Water Resources and Flood Risk Monitoring Technical Standard

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List of acronyms

ADCP	Acoustic Doppler Current Profiler
ASPT	Average Score per Taxon
BGS	British Geological Survey
BMWP	Biological Monitoring Working Party
BSI	British Standards Institution
CCI	Community Conservation Index
CoCP	Code of Construction Practice
CA	Community Area
CFA	Community Forum Area
DNAPL	Dense Non-Aqueous Phase Liquid
EIAR	Environmental Impact Assessment Report
EMS	Environmental Management Strategy
ES	Environmental Statement
GI	Ground Investigation
GIS	Geographic Information System
GW	Groundwater
GWDTE	Groundwater Dependent Terestrial Environment
HDPE	High-Density Polyethylene
QA	Quality Assurance
QC	Quality Control
LNAPL	Light Non-Aqueous Phase Liquid
LEMP	Local Environmental Management Plan
MCERTS	Monitoring Certification Scheme
NFG	Number of Functional Groups
N-TAXA	Number of Taxa
NTAXA	Number of Macrophyte Taxa
MoU	Memorandum of Understanding
PSI	Proportion of Sediment-Sensitive Invertebrates

RCS	River Corridor Survey
RHS	River Habitat Survey
RMHI	River Macrophyte Hydraulic Index
RMNI	River Macrophyte Nutrient Index
RoI	Radius of Influence
SES	Supplementary Environmental Statement
SSSI	Site of Specific Scientific Interest
SSR	Sediment Sensitivity Rating
SW	Surface Water
TDI	Trophic Diatom Index
UKAS	United Kingdom Accreditation Service
uPVC	un-Plasticated Polyvinylchloride
VOC	Volatile Organic Compound
WFD	Water Framework Directive
WHPT	Whalley Hawkes Paisley Trigg

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Project Terminology

The project terminology used within this document can be found in the 'LWM Project Dictionary' (HS2-HS2-PM-GDE-000-000002).

Conventions

Mandatory clauses

The following convention is used to indicate mandatory clauses.

Mandatory clauses are differentiated from the main text of this document by use of a 'black box'. They contain the word 'shall' to indicate their status as a requirement.

Departures

Any intention to not comply with a mandatory clause is considered to be a departure from this Technical Standard.

It is recommended that the designer discusses any proposed departures with HS2 at an early stage.

1 Introduction

1.1 Purpose of this document

1.1.1 This technical standard sets out the Water Resources and Flood Risk Monitoring requirments for HS2 Ltd (the Scheme), which provides a set of high level principles to inform route wide monitoring of the water environment before, during and after construction. It also encourages a consistent route-wide approach to monitoring.

1.1.2 It uses Monitoring Decision Trees supported by Advisory Sheets and detailed appendices to inform discussions and decisions around what should be measured, how, where, how often and for how long.

1.1.3 It is noted that specific flood risk monitoring is not generally required.

1.2 Objectives

1.2.1 The key objectives of water environment monitoring for the Scheme are to:

- Help refine the water environment baseline condition, from which predictions of impact and significant effect were made in the Environmental Impact Assessment stage;
- In combination with design specific data collection, support the ongoing design of the Scheme and construction methods with respect to the water environment;
- Provide baseline monitoring data, to help refine mitigation measures required for minimising adverse effects on the water environment;
- Provide a means to identify actual impacts from the construction and operation of the Scheme, and to trigger mitigation and remedial actions;
- Determine the long-term effectiveness and ongoing management of mitigation measures in protecting the water environment; and
- Contribute to ensuring compliance with relevant environmental legislation.

1.2.2 The key objectives of this technical standard are to:

- Define over-arching principles of water environment monitoring for the Scheme;
- Provide a consistent route-wide approach to monitoring; and
- Inform the development and implementation of Water Resources and Flood Risk Monitoring Plans for the water environment.

1.2.3 This technical standard links with a number of other technical standards .

1.2.4 This technical standard also requires key scheme documents to be consulted, such as the Community Forum Area (CFA), Community Area (CA) assessments and the Water Framework Directive (WFD) assessments, which form part of the Environmental Statement (ES).

1.3 Phases of monitoring

1.3.1 The following terminology has been used to refer to the monitoring phases of the Scheme.

Baseline – data collected to inform a risk based decision on the nature of any monitoring needing to be undertaken before, during and after construction. Examples of pre-baseline data collection activity include the ground investigation work and the WFD surveys.

