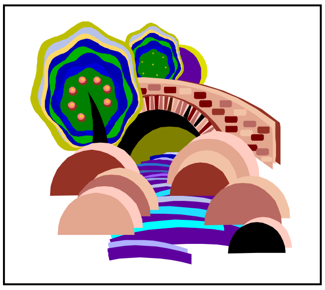


5 INSTRUCTIONS FOR THE MEASUREMENT OF EACH VARIABLE

5.1 OVERVIEW

This chapter provides detailed instructions on the measurement of each field-based and office-based variable. An individual instruction sheet is provided for each variable, and is set out as follows:

VARIABLE NAME	▶ Name of the variable
CATEGORY	▶ Broad category in which the variable falls
CONTROL OR RESPONSE	▶ Whether the variable is control or response
FIELD OR OFFICE	▶ Whether the variable is collected in the field or in the office
UNITS OF MEASUREMENT	▶ The unit of measurement for the variable
INDICATES	▶ What the variable indicates about physical stream condition, or geomorphological processes
METHODS	▶ The method used to measure each physical variable. Diagrams and pictures are included where appropriate.

In the following pages, the control variables are listed first, followed by the response variables.

VARIABLE NAME	Latitude
CATEGORY	Position of the site in the catchment
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Degrees, minutes, seconds
INDICATES	The relative position of sampling sites across the landscape.

The latitude of a site should be recorded in the field to the nearest second, using a GPS. When using a GPS, ensure that you record the datum as set on the GPS unit at the time you record your position.

Alternatively, if a GPS is not available in the field, the grid reference of each site can be derived from maps and converted to latitude using a GIS or GPS. Record the map details such as name, number, scale, datum and adjoining map names and numbers.

VARIABLE NAME	Longitude
CATEGORY	Position of the site in the catchment
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Degrees, minutes, seconds
INDICATES	The relative position of sampling sites across the landscape.

The longitude of a site should be recorded in the field to the nearest second using a GPS. When using a GPS, ensure that you record the datum as set on the GPS unit at the time you record your position.

Alternatively, if a GPS is not available in the field, the grid reference of each site can be derived from maps and converted to longitude using a GIS or GPS. Record the map details such as name, number, scale, datum and adjoining map names and numbers.

VARIABLE NAME	Altitude
CATEGORY	Position of the site in the catchment
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	metres above sea level (m asl)
INDICATES	The position of a sampling site within the catchment and physical stream processes that change along an altitudinal gradient.

The altitude of each site should be read off 1:100 000 scale topographic maps.

VARIABLE NAME	Distance from source
CATEGORY	Position of the site in the catchment
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	km
INDICATES	The position of a sampling site within the catchment and physical stream processes that change along the river continuum.

Distance from source is the distance between the source of the stream and the sampling site (Figure 5.1). Distance from source is measured off maps using a map wheel or similar device.

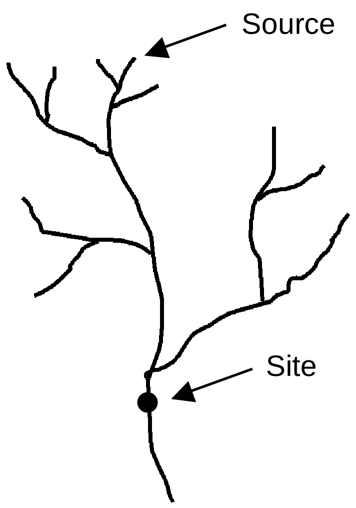


Figure 5.1 Example calculation of distance from source.

VARIABLE NAME	Link magnitude
CATEGORY	Position of the site in the river system
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	Dimensionless
INDICATES	Stream size within a river system context.

Link magnitude is defined as the number of links upstream from the sampling site (Figure 5.2), and is calculated using the method of Shreve (1967). Link magnitude is preferable to the use of stream order, because it encompasses all contributing discharges upstream of a sampling site.

Link magnitude should be derived from maps. However, derivation of link magnitude is sensitive to changes in map scale and a consistent map scale should be used to measure this variable. A 1:25 000 map scale is recommended for the measurement of link magnitude, but where map coverage is limited, the lowest scale possible should be used.

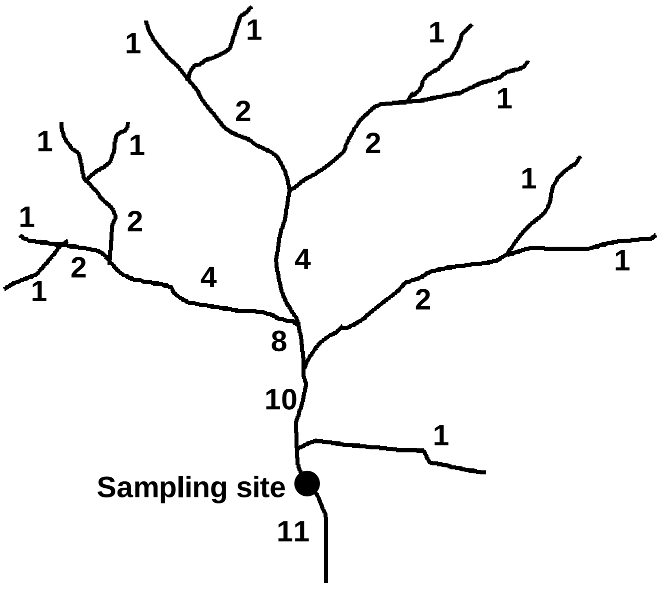


Figure 5.2 Example calculation of link magnitude. Link magnitude at the shown sampling site is 11.

VARIABLE NAME	Alkalinity
CATEGORY	Water chemistry
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	mg $CaCO_3$ l^{-1}
INDICATES	Buffering capacity of water, which in turn is related to catchment geology.

Alkalinity should be determined in the field by acid titration. Alternatively, a water sample may be taken and kept on ice in the field, before determination of alkalinity immediately upon return to the laboratory.

Standard method (A.P.H.A., 1992)
Collect a water sample from one point in the centre of the stream. Place 100ml of river water in a clean beaker with two drops of Methol Red indicator. While swirling the water in the beaker, use a syringe to add Sulfuric Acid (H_2SO_4, 0.02N), drop by drop, until the colour of the water just turns and remains pink (Figure 5.3). Record the amount of acid used in the titration. Alkalinity (as mg $CaCO_3$ l^{-1}) is calculated as:

$$\frac{A * N * 50000}{\text{Water sample volume (ml)}}$$

where:
A = ml H_2SO_4
N = normality of acid (0.02N)

Figure 5.3 Field alkalinity titration. Before addition of acid, the water is green (left) and upon titration endpoint, the water is pink (right).

VARIABLE NAME	Total stream length
CATEGORY	Catchment characteristics
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	km
INDICATES	Travel time of water through the drainage network and availability of sediment for transport.

Total stream length is calculated by measuring the length of all perennial streams within the catchment area upstream of each sampling site. Total stream length is measured off 1:100 000 topographic maps.

Total stream length is also used to calculate the drainage density and mean stream slope variables.

VARIABLE NAME	Drainage density
CATEGORY	Catchment characteristics
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	km
INDICATES	The balance between erosive forces and the resistance of the ground surface. Drainage density is also related to climate, geology, soils and vegetation cover in the catchment.

Drainage density (R_D) is calculated within the catchment area upstream of each sampling site by dividing the total stream length for the catchment (see total stream length variable) by the catchment area (see catchment area upstream of the site variable):

$$R_D = \frac{\sum L}{A}$$

where:

ΣL = total stream length

A = catchment area upstream of the sampling site

Total stream length should be measured in km and catchment area upstream of the sampling site in km^2

The overall unit of measurement for drainage density is km.

VARIABLE NAME	Catchment area upstream of the site
CATEGORY	Catchment characteristics
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	km^2
INDICATES	Relative water yield and the number and size of streams in the catchment.

The catchment area upstream of a site is defined as the total area of catchment that drains into the sampling site (Figure 5.4).

Catchment area upstream of each sampling site is measured off 1: 100 000 scale topographic maps using a planimeter. The boundaries of each catchment are identified by examination of topographic contours.

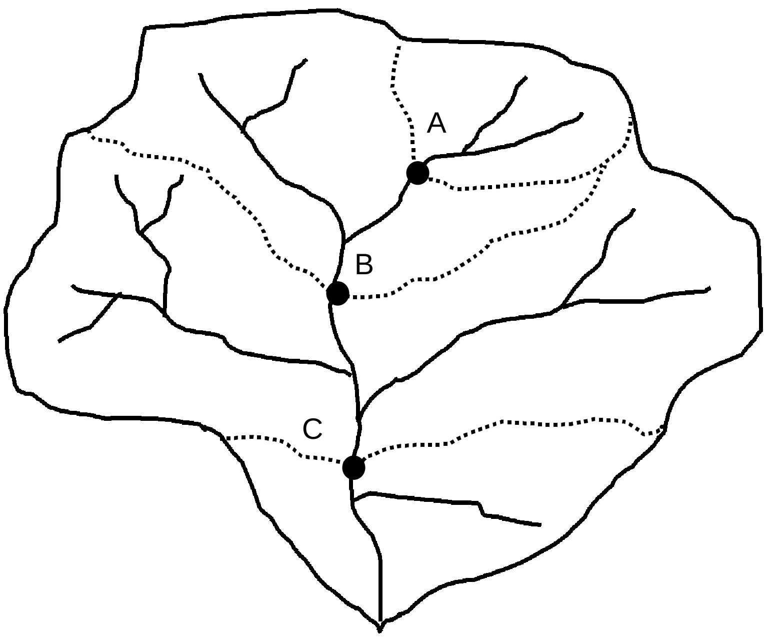


Figure 5.4 Example calculation of catchment area upstream of the sampling site. Catchment areas for successive sites within a catchment are additive. The catchment area of the most upstream site, site A, is calculated first. Then, the catchment area upstream of site B includes the area of site A and B, and the catchment area upstream of site C includes the area of sites A and B and C.

VARIABLE NAME	Elongation ratio
CATEGORY	Catchment characteristics
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	Dimensionless
INDICATES	Catchment shape.

Elongation ratio (R_e) is calculated for the catchment upstream of each sampling site by dividing the diameter of a circle with the same area as the catchment, by the length of the catchment:

$$R_e = \frac{D_c}{L}$$

where:

D_c = the diameter of a circle with the same area as the catchment area upstream of the sampling site[1]

L = the maximum length of the catchment along a line basically parallel to the main stem

---

1.
The formula for calculation of the diameter of a circle with a certain area is:

$\sqrt{[(4 \times \text{area}) / \pi]}$

An example calculation for a catchment with an area of $740 km^2$ is:

$\sqrt{[(4 \times 740) / \pi]} = 30.7 km$

After Gordon *et al.* (1992)

VARIABLE NAME	Relief ratio
CATEGORY	Catchment characteristics
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	Dimensionless
INDICATES	The intensity of erosion processes on slopes which in turn, influences sediment supply and the ability of the river to transport sediment.

Relief ratio (R_r) is calculated for the catchment upstream of each sampling site by dividing the difference in elevation between the highest point in the drainage divide and the sampling site by the length of the catchment:

$$R_r = \frac{h}{L}$$

where:
h = the difference in elevation between the highest point on the drainage divide and the sampling site
L = the maximum length of the catchment along a line approximately parallel to the main stem

The units of h and L should be equal (ie. metres or kilometres) so as to make R_r dimensionless (Gordon *et al.*, 1992).

VARIABLE NAME	Form ratio
CATEGORY	Catchment characteristics
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	Dimensionless
INDICATES	Catchment shape.

Form ratio (R_f) is calculated for the catchment upstream of each site by dividing the area of the catchment by the squared length of the catchment:

$$R_f = \frac{A}{L^2}$$

where:

A = catchment area upstream of the sampling site

L = maximum length of the catchment along a line approximately parallel to the main stem

The units of A and L should be equal (ie. metres or kilometres) so as to make R_f dimensionless (Gordon *et al.*, 1992).

VARIABLE NAME	Mean catchment slope
CATEGORY	Catchment characteristics
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	Dimensionless
INDICATES	Surface run-off rates, and is also related to drainage density and basin relief.

Mean catchment slope (S_b) is calculated for the catchment upstream of each sampling site by dividing the difference in elevation between specific points in the catchment by catchment length:

$$S_b = \frac{\text{(Elevation at 0.85}L\text{) - (Elevation at 0.10}L\text{)}}{0.75L}$$

where:

L = the maximum length of the catchment along a line basically parallel to the main stem

The components 0.85L, 0.10L and 0.75L correspond to points that are located at 85%, 10% and 75% of the catchment length respectively. The point of the stream source is 0% and the point of the sampling site is 100%.

VARIABLE NAME	Mean stream slope
CATEGORY	Catchment characteristics
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	m km^{-1}
INDICATES	Stream slope is related to water velocity.

Mean stream slope (S_c) is calculated within the catchment area upstream of a sampling site by dividing the difference in elevation between the source and the sampling site by the total stream length in the catchment:

$$S_c = \frac{\text{(Elevation at source - elevation at sampling site)}}{\text{Length of stream}}$$

Elevation should be measured in m and the length of stream in the catchment area upstream of the sampling site in km (see the total stream length variable).

VARIABLE NAME	Catchment geology
CATEGORY	Catchment characteristics
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	% area of each geological type
INDICATES	Catchment geology is an important factor that controls many characteristics of a stream system (Schumm, 1977; Knighton, 1984), including the type of material available for weathering, transport and erosion, the network pattern and the topography of the catchment.

Catchment geology should be measured as the area (km^2) that is covered by each geology type within the catchment area upstream of a sampling site. To standardise across different sized catchments, geological areas should be converted to a percentage of the total catchment area upstream of a sampling site.

Geology types can be measured off geological maps using a planimeter. Alternatively, digitised versions of these geology maps may be available and the percent area of each geology type in a catchment can be calculated using a GIS. Information on the availability of digitised geology data can be found at the Australian Geological Survey Organisation's website (http://www.agso.gov.au).

In order to reflect regional conditions the geology types to be measured should be determined by each State or Territory, and may involve seeking advice from a geologist. As a minimum, the chosen geology types should reflect broad Statewide lithological patterns, but geology can be measured in more detail if required. The map scale used to measure catchment geology will reflect the level of detail required, although the availability of geological data may also dictate the scale of the map used. As a guide, the geological types used in the construction of the habitat predictive model of Davies *et al.* (2000) were alluvium, volcanics, metasediments and limestone, measured off a 1:100 000 scale map. If more detail is required, these geological types can be expanded and measured as alluvium, mafic volcanics, felsic volcanics, mafic intrusives, felsic intrusives, shale, siltstone & slate, conglomerates and limestone.

VARIABLE NAME	Rainfall
CATEGORY	Catchment characteristics
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	mean or median annual rainfall (mm)
INDICATES	Determines water availability for runoff and discharge, and effects vegetation cover and the potential for slope erosion.

A measure of mean or median annual rainfall should be obtained for each sampling site. There are two options available for obtaining rainfall data for each sampling site:

1. An exact reading of annual average rainfall

Where available, modelled rainfall data can be used to obtain a reading of the long-term mean or median annual rainfall for each sampling site. BIOCLIM (part of ANUCLIM) is a modelled data package that is able to provide an annual average rainfall figure for any location within Australia. More detail on this package can be found at the Centre for Resource and Environmental Studies (CRES) website at http://cres.anu.edu.au/software.html

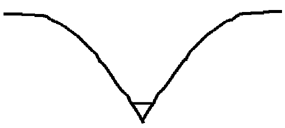
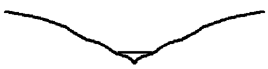
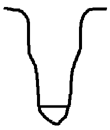
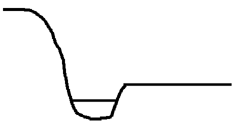
2. Broad rainfall categories

At a lower level of detail that forgoes an actual measurement of rainfall for each sampling site, it may be possible to place sites into categories of mean annual rainfall to correspond with broad rainfall patterns across each State or Territory. For example, in NSW it would be possible to distinguish low rainfall areas in the Western part of the State from high rainfall coastal areas. The Bureau of Meteorology produces detailed climate maps showing broad rainfall bands for each State. More information can be found on the Bureau of Meteorology website at http://www.bom.gov.au/. Alternatively, the CLIMATE SURFACES package produced by CRES may provide data that is useful for determining broad annual rainfall categories. More information can be found on the CRES website at http://cres.anu.edu.au/software.html

VARIABLE NAME: Valley shape
CATEGORY: Valley characteristics
CONTROL OR RESPONSE: Control
OFFICE OR FIELD: Field
UNITS OF MEASUREMENT: Choice of six categories

INDICATES: Valleys exert lateral and vertical control over the stream channel (Church, 1992) and influence the type of channel that will be present.

At each sampling site, visually assess the shape of the surrounding valley as **one** of the following categories:

	steep valley
	shallow valley
	broad valley
	gorge
	symmetrical floodplain
	asymmetrical floodplain

Variable modified from the River Habitat Survey (Raven *et al.*, 1998)

VARIABLE NAME — Channel slope

CATEGORY — Valley characteristics

CONTROL OR RESPONSE — Control

OFFICE OR FIELD — Office

UNITS OF MEASUREMENT — m km^{-1}

INDICATES — Stream gradient, which in turn influences sediment transport and discharge characteristics.

Channel slope is the difference in elevation at the upstream and downstream ends of a stream segment, divided by the length of that segment:

$$\text{Channel slope} = \frac{\text{Change in elevation from upstream to downstream end of segment (m)}}{\text{Segment length (km)}}$$

Channel slope can be measured off 1:100 000 scale topographic maps.

<u>Calculation of segment length</u>

The length of a segment is derived according to the bankfull width of the stream channel (see bankfull channel width variable) at the sampling site (Table 5.1). A stream segment is defined as 1000x the bankfull width of the channel. Streams wider than 50m have a segment length that is limited to 50km.

Table 5.1 Example calculation of segment length for streams of different bankfull width.

Bankfull stream width (m)	Length of stream segment (km)
5	5
10	10
20	20
50	50
100	50

(continued over)

<u>Placement of stream segments relative to sampling sites</u>

The sampling site forms the midpoint of the stream segment (Figure 5.5). In the following example, the sampling site has a bankfull width of 15m. Thus, the corresponding segment length of 15km extends for 7.5km upstream and downstream of the sampling site.

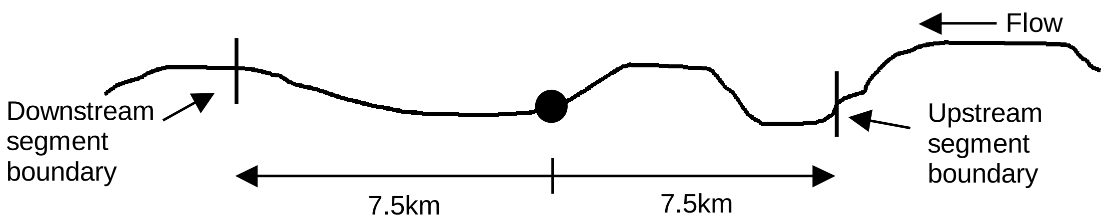


Figure 5.5 Placement of stream segments relative to the sampling site.

VARIABLE NAME	Valley width
CATEGORY	Valley characteristics
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	m
INDICATES	Relative degree of channel constriction.

Valley width is the distance between the first topographic contours on either side of the channel, and should be measured off 1:100 000 scale topographic maps.

Measurements of valley width should be taken along a segment of stream, the length of which is equivalent to 1000x the bankfull channel width of the sampling site (see channel slope variable for further details on stream segments and bankfull channel width variable for further details on bankfull width). Replicate measurements of valley width should be made every 500m along the segment, and an average valley width derived from these replicate measurements.

VARIABLE NAME	Sinuosity
CATEGORY	Planform channel features
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	Dimensionless
INDICATES	Planform channel pattern, which in turn relates to flow dynamics and sediment transport characteristics.

Sinuosity (SI) is an assessment of the degree of irregularity in the path of a channel across the landscape (Figure 5.6) and is measured as the difference between channel length and valley length:

$$SI = \frac{\text{Channel distance (km)}}{\text{Downvalley distance (km)}}$$

The sinuosity of each sampling site should be measured off small scale topographic maps, along a segment of stream with a length equivalent to 1000x the bankfull channel width (see channel slope variable for further details on stream segments and bankfull channel width variable for further details on bankfull width).

