additional to of the substrate, i.e. there will always be substrate, AND then other cover features if present.

The different types of cover features (illustrated in Table 6.2) and descriptions are:

Cover features	Descriptions
Embedded substrate	Refers to the extent to which gravel, cobble and boulders are covered by, or sunken into, the silt, sand or mud of the stream bottom. Generally, as rocks become embedded, the surface area available to macroinvertebrates and fish spawning, shelter and egg incubation) is decreased. (Parsons *et al* 2002).
Woody debris	Large pieces or aggregations of smaller pieces, of wood (eg logs, large tree branches, root tangles). (Simonson *et al* 1993).
Detritus	A non-dissolved product of disintegration, usually pertaining to small organic particles such as leaves, twigs, tree branches, dead macrophytes, etc. When very fine, may appear similar to SILT. (Simonson *et al* 1993).
Submerged instream vegetation	Plants that grow or are adapted to grow beneath the surface of the water most of their life cycle (Simonson *et al* 1993) (includes roots with flow around among it (compared to root wads which are part of substrate))
Emergent instream vegetation	Plants with a significant portion of their biomass above the water (Simonson et al 1993). Ie, plants that are rooted in mud beneath water, but grow tall enough to stick out above water or have leaves that float on the water under normal conditions. Examples would be water lilies and reeds. *www.nps.gov/keaq/forteachers/upload/Emergent%20vegetation.doc*
Algae: Substrate	Eg Diatoms that cover rocks.
Algae: Water column	EG Filamentous algae that occurs in the water column

Table 6.2 Illustrations of cover features

Embedded substrate	Woody debris
	

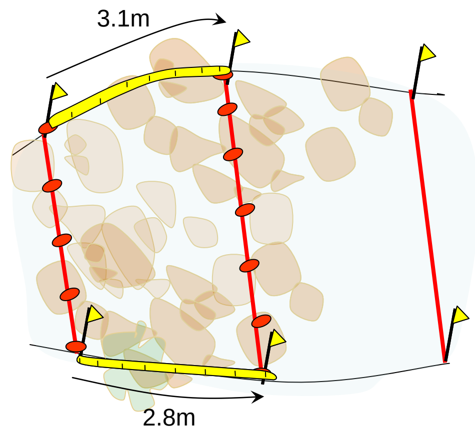
<table>
<tr><th>Detritus</th><th>Submerged instream vegetation</th></tr>
<tr><td></td><td>
Lagarosiphon major (Photo: Rohan Wells, National Institute of Water & Atmospheric Research, www.forestryimages.org)</td></tr>
<tr><th>Emergent Instream vegetation</th><th>Algae water column:</th></tr>
<tr><td>

Instream Phragmites</td><td>
www.virtualviz.com/Pithophora.jpg</td></tr>
<tr><th colspan="2">Algae substrate</th></tr>
<tr><td></td><td>
Taylor 2007</td></tr>
</table>

7 WHAT AND HOW TO MEASURE ALONG THE BANKS BETWEEN CROSS-SECTIONS

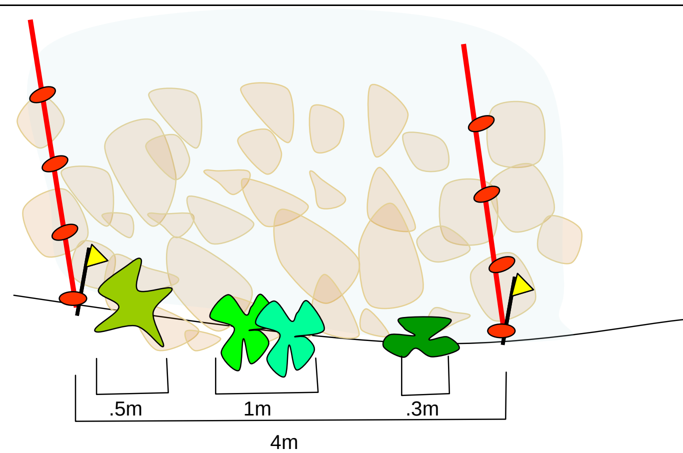
7.1 DISTANCE BETWEEN CROSS-SECTIONS

- Use a tape measure between each of the marker flags and measure the distance.
- This must be done on both banks.
- Document the distance on the field forms



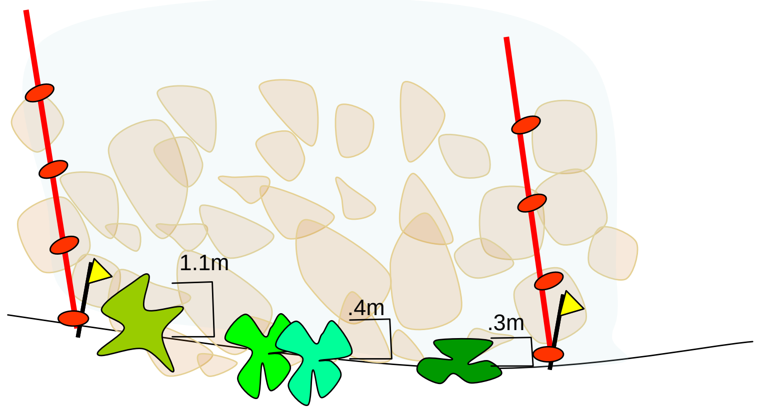
7.2 OVERHANGING AND EMERGENT VEGETATION (EXCL SUBMERGED)

- Estimate the percentage of marginal zone between two cross-sections where overhanging and emergent vegetation occur. (in the example below, this would be 1.8m of a 4 m distance, i.e. approximately 50%)
- This must be done on both banks.
- Document the distance on the field forms



- Estimate the average width of overhanging and emergent vegetation. In the

example below, this would be an average of 0.6m (1.1+.4+.3)/3. In the field, this must be estimated and not calculated.
- This must be done on both banks.
- Document the distance on the field forms



7.3 SUBMERGED VEGETATION

Cf 7.2. Note: Submerged vegetation includes both submerged instream vegetation (as defined in 6.4 as well as ANY PORTION of the emergent vegetation which is under water. Measurements are the same as those described in 7.2. An additional measurement is the average depth of inundation (example in Fig 7.1 and Fig 7.2)