Pre-construction – monitoring to confirm the baseline condition in the period prior to construction.

Construction – monitoring of water environmental impacts during construction.

Post-construction – monitoring to identify any residual impacts following construction and confirm the efficacy of implemented mitigation, along with operational impacts.

1.4 Document structure

1.4.1 Additional to this introduction section, this technical standard is divided into a further three sections, as follows:

- Section 2 provides an overview of the potential impacts to the water environment, as defined through the Environmental Impact Assessment stage;
- Section 3 provides guidance on the development of a Water Resources and Flood Risk Monitoring Plan, which is the main deliverable from this technical standard. Monitoring Decision Trees are presented to help the user identify the likely water environment monitoring needs for both groundwater and surface water;
- Section 4 sets out the requirements and general principles when planning water environment monitoring (both surface water and groundwater). These principles cover monitoring location site selection and specification, monitoring activities and the management of monitoring data;
- Appendix A contains Advisory Sheets, that support the Decision Trees, and provide more detail on monitoring period, frequency, location and parameters;

- Appendix B contains a worked example of how the Monitoring Decision Trees and Advisory Sheets can be used to specify monitoring requirements; and
- Appendices C-E provide more detailed guidelines for monitoring location site selection, monitoring location specification and monitoring activities, respectively.

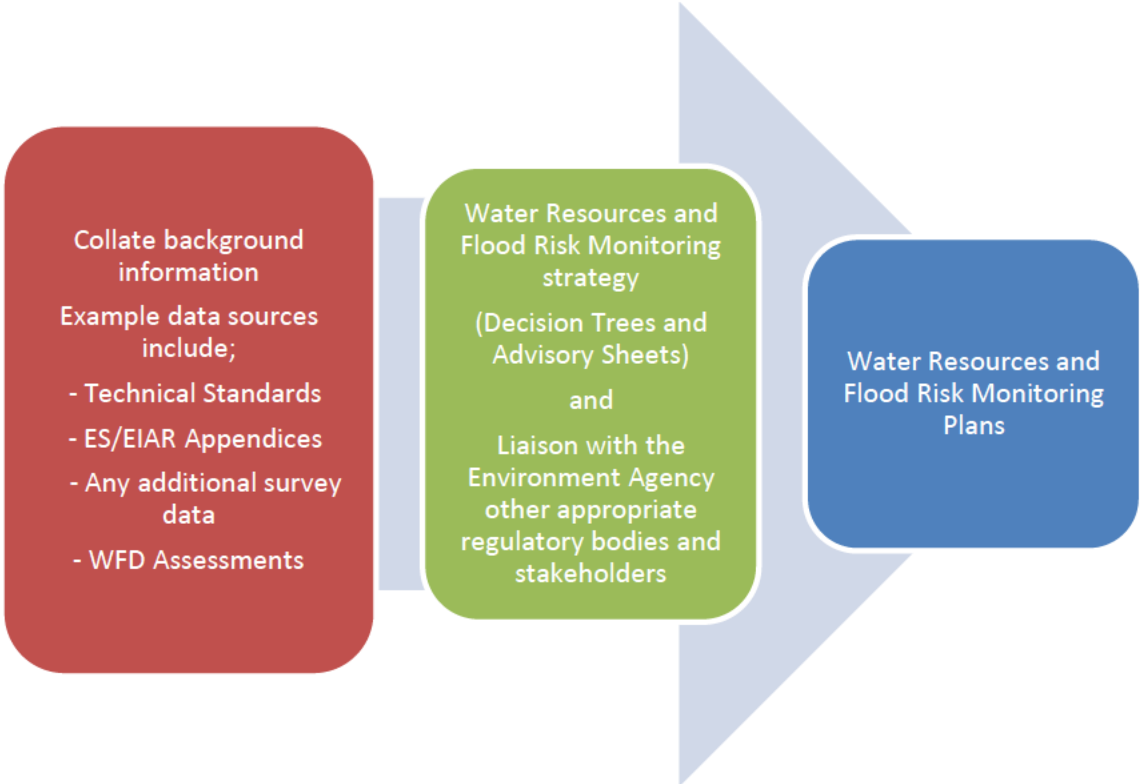
1.5 Use of this technical standard

1.5.1 For those elements of the Scheme identified as posing a risk to the water environment, this technical standard shall be used to inform the development and implementation Water Resources and Flood Risk Monitoring Plans, as referred to in the Code of Construction Practice (CoCP) and Local Environmental Management Plans (LEMPs) .