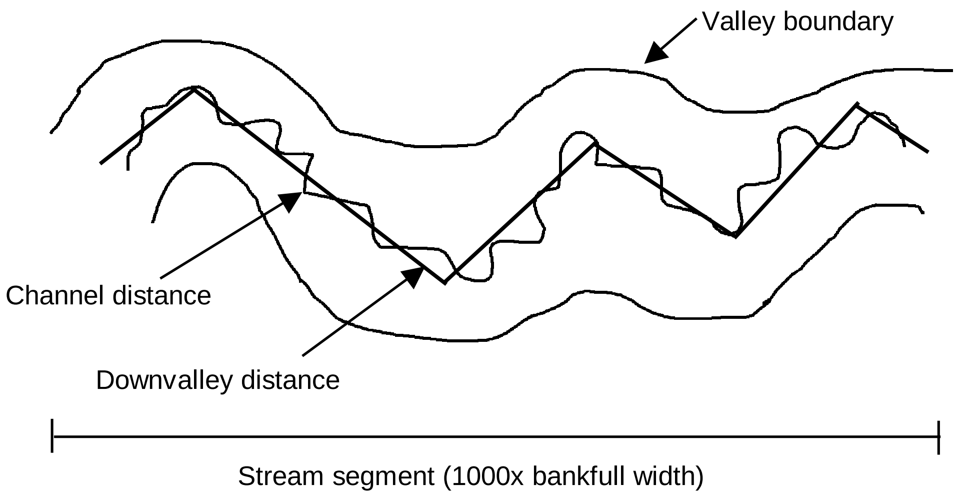


Figure 5.6 Example measurement of sinuosity. Channel distance is the 'exact' distance along the stream channel. Downvalley distance is the 'straight-line' distance along the channel, running approximately parallel to the valley boundaries.

VARIABLE NAME	Catchment landuse
CATEGORY	Landuse
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	% area of each landuse type
INDICATES	Potential disturbance to whole catchment channel, floodplain and slope morphology over time.

Catchment landuse should be measured as the area (km^2) that is covered by each landuse type within the catchment area upstream of a sampling site. To standardise across different sized catchments, landuse areas should be converted to a percentage of the total catchment area upstream of a sampling site.

Landuse should be measured using a GIS. Resolution of different landuse and land cover types will depend on the sensitivity of the initial classification image but as a guide, landuse types should include native forest cover, pine forest cover, native grassland cover, grazing pasture cover, crop cover and urban and other hard surfaces cover. Relevant landuse types will need to be reviewed by each State or Territory and adjusted to represent regional conditions and the availability of data.

VARIABLE NAME	Local landuse
CATEGORY	Landuse
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of eleven categories
INDICATES	Potential disturbances to local channel, floodplain and slope morphology over time.

Local landuse is considered to be the landuse within 500m of the channel banks, along the area adjacent to the sampling site. Local landuse/land cover is visually assessed at each sampling site for the left and right banks as **one** of the following categories:

Landuse category	**Examples**
Native forest	Native forest within a national park, nature reserve or similar
Native grassland (not grazed)	Native grasslands or shrub lands within a national park, nature reserve or similar
Grazing (native or non-native pasture)	Grazing activity on native or non-native pasture in farmland adjacent to the site
Exotic grassland (no grazing)	Non grazed exotic grasses such as manicured lawns, recreation areas or similar
Forestry	Recent native or pine forestry activity adjacent to the sampling site
Cropped	Row cropping activities such as sugar cane, wheat, horticulture etc. Also indicate whether cropping is irrigated or rainfed
Urban residential	Residential areas of cities and towns
Commercial	Shops, offices or similar
Industrial or intensive agricultural	Factories, tanneries, piggeries, feedlots or similar
Recreation	Picnic areas, playgrounds, campgrounds, municipal parks or similar
Other	Indicate the type of landuse present

Variable derived from AUSRIVAS

HYDROLOGY VARIABLES

Discharge regime has a significant influence on the morphology and dynamics of a river system (see Figure 1.1). The overall discharge regime of a river influences many 'response level' stream characteristics such as channel slope, width, depth, bedform geometry, meander wavelength, sinuosity and sediment transport (Knighton, 1994). Thus, it is important to include key measures of discharge regime as control variables in the physical assessment protocol.

Many hydrological variables are available that describe different aspects of discharge regime. Ladson and White (1999) reviewed a set of hydrology variables suitable for potential use within the Victorian Index of Stream Condition (ISC). These authors concluded that most hydrological variables reported in the literature were too detailed for the requirements of the ISC. Thus, the Hydrology Index of the ISC consists of three indicators that measure change in flow from 'natural' conditions: amended annual proportional flow deviation, daily flow variation due to change of catchment permeability and daily flow variation due to peaking hydroelectricity generation (Ladson and White, 1999).

More recently, the Ecosystem Health theme of the National Land and Water Resources Audit (NLWRA) has devised a set of four indices that indicate change in flow from 'natural' conditions. These are:

- index of mean annual flow;
- index of flow duration curve difference;
- index of flow duration variability; and,
- index of seasonal differences.

These indices provide a measure of the deviation in flow volume, duration and seasonal pattern. The physical assessment protocol will use these four NLWRA hydrology indices, because data is relatively easy to obtain for both reference and test sites, and the four indices encompass major aspects of stream discharge regime. Further details of each index are provided in the following pages.

The NLWRA database is currently under construction. However, it is expected that on completion of the modelling phase of the project, data on each of the indices will be available for most areas of Australia. Thus, hydrology variables for the physical assessment protocol will be collected directly from this database, for both reference and test sites. More information on the National Land and Water Resources Audit can be found at http://www.nlwra.gov.au/

VARIABLE NAME	Index of mean annual flow
CATEGORY	Hydrology
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	Dimensionless
INDICATES	Provides a measure of the difference in flow volume between current and natural conditions.

For each sampling site, obtain the National Land and Water Resources Audit index of mean annual flow. The index of mean annual flow (*A*) returns a value of between 0 and 1, where 0 is the most modified mean annual flow condition and 1 is no change in mean annual flow from natural condition. The algorithm for the calculation of the index is:

$$\text{if } \overline{Q_c} > \overline{Q_n} \text{ then } A = \frac{\overline{Q_n}}{\overline{Q_c}} \text{ else } A = \frac{\overline{Q_c}}{\overline{Q_n}}$$

where:

Q_c = mean annual flow under current conditions

Q_n = mean annual flow under natural conditions

Variable derived from the National Land and Water Resources Audit

VARIABLE NAME	Index of flow duration curve difference
CATEGORY	Hydrology
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	Dimensionless
INDICATES	Provides a measure of the overall difference between current and natural flow duration curves.

For each sampling site, obtain the National Land and Water Resources Audit index of flow duration curve difference. The index of flow duration curve difference (*M*) returns a value of between 0 and 1, where 0 is the most altered flow difference and 1 is unaltered from natural conditions. The algorithm for the calculation of the index is:

$$\text{If } n > c \text{ then } M = \frac{1}{p}\sum_{i=1}^{p}\frac{c}{n} \text{ else } M = \frac{1}{p}\sum_{i=1}^{p}\frac{n}{c}$$

where:

M = the difference from 1 of the proportional flow deviation, averaged over *p* daily flow percentile points

n = the natural flow value for percentile point *i*

c = the current flow value for percentile point *i*

The statistic *M* gives equal weighting to each percentile flow, from the lowest flow to the highest flow.

Variable derived from the National Land and Water Resources Audit

VARIABLE NAME	Index of flow duration variability
CATEGORY	Hydrology
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	Dimensionless
INDICATES	Provides a measure of flow regime variability at a daily/monthly time scale.

For each sampling site, obtain the National Land and Water Resources Audit index of flow duration variability. The index of flow duration variability (D_v) returns a value of between 0 and 1, where 0 is the most altered flow duration variability and 1 is no change in flow duration variability from natural conditions. The algorithm for the calculation of the index is:

$$D_v = \frac{Q_{90} - Q_{10}}{Q_{50}}$$

where:
Q_{90} = the 90th percentile flow
Q_{10} = the 10th percentile flow
Q_{50} = median flow

Then, to provide a measure of the difference between current and natural condition, the following equation is used:

$$\text{If } D_{vc} > D_{vn} \text{ then } \frac{D_{vn}}{D_{vc}} \text{ else } \frac{D_{vc}}{D_{vn}}$$

where:
c = current conditions
n = natural conditions

Variable derived from the National Land and Water Resources Audit

VARIABLE NAME	Index of seasonal differences
CATEGORY	Hydrology
CONTROL OR RESPONSE	Control
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	Dimensionless
INDICATES	Seasonal changes can occur as changes in amplitude (the difference between the highest and lowest monthly flows) or period (the months in which the flow is conveyed).

For each sampling site, obtain the National Land and Water Resources Audit index of seasonal differences. This index contains two components: amplitude and change in period. Both components return a value of between 0 and 1, where 0 is the most altered seasonal difference and 1 is no change in seasonal difference from natural conditions. The algorithm for the calculation of seasonal amplitude (*SA*) is:

$$SA = \frac{\left[h_c/h_n + l_c/l_n \right]}{2}$$

where:

h = the highest mean monthly flow

l = the lowest mean monthly flow

c = current conditions

n = natural conditions

The algorithm for the calculation of seasonal period (*SP*) is:

$$SP = 1 - \frac{1}{12}\left(if\left|H_c - H_n\right| \leq 6 then \left|H_c - H_n\right|, lookuptable + if\left|L_c - L_n\right| \leq 6 then \left|L_c - L_n\right|, lookuptable \right)$$

The statistic *SP* is defined as the difference from 1 of the sum of the differences between the numerical values of the months with the highest mean monthly flow (*H*) and the numerical values of the months with the lowest mean monthly flow (*L*) for current and natural conditions (subscript *c* and *n* respectively).

Variable derived from the National Land and Water Resources Audit

VARIABLE NAME	USEPA Habitat Assessment High Gradient Streams
CATEGORY	Physical condition indicators and habitat assessment
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Score (0-20) for each habitat assessment parameter Score (out of 200) for the overall habitat assessment
INDICATES	Overall condition assessment incorporating a range of parameters that emphasise biologically significant aspects of the stream habitat (Barbour *et al.*, 1999)

The USEPA habitat assessment for high gradient streams should be used in streams located in moderate to high gradient landscapes, with substrates composed predominantly of coarse sediment particles (ie. gravel or larger) or frequent coarse particulate aggregations (Barbour *et al.*, 1999). These types of streams will be found predominantly in low energy unconfined and high energy confined zones (see Part 2).

The high gradient habitat assessment contains 10 parameters (Table 5.2), each of which is considered a separate variable for the purposes of the physical assessment protocol. Each habitat assessment parameter is visually assessed at each high gradient sampling site, and scored according to a continuum of conditions ranging from poor through to excellent. These poor, marginal, sub-optimal and optimal categories are used as a guide to assign each parameter a score between 1-20. Low scores are indicative of poor or degraded habitat conditions. A total habitat assessment score is also calculated as the sum of the scores for each parameter.

Details of the observable states that comprise each condition category for each parameter are provided on the data sheets. More information, including explanatory photographs, can be obtained from Barbour *et al.* (1999) or from the USEPA website at http://www.epa.gov/owow/monitoring/rbp/

(continued over)

Table 5.2 Parameters measured in the USEPA habitat assessment for high gradient streams. Compiled from Barbour *et al.* (1999)

Parameter	Broad description and ecological relevance
Epifaunal substrate / available cover	Includes the relative quantity and variety of natural structures in the stream such as cobble (riffles), large rocks, fallen trees, logs and branches that are available as refugia, feeding or spawning/nursery sites for aquatic macrofauna. A wide variety or abundance of submerged structures in the stream provides macroinvertebrates and fish with a large number of niches, thus increasing habitat diversity.
Embeddedness	Refers to the extent to which rocks (gravel, cobble and boulders) and snags 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.
Velocity / depth regime	The occurrence of slow-deep, slow-shallow, fast-deep and fast-shallow velocity patterns relates to habitat diversity and the ability of the stream to provide and maintain a stable aquatic habitat.
Sediment deposition	Measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many organisms.
Channel flow status	Measures the degree to which the channel is filled with water. The flow status will change as the channel enlarges (e.g. aggrading streambeds with actively widening channels) or as flow decreases because of dams, diversions or drought. When water does not cover much of the streambed, the amount of suitable habitat for aquatic organisms is reduced.
Channel alteration	Is a measure of large scale changes in the shape of the stream channel. Straightened or altered channels have fewer natural habitats for aquatic organisms than do naturally meandering streams.
Frequency of riffles (or bends)	Measures the sequence of riffles or bends. Riffles are a source of high quality habitat and diverse fauna and therefore, an increased frequency of occurrence greatly enhances the diversity of the stream community. For high gradient streams where distinct riffles are uncommon, a run/bend ratio can be used as a measure of habitat availability.
Bank stability	Measures whether the stream banks are eroded, or have the potential for erosion. Steep banks are more likely to collapse and suffer from erosion than gently sloping banks.
Bank vegetative protection	Measures the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur.
Riparian vegetative zone width	Measures the width of natural vegetation from the edge of the stream bank out through the riparian zone. The vegetative zone serves as a buffer to pollutants entering a stream from runoff, controls erosion and provides habitat and nutrient input to the stream.
Total habitat score	Overall assessment of habitat condition. Calculated as the sum of the scores for each of the 10 habitat assessment parameters.

VARIABLE NAME	USEPA Habitat Assessment Low Gradient Streams
CATEGORY	Physical condition indicators and habitat assessment
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Score (0-20) for each habitat assessment parameter Score (out of 200) for the overall habitat assessment
INDICATES	Overall condition assessment incorporating a range of parameters that emphasise biologically significant aspects of the stream habitat (Barbour *et al.*, 1999)

The USEPA habitat assessment for low gradient streams should be used in streams located in low to moderate gradient landscapes, with substrates composed predominantly of fine sediment or infrequent aggregations of coarse (gravel or larger) sediment particles (Barbour *et al.*, 1999). These types of streams will be found predominantly in transition and lower zones (see Part 2).

The low gradient habitat assessment contains 10 parameters (Table 5.3), each of which is considered a separate variable for the purposes of the physical assessment protocol. Each habitat assessment parameter is visually assessed at each low gradient sampling site, and scored according to a continuum of conditions ranging from poor through to excellent. These poor, marginal, sub-optimal and optimal categories are used as a guide to assign each parameter a score between 1-20. Low scores are indicative of poor or degraded habitat conditions. A total habitat assessment score is also calculated as the sum of the scores for each parameter.

Details of the observable states that comprise each condition category for each parameter are provided on the data sheets. More information, including explanatory photographs, can be obtained from Barbour *et al.* (1999) or from the USEPA website at http://www.epa.gov/owow/monitoring/rbp/

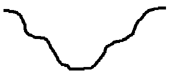
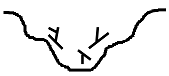
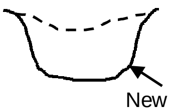
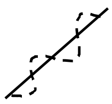
(continued over)

Table 5.3 Parameters measured in the USEPA habitat assessment for low gradient streams. Compiled from Barbour *et al.* (1999).

Parameter	**Broad description and ecological relevance**
Epifaunal substrate / available cover	Includes the relative quantity and variety of natural structures in the stream such as cobble (riffles), large rocks, fallen trees, logs and branches that are available as refugia, feeding or spawning/nursery sites for aquatic macrofauna. A wide variety or abundance of submerged structures in the stream provides macroinvertebrates and fish with a large number of niches, thus increasing habitat diversity.
Pool substrate characterisation	Evaluates the type and condition of bottom substrates found in pools. Firmer sediment types (gravel, sand) and rooted aquatic plants support a wider variety of organisms than a pool substrate dominated by mud or bedrock and no aquatic plants.
Pool variability	Rates the overall mixture of pool types found in streams, according to size and depth. A stream with many pool types will support a wide variety of aquatic species.
Sediment deposition	Measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many organisms.
Channel flow status	Measures the degree to which the channel is filled with water. The flow status will change as the channel enlarges (e.g. aggrading streambeds with actively widening channels) or as flow decreases because of dams, diversions or drought. When water does not cover much of the streambed, the amount of suitable habitat for aquatic organisms is reduced.
Channel alteration	Is a measure of large scale changes in the shape of the stream channel. Straightened or altered channels have fewer natural habitats for aquatic organisms than do naturally meandering streams.
Channel sinuosity	Evaluates the meandering or sinuosity of the stream. A high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to handle surges when the stream fluctuates as a result of storms.
Bank stability	Measures whether the stream banks are eroded, or have the potential for erosion. Steep banks are more likely to collapse and suffer from erosion than gently sloping banks.
Bank vegetative protection	Measures the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur.
Riparian vegetative zone width	Measures the width of natural vegetation from the edge of the stream bank out through the riparian zone. The vegetative zone serves as a buffer to pollutants entering a stream from runoff, controls erosion and provides habitat and nutrient input to the stream.
Total habitat score	Overall assessment of habitat condition. Calculated as the sum of the scores for each of the 10 habitat assessment parameters.

VARIABLE NAME	Channel modifications
CATEGORY	Physical condition indicators and habitat assessment
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of twelve categories
INDICATES	Human induced changes to the channel

At each sampling site, indicate the presence of channel modifications corresponding to **one or more** of the following categories:

	Natural No modifications		Reinforced
	Desnagged		Revegetated
	Dams and diversions		Infilled
	Resectioned		Berms[1] or embankments
	Straightened	Signs of work still visible	Recently channelised
	Realigned	Works old and vegetated	Channelised in the past

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

1.
A berm is a natural or artificial levee, dike, shelf, ledge, groyne or bench along a streambank that may extent laterally along the channel or parallel to the flow to contain the flow within the streambank (Armantrout, 1998).

VARIABLE NAME	Artificial features
CATEGORY	Physical condition indicators and habitat assessment
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of six categories
INDICATES	Presence of artificial features in the stream

At each sampling site, indicate the presence of **one or more** of the following artificial features within the channel:

Category	**Examples**[1]
major weir	Concrete, stone or rubble weir across the entire width of channel that substantially modifies stream flow.
minor weir	Concrete, stone or rubble weir that only partially modifies stream flow.
culvert	Arched pipeline or channel for carrying water beneath and road or railway.
bridge	Small or large bridge within the area of the sampling site
ford	Road or stock crossing passing through the stream. May be constructed of concrete or streambed materials.
other	State other structures present in the stream channel (e.g. aboriginal fish traps, jetties, boat ramps etc.)

Additionally, record a description of the types of structures present within the length of the sampling site. For example, a minor weir present at a sampling site may be a set of concrete stepping-stones across a stream in an urban area, or a ford may be a fire trail crossing through a stream in a National Park.

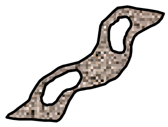
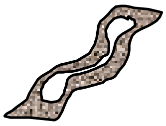
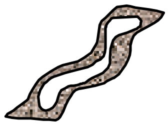
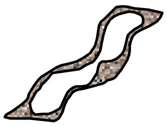
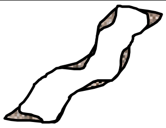
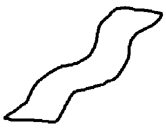
Include only local features in this variable. Do not include major impoundments, unless the sampling site is immediately upstream or downstream of a major impoundment structure.

Variable modified from the River Habitat Survey (Raven *et al.*, 1998)

1\.
Examples are not exhaustive

VARIABLE NAME	Physical barriers to local fish passage
CATEGORY	Physical condition and habitat assessment
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of six categories
INDICATES	Potential of the sampling site to allow native fish migration under low flow, base flow and high flow conditions.

At each sampling site, visually assess the potential for the migratory passage of fish along the length of the sampling site under low flow, base flow and high flow conditions. Physical barriers that may inhibit fish passage through the reach include weirs, fords and culverts, sediment slugs (e.g. sand slugs), log jams and waterfalls. Do not include the effects of major impoundments in this variable.

	No passage No connectivity between pools
	Very restricted passage Low connectivity between pools
	Moderately restricted passage Moderate connectivity between pools
	Partly restricted passage Localised obstructions present but overall passage through reach possible
	Good passage Most of the channel area unobstructed
	Unrestricted passage All of the channel area unobstructed

At each sampling site, make a separate assessment of the potential for the passage of fish through the length of the sampling site under:

a. Base flow conditions[1]
b. Low flow conditions[1]
c. High flow conditions[1]

In otherwords, how 'easy' would it be for a fish to travel through the length of the sampling site under base flow, low flow and high flow conditions?

Choose **one** category only for each sampling site and each flow condition. In the diagrams opposite, the white patches represent water and the textured patches represent obstructions.

Also record the type of physical barriers that are present within a sampling site (e.g. sand slug, culvert etc.)

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

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1. Base flow level is identified by the limit of terrestrial grasses, eroded area or the boundary of bank sediment types. Low flow level is equivalent to the reduction in flow that would occur during the dry season or during a drought. High flow level is equivalent to the bankfull capacity of the channel.

VARIABLE NAME	Planform channel pattern
CATEGORY	Planform channel features
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Office
UNITS OF MEASUREMENT	Choice of ten categories
INDICATES	The type of channel present, which in turn is related to flow dynamics and sediment relations.

Assign the type of channel present along the segment (see channel slope variable) within which the sampling site sits, into **one** of the following categories. It is important to interpret this variable with the aid of maps and aerial photos, because planform pattern is difficult to decipher locally in the field. However, braided, anastomosing, swampy and overland channel patterns should be verified in the field when visiting the sampling site.