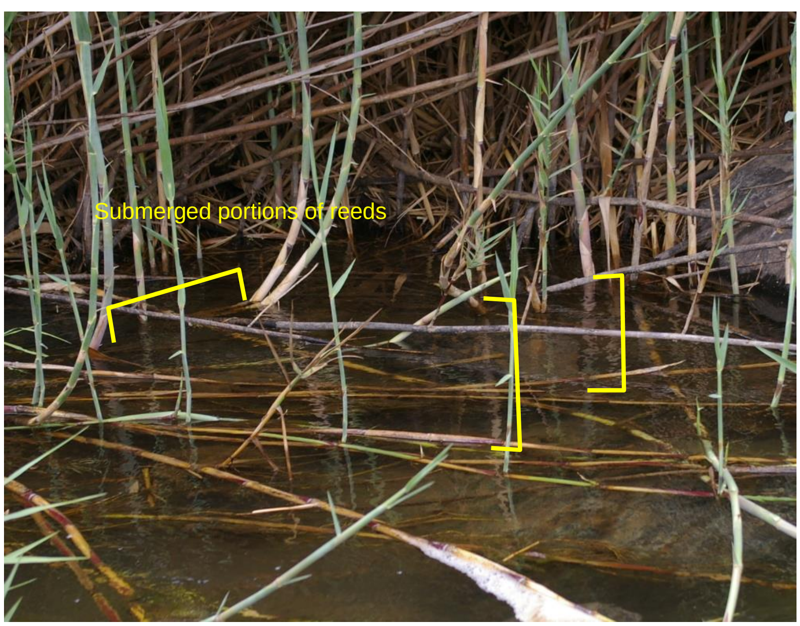


Figure 7.1 Submerged portions of reeds

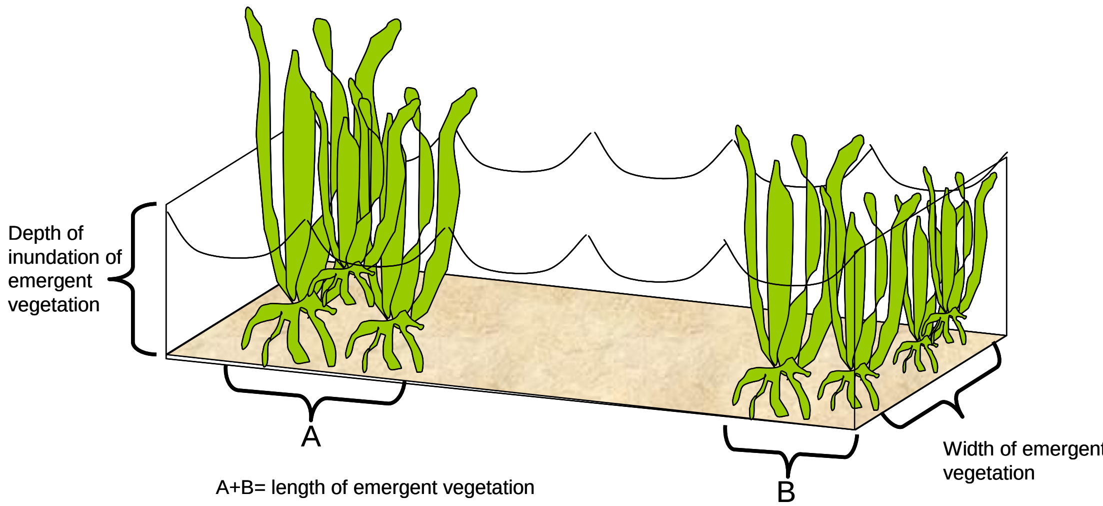


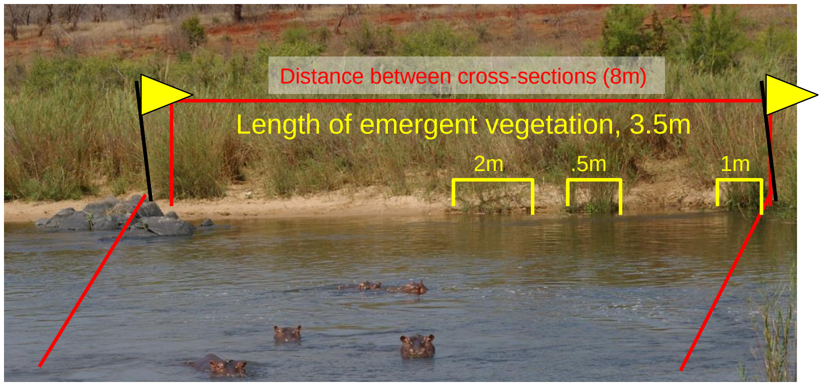
Figure 7.2 Illustration of length, width and depth of inundation of emergent vegetation (sketch by A Deacon)

7.4 ROOTS AND UNDERCUT BANKS

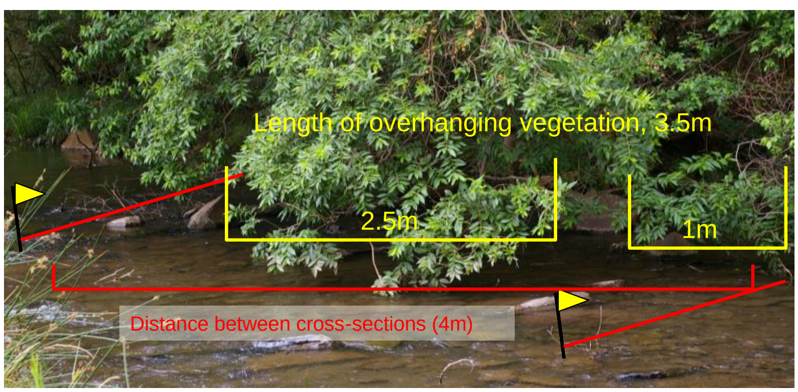
Undercut banks: Banks that overhang the water surface.

Estimate the percentage of the total distance of wetted unit length that consists of roots and undercut banks.