1.5.2 The content of the Water Resources and Flood Risk Monitoring Plans will be informed by:

- A range of key data sources, such as those highlighted in the red box in Figure 1 below. Of particular importance are updated assessments as part of the Groundwater Protection and Land Quality Technical Standards (HS2-HS2-EV-STD-000-000010 and HS2-HS2-EV-STD-000-000027 respectively);
- This technical standard including the Monitoring Decision Trees and Advisory Sheets in section 3 and Appendix A; and
- Liaison with the Environment Agency and other appropriate regulatory bodies and stakeholders.

Figure 1: The process of developing Water Resources and Flood Risk Monitoring Plans



2 Potential impacts to the water environment

2.1 Introduction

2.1.1 This section provides an overview of the potential impacts of the Scheme on the water environment as set out in the ES and its appendices. In particular, it references the Community Forum Area (CFA) or Community Area (CA) site-specific water resource assessments and the route wide WFD assessments.

2.1.2 These assessments will inform decisions on the type of water environmental monitoring needed before, during and after construction. It should be noted that findings set-out in these assessments do need to be considered alongside site-specific discussions with the Environment Agency in developing Water Resources and Flood Risk Monitoring Plans.

2.2 Potential impacts to the water environment

2.2.1 The potential impacts to the water environment as a result of the Scheme are presented within the ES.

2.2.2 A source-pathway-receptor model was used in the ES to identify potential impacts on the water environment and on WFD compliance from the various elements of the Scheme.

2.2.3 The ES assessments looked at all scheme elements, temporary and permanent, which have the potential to impact surface and groundwater bodies and potentially affect WFD status. It is noted that many of these assessments are likely to be updated as further information and design becomes available.

2.2.4 Table 1 and Table 2 below, based on versions used in the ES, highlight which elements of the Scheme may result in what type of impact on surface and groundwater receptors respectively.

Table 1: Scheme elements and potential impacts to surface water environment (based on version used in the Phase One ES)

Impact considered	**Bored tunnel**	**Green tunnel**	**Viaduct**	**Clear span bridge**	**Bridge with footings in water body**	**Culvert**	**Siphon**	**River diversion/ realign-ment**	**Cutting**	**Retain-ing wall**	**Embank-ments**	**Stations**
Footprint	✓	✓	✓	×	✓	✓	✓	✓	×	✓	✓	✓
Changes in flow velocity and volume due to discharge of water to a surface water body	✓	✓	×	×	×	×	×	×	✓	✓	×	×
Noise and vibration during construction	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Shading	×	×	✓	✓	✓	✓	✓	×	×	×	✓	×
Drainage	×	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓
Changes to water body hydromorphology leading to changes in river processes and habitats upsteam and downstream	×	×	✓	×	✓	✓	✓	✓	×	×	×	×
Change in water quality due to discharge of water to a surface water body	✓	✓	×	×	×	×	×	×	✓	✓	×	×
Creation of new habitats	×	×	×	×	×	×	×	✓	×	×	×	×
Settlement of ground leading to enhancement of fractures and increased vertical permeability where applicable	✓	×	×	×	×	×	×	×	×	×	×	×

Table 2: Scheme elements and impacts to groundwater environment (based on version used in the Phase One ES)

Impact considered	**At grade**	**Embankment**	**Cutting**	**Retaining walls**	**Stations**	**Bored tunnel**	**Green tunnel**	**Viaduct foundations**
Lowering of groundwater levels and reduction in groundwater contributions to surface water bodies, GWDTE or groundwater abstractions by temporary dewatering/permanent groundwater control	×	×	✓	✓	✓	×*	✓	×
Distributing or mobilising existing poor quality groundwater by temporary dewatering or depressurisation and permanent groundwater control	×	×	✓	✓	✓	✓	✓	×
"Damming" of groundwater flow and reduction in groundwater contributions	×	×	×	✓	✓	✓	✓	✓
Creating or altering of pathways along which existing poor quality groundwater can migrate	×	×	✓	✓	✓	✓	✓	✓
Introduction of contaminants during construction processes	×	×	✓	✓	✓	✓	✓	✓

*Vent shafts and cross passages may require temporary dewatering.