	Straight Very little curvature
	Mildly sinuous Mild curvature
	Irregular Irregular sinuous channel that displays irregular turns and bends without repetition of similar features
	Regular meanders A clear repeated meander pattern formed in a simple channel that is well-defined by cutting outside of a bend
	Irregular meanders Meander pattern is repeated irregularly
	Tortuous A repeated pattern characterised by angles greater than 90^{o}

(continued over)

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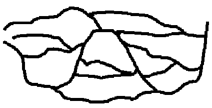
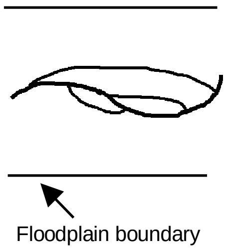
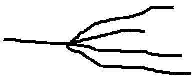
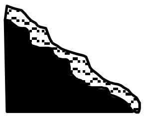
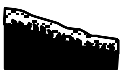
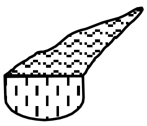
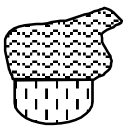
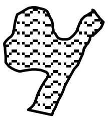
	Braided Multiple channels that divide into a network of branching and reuniting channels. **Channels are separated from each other by mobile bars or islands**. Channel sediment is generally coarse (sand and gravel). Bankfull level is not well defined.
	Anastomosing Multiple channels (main and anabranch) that divide into a network of branching and reuniting channels. **Channels are separated from each other by stable islands, that are relatively wide in comparison to the channel and which are usually vegetated.** Channel sediment is generally fine (sand, silt and clay). Bankfull level of each channel is well defined, but the whole system sits within a wide floodplain.
	Swampy Swampy areas of the river system characterised by low gradient but permanent sub-surface or surface water flow
	Channelised A channel that has been artificially straightened
	Overland Overland flow not contained within a well defined channel

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Extent of bedform features
CATEGORY	Planform channel features
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	% area of each feature
INDICATES	Form process associations, which in turn reflect sediment availability and flow energy conditions acting at different positions along a river course.

At each sampling site record the percentage area of the channel covered by each of the following bedform types, and where possible, also estimate the dimensions of each type. The sum of percentages for all bedform types should total 100%. Where the bedform type is not present at the sampling site, enter 0%.

	Waterfall Height > 1m Gradient > 60°
	Cascade Step height < 1m Gradient 5-60° Strong currents
	Rapid Gradient 3-5° Strong currents Rocks break surface
	Riffle Gradient 1-3° Moderate currents Surface unbroken but unsmooth
	Glide Gradient 1-3° Small currents Surface unbroken and smooth
	Run Gradient 1-3° Small but distinct & uniform current Surface unbroken
	Pool Area where stream widens or deepens and current declines
	Backwater A reasonable sized (>20% of channel width) cut-off section away from the channel

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Floodplain width
CATEGORY	Floodplain characteristics
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	m
INDICATES	The size of the floodplain

At each sampling site with a distinct floodplain, visually estimate the average width of the floodplain on both sides of the channel (Figure 5.7). Where visibility is poor, examine the left and right banks separately. The longitudinal length of floodplain considered should be equal to the length of the sampling site. For confined channels with no floodplain, record floodplain width as zero.

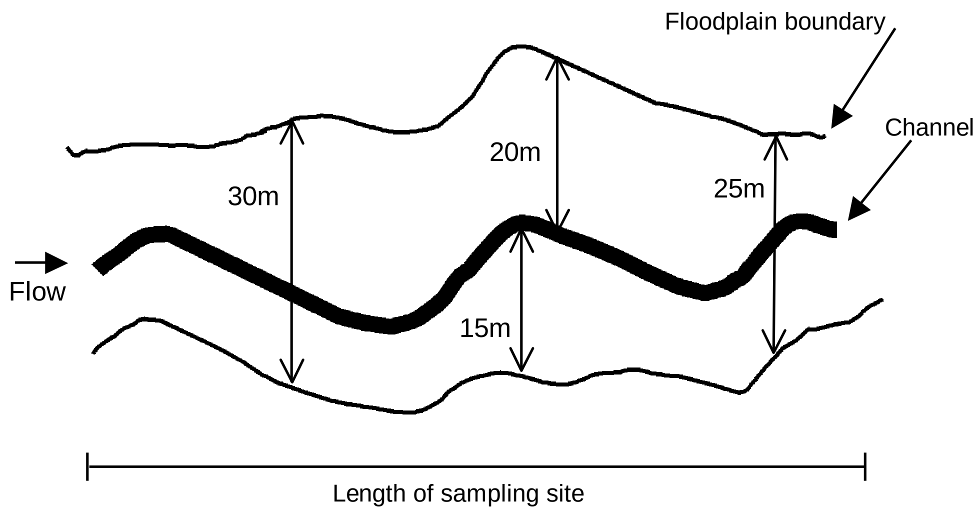


Figure 5.7 Example calculation of floodplain width. The overall average floodplain width for this example is 22.5m.

VARIABLE NAME	Floodplain features
CATEGORY	Floodplain characteristics
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of three categories
INDICATES	Features of the floodplain are an indication of the relationship between the channel and the floodplain

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At each sampling site with a distinct floodplain, record the presence of **one or more** of the following floodplain features. If not visible locally from the sampling site, the presence of floodplain features should be recorded from maps or aerial photos, within a 20km radius of the sampling site. Flood channels and remnant channels can often be identified in the field, although identification of remnant channels may also require interpretation of maps or aerial photographs.

Feature	**Description**
Oxbows / billabongs	Body of water occupying a former meander of a river isolated by a shift in the stream channel (Figure 5.8)
Remnant channels	Remnant channels of rivers formed during a different or previous hydrological regime. May be infilled with sediment. Remnant channels are historical and thus, currently inactive (i.e. no longer connected to the river) (Figure 5.8)
Prominent flood channels	A channel that distributes water onto or through the floodplain and which returns water to the main channel as the flood recedes. Flood channels are currently active and connected to the river (Figure 5.8)
Scroll systems	One of a series of short, crescentic, slightly sinuous strips or patches of coarser alluvium formed along the inner bank of a stream meander and representing the beginnings of a floodplain (Figure 5.8)
Splays	A small alluvial fan or other outspread deposit formed where an overloaded stream breaks through a levee and deposits its material on the floodplain (Figure 5.8)
Floodplain scours	A floodplain feature that has been formed by the concentrated clearing and digging action of flowing water. Scour features may take many forms, including linear, crescentic or erratic scour holes

(continued over)

Variable modified from the River Habitat Audit Procedure (Anderson, 1993a).

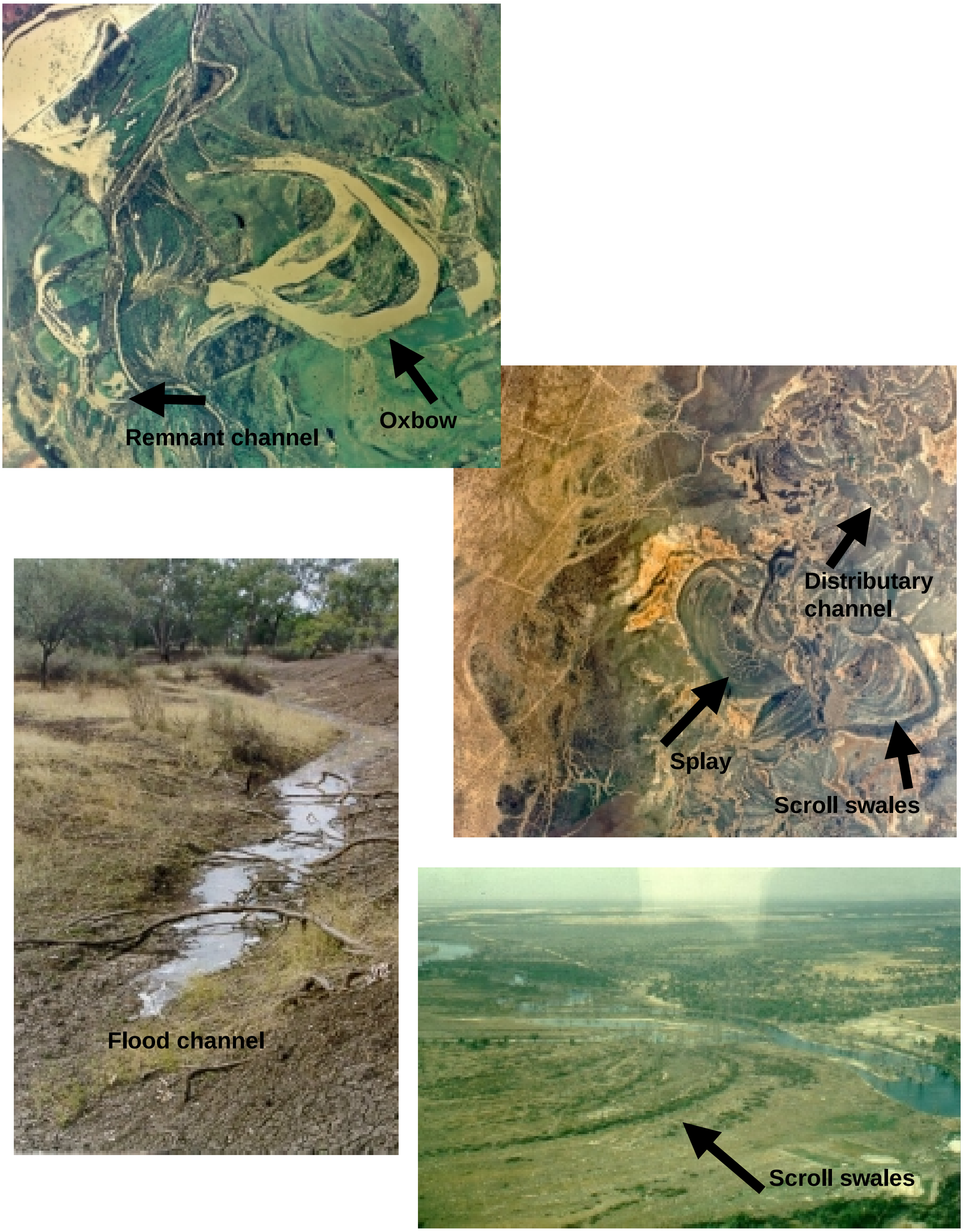
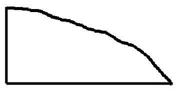


Figure 5.8 Examples of floodplain features, identified from aerial photographs and in the field.

VARIABLE NAME	Bank shape
CATEGORY	Bank characteristics
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five categories
INDICATES	The shape of the bank is related to the conveyance of water along the channel.

Choose **one** category that represents the predominant shape of the left and right banks along the length of the sampling site.

	concave
	convex
	stepped
	wide lower bench
	undercut

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Bank slope
CATEGORY	Bank characteristics
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five categories
INDICATES	The slope of the bank is related to the conveyance of water along the channel, and to the susceptibility of the bank to erosion

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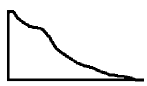
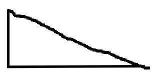
Choose **one** category that represents the predominant slope of the left and right banks along the length of the sampling site.

	vertical Slope 80-90°
	steep Slope 60-80°
	moderate Slope 30-60°
	low Slope 10-30°
	flat Slope <10°

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Bank material
CATEGORY	Bank characteristics
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	% composition of seven sediment sizes
INDICATES	Banks composed of certain sediment types may be more susceptible to erosion

---

At each cross section, visually assess the percent composition of the bank sediments within the area lying 5m either side the cross-section. Left and right banks are assessed separately. Where the channel has a distinct upper and lower bank (i.e. benches), assess the lower bank only. The total composition of each of the following seven sediment size categories should equal 100%.

Sediment category	Size
Bedrock	
Boulder	> 256mm
Cobble	64 – 256mm
Pebble	16 – 64mm
Gravel	2 – 16mm
Sand	0.06 – 2mm
Fines (silt and clay)	< 0.06mm

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Bedrock outcrops
CATEGORY	Bank characteristics
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	% cover of bedrock along banks
INDICATES	Presence of bedrock may protect banks from erosion

At each sampling site, visually assess the percentage of the left and right banks that contain bedrock outcrops (Figure 5.9 and 5.10).

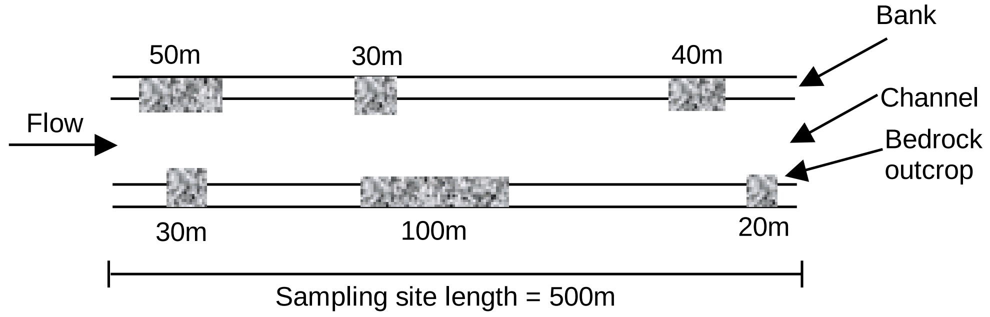
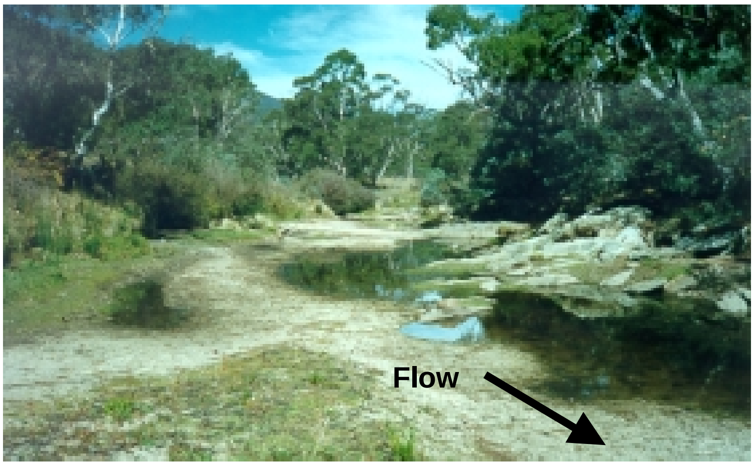


Figure 5.9 Example calculation of the percentage of bedrock outcrops along the banks of a sampling site that is 500m in length. On the left bank, the percent bank cover by bedrock outcrops is 24% (total 120m of bedrock outcrop along 500m of bank) and on the right bank, the percent cover is 30% (total 150m of bedrock outcrop along 500m of bank). The diagram is not to scale.

Figure 5.10 Example of a bedrock outcrop located along a bank. Note that the left bank contains bedrock outcrops but the right bank does not.



VARIABLE NAME	Artificial bank protection measures
CATEGORY	Bank characteristics
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of ten categories
INDICATES	Presence of structures that have been built to protect the bank from erosion.

At each sampling site, indicate the presence of **one or more** of the following bank protection features:

rock wall or layer
fence structures
fenced stock watering points
fenced human access
logs strapped to bank
concrete channel lining
rip rap
levee banks
vegetation plantings
other

Variable modified from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Factors affecting bank stability
CATEGORY	Bank characteristics
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of eleven categories
INDICATES	Factors that may contribute to bank erosion and instability

---

At each sampling site, indicate the presence of **one or more** of the following factors that may negatively influence the stability of either the left or right banks:

Category	**Example**[1]
Flow and waves	Bow waves from boats, or waves from turbulent flows
Seepage	From a landfill, water storage etc.
Runoff	Increased runoff from adjacent land that is unvegetated
Stock access	Cattle, sheep or horse access to the channel
Human access	Recreation point such as a picnic area or boat ramp
Feral animals	Goat, buffalo or horse access to the channel
Ford, culvert or bridge	Presence of bridges, culverts or fords that change channel dynamics
Clearing of vegetation	Forestry activity, land clearance to create grazing areas, riparian vegetation removal etc.
Reservoir release or irrigation offtake regime	Rapid release or draw down of instream flows that may increase the potential for bank slumping
Mining	Including gravel or sand extraction, existing or recent mining operations etc.
Drain pipes	Stormwater or waste-water pipes that may increase local discharge or turbulence
None	Banks are in excellent condition and are not impacted by any of the above factors

Variable modified from the River Habitat Audit Procedure (Anderson, 1993a).

1.
Examples are not exhaustive

VARIABLE NAME	Large woody debris
CATEGORY	Instream vegetation and organic matter
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	% cover of sampling site
INDICATES	Large woody debris is an important ecological component of lowland and upland streams, and can alter flow and other channel characteristics

---

Visually estimate the percent cover of large woody debris within the bankfull channel area, along a length of stream that is equal to the length of the sampling site.

Large woody debris is defined as logs and branches that are greater than 10cm in diameter and greater than 1m in length (Gippel, 1995).

VARIABLE NAME	Macrophyte cover
CATEGORY	Instream vegetation and organic matter
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	% cover of different macrophyte types
INDICATES	Macrophytes are an important ecological component of streams and can alter flow and other channel characteristics.

At each sampling site, visually estimate the percentage of the stream area covered by submerged, floating and emergent macrophyte types of any species (Figure 5.11). Stream area is equivalent to the length of the sampling site and the width of the wetted channel (under baseflow conditions).

Figure 5.11 Examples of macrophyte types: submerged (left), emergent (top right) and floating (bottom right).

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Macrophyte species composition
CATEGORY	Instream vegetation and organic matter
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	% cover of different macrophyte species
INDICATES	Macrophytes are an important ecological component of streams, and can alter flow and other channel characteristics.

Record the presence of the common macrophyte species[1] at the sampling site and indicate which of these are exotic species. The field guide titled "A Field Guide to Waterplants in Australia" (Sainty and Jacobs, 1994) will assist in macrophyte identification. If any species present at a site is unknown, collect a sample for identification at a later time.

Then, for each of the species present, both native and exotic, visually estimate the percent cover of this species within the stream area. Stream area is equivalent to the length of the sampling site and the width of the wetted channel (under baseflow conditions).

Variable derived from AUSRIVAS

1.
The macrophyte taxa initially included on the data sheets are a guide only and may need to be adjusted to suit regional conditions.

VARIABLE NAME	Shading of channel
CATEGORY	Riparian vegetation
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five % shading categories
INDICATES	The amount of light reaching the channel is important for instream ecological processes and is an indirect relative measure of riparian vegetation density

---

At each sampling site, visually estimate the percentage of the stream area that would be shaded by riparian vegetation when the sun is directly overhead (Figure 5.12). The stream area is equivalent to the length of the sampling site and the width of the wetted channel (under baseflow conditions).

Figure 5.12 Examples of channel shading: <5% shading (left) and >76% shading (right).

Variable derived from AUSRIVAS

VARIABLE NAME	Extent of bank trailing vegetation
CATEGORY	Riparian vegetation
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of four categories
INDICATES	Vegetation that trails from the bank into the water provides an important habitat for aquatic biota

---

Visually estimate the occurrence and density of trailing bank vegetation along the length of the sampling site as **one** of the following categories:

nil
slight
moderate
extensive

Trailing bank vegetation is the component of the terrestrial riparian vegetation that has direct contact with the water (under baseflow conditions) and which provides habitat and shelter for macroinvertebrates and fish (Figure 5.13). Trailing bank vegetation is generally found along the banks of slow flowing areas such pools and backwaters, although it is often present on the banks of riffles and runs.

Figure 5.13 Examples of trailing bank vegetation: extensive (left) and nil (right).

Variable derived from AUSRIVAS

VARIABLE NAME	Riparian zone composition
CATEGORY	Riparian vegetation
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	% cover of different riparian components
INDICATES	Riparian vegetation is important for lateral stability of the channel and has a direct relationship to many aspects of channel character.

The riparian zone is defined as the area from the water's edge (under baseflow conditions) to a distance from the bank where the stream still interacts with and influences the type and density of the bank-side vegetation (Nichols *et al.*, 2000).

At each sampling site, identify the riparian zone and visually estimate the percentage area of the riparian zone that is covered by **each** of the following components:

trees >10m in height
trees <10m in height
shrubs
grasses, ferns and sedges

The percent cover of each of these four vegetation components within the riparian zone is estimated in planview for the left and right banks together, along the entire length of the sampling site. Schematic drawings to assist in determining the relative percent cover of vegetation are provided in Figure 5.14. Because of the 'layering' effect found within the riparian zone (ie. shrubs can grow under trees, grasses can grow under trees etc.), the sum total percent cover of all four vegetation components may be greater than 100%, but must follow two rules:

- the total percent cover of the trees >10m and the trees <10m components must not exceed 100%
- percent cover of the shrubs and grasses/ferns/sedges components are treated separately and may each total 100%

Both native and exotic species should be included in the assessment of riparian composition. Where known, include a description of the main species present or the main vegetation types present (e.g. native grasses, rainforest, willows, river red gum, tea tree, casuarina, blackberries, paragrass etc.) in each vegetation component.