7.5 ILLUSTRATIONS OF THE ABOVE MEASUREMENTS


Distance between cross-sections (8m)
Length of emergent vegetation, 3.5m
2m
.5m
1m


Length of undercut bank


Length of overhanging vegetation, 3.5m
2.5m
1m
Distance between cross-sections (4m)


Width of overhanging vegetation, 1.5m
1.5m

8 TAKING OF PHOTOGRAPHS

Photographs are used for the following (modified from Heitke *et al* 2008):

- Photos are important for relocating sites, and to illustrate the upstream and downstream GHU so that during follow-up monitoring the same points can be found.
- Photos are important to document reach condition, and detecting change through time. The photos therefore provide important baseline information on the state of the GHU which is used as a first level visual assessment, as well as an essential record of the trend of change (if any).
- Photos are included in annual reports and presentations.

Photos are one of the easier tasks that you will perform, relax, take your time and take quality photos.

8.1 GENERAL INFORMATION: HOW TO TAKE PHOTOGRAPHS

- Stick flag markers at the upstream and downstream borders, preferably on both banks.
- Always take the Reach ID/Date photo first. The remaining photos can be taken in any order.
- Do not zoom, set the resolution to best.
- To ensure proper lighting, do not take photos looking into the sun, take photos with the sun at your back. Also, try to minimize photographs where part of the frame is in the shadows and part in the sun.
- Hold the camera 1.5 meters from the ground (use a depth rod as a guide) or use a tripod.

There are 2 different scenarios for shooting photographs:

- Baseline: Taking photos at a new site which has not yet been sampled.
- Monitoring: Duplicating photos from a previously sampled site.

8.2 PHOTO POINTS OF NEW SITES

- For all photos, one can use a black board with the key info written and place that in a corner of the photograph. Or, you can take a photo of the black board and then the photo. You can even take a photo of an A4 page with the information written on using a cokie pen. This helps organising the photos so that you are not later unsure where the photo was taken.
- Take notes of where each photo is taken. This is useful for follow-up monitoring.
- Reach ID/Date: Write the stream name, site name, GHU number and date, and take a photo that gives the best view of the site as a whole. The photo should

preferably be a landscape (composite) photo consisting of 2 or three photos.

- Take photographs of the benchmarks. Use a marker or a person pointing to the benchmark. Take photos with some distinctive feature somewhere in the background to provide perspective.
- The bottom and top of the GHU: Take a photograph looking both upstream and downstream. Stand facing either upstream or downstream to the channel at a distance of 5 meters. Make sure the flags are visible. If possible, stand at the downstream border and take the photo to the upstream border (if visible) and vice versa. If this is not possible, take a photo from the downstream border upstream and then another photo upstream from the point from which you can see the upstream border (and vice versa).
- Upstream and downstream border cross-sections: Take a photograph with the tape stretched across the channel and the flag markers visible. Stand parallel to the channel at a distance of 5 or 10 meters (> 8 meter width category).
- Take photos of the riparian zone in each transect block (between cross-sections) that shows as much of the character of the zone as possible. If possible, stand in the middle of the river and photograph both banks.

Some points to remember when taking photos at new sites:

- Try to include both banks in the photo. For smaller streams stand back from the object of interest. For larger stand back 10 meters or at the best distance to assure you can see both banks.
- Try and disperse your photos throughout the sample reach, this will lead to a better documented reach.

8.3 PHOTO POINTS FROM PREVIOUSLY SAMPLED SITES

- Objective: to duplicate old photos as closely as possible in order to determine how a specific location has changed through time. For example we want to be able to put a 2003 stream photo beside the 2008 stream photo and easily tell that the photos were taken from the same exact location, with the same boulder in the lower left corner, with the horizon line in the middle of the both photos.
- Photos should be duplicated as closely as possible using the following procedures:
  - → Old photos will be provided when you sample an old site.
  - → Use an old photo's description (10m US from boundary, facing DS, etc) to help you re-locate where it was taken. Beware; old photo descriptions may have errors. It is more important to duplicate the photo than it is to duplicate the description info.
  - → After relocating where the old photo was taken from, visually compare the old photo with what you are seeing through the camera's viewfinder.
  - → Pay particular attention to the corners of the old photo, does your photo have the same features in each corner?
  - → Does your photo look like it is too close or too far away? If so move.

- → Is the horizon the same? For example, is the meadow behind the stream towards the top of the old photo, but near the middle of yours? If so make the necessary adjustments.
- → Once you take the new photo, compare it to the old version. If they don't match, shoot it again.

- Record the year of the photo you are duplicating.

Missing or Unrepeatable Old Photos:

- If a photo is missing or unrepeatable (horribly out of focus, no description, etc), take a new photo and leave the 'year repeated' blank.

8.4 SUMMARY OF PHOTOS REQUIRED

- Take photographs and ensure all photographs are either labelled or information written down. These photographs should include the following:
  - → 1. Photo of site
  - → 2. Photo of benchmarks
  - → 3 & 4. Photo of GHU (upstream and downstream)
  - → 5. Photo of each cross-section (*cf* chapter 4) (note where the cross-section represents an upstream or downstream border.
  - → 6 & 7. Photo of riparian zone on both banks
  - → Any other significant photographs.

A diagram of photo-taking sequence and a related set of photographs illustrate the range that should be taken at each GHU is provided in Figure 8.1 and Table 8.1.