2.3 Site-specific water resource assessments and WFD assessments

2.3.1 Of particular value to this technical standard and to the development of the Water Resource and Flood Risk Monitoring Plans are the Community Forum Area (CFA)/Community Area (CA) site-specific water resources assessments and the route wide WFD assessments.

2.3.2 These assessments were originally produced for the EIA. They both detail areas where risks of adverse impacts on the water environment from the Scheme have been identified. In addition, both data sources identify the nature of the impact and the receptors potentially impacted.

2.3.3 As more data on current conditions and design becomes available these are likely to be updated and revised as part of design development and following further investigations (for example geotechnical) according to the requirements of the technical standards .

Site-specific water resource assessments

2.3.4 The CFA/CA site-specific assessments present the predicted impacts of the Scheme on the water environment before and after mitigation.

2.3.5 The site-specific water resource assessments are tabulated in each specific Technical Appendix by surface water and groundwater receptors. The tables list receptors on the left hand side and contain columns for design elements and impact effects.

The scheme WFD compliance assessment

2.3.6 The WFD assessments set out a risk based assessment of what WFD elements (e.g. chemistry, aquatic ecology, hydromorphology) might be impacted by which scheme elements (e.g. culverts, diversions/realignments, dewatering) and where.

2.3.7 In the WFD assessments, the potential impacts from the Scheme elements have been colour coded according to their potential effect on the WFD status class, as indicated in Table 3. This colour coding is used in the Decision Trees to indicate the likely need for monitoring for each scheme element.

Table 3: Colour coding used in WFD status risk screening tables

Impact type	
Dark blue	Impacts when taken on their own have the potential to lead to significant improvement
Light blue	Impacts when taken on their own have the potential to lead to minor localised or temporary improvement
Green	No measurable change to any quality elements
Yellow	Impacts when taken on their own have the potential to lead to minor localised or temporary effect
Amber	Impacts when taken on their own have the potential to lead to widespread or prolonged effect
Red	Impacts when taken on their own have the potential to lead to widespread or prolonged effect even with mitigation in place

2.3.8 These WFD assessments are tabulated in Annex A of the ES by surface water body and Annex B of the ES by groundwater body. The tables are structured with the WFD quality elements listed on the left hand side and scheme elements presented along the top of the matrix. An example is included in Table 4. Individual impacts arising from each scheme element are grouped into a set of columns under the Scheme element.

2.3.9 The WFD status risk screening tables will be updated in response to various design developments according to the Technical Standard – Water Framework Directive Compliance Process.

Table 4: An example of WFD status risk screening table taken from the Phase One ES Volume 5 Water Resources Route-wide appendix