Variable derived from AUSRIVAS

1% COVER

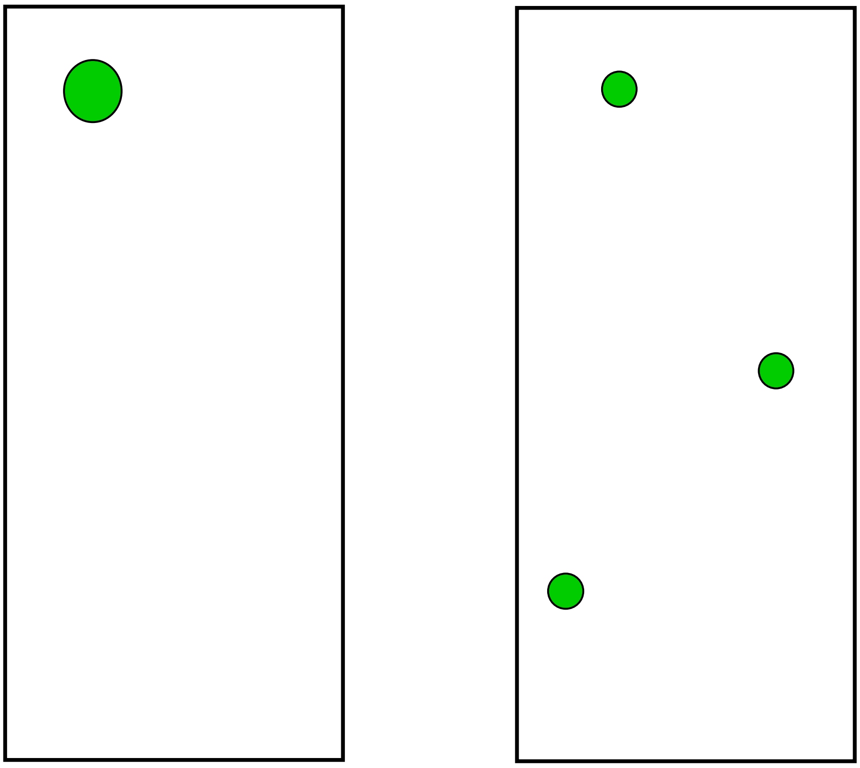
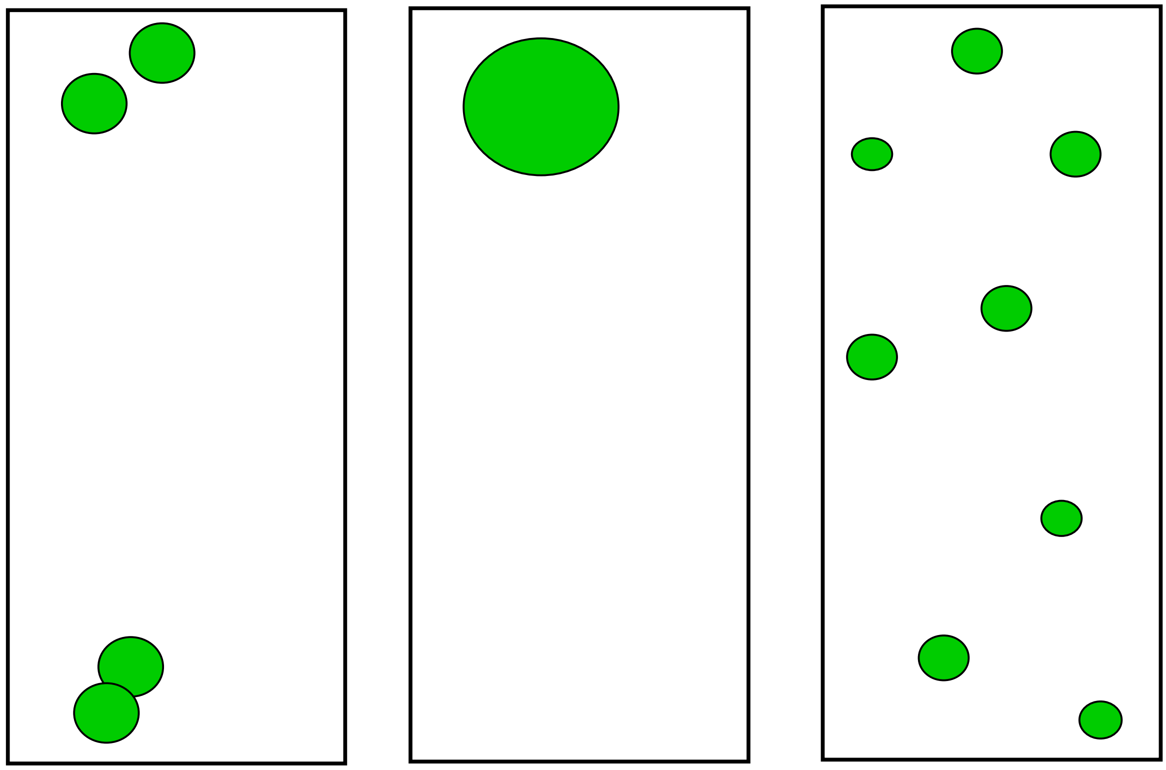


Figure 5.14 Schematic diagrams of 1%, 5%, 10%, 20%, 40%, 60% and 80% vegetative cover within the riparian zone. These schematic diagrams are used in conjunction with the riparian zone composition and native and exotic riparian vegetation variables. Drawings are modified from schematic diagrams presented in White and Ladson (1999), and are reproduced with kind permission of the Department of Natural Resources and Environment, Victoria.

(continued over)

5% COVER



10% COVER

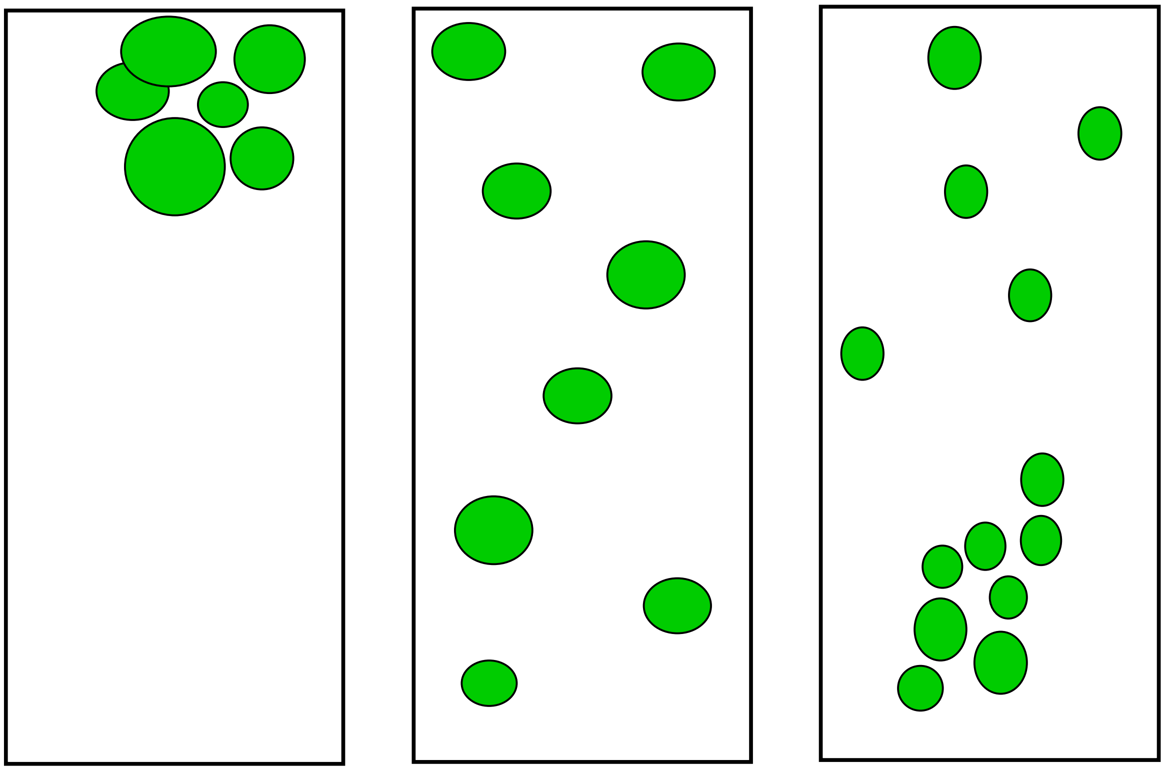
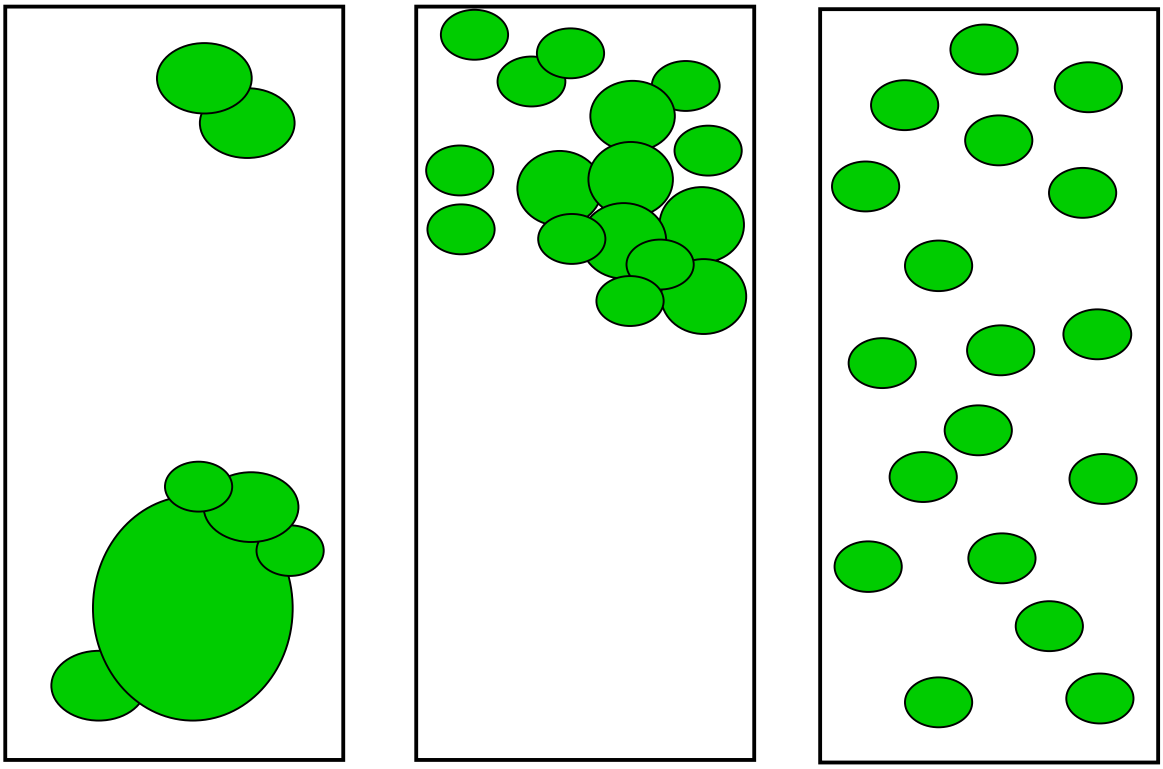


Figure 5.14 (cont.)

20% COVER



40% COVER

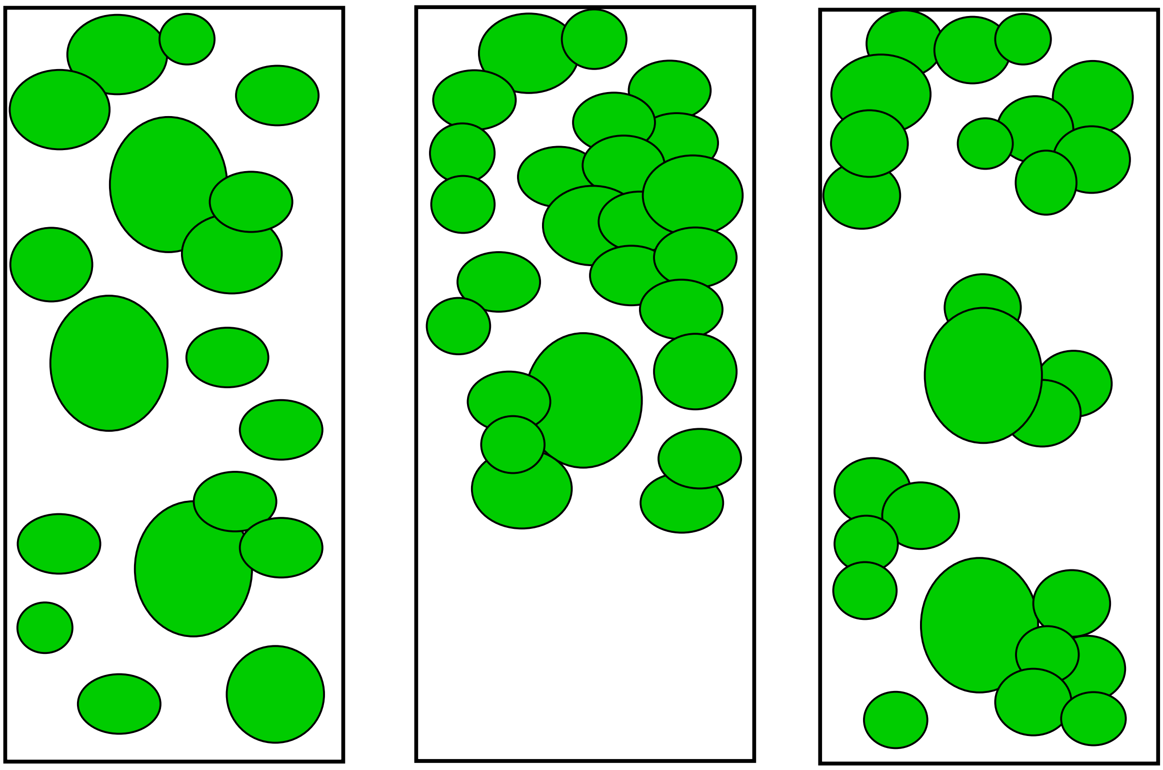
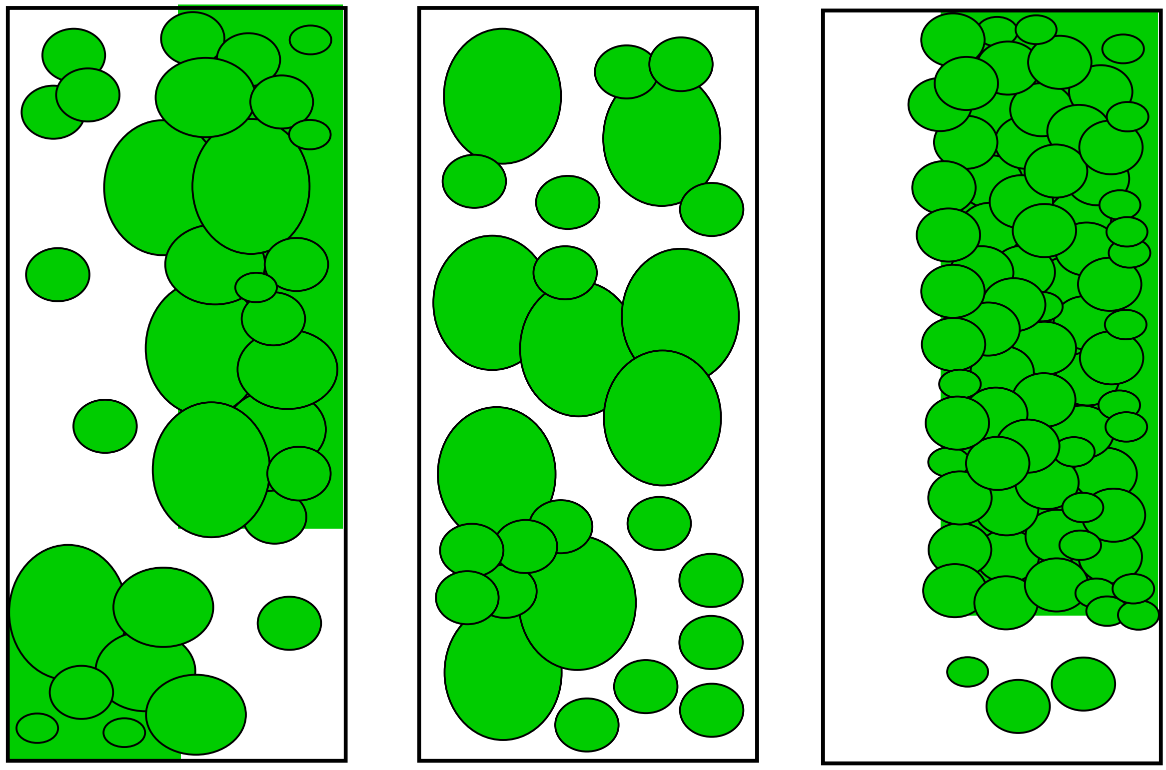


Figure 5.14 (cont.)

60% COVER



80% COVER

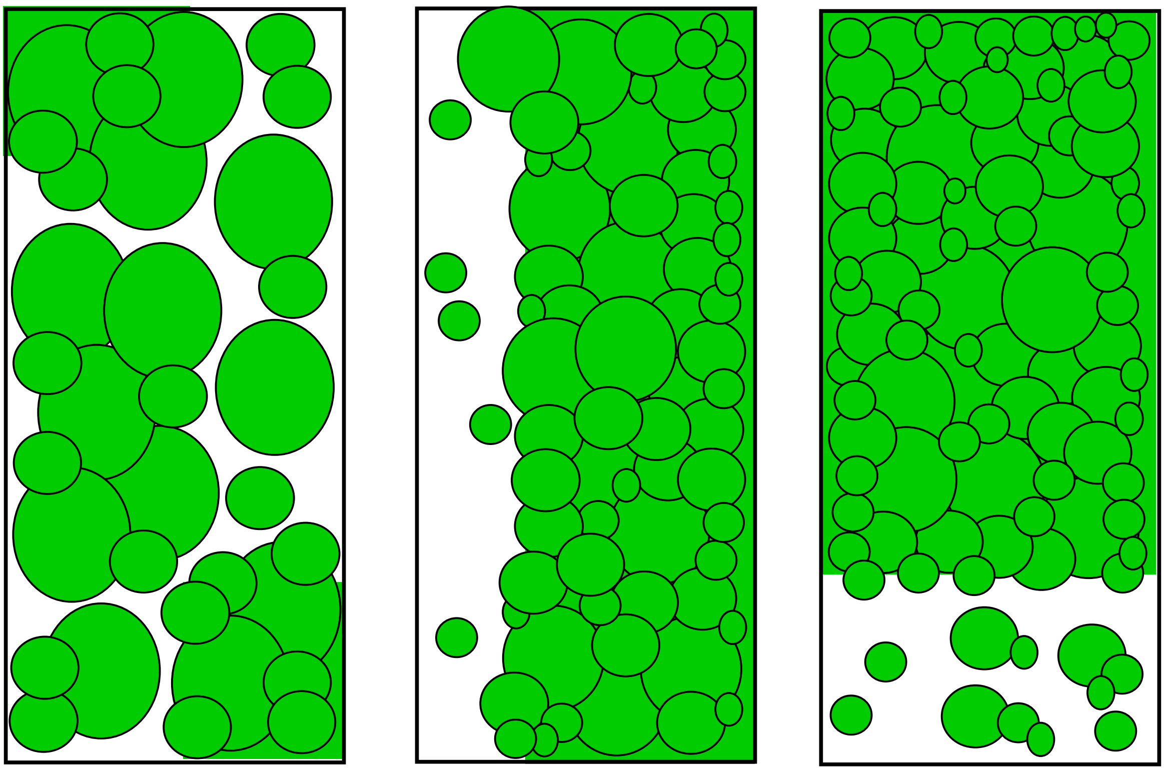


Figure 5.14 (cont.)

VARIABLE NAME	Native and exotic riparian vegetation
CATEGORY	Riparian vegetation
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	% cover of native and exotic vegetation
INDICATES	The relationship between channel character and riparian vegetation changes with a shift from native to exotic vegetation.

At each sampling site, visually estimate the percent cover of native and exotic riparian vegetation for the left and right banks together, along the entire length of the sampling site. Schematic drawings to assist in determining the relative percent cover of vegetation are provided in Figure 5.14. Percent native vegetation and percent riparian vegetation must total 100%, regardless of the density of the riparian vegetation at the sampling site.

Variable derived from AUSRIVAS

VARIABLE NAME	Regeneration of native woody vegetation
CATEGORY	Riparian vegetation
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of three categories
INDICATES	Regeneration of woody vegetation is related to the recovery of the riparian zone from previous disturbance

---

Along the length of each sampling site, visually assess the regeneration of native woody vegetation on the left and right banks together. Do not assess vegetation on instream islands, but include vegetation on bars joined to the banks. Native woody vegetation is defined as immature woody plants under 1m in height.

To measure this variable, first assess whether the sampling site is located in an undisturbed forest[1] that has no evidence of clearing, weeds, stock access at any time or other disturbances to the banks such as campgrounds or picnic areas. It is assumed that these sites would have natural rates of regeneration.

If the site is not located in an undisturbed forest, assess the regeneration of native woody vegetation as **one** of the following categories. Photos are provided in Figure 5.15 to aid in the interpretation of this variable.