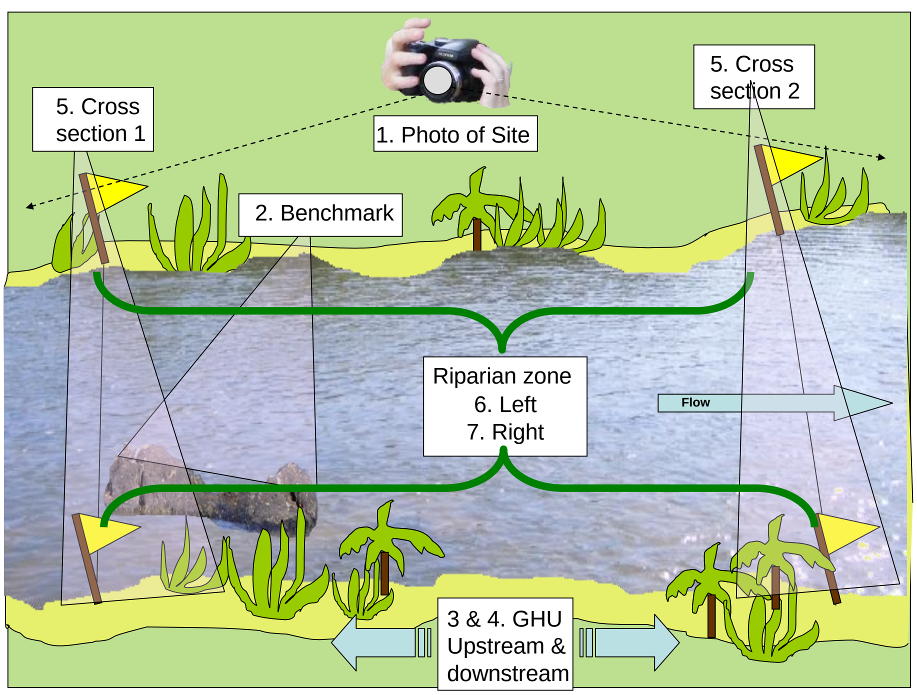


Figure 8.1 Photos sequence linked to the steps above (illustration and photos by A Deacon)

Table 8.1 An example of a range of photographs that should be taken of a EWRM site

1. Site Photo

3 & 4. Photo of GHU (upstream and downstream)

2. Photo of benchmark

5. Photo of each cross-section (*cf* chapter 4)

6 & 7. Photo of riparian zone on both banks

9 HOW TO DO A DISCHARGE MEASUREMENT

The available habitat is largely dependant on the discharge on the day of measurement. The higher the discharge, the higher the percentage of Fast flows eg. It is therefore necessary to know what the discharge is every during monitoring so that one can determine whether changes in habitat is due to a change in flows.

9.1 STREAM DISCHARGE – GENERAL (MODIFIED FROM PECK *ET AL* 2006)

Stream discharge is equal to the product of the mean current velocity and vertical cross sectional area of flowing water. No single method for measuring discharge is applicable to all types of stream channels. The preferred procedure for obtaining discharge data is based on "velocity-area" methods. For streams that are too small or too shallow to use the equipment required for the velocity-area procedure, an alternative procedure is also presented. This procedure is based on timing the movement of a neutrally buoyant object (e.g. a plastic golf ball, a small rubber ball, or an orange) through a measured length of the channel, after measuring one or more cross-sectional depth profiles within that length.

9.2 VELOCITY-AREA PROCEDURE (MODIFIED FROM PECK *ET AL* 2006)

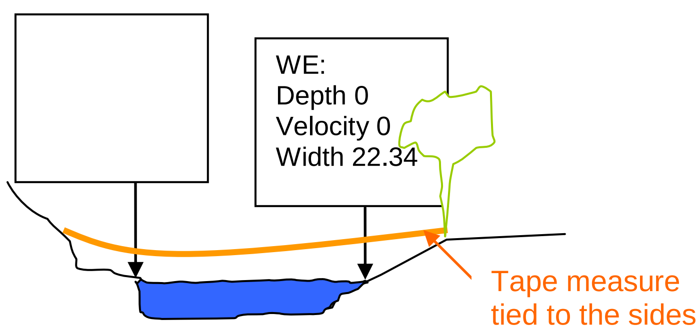
Because velocity and depth typically vary greatly across a stream, accuracy in field measurements is achieved by measuring the mean velocity and flow cross-sectional area of many increments across a channel (see the figure in Table 9.1). Each increment gives a subtotal of the stream discharge, and the whole is calculated as the sum of these parts. Discharge measurements are made at only one carefully chosen channel cross-section. It is important to choose a channel cross-section that is as much like a canal as possible. A glide area with a U-shaped channel cross-section that is free of obstructions provides the best conditions for measuring discharge by the velocity-area method. You may remove rocks and other obstructions to improve the cross-section before any measurements are made.

9.3 STEP BY STEP PROCEDURE TO APPLY THE VELOCITY-AREA PROCEDURE

The step by step procedure for obtaining depth and velocity measurements is provided in Table 9.1. It must be noted that for EWRM for EWR studies, a current velocity meter is required as it is more accurate than the Velocity Rod.

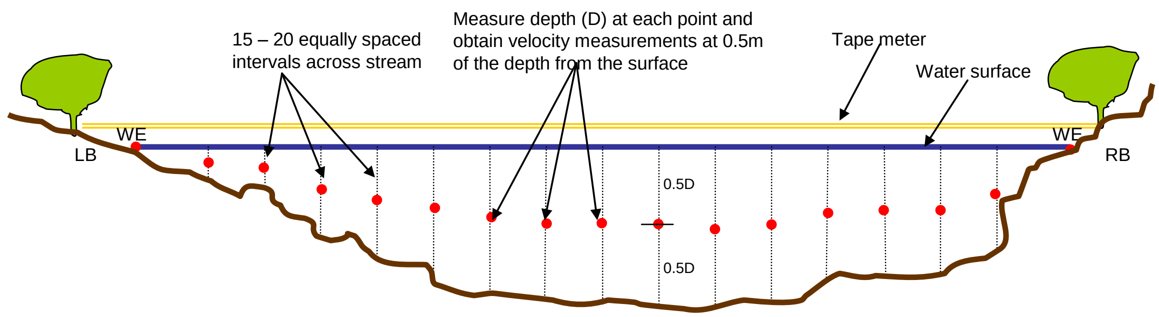
Table 9.1 Velocity-area procedure for determining stream discharge

- Select a uniform cross-section for discharge determination that has most of the following qualities (Peck *et al* 2002)
  - → Segment of stream above and below cross-section is straight.
  - → Depths mostly greater than 15 cm, and velocities mostly greater than 0.15 m/s. Do not measure discharge in a pool.
  - → "U" shaped, with a uniform streambed free of large boulders, woody debris or brush, and dense aquatic vegetation.
  - → Flow is relatively uniform, with no eddies backwaters, or excessive turbulence.
- Stretch a tape meter across the stream, perpendicular to flow. Do not let the tape meter touch the water. In areas that are deep and/or fast, a calibrated rope is recommended so that one can 'hang' on to it.
- Divide the width of the wetted stream into 15 – 20 equal-sized intervals.
- If you are using a flow meter that does not measure velocity directly, decide on the time interval over which velocity must be measured. The more complex the cross-section, the longer the period of measurement.
- Stand downstream of the rod or tape and to the side of the first interval point (closest to the left bank if looking downstream).
- Note the measurement where the flow level starts (Water's edge (WE)). At this point the depth could be zero, depending on the shape of the channel. (RB (looking downstream) in illustration below). If there is sufficient depth (so that the propeller is under water), measure the flow rate (LB in illustration).