A. Risk screening of potential to cause deterioration of current WFD status

	Groundwater body					Scheme Elements	Green Tunnel			
							Burton Green Tunnel (CFA18)		Stoneleigh Park Retaining Wall (Cut) (CFA18)	
							146-L1		137-L1	
	GB40902G302200					Phase	Construction & Operation		Construction & Operation	
	Warwickshire Avon - Coal Measures Coventry	Current status	Confidence	Risk	Status objective	Identified quantitative impacts	Lowering of groundwater levels and reduction in groundwater contributions to surface water bodies, GWDTEs or groundwater abstractions by temporary dewatering/ permanent groundwater control	"Damming" of groundwater flow and reduction in groundwater contributions	Lowering of groundwater levels and reduction in groundwater contributions to surface water bodies, GWDTEs or groundwater abstractions by temporary dewatering/ permanent groundwater control	"Damming" of groundwater flow and reduction in groundwater contributions
WFD classification elements	**1.Saline or other intrusions.** To identify groundwater bodies where the intrusion of poor quality water as a result of groundwater abstraction is leading to sustained upward trends in pollutant concentrations or significant impact on one or more groundwater abstractions.	Good	High	Probably Not At Risk	Good Ecological Status by 2015	Predicted change to status elements (green = none, amber = possibly, red = likely)	No impacts identified as result of scheme element	No impacts identified as result of scheme element	No impacts identified as result of scheme element	No impacts identified as result of scheme element
	2. Surface water. To assess the impact of groundwater abstractions on the ecological status of surface water bodies.	Poor	Low	At Risk	Good Ecological Status by 2015		Tunnel is in surface water divide between Finham and Canley Brooks. Embedded mitigation to reintroduce water to ground via SuDS in catchment of Canley Brook. Localised impacts on headwaters possible.	Tunnel is in surface water divide. Backfill around tunnel. Tunnel does not penetrate whole aquifer. Track drainage discharged in Canley Brook catchment. No significant impacts predicted.	River Avon (Claycoton GB109054043920) adjacent to scheme element, River Avon (Warks GB109054043840) at N end. Water pumped to attenuation pond adjacent to River Avon (Claycoton), reducing impacts on surface flows. Cut-off walls will help reduce dewatering volumes.	Retaining wall may reduce baseflow to the River Avon locally, particularly over the stretch where the cutting is approximately parallel to the river. Effects offset by discharge point.
	3. Groundwater Dependent Terrestrial Ecosystems (GWDTEs). To assess the impact of groundwater abstractions on the condition of GWDTEs.	Good	High	Not At Risk	Good Ecological Status by 2015		Crosses Big Poors & Little Poors Wood LWS and near to Black Waste Wood AW, both potential GWDTEs. Cutting crosses Kenilworth to Balsall Railway Embankment LWS and is near to Beanit Farm Hedge LWS; neither considered GWDTE. Loss of habitat beneath scheme element footprint not assessed. Embedded mitigation to reintroduce water to ground via SuDS to the SE downstream of tunnel. Localised impacts possible.	Crosses Big Poors & Little Poors Wood LWS and near to Black Waste Wood AW, both potential GWDTEs. Cutting crosses Kenilworth to Balsall Railway Embankment LWS and is near to Beanit Farm Hedge LWS; neither considered GWDTE. Loss of habitat beneath scheme element footprint not assessed. Backfill around tunnel. Tunnel does not intercept whole aquifer. No impacts identified as result of scheme element	River Avon LWS is within ROI of cutting. Cutting crosses Stoneleigh Park LWS; not considered a GWDTE. Water pumped to attenuation pond adjacent to River Avon (Claycoton), reducing impacts on surface flows. Cut-off walls will help reduce dewatering volumes.	River Avon LWS is within ROI of cutting. Retaining wall may reduce baseflow to the River Avon locally, particularly over the central stretch where the cutting is approximately parallel to the river. Effects offset by discharge point.
	4. Water balance. To identify groundwater bodies where abstractions exceed the available resource.	Poor	Low	Probably At Risk	Good Ecological Status by 2015		Cutting will require dewatering during construction. Embedded mitigation to reintroduce water to ground via SuDS.	Backfilling around tunnel reduces need for ongoing dewatering.	Cutting will require dewatering. Water pumped to attenuation pond adjacent to River Avon. Nearby abstractions are outside predicted RoI.	Local influence on flow regime. No significant impacts predicted.

Quantitative status	Poor

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3 Developing a water resources and flood risk monitoring plan

3.1 Introduction

3.1.1 This section provides guidance on how to use this technical standard in developing Water Resources and Flood Risk Monitoring Plans for the water environment in a consistent manner.