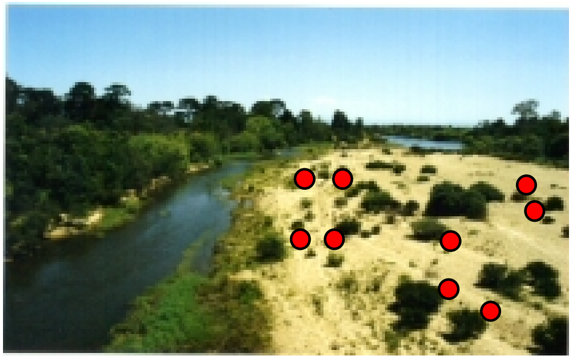
Category	**Description**
Abundant (>5% cover) and healthy	Greater than 5% cover of healthy native regeneration. At least a few taxa of native woody vegetation present, with a range of plant heights and no obvious signs of stress or extensive predation from stock, rabbits, insects etc.
Present	Between 1% and 5% cover of native regeneration, or greater than 1% of unhealthy regeneration. Few taxa of woody vegetation present, most regeneration around the same height and obvious signs of stress or extensive predation from stock, rabbits, insects etc. (as evidenced by many eaten or browned leaves)
Very limited (<1% cover)	Less than 1% cover of native regeneration

Variable derived from the Index of Stream Condition (White and Ladson, 1999 and Department of Natural Resources and Environment, Victoria)

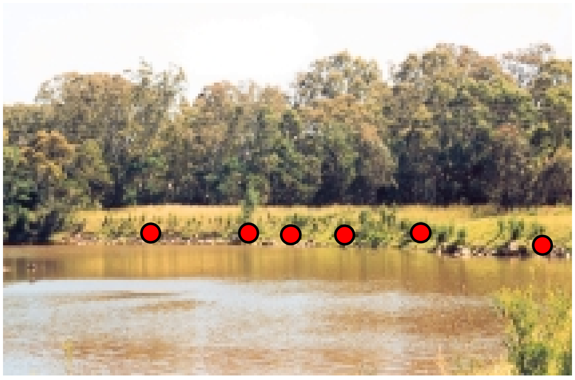
1.
At sites located in areas that would not naturally contain woody vegetation in the riparian zone (eg. frost hollows, native grasslands), substitute woody vegetation with an equivalent type of vegetation. Make a note on the data sheet that this substitution has been made.

a. Abundant and healthy

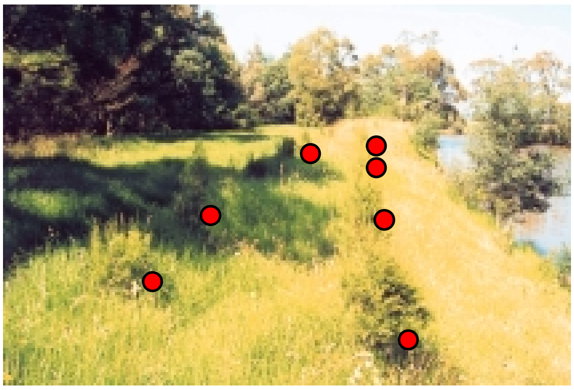
Extensive regeneration in healthy condition along the face of the bank. A few species present.



Greater than 5% cover on bar of regeneration in healthy condition.



Extensive healthy regeneration along the face of the bank.



Two rows of healthy swamp paperbark planted along a bank.

Figure 5.15. Examples of regeneration of indigenous woody vegetation for three categories: a) abundant and healthy, b) present and c) very limited. Dots show the regeneration of native woody vegetation. Examples are taken from Ladson and White (1999) and are reproduced with kind permission of the Department of Natural Resources and Environment, Victoria.

b. Present

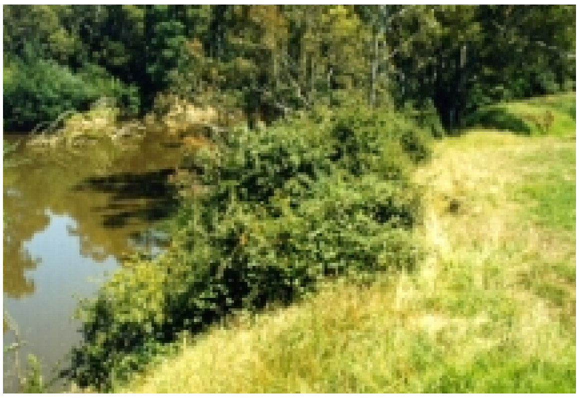
Figure 5.15 (cont.)

c. Very limited regeneration

This land grazed to the edge of the stream and there is no regeneration of indigenous woody vegetation.

No native regeneration is present under these willows.

This land is also grazed to the edge of the stream and there is no regeneration.



Infestation of exotic woody vegetation (blackberry gorse). No native regeneration.

Figure 5.15 (cont.)

VARIABLE NAME	Riparian zone width
CATEGORY	Riparian vegetation
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	m
INDICATES	Riparian vegetation is important for lateral stability of the channel and has a direct relationship to many aspects of channel character (Brierley *et al.*, 1996)

The riparian zone is defined as the area from the water's edge (under baseflow conditions) to a distance from the bank where the stream still interacts with and influences the type and density of the bank-side vegetation (Nichols *et al.*, 2000).

At each cross-section, estimate the width of the riparian zone on the left and right banks separately. It is preferable to measure distances with a tape measure at a number of sites, until estimates can be made with accuracy. The left and right bank measures of riparian zone width should be averaged to give an overall riparian width for the sampling site (Figure 5.16).

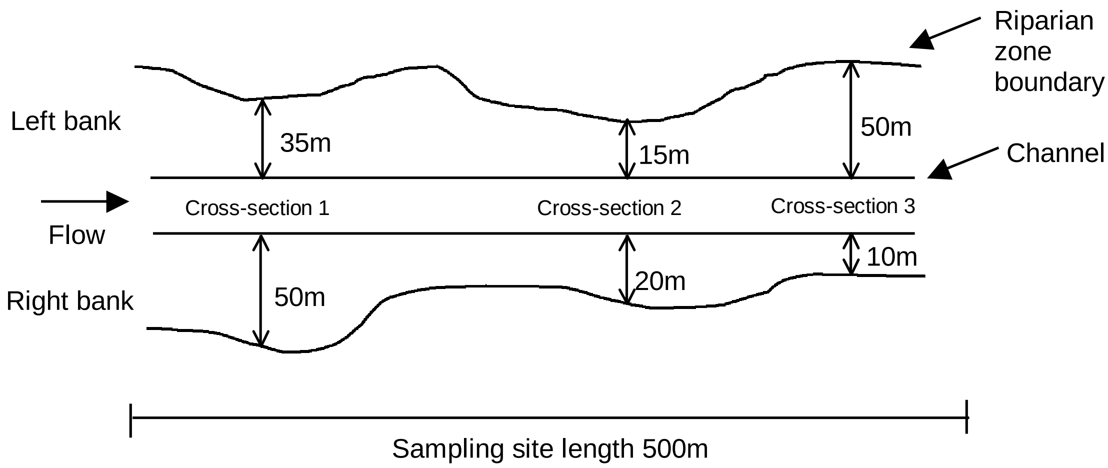


Figure 5.16 Example calculation of riparian zone width at a sampling site with three cross-sections. Readings of riparian zone width are made at each cross-section and averaged. In the above example, the average width of the riparian zone on the left bank is 33m and the average width of the riparian zone is 27m on the right bank. Overall average riparian width is 30m.

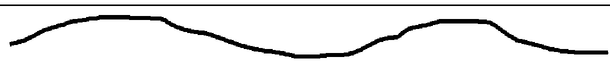
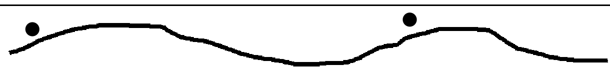
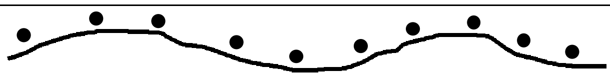
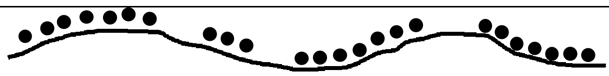
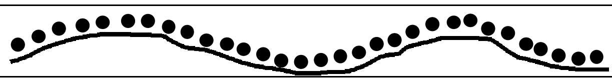
Variable derived from AUSRIVAS

VARIABLE NAME	Longitudinal extent of riparian vegetation
CATEGORY	Riparian vegetation
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of six categories
INDICATES	Patchiness of riparian vegetation, which in turn, indicates previous disturbance or clearance of the riparian zone

---

Along the length of each sampling site, visually assess the longitudinal extent, or patchiness, of the riparian zone on the left and right banks separately. Include only the tree and shrub layer components (native or exotic) in the assessment of longitudinal extent, and disregard the ground cover layer. However, for sites where the riparian zone is naturally composed entirely of native grasses, either along the entire site length or in significant patches, include grasses in the assessment of longitudinal extent.

Assess longitudinal extent of riparian vegetation using **one** of the following categories:

Category	**Description and examples[1] (shown for one bank only)**
None	 No trees or shrubs, only exotic grasses or pasture
Isolated / scattered	 Isolated trees or shrubs among exotic grasses or pasture
Regularly spaced, single	 Planted poplars
Occasional clumps	 Clumps of tea tree scrub among exotic grasses or pasture
Semi-continuous	 Native forest with cleared areas of exotic grasses
Continuous	 Undisturbed native forest, river red gum canopy

Variable derived from the River Habitat Survey (Raven *et al.*, 1998)

1.
Examples of vegetation types are not exhaustive

VARIABLE NAME — Overall vegetation disturbance rating

CATEGORY — Riparian vegetation

CONTROL OR RESPONSE — Response

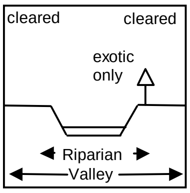
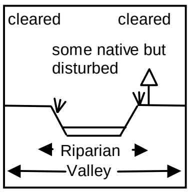
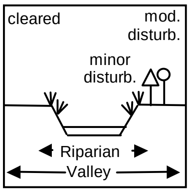
OFFICE OR FIELD — Field

UNITS OF MEASUREMENT — Choice of six categories

INDICATES — Even with an intact riparian zone, vegetation on the land adjacent to the riparian zone can influence characteristics of the stream channel

---

This variable considers the condition of the riparian zone and the surrounding valley vegetation simultaneously. The riparian zone is the portion of vegetation that interacts with the stream (see riparian zone composition variable for full definition) and the valley vegetation is the vegetation that is present in the valley in which the channel sits. At each sampling site, assess the condition of the riparian and valley vegetation on the left and right sides together, as **one** of the following categories:

Category	Riparian vegetation	Valley vegetation
 Extreme disturbance	Absent or severely reduced. Vegetation present is extremely disturbed (ie. dominated by exotic species with native species rare or completely absent)	Agriculture and/or cleared land BOTH sides. Plants present are virtually all exotic species (willows, pines, blackberries etc.)
 Very high disturbance	Some native vegetation present, but it is severely modified BOTH sides by grazing or the intrusion of exotic species. Native species severely reduced in number and cover.	Agriculture and/or cleared land BOTH sides. Plants present are virtually all exotic species (willows, pines, blackberries etc.)
 High disturbance	Riparian vegetation moderately disturbed by stock or through the intrusion of exotic species, although some native species remain	Agriculture and/or cleared land on ONE side, native vegetation on the other side clearly disturbed or with a high percentage of introduced species present.
	Note: Sites with valley vegetation cleared BOTH sides but with riparian vegetation in good condition (eg. fenced off from stock) should be included in this category	

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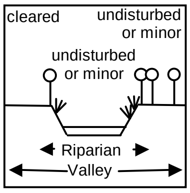
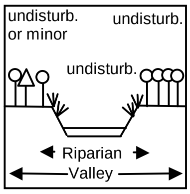
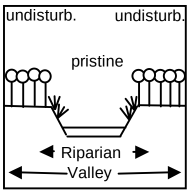
Category	**Riparian vegetation**	**Valley vegetation**
 Moderate disturbance	Native vegetation on BOTH sides with canopy intact or with native species widespread and common in the riparian zone. The intrusion of exotic species is minor and of moderate impact	Agriculture and/or cleared land on ONE side, native vegetation on the other in reasonably undisturbed state
 Low disturbance	Native vegetation present on BOTH sides of the river and in relatively good condition with few exotic species present. Any disturbance present is relatively minor.	Native vegetation present on BOTH sides of the river, with a virtually intact canopy and few exotic species.
 Very low disturbance	Native vegetation on both sides of the river in an undisturbed state. Exotic species are absent or rare. Representative of natural vegetation in excellent condition.	Native vegetation present on both sides of the river with an intact canopy. Exotic species are absent or rare. Representative of natural vegetation in excellent condition.

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Local impacts on streams
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of seventeen categories
INDICATES	Local activities that may be impacting on stream habitat

---

Indicate whether **one or more** of the following activities or potential impacts are present at the sampling site or in the local area. Where possible, include a brief description of each selected impact. For example, grazing may be by sheep or cattle, water extraction may be irrigation or rural domestic, litter may be urban rubbish or old car bodies etc.

sand or gravel mining
other mining
road
bridge / culvert / wharf
ford / ramp
discharge pipe
forestry activities
sugar mill
sewage effluent
irrigation run-off or pipe outlet
channel straightening
river improvement works
water extraction
dredging
grazing
litter
recreation
other

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Turbidity (visual assessment)
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of four categories
INDICATES	Water clarity and the presence of suspended material in the water

---

At each sampling site, visually assess the turbidity of the water as **one** of the following categories:

Category	**Description**
clear	water very clear in pools and shallows
slight	water slightly turbid in pools and/or shallows
turbid	water moderately turbid in pools and/or shallows
opaque	water very turbid in both pools and shallows

Turbidity refers to the relative clarity of water and measures the extent to which light penetration is reduced from <u>suspended</u> materials such as clay, mud, organic matter or plankton. The presence of <u>dissolved</u> materials derived from plant leachates can also reduce water clarity (e.g. blackwater streams) and in such cases, water will be 'tea' coloured. The type of material causing any reduction in water clarity should be noted on the data sheet at each sampling site.

Variable derived from AUSRIVAS

VARIABLE NAME	Water level at the time of sampling
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five categories
INDICATES	Whether flows are elevated or reduced at the time of sampling

---

At each sampling site, indicate the water level on the day of sampling as **one** of the following categories. Water level should be measured relative to the baseflow water mark, which is evidenced by the limit of terrestrial grasses, eroded area or boundary changes in bank sediments.

Category	**Description**
Dry	Dry channel
No flow	Water present but flow is severely or completely reduced
Low	Flow at time of sampling lower than baseflow water mark
Baseflow	Flow at time of sampling equal or almost equal to baseflow water mark
High	Flow at time of sampling substantially higher than baseflow water mark
Flood	Flood conditions. Sampling not recommended.

Variable derived from AUSRIVAS

VARIABLE NAME	Sediment oils
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of four categories
INDICATES	Chemical pollution

At each sampling site, examine the sediment and visually assess the presence of oily residues as **one** of the following categories:

absent
light
moderate
profuse

Variable derived from AUSRIVAS

VARIABLE NAME	Water oils
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five categories
INDICATES	Chemical pollution

At each sampling site, note the presence of oils on the water surface as **one** of the following categories:

slick
sheen
globs
flecks
none

Variable derived from AUSRIVAS

VARIABLE NAME	Sediment odours
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of six categories
INDICATES	Chemical pollution or deoxygenation in the sediments

At each sampling site, take a scoop of sediment and smell for odours that correspond to **one or more** of the following categories:

normal odour / no odour[1]
sewage
petroleum
chemical
anaerobic[2]
other

Variable derived from AUSRIVAS

1. Unpolluted sediments may have a naturally 'earthy' odour
2. Hydrogen sulphide ('rotten egg gas') is an odour commonly encountered in anaerobic, or deoxygenated, sediments

VARIABLE NAME	Water odours
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five categories
INDICATES	Chemical or organic pollution in the water

At each sampling site, note the presence of any odours emanating from the water, as **one or more** of the following categories:

normal odour / no odour
sewage
petroleum
chemical
other

Variable derived from AUSRIVAS

WATER CHEMISTRY

There are a large number of chemical variables that can be measured to indicate specific aspects of water quality. The physical assessment protocol provides a method for the assessment of physical stream condition and as such, emphasis has been placed on physical, rather than chemical components. However, several basic water quality variables have been included in the protocol, to correspond with those measured in AUSRIVAS. The rationale for inclusion of these variables is both biological and physical. For example, dissolved oxygen, pH, temperature and turbidity can effect the structure and composition of biological communities, whereas conductivity and turbidity are indirect indicators of fluvial processes occurring within a river system. Total phosphorus and total nitrogen broadly describe the nutrient status of the stream and may be direct or indirect indicators of human or agricultural impacts on streams. Other water quality variables can be added to the protocol to suit specific State or Territory conditions.

Each of these water quality variables is measured instantaneously on the day of sampling and can be used to flag impacts that may effect biological communities (e.g. low dissolved oxygen), or to flag impacts that may indicate the physical condition of the surrounding catchment (e.g. high turbidity). In addition, these basic water quality variables can be compared against existing long-term water quality monitoring data, or to guideline levels reported in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. These guidelines can be accessed via the Environment Australia home page at http://www.environment.gov.au/science/water/

While it is important to measure basic water quality variables when at a sampling site, these instantaneous measurements can not be used as response variables in a predictive model, because they are generally highly variable over diurnal, seasonal and long-term time spans. However, where long-term water quality monitoring data (or modelled water quality data) are available for all reference sites, long-term average values can be used as a response variable. Then, instantaneous measurements of water quality at a test site are valid and can be compared against the average long - term values contained in the reference site database.

VARIABLE NAME	Basic water chemistry and nutrients[1]
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Various
INDICATES	Status of pH, conductivity, temperature, dissolved oxygen, conductivity, phosphorus and nitrogen at the time of sampling

---

The basic water chemistry variables measured at each sampling site are:

Variable	Units	Description
Temperature	°c	Temperature of the water at the time of sampling.
Electrical conductivity	µS cm^{-1}	Measures the total concentration of inorganic ions (salts) in the water.
Dissolved oxygen	mg l^{-1}	Reflects the equilibrium between oxygen consuming processes (e.g. respiration) and oxygen releasing processes (e.g. photosynthesis). Can also be converted to dissolved oxygen % saturation, which essentially adjusts for altitude and temperature effects on oxygen concentration.
Turbidity	NTU or FNU	Measures the presence of suspended particulate and colloidal matter such as suspended clay, silt, phytoplankton and detritus.
pH	-	Measure of the acidity or alkalinity of the water.
Total phosphorus	mg l^{-1}	Indicator of nutrient status
Total nitrogen	mg l^{-1}	Indicator of nutrient status

All water chemistry variables are taken from one place in the sampling site and should be collected before disturbing the streambed by wading around the site.

(continued over)

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1. Other water quality variables can be included if required by each State or Territory.

Water chemistry variables such as temperature, conductivity, dissolved oxygen, pH and turbidity should be measured in the field using an appropriate measurement apparatus (e.g. Hydrolab or hand held meters). When taking a reading, be sure to stand downstream from the measurement apparatus (Figure 5.17), and make sure that any instruments used in the field are correctly calibrated.

Water chemistry variables such as total phosphorus and total nitrogen require the collection of a water sample (Figure 5.17). Be sure to follow the standard procedures for collection of water samples, to avoid sample contamination or deterioration.

Figure 5.17 Collection of water quality variables using a Hydrolab (left) and collection of a water sample for laboratory analysis (right).

VARIABLE NAME	Filamentous algae cover
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five % cover categories
INDICATES	Excess filamentous algae growth may be indicative of nutrient enrichment

---

At each cross-section, visually estimate the percent cover of filamentous algae growing on organic or inorganic substrates within an area of stream 5m either side of the cross-section. Choose **one** of the following categories that correspond to the percent cover of filamentous algae within the assessment area:

Category	**Equivalent percent cover**
very low	<10%
low	10 – 35%
moderate	35 – 65%
high	65 – 90%
very high	>90%

Figure 5.18 Filamentous algae.

Variable derived from AUSRIVAS

VARIABLE NAME	Periphyton cover
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five % cover categories
INDICATES	Excess periphyton growth may be indicative of nutrient enrichment

---

At each cross-section, visually estimate the percent cover of periphyton growing on organic or inorganic substrates within an area of stream 5m either side of the cross-section. Choose **one** of the following categories that correspond to the percent cover of periphyton within the assessment area:

Category	Equivalent percent cover
very low	<10%
low	10 – 35%
moderate	35 – 65%
high	65 – 90%
very high	>90%

Figure 5.19 Periphyton cover.

Variable derived from AUSRIVAS

VARIABLE NAME	Moss cover
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five % cover categories
INDICATES	In upland sites, presence of moss may indicate the time since the last high flow event that moved bed sediments

---

At each cross-section, visually estimate the percent cover of moss growing on substrates within an area of stream 5m either side of the cross-section. Choose **one** of the following categories that correspond to the percent cover of moss within the assessment area:

Category	**Equivalent percent cover**
very low	<10%
low	10 – 35%
moderate	35 – 65%
high	65 – 90%
very high	>90%

Variable derived from AUSRIVAS

VARIABLE NAME	Detritus cover
CATEGORY	Site observations
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five % cover categories
INDICATES	Detritus is an important food resource for macroinvertebrates.