- At each point where you measure, document the chainage (where the measuring point is on the tape measure).
- At each point, measure the depth using
  - → a depth rod;
  - → a calibrated current meter pole;
  - → the Velocity Rod turned sideways (*cf* 6.2).

▪	At each point, measure the velocity. If using a current meter, the current meter must be spaced at 50% of the depth for rivers with depth mostly < 1m. As deeper rivers are much more complex to measure in terms of time and equipment, it is assumed that EWRM sites of this size will be placed close to a gauging structure.
▪	Stand downstream of the propeller or Velocity Rod to avoid disrupting the stream flow. Face the probe upstream at a right angle to the cross-section, even if local flow eddies hit at oblique angles to the cross-section
▪	Document the information for each point on a field sheet or directly into the Comp-RHAM.



Modified from Peck *et al* 2006

Note the following:

- Avoid big rocks immediately upstream of the cross-section as there will be no flow at that point.
- Avoid circular flow (eddies) at the sides of the river.
- Avoid excess vegetation on the margins with flow flowing through it.
- Avoid filamentous algae – it clogs the propeller.
- Avoid too rough a surface flow and irregular flow.
- Velocity should be sufficient to turn the propeller.
- If there are rocks blocking the flow, but there is a lot of surface flow, take a surface velocity and note that. Note that the spreadsheet does not cater for surface velocity and you would have to contact somebody to sort that out.

9.4 NEUTRALLY BUOYANT OBJECT PROCEDURE (Modified from Peck *et al* 2006)

In very small, shallow streams where the standard velocity-area method cannot be applied, obtain an estimate of discharge using the neutrally buoyant object method. The required pieces of information are the mean flow velocity in the channel and the cross-sectional area of the flow. Estimate the mean velocity measuring the time it takes for a neutrally buoyant object to flow along a measured length of the channel. Determine the channel cross-sectional area from a series of depth measurements along one or more channel cross-sections. Since the discharge is the product of mean velocity and channel cross-sectional area, this method is conceptually very similar to the standard velocity-area method.

Examples of suitable objects include small rubber balls, ‘wiffle-type” practice golf balls, or small sticks. The object must float very low in the water. It should also be small enough that it does not drag on the bottom. Choose a stream segment that is roughly uniform in cross-section, and that is long enough to require 10 to 30 seconds for an object to float through it. Select one to three cross-sections to represent the channel dimensions within the segment, depending on the variability of width and/or depth. Determine the stream depth at 5 equally spaced points at each cross-section. Measure the time required for the object to pass through the segment that includes all of the selected cross-sections. Repeat the timing two more times. Record the data.

If you have to follow this method for determining discharge, the calculation cannot be done within the Comp-RHAM.

9.5 ESTIMATE USING AVERAGE-WIDTH-VELOCITY

If you cannot undertake a flow measurement using the above described methods, undertake the following:

- Select a uniform cross-section.
- Estimate inundated channel width.
- Estimate average depth across width.
- Estimate the velocity across the ‘cross-section’. If you cannot visually estimate this, time the drift of a piece of wood, orange, etc over a known length. You could also use a Velocity Rod, or a flow meter at one or two points at what visually appears to be average velocity.
- Multiply the average depth, with the estimated inundated channel width with the average velocity to determine the discharge.

9.6 GAUGED MEASUREMENTS

Gauged measurements such as at a gauging weir or rated section usually provide the most accurate and easiest measurement. The following process must be followed to determine the discharge:

- Ensure that there are no significant abstractions or incoming flow between the site and the gauge.
- Read the gauge plate (stage)
- Obtain the rating table from the DWAF website to read off the flow.
- Document the stage and discharge.

10 RHAM WATER QUALITY INDICATORS

10.1 INTRODUCTION

This section describes a visual assessment of potential water quality issues at the monitoring site. Use the site-based water quality indicators according to rating tables provided and indicate whether ratings are:

(a) relative to knowledge of the natural state of the catchment, or
(b) previous sampling surveys.

Note that the inclusion of indicators is to assist in the interpretation and review of water quality status and provide information for management intervention. It is assumed that:

1. a present state assessment for water quality has been undertaken;
2. a baseline has been set for the site; and
3. EcoSpecs and TPCs for water quality have been set.

This method MUST accompany the use of the Rapid Diatom Riverine Assessment Method (R-DRAM) (Appendix X) for interpretation.

10.2 ON-SITE ACTIVITIES

Conduct the following activities when arriving at site:

- Note whether site assessment is relative to natural state or previous site survey.
- Note land-use at the site that may impact on water quality, e.g. industrial site, urban, peri-urban, informal housing, subsistence v. commercial farming.
- Note flow e.g. slow, medium or fast.
- Take fixed-point photographs of areas of concern, for comparison during later surveys. This task may be covered by photographs required in Section x, but also requires **additional** photographs of water quality impact areas specifically, if required and relevant.
- Complete the rating table in the field form (provided at the end of the chapter) for the following water quality indicators – see Section 9.4 for metrics and individual rating tables:
  - → Anthropogenic activities at the site that result in impaired in-stream water quality.
  - → Odours that may suggest poor water quality.
  - → Water column colour, e.g. green may indicate eutrophication.
  - → Water clarity as an indicator of suspended sediment loads. This measure may be used as a surrogate for turbidity measurements, e.g. using a Secchi disk or turbidity tube.
  - → Water surface and riparian bank and vegetation indicators of potential

water quality impacts, e.g. visible scum or purple sheen on the surface, or salt deposits on the bank or riparian vegetation.

- → Extent of algal growth on rocks, i.e. periphyton (note there is a link to the habitat assessment method developed for the biological monitoring programme).
- → Visible biotic responses, e.g. fish kills.