At each cross section, visually estimate the percent cover detritus (sticks less than 10cm diameter and 1m long (ie. not large woody debris), twigs and terrestrially derived vegetation within an area 5m either side of the cross-section. Choose **one** of the following categories that correspond to the percent cover of detritus within the assessment area:

Category	**Equivalent percent cover**
very low	<10%
low	10 – 35%
moderate	35 – 65%
high	65 – 90%
very high	>90%

Variable derived from AUSRIVAS

VARIABLE NAME	Extent of bars
CATEGORY	Physical morphology and bedform
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	% extent of bars
INDICATES	Increased bar formation may be associated with increasing sedimentation or reduced instream flows

---

A bar is a submerged or exposed ridge-like accumulation of sand, gravel or other alluvial material formed in the channel where a decrease in velocity induces deposition (Armantrout, 1998).

At each sampling site, visually estimate the percentage of the streambed area that protrudes to form a bar of any type (Figure 5.20). Also record the dominant sediment particle size of the bars. Streambed area is equivalent to the length of the sampling site and the width of the wetted channel (under baseflow conditions). Bars can be unattached (e.g. islands) or attached to the banks.

Figure 5.20 Examples of bars in a river channel.

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Type of bars
CATEGORY	Physical morphology and bedform
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of nine categories
INDICATES	The types of bars present in a channel are indicative of channel behaviour and channel forming processes

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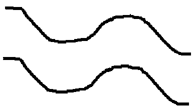
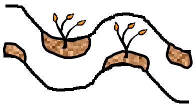
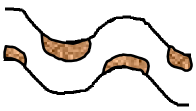
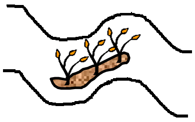
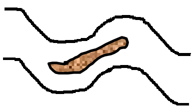
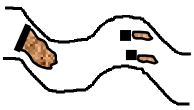
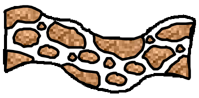
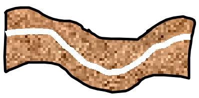
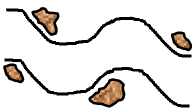
Indicate the presence of **one or more** of the following bar types along the length of the sampling site:

	bars absent
	side/point bars VEGETATED
	side/point bars UNVEGETATED
	mid-channel island VEGETATED
	mid-channel island UNVEGETATED

	bars formed around obstructions
	braided channel
	infilled channel
	high flow deposits

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Channel shape
CATEGORY	Physical morphology and bedform
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of twelve categories
INDICATES	The shape of the channel influences many aspects of channel character including discharge, sediment transport and bedform features

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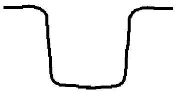
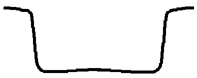
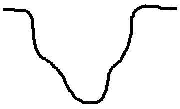
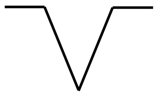
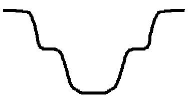
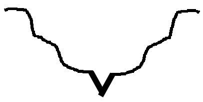
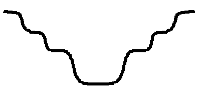
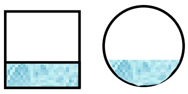
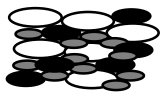
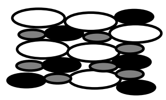
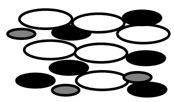
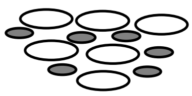
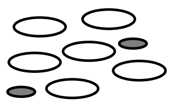
At each sampling site, examine the overall shape of the channel as **one** of the following categories:

	**U shape** Most common natural channel type		**Box** Commonly encountered with severe gully erosion
	**Flat U shape**		**Wide box**
	**Deepened U shape** May be naturally incised channels		**V shaped**
	**Widened or infilled**		**Trapezoid** Engineered channel shape
	**Two stage** Lowland channel with one bench		**Concrete V** Engineered channel shape
	**Multi stage** Lowland channel with >1 bench		**Culvert or pipe**

Variable modified from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Bed compaction
CATEGORY	Substrate
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five categories
INDICATES	Partially determines the erodibility or stability of the bed material.

After examination of the substratum and the bed along the length of the sampling site[1], assess the overall character of bed sediment compaction as **one** of the following categories. The term 'dislodge' refers to the ability to pull individual rocks of different sizes from the streambed with the hands. The term 'overlapping' refers to the relative location of rocks on the streambed (ie. whether they sit on top of each other or next to each other).

	Tightly packed, armoured Array of sediment sizes, overlapping, tightly packed and very hard or impossible to dislodge
	Packed, but not armoured Array of sediment sizes, overlapping, tightly packed but can be dislodged with moderate effort
	Moderate compaction Array of sediment sizes, little overlapping, some packing but can be dislodged with moderate effort
	Low compaction (1) Limited range of sediment sizes, little overlapping, some packing and structure but can be dislodged very easily
	Low compaction (2) Loose array of fine sediments, no overlapping, no packing and structure and can be dislodged very easily

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

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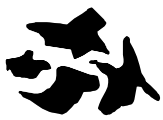
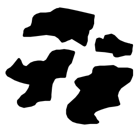
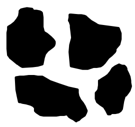
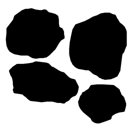
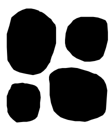
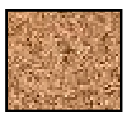
1. In wadeable streams, the bed can be examined visually along the length of the sampling site. In large rivers, the bed should be examined in relation to the range of sediment sizes present at the sampling site (see substrate composition variable). Generally, beds comprised of gravel, sand and silt sediment sizes are not compacted and are easily moved. Thus, these bed types should be allocated to the low compaction (1) or (2) categories.

VARIABLE NAME	Sediment angularity
CATEGORY	Substrate
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of six categories
INDICATES	Indicates the degree of material reworking.

After visual examination of the substratum and the bed along the length of the sampling site, assess the overall angularity of the cobble, pebble and/or gravel sediment fractions as **one** of the following categories. Do not include bedrock in the assessment of angularity. Where the cobble, pebble AND gravel fractions are not present at a sampling site (e.g. in lowland rivers), select the 'not present' category.

	very angular
	angular
	sub-angular
	rounded
	well-rounded
	cobble, pebble **and** gravel fractions not present

Variable derived from the River Habitat Audit Procedure (Anderson, 1993a).

VARIABLE NAME	Bed stability rating
CATEGORY	Substrate
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five categories
INDICATES	Whether the bed is eroding or degrading

The bed stability rating is an assessment of the overall stability of the whole sampling site. The bed stability rating is not a measure of localised patches of deposition or erosion within the sampling site (ie. normal sediment accumulation on a bar located at the inside of a stream bend, White and Ladson, 1999). Rather, this variable asks the question "does the sampling site, as an overall unit, show signs of large scale bed deposition or erosion that may continue outside the bounds of the sampling site?"

With a picture of the links between the sampling site and the surrounding catchment and adjacent river sections in mind, visually assess bed stability at the sampling site as **one** of the following categories:

Unstable ERODING ↑ Stable ↓ Unstable DEPOSITING

Category	Description
Severe erosion	Streambed scoured of fine sediments[1]. Signs of channel deepening. Bare, severely eroded banks. Erosion heads. Steep streambed caused by erosion.
Moderate erosion	Little fine sediment[1] present. Signs of channel deepening. Eroded banks. Streambed deep and narrow. Steep streambed comprised of unconsolidated (loosely arranged and unpacked) material.
Bed stable	A range of sediment sizes present in the streambed. Channel is in a 'relatively natural' state (not deepened or infilled). Bed and bar sediments are roughly the same size. Banks stable. Streambed comprised of consolidated (tightly arranged and packed) material, may be covered with algae.
Moderate deposition	Moderate build-up of fine sediments[1] at obstructions and bars. Streambed flat and uniform. Channel wide and shallow.
Severe deposition	Extensive build up of fine sediments[1] to form a flat bed. Channel blocked, but wide and shallow. Bars large and covering most of the bed or banks. Streambed comprised of unconsolidated (loosely arranged and unpacked) material.

(continued over)

1. Fine material generally corresponds to the sand, silt and clay sediment fractions

Figure 5.21 Examples of bed stability. Severe erosion (top left), moderate erosion (top right), bed stable (centre), moderate deposition (bottom left) and severe deposition (bottom right).

Variable modified from the River Habitat Audit Procedure (Anderson, 1993a) and Index of Stream Condition (Ladson and White, 1999 and Department of Natural Resources and Environment, Victoria)

VARIABLE NAME	Sediment matrix
CATEGORY	Substrate
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	Choice of five categories
INDICATES	The relative composition of the matrix and interstitial components of the streambed sediments

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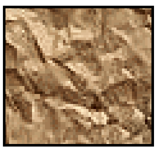
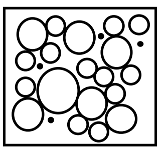
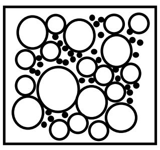
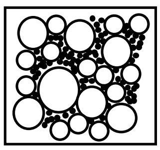
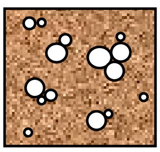
The sediment matrix variable is derived from sedimentological theories which state that two types of sediment can be characterised on the bed of a river:

1. **the framework** – which is the coarse population of sediments
2. **the matrix** – which is the finer population of sediments

Hence, riverbed sediments can be classified into five categories that represent the relationship between the framework and the matrix sediment components: open framework, matrix filled contact framework, framework dilated, matrix dominated and bedrock (Thoms, 1988). These categories also indicate the amount of interstitial space available within the riverbed.

After visual examination of the substratum and the bed along the whole length of the sampling site, assess the overall character of the sediment matrix as **one** of the following categories:

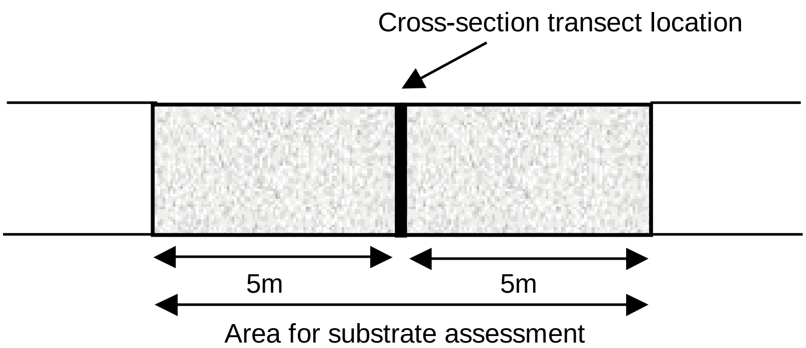
	Bedrock
	Open framework 0-5% fine sediment, high availability of interstitial spaces
	Matrix filled contact framework 5-32% fine sediment, moderate availability of interstitial spaces

	Framework dilated 32-60% fine sediment, low availability of interstitial spaces
	Matrix dominated >60% fine sediment, interstitial spaces virtually absent

VARIABLE NAME	Substrate composition
CATEGORY	Substrate
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Field
UNITS OF MEASUREMENT	% cover of seven size categories
INDICATES	Substrate characteristics are directly related to geomorphological processes and in turn, substrate is a major factor controlling the occurrence of macroinvertebrates.

Streambed sediment, or substrate, is visually assessed at each sampling site as the percent cover of each of seven size categories, within the area around the cross-section.

The area for assessment of substrate extends for 5m either side of the cross-section transect, regardless of the type of bedform types contained within that area:



Within this 10m long area, assess the relative percent cover of **each** of the following size classes:

Sediment category	**Size**
Bedrock	
Boulder	> 256mm
Cobble	64 – 256mm
Pebble	16 – 64mm
Gravel	2 – 16mm
Sand	0.06 – 2mm
Fines (silt and clay)	< 0.06mm

The sum of all the substrate categories must equal 100%.

(continued over)

Stream substrate should be assessed to a depth of 10-20cm into the bed. In wadeable streams, sediment should be dislodged and both the surface and sub-surface layers examined. In deep pools or large rivers, sediment should be sampled using a grab sampler or similar device.

Overall substrate composition at the sampling site is calculated separately for each size category by averaging the percent cover obtained at each of the two or three cross-sectional areas used for assessment.

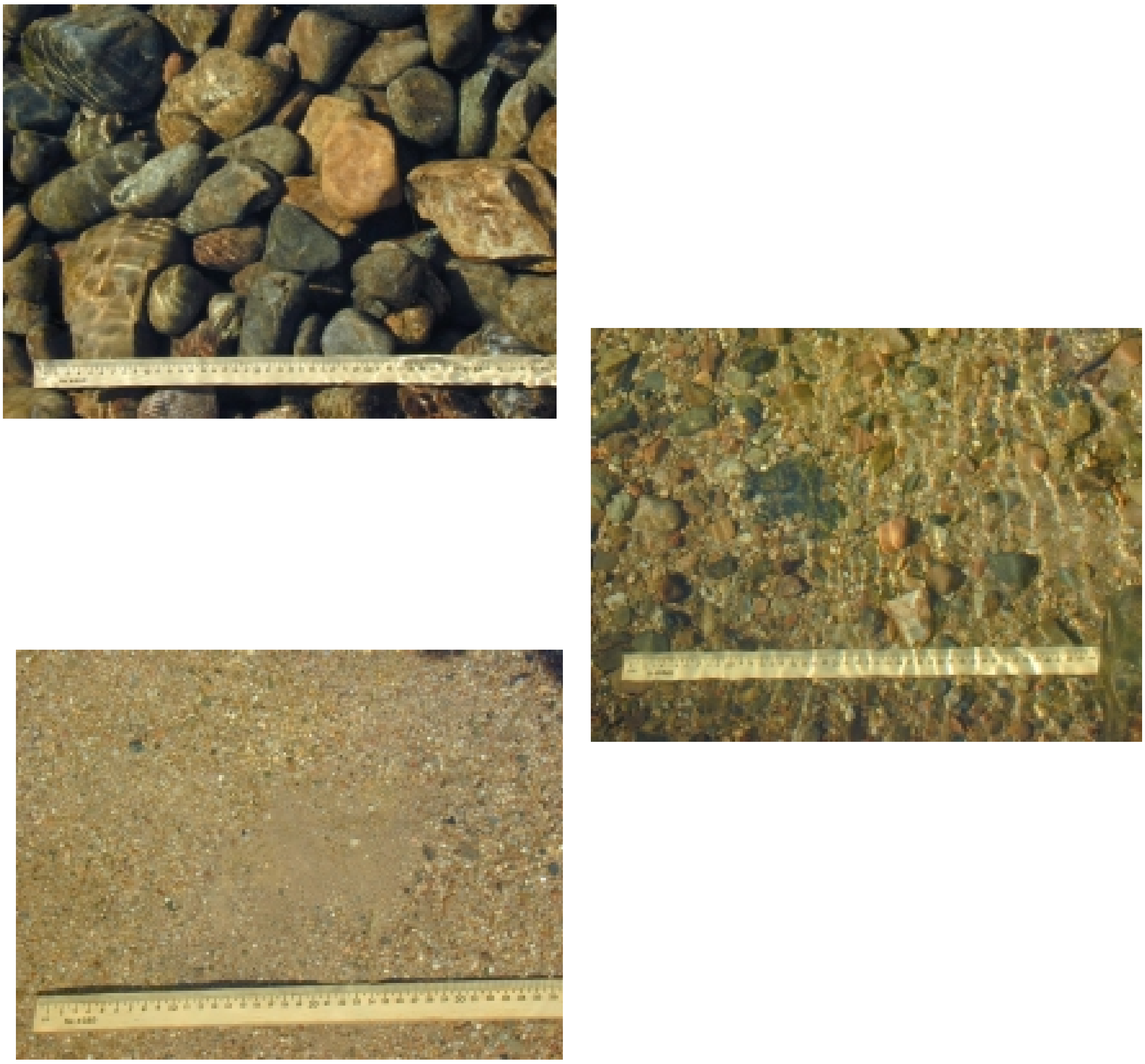


Figure 5.22 Examples of different sediment classes: cobble (top), gravel and pebble (middle) and sand and gravel (bottom).

Variable derived from AUSRIVAS

CHANNEL CROSS-SECTIONS

WHAT IS A CROSS-SECTION?

In a geomorphological survey, thorough description of the physical characteristics of a stream reach generally includes measurement of several cross-section profiles (Gordon *et al.*, 1992). 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 areal 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. Aspects of channel dimension can also be used to calculate complex geomorphological or hydrological parameters such as Mannings *n* or stream power, although these are not included in the current protocol.

WHAT AMOUNT OF EFFORT AND EQUIPMENT IS REQUIRED TO MEASURE A CROSS-SECTION?

Channel cross-sections can be measured using survey equipment, although in the current protocol, equipment is kept to a minimum (Figure 5.23) and channel cross-sections will be taken using measuring tapes. 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 (Figure 5.24). Specific components of the cross-section will be discussed further in the next section.

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. At some sampling sites, cross-sectional measurements may also be made from a bridge. To take depth measurements along a horizontal transect, a marked pole (e.g. a metre ruler, survey staff or custom made device) can be used, or in slow flowing areas a weighted tape measure or weighted and marked rope is also suitable. Another method that has been used successfully in the River Habitat Audit Procedure (Anderson, 1993a) is to rig a depth sounder onto a rubber flotation board, that can be pushed, pulled or placed across the river to take depth measurements at the required intervals.

It is important that the required numbers of cross-sections are measured at every sampling site. Thus, preparation for a field trip should include planning of the logistics and equipment required to make cross-sectional measurements at all sampling sites, even those located on large or deep rivers. <u>Health and safety issues must be taken into consideration when planning cross-section sampling in any type of river.</u>

Figure 5.23 Equipment required for measuring cross-sections in a wadeable stream. Note that the metre ruler and weighted rope are interchangeable, depending on stream depth. Waders are not shown because wading shoes were used at this site. Additionally, this photo represents the equipment that needs to be carried to assess the whole of a wadeable sampling site, once water quality measurements have been taken.

WHAT DOES A CROSS-SECTION LOOK LIKE?

The components that must be measured at each cross-section are detailed in Figure 5.24 and are described as follows:

Stream width at the water surface is the width of the water surface at the time of sampling.

Baseflow stream width is the width of the stream at a point corresponding to baseflow conditions. The baseflow water mark is evidenced by the limit of terrestrial vegetation, eroded area or a break in bank sediment. Under baseflow conditions, baseflow stream width will be equivalent to stream width at the water surface.

Bankfull channel width is the width of the channel between the top of the banks. Bankfull level is the point at the top of the channel where under high flow conditions, the water level would be even with the top of the banks, or in a floodplain river, at the point just before water would spill over onto the floodplain. Further information on the identification of bankfull level is provided in Figure 5.31.

Bank height is the height of the bank measured from the baseflow water mark to the top of the banks. Bank height is measured at both the left and right banks.

Bank width is the width of the bank, extending from the edge of the stream (at the watermark) to the bankfull point. Bank width is measured at both the left and right banks.

Vertical distance between water surface and baseflow water mark is the height difference between the water surface and the baseflow water mark. Vertical distance between water surface and baseflow water mark is measured to compensate for conditions where flow is below normal levels at the time of sampling. This component is measured at both the left and right banks.

Vertical water depths and horizontal distances are measured together at several points across the width of the stream. At each horizontal distance from the edge of the stream, water depth is recorded.

Each of these components are used in various combinations to calculate cross-sectional variables (see section titled 'What variables are derived from a cross-section?') and thus, it is vital to make all of these measurements at each cross-section.

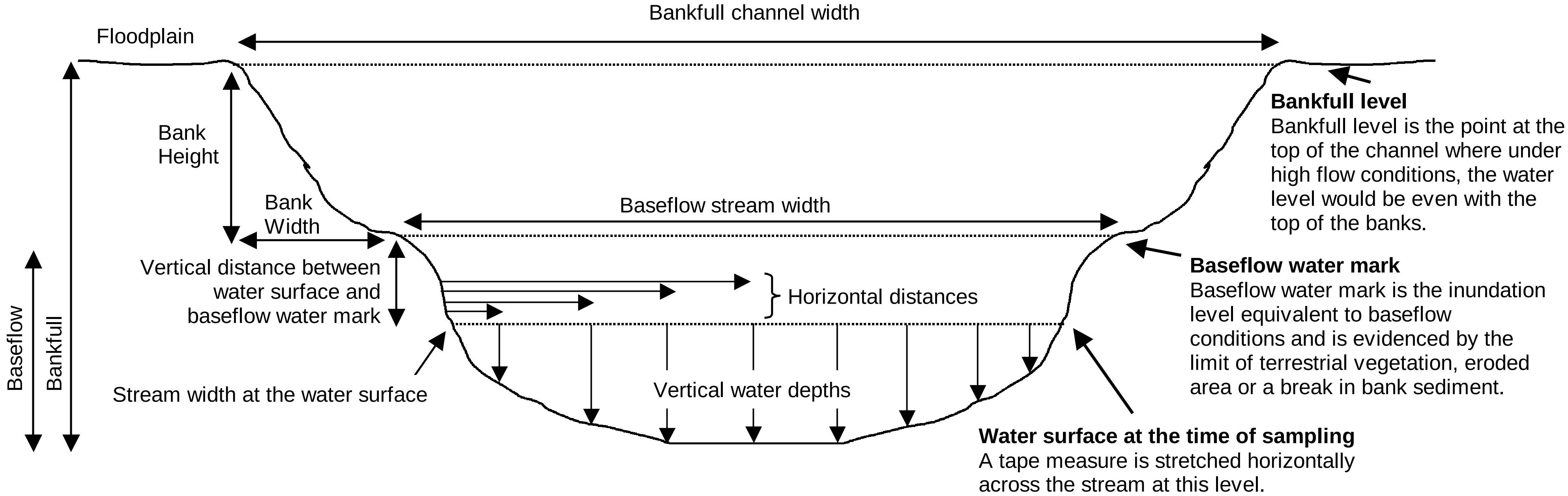


Figure 5.24 Components of a channel cross-section. A tape measure is stretched across the surface of the water and the vertical water depth and horizontal distance from the bank are both measured at several points across the entire channel width. Bank height and the distance between the water surface and the water mark are measured on the left and right sides of the channel. Refer to text for more information.

WHAT IS THE PROCEDURE FOR MEASURING A CROSS-SECTION IN THE FIELD?

The field procedure for measuring a cross-section is as follows:

1. At the point where the cross-section is to be located, identify the bankfull level, baseflow water mark level and the present water level. Decide whether the flow level is roughly equal to baseflow condition and thus, whether the stream width at the watermark is the same as the stream width at the present water surface. Further information on the identification of bankfull level is given in the section titled 'How are the bankfull and baseflow water mark levels identified in different channel types?'
2. Stretch a tape measure across the surface of the water from one edge of the stream to the other and secure both ends. Record the stream width at the water surface (Figure 5.25).
3. With the tape measure still in place move back across the stream and record the vertical water depth at a minimum of 5 and a suggested maximum of 15 points across the tape measure, using the metre ruler or weighted rope, or similar (Figure 5.26). The number of points measured will depend on the width and heterogeneity of the channel and in large streams, more than 15 points may be required to characterise the streambed profile. Points do not have to be regularly spaced, but where possible, should represent breaks in the streambed profile. Be sure to record the horizontal distance across the tape measure for each depth measurement because these distances are critical to the calculation of cross-sectional dimensions.
4. Move back across the stream and measure bank height and bank width. Bank height is usually measured with a metre ruler (Figure 5.27) but for wide banks, a tape measure can be used to aid identification of bank height (Figure 5.27). Bank width can be measured with a tape measure (Figure 5.27) or estimated when access is difficult. Where necessary, also measure vertical distance between the water surface and the baseflow water mark. In situations where the water level at the time of sampling is equal to the baseflow water mark, the vertical distance between the water surface and the baseflow water mark will be zero.
5. With one person at either side of the stream, measure stream width at the water mark using the tape measure. In situations where the water level at the time of sampling is equal to the baseflow water mark, the stream width at the baseflow water mark will be the same as the stream width at the water surface.
6. Return to the starting bank and measure bank height, bank width (Figure 5.27) and where necessary, vertical distance between the water surface and the water mark. In situations where the water level at the time of sampling is equal to the water

mark, the vertical distance between the water surface and the water mark will again be zero.

7. Sketch the cross-sectional channel shape, including the location of bars or braids, and indicate where the bankfull and baseflow water mark levels were located.
8. In situations where it is difficult to stretch a tape measure across the stream, lateral thinking can be applied to take the cross-section. For example, in a wide wadeable stream with difficult access across the channel, horizontal distances can be estimated by pacing or by using a small 5m rope and vertical depths can be taken with a weighted rope (Figure 5.28). In a small deep stream, the weighted rope can be tied to the end of a survey staff or similar and held out over the water to take horizontal distance and vertical depth measurements (Figure 5.28).

In summary, a cross-section requires measurement of the following components:

- stream width measured at the baseflow water mark level
- stream width measured at the water level at the time of sampling
- bank height for both banks
- bank width for both banks
- vertical distance between the water mark level and the water level at the time of sampling, for both banks
- between 5 and 15 water depth measurements taken at recorded intervals across the stream
- channel width measured at bankfull level, which is a function of stream width at the water mark and left and right bank widths (see data sheet)

Figure 5.25 Stretching the tape measure across the stream at the start of a cross-section.

Figure 5.26 Measurement of vertical water depths across at a cross-section in a wadeable stream, using a weighted rope or metre ruler.

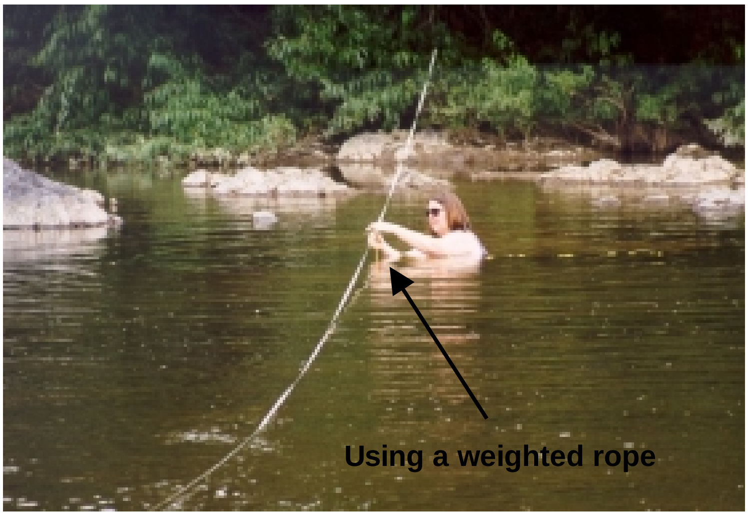
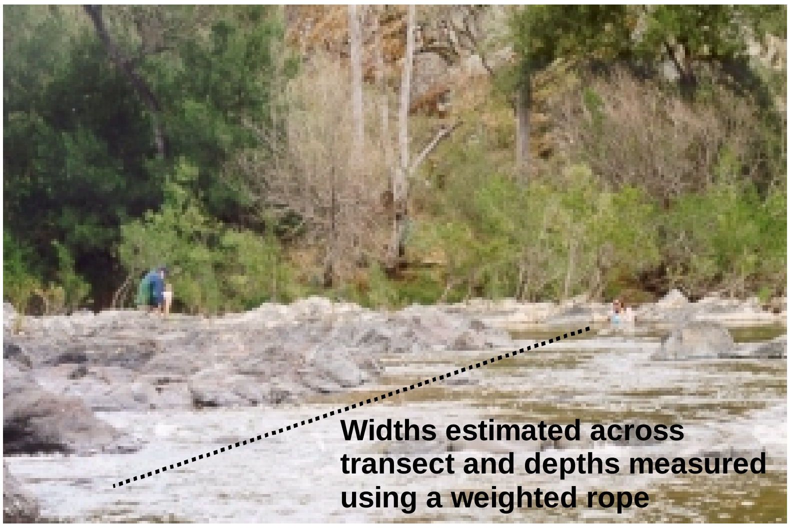


Figure 5.27 Measurement of bank height using a metre ruler or metre ruler and tape measure on a wide bank. In the photo on the right, bank width can also be measured with the tape measure.

Figure 5.28 Measurement of cross-sections in some difficult wadeable streams. In the top photo the bed was bedrock based and difficult to walk across with the tape measure, so horizontal distances were estimated and depths were measured with a weighted rope. In the bottom photo, the small urban stream was deep and dirty so a survey staff was used to take horizontal distances. Vertical depths were taken using an attached weighted rope.



HOW MANY CROSS-SECTIONS ARE NEEDED AT EACH SAMPLING SITE, AND WHERE ARE THEY PLACED?

The number and placement of cross-sections at each sampling site is dependent on the relative heterogeneity of the channel.

Homogeneous sampling sites

Two cross-sections should be measured at sampling sites that have a relatively uniform channel shape and sediment composition (Figure 5.29). These types of sampling sites generally correspond to large, low gradient rivers without riffles. The two cross-sections should be placed close to the upstream and downstream boundaries of the sampling site. These cross-sections should not be located on the apex of a bend.

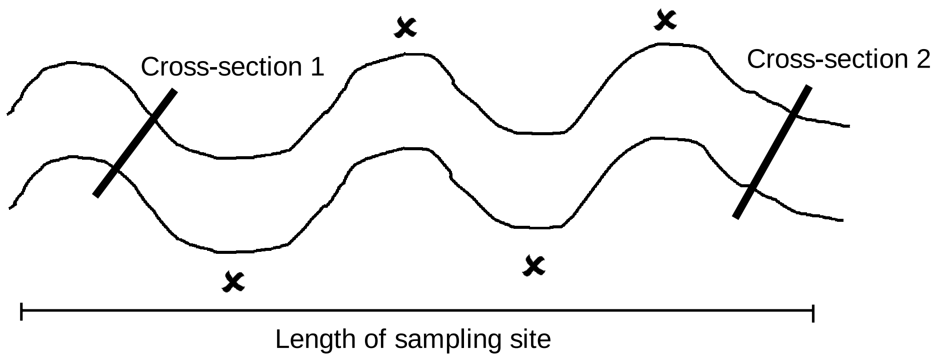


Figure 5.29 Example placement of cross-sections at a homogeneous sampling site. Crosses indicate the apex of bends, where cross-sections should not be placed.

Heterogeneous sampling sites

Three cross-sections should be measured at sampling sites that have a relatively complex channel shape and sediment composition (Figure 5.30). These types of sampling sites generally correspond to small to medium wadeable rivers with a cascade or riffle-pool flow character. The three cross-sections should be placed to represent the different types of bedform units present at the sampling site (ie. riffles, pools, runs) and **must include at least one pool**. In most streams, appropriate placement of cross-sections would include one riffle, one run and one pool, spread throughout the entire length of the sampling site. Again, cross-sections should not be placed on the apex of a bend.

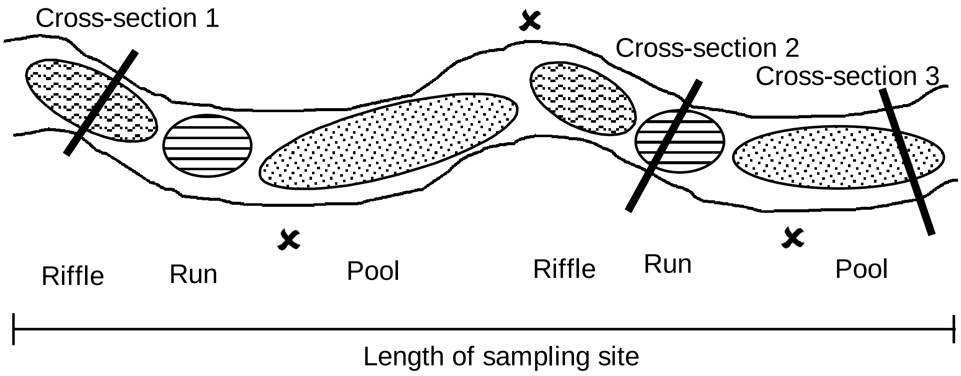


Figure 5.30 Example placement of cross-sections at a heterogeneous sampling site. Crosses indicate the apex of a bend where cross-sections should not be placed.

HOW ARE THE BANKFULL AND BASEFLOW WATER MARK LEVELS IDENTIFIED IN DIFFERENT CHANNEL TYPES?

Accurate identification of the bankfull channel and baseflow water mark levels is fundamental to the measurement of cross-sections. The placement of bankfull and watermark levels at cross-sections located in different channel types is explained in Figure 5.31.

Bankfull channel level is the point within the stream channel where the water level would fill the channel to the tops of the banks. The 'tops of the banks' varies according to channel type (Figure 5.31).

The baseflow water mark level is generally evidenced by the limits of terrestrial vegetation, scour lines, growth of macrophytes or abrupt changes in bank slope (Figure 5.24). However, the baseflow water mark level can be difficult to identify in some situations, using the above criteria. An additional method that can be used to aid the identification of the baseflow water mark level is residual pool depth (Lisle, 1987). Residual pool depth is the difference in depth or bed elevation between a pool and the downstream riffle crest. Residual pool depth is measured by surveying a pool with a tape measure and ruler and subtracting the depth of the riffle crest from those in the pool. A detailed description of the residual pool depth method is available to down load from the United States Forest Service website at http://www.rsl.psw.fs.fed.us/projects/water/Lisle87.pdf

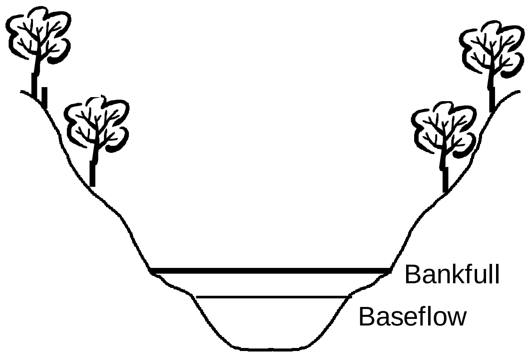
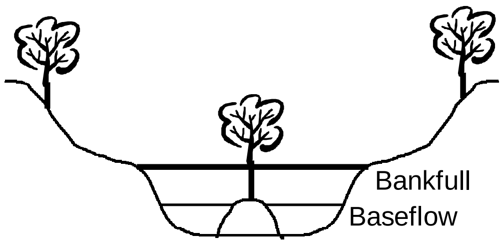
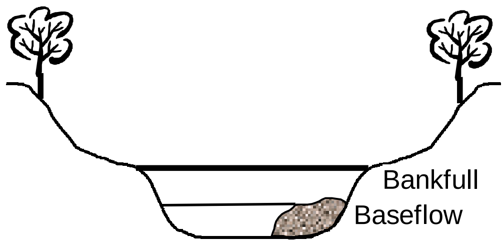
	**Confined upland** Confined channels have no floodplain development and are generally found in upland areas with steep valleys. Under undisturbed conditions, bankfull width is usually not much larger than baseflow width. The bankfull level in a confined channel is evidenced by the limit of terrestrial vegetation, the growth of macrophytes, the presence of moss or lichen, the presence of scour marks or an abrupt change in bank slope.
	**Channelised** This type of stream is found where islands (i.e. bars) have formed within the channel. The bars may be vegetated or unvegetated. The placement of a cross-section should run across the bars. Bankfull width should include the bar portion, but baseflow width should break around the bar portion.
	**Channel with instream bars** This type of stream occurs where bars have formed and are attached to the banks. The placement of a cross-section should run across the bars. Bankfull width should include the bar portion, but baseflow width should not include the bar portion if it is not within the baseflow area.

Figure 5.31 Identification of bankfull level in different channel types. Baseflow water mark level is also drawn on for context, however, the actual position of the water mark level relative to the bankfull level can only be determined after examination in the field.

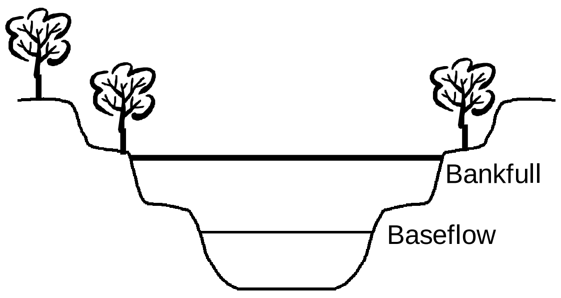
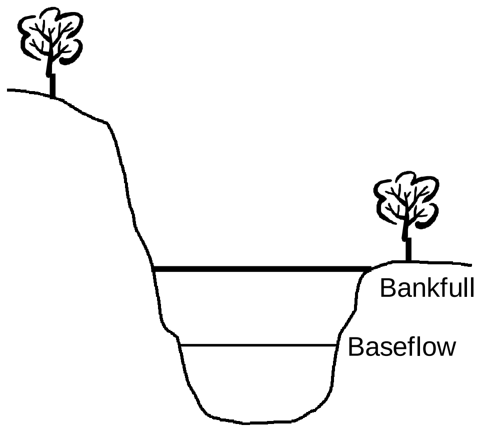
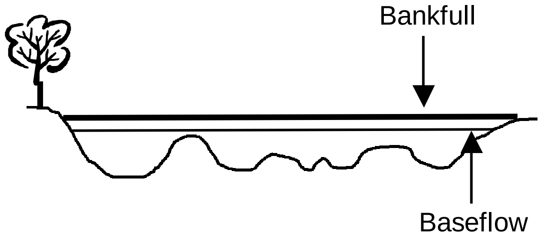
	**Terraced channel** Terraced channels are channels in which the banks are characterised by bench formations. Terraced channels generally occur in lowland floodplain rivers. Regardless of the number of benches present, bankfull width is always measured to the top of the first bench only.
	**One bank higher than the other** When one bank is higher than the other, bankfull width is measured to the top of the lowest bank. This is because the top of the lowest bank represents the point where water would overtop the bank and spill onto the floodplain.
	**Braided channels** Braided channels contain multiple channels that diverge and converge around many islands. Banks may be poorly defined in these types of channels, although the lateral limit of the channel can often be identified. Cross-sectional bankfull width and baseflow width of should be measured across all the threads of a braided channel.

Figure 5.31 (cont.)

WHAT VARIABLES ARE DERIVED FROM A CROSS SECTION?

The variables derived from data collected at the cross-sections are given in Table 5.4. Several of these variables are derived directly from field cross-section measurements, several are derived following office-based adjustments and several are derived using the AQUAPAK[1] computer package. Instructions for the calculation of each variable are provided in the following pages.

Table 5.4 Variables derived from cross-section data.

Variable	Derivation
Bankfull channel width	Calculated directly from the cross-section data collected in the field
Bankfull channel depth	Cross-section data collected in the field is adjusted in the office
Baseflow stream width	Taken directly from the cross-section data collected in the field
Baseflow stream depth	Cross-section data collected in the field is adjusted in the office
Bank width	Calculated directly from the cross-section data collected in the field
Bank height	Calculated directly from the cross-section data collected in the field
Bankfull width:depth ratio	Calculated using the bankfull channel width and bankfull channel depth variables
Bankfull cross-sectional area[2]	Calculated in AQUAPAK using adjusted cross-section data
Bankfull wetted perimeter[2]	Calculated in AQUAPAK using adjusted cross-section data
Baseflow cross-sectional area[2]	Calculated in AQUAPAK using adjusted cross-section data
Baseflow wetted perimeter[2]	Calculated in AQUAPAK using adjusted cross-section data

In addition to these variables, substrate composition, bank material, riparian zone width, filamentous algae cover, periphyton cover, moss cover and detritus cover will also be measured in the immediate vicinity of the cross-section. Further information on these variables are provided on each instruction sheet.

1.
AQUAPAK is a package of stand-alone, IBM compatible computer programs which supplement the text "Stream Hydrology: An Introduction for Ecologists" (Gordon *et al.*, 1992). Among other functions, AQUAPAK calculates the channel cross-sectional area and wetted perimeter variables. AQUAPAK can be purchased for $20 from the Centre for Environmental and Applied Hydrology, Department of Civil and Environmental Engineering, The University of Melbourne, Victoria, 3010. An order form is provided in Appendix 3.
2.
Bankfull cross-sectional area and baseflow cross-sectional area are the same variable but calculated for the bankfull and baseflow areas of the channel respectively (Figure 5.24). Likewise, bankfull wetted perimeter and baseflow wetted perimeter are also calculated the same way.

VARIABLE NAME	Bankfull channel width
CATEGORY	Cross-sectional dimension
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Both
UNITS OF MEASUREMENT	m
INDICATES	Bankfull stage is an important control on alluvial channels (Gordon *et al.*, 1992)

Bankfull channel width is recorded directly at each cross-section as the sum of the stream width at the water mark and the left and right bank widths (see Figure 5.24). Bankfull channel width for the sampling site should be calculated as an average of all measurements taken at the two or three cross-sections in each sampling site.

VARIABLE NAME	Bankfull channel depth
CATEGORY	Cross-sectional dimension
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Both
UNITS OF MEASUREMENT	m
INDICATES	Bankfull stage is an important control on alluvial channels (Gordon *et al.*, 1992)

Bankfull channel depth is the average depth of the channel at the bankfull level (see Figure 5.24). Calculation of bankfull channel depth at each cross-section involves the addition of bank height to the baseflow stream depth measurements (Figure 5.32).

The overall bankfull channel depth for the sampling site is calculated as the average channel depth of the two to three cross-sections measured at each sampling site.