10.3 DATA INTERPRETATION AND THRESHOLDS OF PROBABLE CONCERN (TPCS)

For each of the water quality indicators (other than visible biotic response), the following rating system is used:

0 = natural / no impact
1 = small impact
2 = moderate impact
3 = large impact
4 = serious impact
5 = extreme impact

TPCs are set according to the Ecological Importance and Sensitivity (EIS) of the site. If a TPC is exceeded, a management intervention is required. The management action to be undertaken is determined by the indicator exceeded and its significance to the water quality impact on the ecological state of the site.

Low or Moderate EIS:
Should any indicator **exceed 2**, i.e. a large to extreme impact, a management intervention should be initiated, e.g. move up to the next level of monitoring, more frequent biomonitoring, more frequent assessments of that site, or identification of the cause (e.g. through biological monitoring).

High EIS:
Should any indicator **exceed 1**, i.e. a large to extreme impact, a management intervention should be initiated, e.g. move up to the next level of monitoring, more frequent biomonitoring, more frequent assessments of that site, or identification of the cause.

10.4 CLARIFICATION PER WATER QUALITY INDICATOR

10.4.1 Anthropogenic activities

Anthropogenic activities have impacts on in-stream water quality and obvious sources of activities that can result in impaired in-stream water quality must be noted.

ANTHROPOGENIC ACTIVITIES	RATING					
	0	1	2	3	4	5
Ploughing along banks						
Sand-winning						
Cattle watering or crossing point						
Abstraction point						
Discharge point						
Chemical spill, e.g. abandoned pesticide containers, spillage from pumps, vehicle accidents						
Car washing						
Laundry washing						
In-stream building activities						
Litter						
Dump site						
Other (List, e.g. weir immediately upstream)						

10.4.2 Odour

Indicate the type of odour that is present at the site, if any. NOTE WHETHER ODOURS ARE ASSOCIATED WITH THE SEDIMENT IN THE RIPARIAN ZONE. The following odours have been identified:

a. Sewage
b. Cattle, e.g. cattle-watering point
c. Chemical, e.g. chlorine or pesticides
d. Anaerobic, e.g. hydrogen sulphide (or "rotten egg" smell normally associated with sediments).
e. Other: describe if possible

WATER QUALITY INDICATOR	RATING					
	0	1	2	3	4	5
Odour type 1 – sewage						
Odour type 2 – cattle						
Odour type 3 – chemical						
Odour type 4 – anaerobic						
Odour type 5 – other						

10.4.3 Colour

Indicate the colour of the water column at the site, if discoloured. The following colours can be identified:

a. Brown-black, indicating humics or low pH. DO NOT SCORE IF NATURAL, E.G. WESTERN CAPE STREAMS.

b. Milky, indicating possible chemical pollution
c. Green, indicating algal growth in the water column and probable eutrophication.
d. Orange, indicating presence of iron-oxidizing bacteria or acid mine drainage.
   NOTE THAT THIS IS NOT TURBIDITY.
e. Other: describe if possible

WATER QUALITY INDICATOR	RATING					
	0	1	2	3	4	5
Colour type 1 – brown-black						
Colour type 2 – milky						
Colour type 3 – green						
Colour type 4 – orange						
Colour type 5 – other						

10.4.4 Clarity

Turbidity can be described as the following levels of clarity if a turbidity meter, turbidity tube or Secchi disk is not available to conduct a quantitative measurement. Complete the table below according to the extent of suspended or dissolved solids seen at the site.

WATER QUALITY INDICATOR	RATING					
	0	1	2	3	4	5
Clarity						

0: no turbidity in the water column
1: slightly turbid
2: moderately turbid
3: largely turbid
4: seriously turbid
5: extremely turbid or opaque throughout the site

Note whether the clarity is reduced by materials **dissolved** in the water colour, or **suspended** in the water column.

10.4.5 Water surface and riparian bank and vegetation clues

The presence of deposits on the surface of the water and riparian banks or vegetation may be indicative of potential water quality impairment.

SURFACE WATER QUALITY INDICATOR	RATING					
	0	1	2	3	4	5
Scum (e.g. from elevated organics)						
Foam (e.g. detergent use)						
Purple / oily sheen (e.g. diesel + oils)						
Visible salt deposits on banks and vegetation						
Other						

10.4.6 Extent of algal growth on rocks

The presence of algal growth on rocks, i.e. periphyton, may indicate eutrophication or elevated nutrients in the water column. It is important to compare these indicators to the natural state as some rivers may have naturally high nutrient levels due to geological and other factors.

WATER QUALITY INDICATOR	RATING					
	0	1	2	3	4	5
Extent of algal growth on rocks						

0: no periphyton growth on rocks
1: slight periphyton growth
2: moderate growth
3: large periphyton growth
4: serious periphyton growth
5: extreme coverage of rocks

10.4.7 Visible biotic response

Any visible biotic responses displayed by megafauna, e.g. fish kills, should be noted and will require an immediate management action. A more detailed water quality assessment will need to be conducted immediately, including toxicity testing of in-stream water.

VISIBLE BIOTIC RESPONSE	Yes	No
Visible fish kill		
Visible other species (note species)		

10.5 FIELD FORMS

Attached in Chapter 17.

11 SEMI- AND NON-WADEABLE RIVERS

11.1 WHEN IS A RIVER NON-WADEABLE?

In wadeable streams, cross-sections are relatively easy to measure because the entire width of the stream can be accessed, even in pools. Accessibility makes cross-sections slightly more difficult to measure in deep pools and large lowland rivers; however, there are many simple ways to sample cross-sections in these types of rivers. For example, in large rivers a boat can be used to access the width of the river or in medium sized rivers, a canoe, small boat or sometimes even a Li-Lo (air mattress) can be used to access the centre of deep pools. When weather, flow and water quality conditions are safe, cross-sections can be performed by swimming across the stream (Parsons 2002).

The following river GHUs are considered non-wadeable:

CROSS-SECTIONS CANNOT BE MEASURED WHEN RIVERS ARE NON-WADEABLE. FOR EWRM, A RIVER OR GHU IS CONSIDERED NON-WADEABLE UNDER THE FOLLOWING CONDITIONS:

- The river is too deep that you cannot stand (i.e. cannot feel the substrate). Or if you cannot see the bottom.
- Bad water quality is a strong possibility and the river is too deep to use waders safely.
- The current is too strong even under low flow conditions.
- If crocodiles or hippos are present and the river is deep and/or limited visibility.
- Any other safety issues.