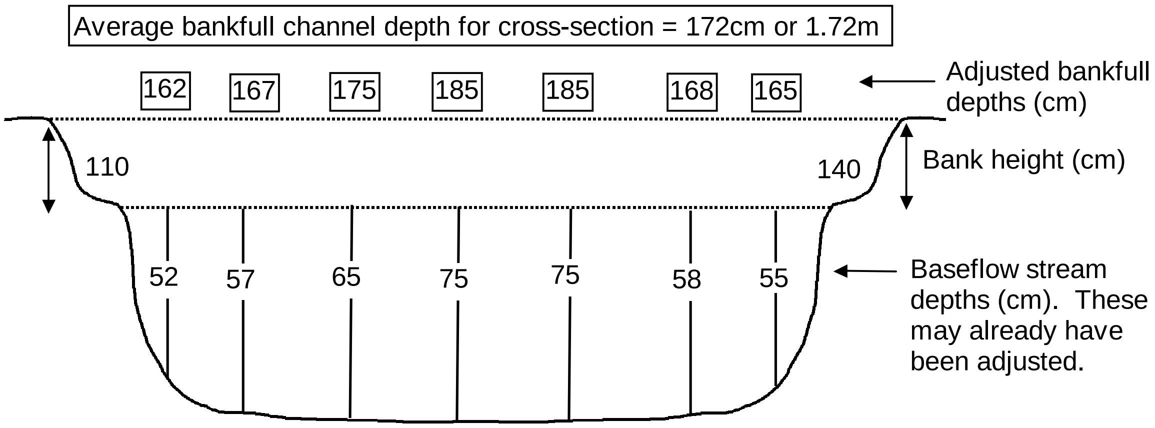


Figure 5.32 Example calculation of bankfull channel depth for one cross-section. Note that the only the smallest bank height (110cm) is added to the baseflow depths because if the banks are different heights, the smaller value represents the point where the water overtops the banks. Alternatively, the average (left and right) bank height can be added to the baseflow depths. Also, note that baseflow stream depths may have been previously adjusted if the water level at the time of sampling was below baseflow. Refer to the baseflow stream depth variable for information on these adjustments.

VARIABLE NAME	Baseflow stream width
CATEGORY	Cross-sectional dimension
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Both
UNITS OF MEASUREMENT	m
INDICATES	Baseflow stream width is related to the amount of wetted habitat available under baseflow conditions

---

Baseflow stream width is recorded directly at each cross-section as the stream width at the water mark (see Figure 5.24). Baseflow stream width for the sampling site should be calculated as an average of all measurements taken at the two or three cross-sections in each sampling site.

VARIABLE NAME	Baseflow stream depth
CATEGORY	Cross-sectional dimension
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Both
UNITS OF MEASUREMENT	m
INDICATES	Baseflow stream depth is an indicator of channel size, which in turn influences discharge capacity. Baseflow stream depth is also related to the amount of wetted habitat area within the channel.

Baseflow stream depth is the average depth of the channel at the watermark level (see Figure 5.24). Calculation of baseflow stream depth from the vertical water depth measurements recorded at each cross-section in the field may require some adjustments, to compensate for flows that were below baseflow levels at the time of sampling.

If the water surface at the time of sampling was equal to the baseflow water mark, then baseflow stream depth is simply calculated as the average of all the water depth measurements that were taken across the width of the cross-section.

If the water surface at the time of sampling was below the baseflow water mark, then the water depth measurements must be adjusted up to baseflow levels. To do this, add the vertical distance between the water surface and the baseflow mark to each of the water depth measurements (Figure 5.33).

Regardless of whether adjustments are required at an individual cross section, the overall stream depth for the sampling site is the average depth of the two to three cross-sections measured at each sampling site.

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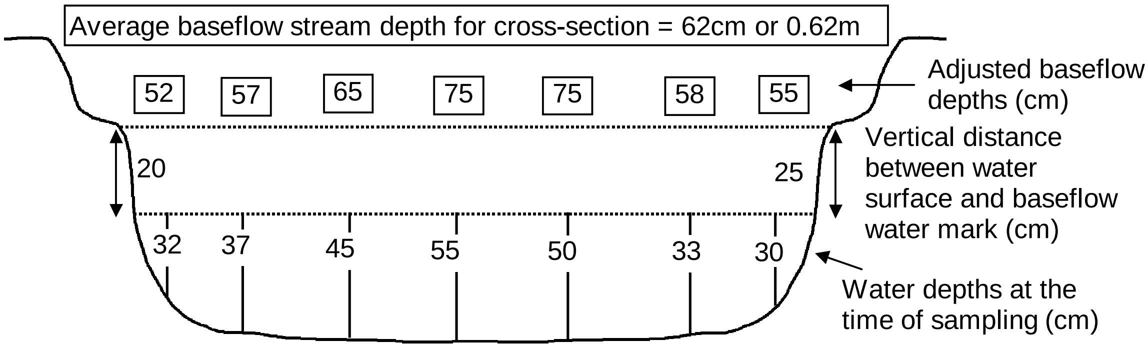


Figure 5.33 Example calculation of adjusted baseflow stream depths, for one cross-section. Note that the left bank vertical distance between the water surface and the baseflow water mark (20cm) is added to the water depths on the left of the channel and the right bank vertical distance (25cm) is added to the water depths on the right of the channel.

VARIABLE NAME	Bank width
CATEGORY	Cross-sectional dimension
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Both
UNITS OF MEASUREMENT	m
INDICATES	Represents the width of the bank relative to baseflow stream width. In some situations, overly wide banks may indicate severe erosion.

Bank width is recorded directly at the left and right banks of each cross-section (see Figure 5.24). Bank width should be averaged for the left and right banks of each cross-section, and then bank width for the sampling site should be calculated as an average of the two or three cross-sections in each sampling site.

VARIABLE NAME	Bank height
CATEGORY	Cross-sectional dimension
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Both
UNITS OF MEASUREMENT	m
INDICATES	Bank height is related to channel confinement and to channel volume

---

Bank height is recorded directly at the left and right banks of each cross-section (see Figure 5.24). Bank height should be averaged for the left and right banks of each cross-section, and then bank height for the sampling site should be calculated as an average of the two or three cross-sections in each sampling site.

VARIABLE NAME	Bankfull width to depth ratio
CATEGORY	Cross-sectional dimension
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Both
UNITS OF MEASUREMENT	Dimensionless
INDICATES	Cross sectional channel shape at the bankfull level (Gordon *et al.*, 1992; Armantrout, 1998) which in turn, determines the maximum cross sectional flow that can be transported through the system (Brierley *et al.*, 1996)

Width to depth ratio (*W:D*) is calculated for each cross section taken at each sampling site by dividing bankfull channel width by bankfull channel depth (see the bankfull channel width instruction sheet and the bankfull channel depth instruction sheet):

$$W : D = \frac{W}{D}$$

where:
W = bankfull channel width (m)
D = bankfull channel depth (m)

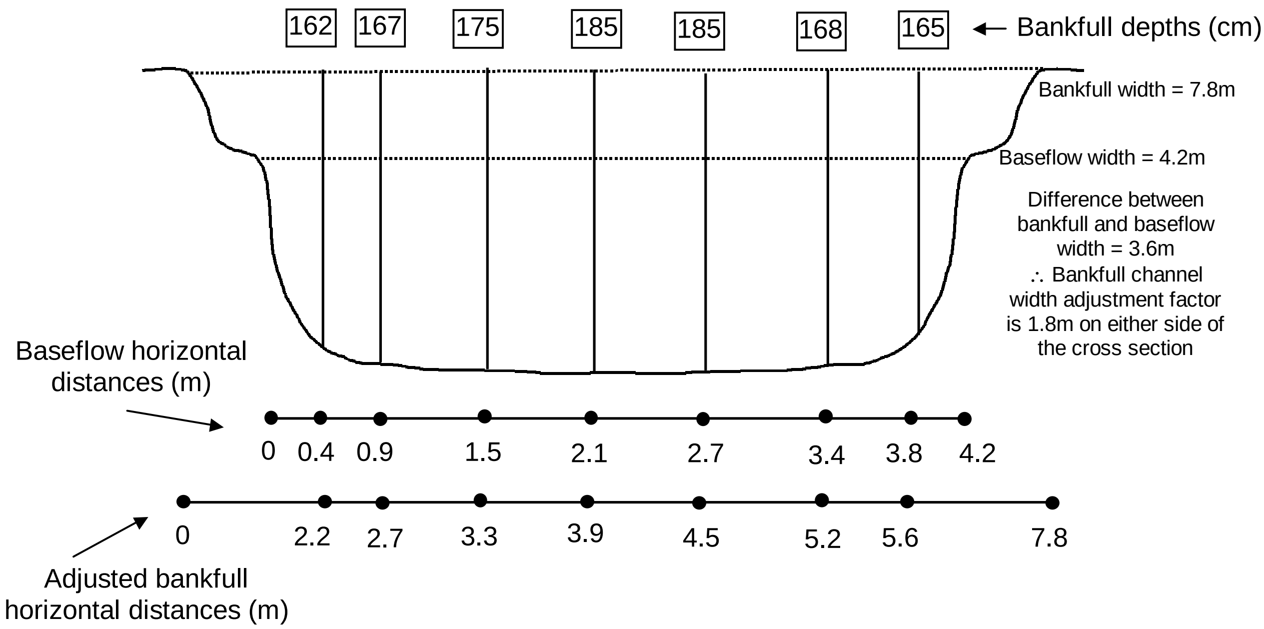
A width to depth ratio should be calculated for the two or three cross sections taken at a sampling site, and averaged to provide an overall width to depth ratio for the sampling site.

VARIABLE NAME	Bankfull cross-sectional area
CATEGORY	Cross-sectional dimension
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Both
UNITS OF MEASUREMENT	m^2
INDICATES	Bankfull stage is an important control on alluvial channels (Gordon *et al.*, 1992)

Bankfull cross-sectional area is calculated for each cross-section using the AQUAPAK computer package. Data are prepared by deriving a set of coordinates from the horizontal distances across the bankfull width of the cross-section and the bankfull stream depth measurements (Figure 5.34). These coordinates are entered into AQUAPAK and bankfull cross-sectional area is calculated using the XSECT program.

The overall bankfull cross-sectional area for the sampling site is calculated as the average area of the two to three cross-sections measured at each sampling site.

(continued over)



These measurements are entered into AQUAPAK as the following coordinates

Horizontal distance (m)	**Bankfull depth (m)**
0	0
2.2	1.62
2.7	1.67
3.3	1.75
3.9	1.85
4.5	1.85
5.2	1.68
5.6	1.65
7.8	0

Figure 5.34 Example derivation of AQUAPAK data for the calculation of bankfull cross-sectional area. Coordinates are comprised of adjusted bankfull horizontal distances and bankfull channel depth measurements. To derive adjusted bankfull horizontal distances, a factor that is equivalent to the width of each bank is added to each of the original baseflow horizontal distances. Instructions on the calculation of bankfull channel depths are provided with the bankfull channel depth variable.

VARIABLE NAME	Bankfull wetted perimeter
CATEGORY	Cross-sectional dimension
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Both
UNITS OF MEASUREMENT	m
INDICATES	Bankfull wetted perimeter is related to the amount of wetted habitat area within the channel

---

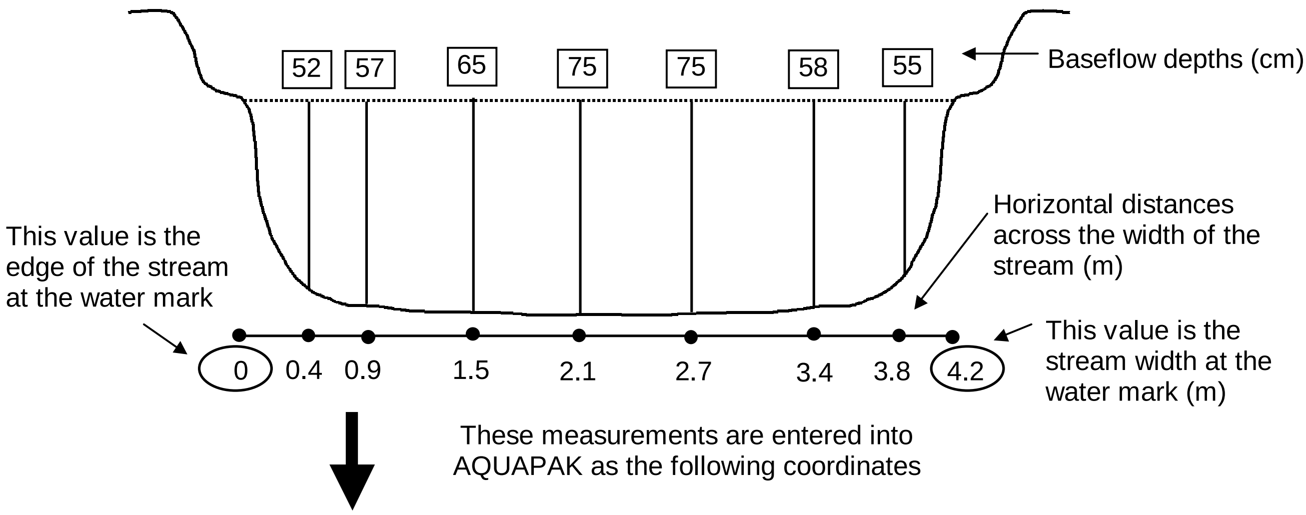
Bankfull wetted perimeter is the distance along the streambed and banks under bankfull conditions (Gordon *et al.*, 1992). Wetted perimeter is calculated in the XSECT program of AQUAPAK, using **the same coordinates used to calculate bankfull cross-sectional area** (see bankfull cross-sectional area variable for instructions on the derivation of coordinates).

VARIABLE NAME	Baseflow cross-sectional area
CATEGORY	Cross-sectional dimension
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Both
UNITS OF MEASUREMENT	m^2
INDICATES	Baseflow cross-sectional area is an indicator of channel size, which in turn influences discharge capacity. Baseflow cross-sectional area is also related to the amount of wetted habitat area within the channel.

Baseflow cross-sectional area is calculated for each cross-section using the AQUAPAK computer package. Data are prepared by deriving a set of coordinates from the horizontal distances across the baseflow width of the cross-section and the baseflow stream depth measurements (Figure 5.35). These coordinates are entered into AQUAPAK and baseflow cross-sectional area is calculated using the XSECT program.

The overall baseflow cross-sectional area for the sampling site is calculated as the average area of the two to three cross-sections measured at each sampling site.

(continued over)



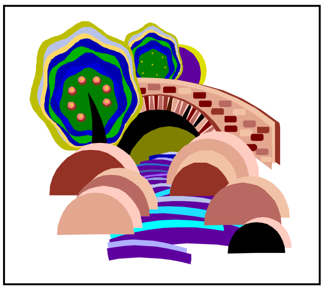
Horizontal distance (m)	Baseflow depth (m)
0	0
0.4	0.52
0.9	0.57
1.5	0.65
2.1	0.75
2.7	0.75
3.4	0.58
3.8	0.55
4.2	0

Figure 5.35 Example derivation of AQUAPAK data for the calculation of baseflow cross-sectional area. Coordinates are comprised of the horizontal distances across the baseflow width of the stream and the baseflow depths. Instructions on the calculation of baseflow depths are provided with the baseflow stream depth variable. Note that when there is a difference between baseflow level and water level at the time of sampling, one additional coordinate can be added to each side of the cross-section. On the right side, the vertical coordinate would be the vertical distance between the water surface and the water mark and the horizontal coordinate would be the stream width at the water surface (see Figure 5.24). On the left side, the vertical coordinate would be the vertical distance between the water surface and the water mark and the horizontal coordinate would be the difference between baseflow stream width and stream width at the time of sampling, minus the distance of the first horizontal coordinate measured.

VARIABLE NAME	Baseflow wetted perimeter
CATEGORY	Cross-sectional dimension
CONTROL OR RESPONSE	Response
OFFICE OR FIELD	Both
UNITS OF MEASUREMENT	m
INDICATES	Baseflow wetted perimeter is related to the amount of wetted habitat area within the channel

---

Baseflow wetted perimeter is the distance along the streambed under baseflow conditions. Wetted perimeter is calculated in the XSECT program of AQUAPAK, using **the same coordinates used to calculate baseflow cross-sectional area** (see baseflow cross-sectional area variable for instructions on the derivation of coordinates).



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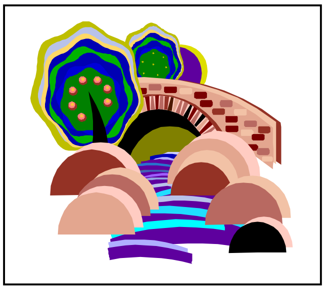

7 APPENDICES

APPENDIX 1

DATA STANDARDISATION AND RECOMMENDATIONS FOR TRAINING OF FIELD SAMPLING TEAMS

When implemented on a National scale, the AUSRIVAS physical assessment protocol will provide a standardised tool for the assessment of physical stream condition. As such, it is important that the data collected by each State or Territory conforms to the standard methods set out in this protocol. It is desirable to avoid deviations from these methods, because each deviation has the potential to effect the production of robust and reliable predictive models.

As mentioned in Part 3, the collection of field data for the physical assessment protocol is analogous to the collection of macroinvertebrates for the AUSRIVAS models and thus, it is vital that a full set of reliable, high quality data are collected. This protocol contains detailed information about the collection of each office and field based variable (Part 5). **This information should be adopted as standard procedure**. However, there is a 'conceptual limit' to the types of information that can be portrayed in text and it is essential to extend the content of this manual to a field based learning and training exercise. Training of sampling teams will ensure that the field data is of high quality, is measured in the appropriate format, and is consistent across sampling teams. In turn, these factors will contribute to the reliability and robustness of predictive models.

Field sampling teams, or representative members of each team, should be trained in standard procedure **prior to the commencement of reference site sampling**. This training exercise will ensure that data collection methods are identical and consistent across sampling teams. **Training should be conducted in a range of river types, and should include at least one large river**. It is recommended that sampling teams simultaneously attend this training exercise, and confer with each other to standardise a procedure for the collection of each individual variable. Specific aspects of data collection that should be demonstrated and synchronised during the training exercise include:

- sequence of work at a sampling site
- identification of bankfull and baseflow levels
- procedure for measuring cross-sections
- assessment and interpretation of each individual variable
- estimation of distances

In addition, some States or Territories may need to add new variables, or make minor modifications to some variables to reflect locally encountered conditions (e.g. macrophyte species). Any additions or modifications must be made cautiously, and updated on the data sheets. All new or modified variables should be included in the training exercise.

APPENDIX 2

FIELD SAMPLING EQUIPMENT LIST[1]

Cross-sections in wadeable rivers
Tape measure for horizontal measurements (100m or 30m depending on river size)
Metre ruler or weighted tape measure/rope for vertical measurements
Small gardening trowel to dislodge and examine substrate

Cross-sections in large rivers or deep pools
100m tape measure for horizontal measurements
Weighted tape measure/rope or depth sounder for vertical measurements
Boat, canoe (or similar) for access
Device such as an Eckman grab or scoop on a long pole to sample sediment

General
Water quality measurement instruments (e.g. Hydrolab) and sundry equipment (e.g. sample bottles, esky) if required
Alkalinity measurement kit – plastic beaker, 0.02N H_2SO_4 (Sulfuric Acid), Method Red indicator, plastic syringe, gloves
GPS
A copy of this protocol document
Data sheets
Spare 100m and 30m tape measures
Spare metre rulers
Spare weights and ropes
Maps
Macrophyte identification guide
Terrestrial plant identification guide
Plastic bags for macrophyte samples
Camera, film and batteries
Pencils (lots) and pencil sharpener
Waterproof marker pens
Clipboards
Calculator
Waders/wetsuit/swimsuit
Towel and change of clothes
Backpack for carrying field gear
Clinometer

Health and safety equipment
First aid kit
Sun protection gear
Wet weather gear
Survival gear
4WD recovery gear
Communication and emergency notification equipment
Maps and GPS or compass

1. Note that this list is not exhaustive, and should be used as a guide only

APPENDIX 3
AQUAPAK ORDER FORM

AQUAPAK SOFTWARE

AQUAPAK software is a package of stand alone computer programs, written in FORTRAN77, which supplements the text ***Stream Hydrology: An Introduction for Ecologists*** by N.D. Gordon, T.A. McMahon and B.L. Finlayson (John Wiley & Sons Ltd., UK, 1992, 526 pp).

The software package includes routines for computing:

Autocorrelation	Water surface profiles	Colwell's indices
Units conversion	Double mass curve	Flood frequency
Flow duration curves	Froude numbers	Statistics
Koppen classification	Manning's functions	Discharge calcs
Simple regression	Rosgen's classification	Spell analysis
Particle sphericity	Low flow frequency	

The programs are interactive and user-friendly, and can run on IBM compatible personal computers. Many of the programs include graphical output.

To obtain a copy of the software, complete the details below and return to:

AQUAPAK Software
Centre for Environmental Applied Hydrology
Department of Civil & Environmental Engineering
The University of Melbourne
Victoria 3010
AUSTRALIA

or fax to: +61 3 8344 6215

The price of the software is Aus$20.00 or US$15.00 (which includes the cost of two high density 3.5" discs, postage and handling). This may be paid by Bankcard, Mastercard or Visa.

Payment details:
Bankcard / Mastercard / Visa No: ....…………….…………..........

Name on card: .... Expiry date: ....

AQUAPAK to be sent to:

Name: ....………..

Organization: ....………..

Address: ....………....

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