Examples are provided in Fig 13.1

Figure 11.1 Letaba River – Two Pool GHUs with hippos and crocodiles, i.e. non-wadeable

11.2 NON-WADEABLE RIVERS APPROACH

Many wadeable stream techniques are not feasible or relevant to large river systems (Flotermeisch *et al*, 2006). These complications have led many river assessment programs to:

- omit biological assessment of large rivers,
- simply apply wadeable methods to wadeable areas of larger rivers, or
- drop certain assessment parameters that are more difficult to measure in large rivers.

In general, most recommendations are based on the use of boats for non-wadeable rivers (Hughes, 2008; Lazorchak *et al*, 2000; Parsons 2002). However, due to the time constraints associated with a rapid assessment, as well as the equipment required, these approaches are not deemed rapid. It is acknowledged that these rivers will require less rapid assessments and sophisticated equipment. Boats are also not always safe to use in rivers where hippos are present.

In the interim, until a protocol is developed for these rivers, it is recommended that monitoring is aimed towards (Peck *et al.* 2006):

- Riparian zone characterization.
- Rapid habitat and/or visual assessments.
- Sampling near stream margins.
- Any data that can be collected – dependant on safety

These monitoring activities mostly fall into the partially wadeable (or semi-wadeable) classification (*cf* 13.3).

Where the semi-wadeable techniques are not possible to apply, or time constraints that a pool eg must be treated as non-wadeable, the following is recommended:

- Measure the GHU width and length with a range finder if crossing the river is not possible.
- Take detail photographs of the GHU as follows:
- Marginal zones on both banks.
- Upstream border of the GHU.
- Downstream border of the GHU.
- Composite photo from a high point if possible to include the whole GHU.

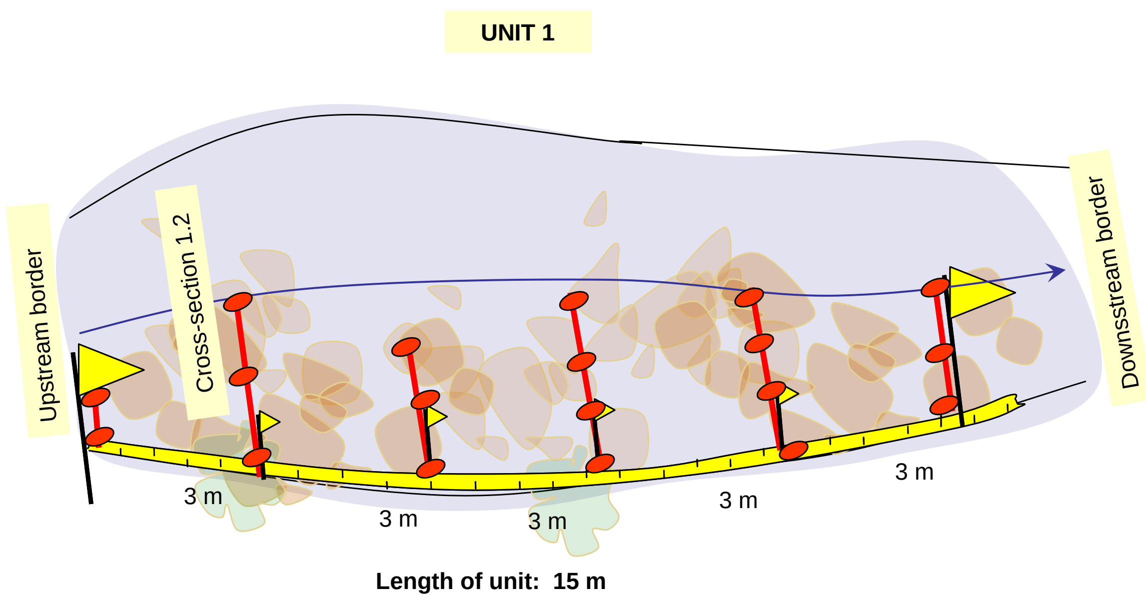
11.3 SEMI-WADEABLE RIVERS APPROACH

It is proposed that the same RHAM measurements are undertaken for semi-wadeable rivers than for wadeable rivers. However, this would mean that cross-sections will only cover a certain portion of the river (pending safety). It could also mean that measurements can only be undertaken from one river bank to a point in the river where it becomes unsafe to work further. The bank that cannot be measured must be photographed in detail.

Follow-on monitoring will require the exact same length of river and number of cross-sectional points to be measured to be comparable to the baseline.

The measurements are illustrated in Figure 13.2.

Figure 11.2 RHAM surveys in a Semi-wadeable river



12 SUMMARY OF STEP BY STEP CHECKLIST TO SET UP BASELINE FOR RHAM

12.1 BASELINE MONITORING

WHEN TO UNDERTAKE BASELINE MONITORING

The RHAM must be undertaken during the dry season, i.e. low flow conditions. As all follow-on monitoring must be undertaken during similar conditions, it is imperative that the baseline is not undertaken during high flows or floods.

The list below provides a step by step checklist for establishing the RHAM baseline. The assumption is that the locality of the site is available.

STEPS	MANUAL
DELINEATION, CROSS-SECTION & POINT MEASUREMENTS	**3, 4, 5**
Print out the field forms	17
Complete information such as quat, EcoRegion, Geomorph zone etc	3.3
Identify the range of GHUs present at the site.	4.1, 4.2
Identify the most important GHU for the instream biota.	4.1, 4.3
Identify the most sensitive GHU in terms of habitat.	4.1, 4.3
Determine the key GHU.	4.1, 4.3
Select the additional GHUs	4.3
Document the reasons for selecting the GHUs	4.3
Select or install a benchmark to fix the upstream boundary of the GHU	4.4.1, Table 4.2
GPS and photograph the benchmarks	4.4.3
Fix the upstream boundary of the GHU and mark with flag markers	4.4.2, Table 4.2
Document where the upstream boundary of the GHU is.	
Place the tape measure along the length of the bank.	4.4.2, 5.5
Estimate where the downstream border is and mark with flag markers.	4.4.2, Table 4.2

Estimate the average width of the GHU (pace it off, or use tape measure.	
Document the average width	
Use the preliminary guidelines to estimate required cross-sections.	5.4
Consider required cross-sections, whether GHU is key habitat and homogeneity of GHU and decide on number of cross-sections and the distance between each cross-section	5.5
Walk downstream from the upstream border along the tape measure and place flags at each cross-section.	5.5
Evaluate where your preliminary downstream border is compared to your last cross-section. Determine whether the last cross-section is on the border..	5.5
GPS the downstream border	4.4.2, Table 4.2
Document where the downstream border is in relation to the upstream border	5.5
Take photographs of the upstream and downstream borders	8
Mark the cross-sections on the other bank with the flag markers	5.5
Document the distances on both banks between the cross-sections	5.5
Take all other photographs required	8
Use the estimated average width and decide on the number of the cross-section points.	5.4, 5.6
Measure from WE and at each point measure depth, velocity, substrate and other cover features.	5.6, 6.3, 6.4, 6.5
Use field forms to document information or input directly into database.	17
Start at first cross-section (i.e. upstream border).	
When ending up on the other bank, measure the bank measurements between cross-sections.	7.2, 7.3, 7.4, 7.5
Come back along the 2nd cross-section, measuring the cross-section points.	
Back at the bank where you started, measure the bank measurements between the first and second cross-section.	
Then measure the bank measurements on the same bank between the second and third cross-section.	
Continue along the 3rd cross-section and repeat the process to end of unit.	
Repeat the above process for the other GHUs	
DO A DISCHARGE MEASUREMENT	9.3, Table 9.1

Select a uniform cross-section	Table 9.1
Stretch a tape measure across the stream perpendicular to flow	Table 9.1
Divide the width of the wetted stream into 15 – 20 equal sized intervals	Table 9.1
Stand downstream of the tape measure and measure the depth and velocity at each point, starting at WE and stopping at WE.	Table 9.1
At each point where you measure, also document the Chainage	Table 9.1
Document the information	Table 9.1
Transfer the information into the RHAM Excel to calculate the flow	Table 9.1
COLLECT DIATOM INFORMATION	
Choose suitable substratum from a flowing section of the river	
Carry substrata back to the bank	
Collect 20 – 50 ml of water in plastic tub	
Place stone or macrophyte over the tub	
Brush upper surface of stones/stems of the macrophytes vigorously with a new/clean toothbrush to remove the diatoms. Avoid the under surfaces and sections with sludge and sediment.	
Use little of the stream water in the tub to rinse the diatoms from the toothbrush and substrate into the tub.	
Brush and rinse at least 3 times per substrate.	
Water in tub should be brown and turbid.	
Mix the brown suspension in the tub and pour it into 2 sample bottles. Return any remaining suspension to the river.	
Seal and label the bottles, and keep in cool place for remainder of site visit. Add preservative (e.g. ethanol) if available to one of the sample bottles (10ml ethanol: 100ml sample). Store the other bottle (refrigerate) until the analysis is finished	
COLLECT PHYSICO-CHEMICAL INFORMATION (MEASUREMENTS AND OBSERVATIONS)	
Odours	10
Colour intensity	10
Colour description	10
Oiliness	10
Clarity	10

Temperature	10
Oxygen concentration	10
Oxygen saturation	10
pH	10
Conductivity	10

13 SUMMARY OF STEP BY STEP GUIDELINE TO UNDERTAKE FOLLOW-ON MONITORING

13.1 FOLLOW-ON MONITORING

WHEN TO UNDERTAKE FOLLOW-ON MONITORING

The follow-on monitoring should be undertaken in similar conditions as for the baseline, otherwise it will be difficult to determine whether a change in habitat availability is due to different flow conditions or anthropogenic changes.

The following is a step by step checklist of what is required when doing the follow-on monitoring.

STEPS
Collate all info documented during the baseline or any previous follow-on monitoring.
Find the benchmark and from their the upstream border of the upstream GHU.
Determine based on the visual changes, as well as the time available for the survey, whether all the cross-sections require physical monitoring and or all the GHUs.
Place flags at the border of the GHUs and all other cross-section using the tape measure and photos to identify the cross-sections
Take comparable photographs to the baseline and previous monitoring set.
Measure from WE and at each point measure Chainage, the depth, velocity, substrate and other cover features.
Use field forms to document information or input directly into database.
Start at first cross-section (i.e. upstream border).
When ending up on the other bank, measure the bank measurements between cross-sections.
Repeat the above process for the other GHUs and cross-sections
DO A DISCHARGE MEASUREMENT
Select a uniform cross-section
Stretch a tape measure across the stream perpendicular to flow

Divide the width of the wetted stream into 15 – 20 equal sized intervals
Stand downstream of the tape measure and measure the depth and velocity at each point, starting at WE and stopping at WE.
At each point where you measure, also document the Chainage
Document the information
Transfer the information into the RHAM Excel to calculate the flow
COLLECT DIATOM INFORMATION
Choose suitable substratum from a flowing section of the river
Carry substrata back to the bank
Collect 20 – 50 ml of water in plastic tub
Place stone or macrophyte over the tub
Brush upper surface of stones/stems of the macrophytes vigorously with a new/clean toothbrush to remove the diatoms. Avoid the under surfaces and sections with sludge and sediment.
Use little of the stream water in the tub to rinse the diatoms from the toothbrush and substrate into the tub.
Brush and rinse at least 3 times per substrate.
Water in tub should be brown and turbid.
Mix the brown suspension in the tub and pour it into 2 sample bottles. Return any remaining suspension to the river.
Seal and label the bottles, and keep in cool place for remainder of site visit. Add preservative (e.g. ethanol) if available to one of the sample bottles (10ml ethanol: 100ml sample). Store the other bottle (refrigerate) until the analysis is finished
COLLECT PHYSICO-CHEMICAL INFORMATION (MEASUREMENTS AND OBSERVATIONS)
Odours
Colour intensity
Colour description
Oiliness
Clarity
Temperature
Oxygen concentration

Oxygen saturation
pH
Conductivity

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