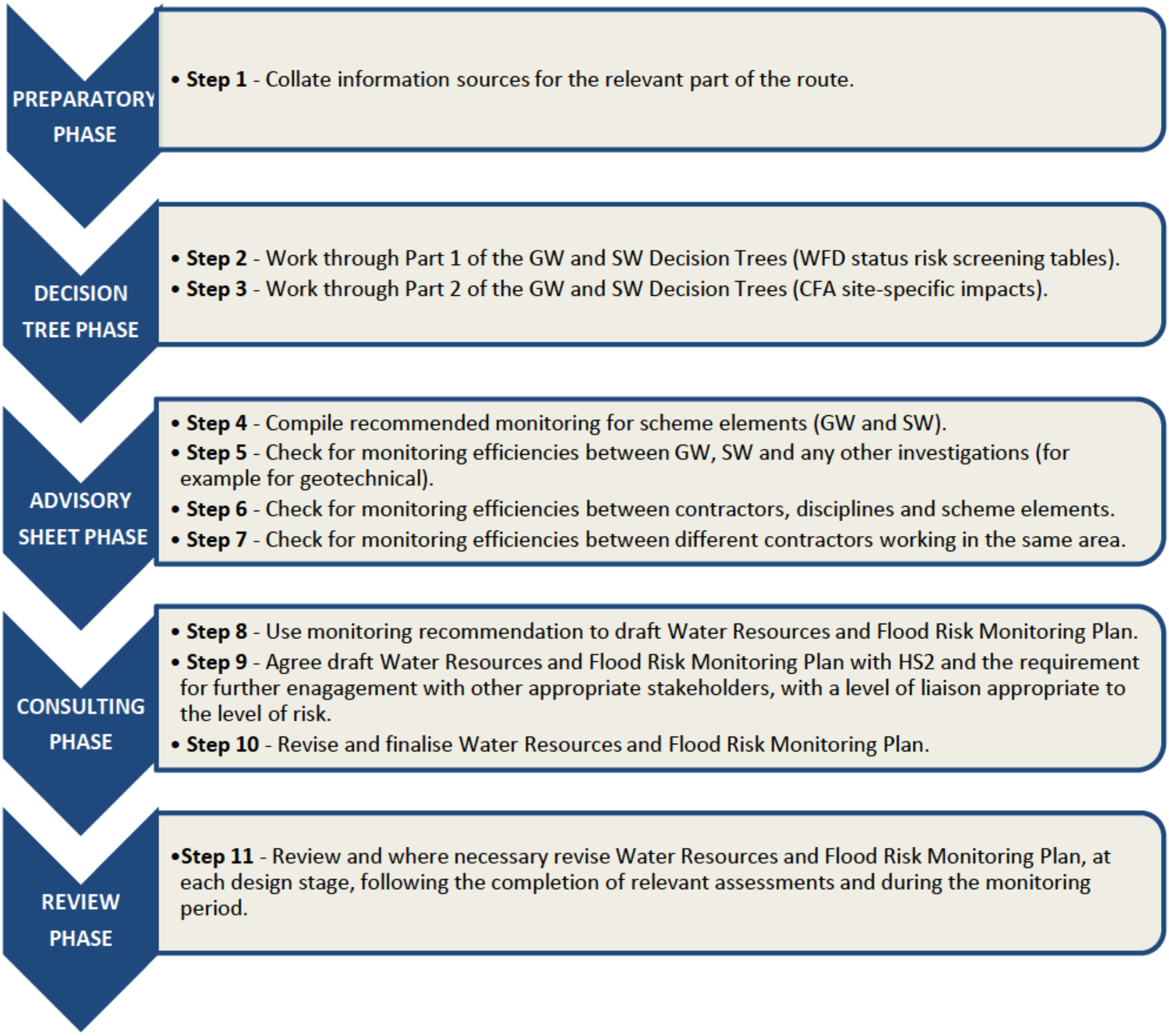
3.2 Overview of the process

3.2.1 The five phase process, identified in Figure 2, to develop Water Resources and Flood Risk Monitoring Plans shall be followed.

3.2.2 In summary, the user collates the necessary background information for the relevant part of the route (Preparatory Phase) and then uses two Monitoring Decision Trees to help identify whether surface or groundwater monitoring is likely to be needed (Decision Tree Phase). The outcomes of the Decision Trees link to a series of Monitoring Advisory Sheets that set out more advice on what should be monitored, where, how often and for how long (Advisory Sheet Phase). This information informs the development of a Water Resources and Flood Risk Monitoring Plan for that part of the route to be discussed and agreed with the Environment Agency and other key stakeholders (Consulting Phase). Water Resources and Flood Risk Monitoring Plans will need to be reviewed and, where necessary revised at each design stage, following the completion of relevant assessments and during the monitoring period (Review Phase).

3.2.3 Ideally the process of developing Water Resources and Flood Risk Monitoring Plans would be undertaken after all groundwater, surface water and land quality assessments have been concluded; however, due to timeframes they are likely to be developed alongside.

Figure 2: Steps in developing the Water Resources and Flood Risk Monitoring Plan



3.3 Preparatory phase

3.3.1 The following background information[1] shall be obtained in Step 1 to inform the identification of water environment monitoring needs and the development of associated Water Resources and Flood Risk Monitoring Plans.

- HS2 Ltd ES – Volume 5 Technical Appendices, Water Resources:

[1] Specific references have been included here to the HS2 Ltd Phase One ES and SES, however it is intended that this technical standard will also apply to HS2 Ltd Phase Two ES.

- Route-wide appendix – Annex A – Surface water WFD assessments;
- Route-wide appendix – Annex B – Groundwater WFD assessments; and
- Water resources assessment – for the CFA(s) of interest.

- HS2 Ltd SES and Additional Provisions – Volume 5 Technical Appendices, Water Resources:
  - Route-wide appendix – Annex A – Surface water WFD assessments;
  - Route-wide appendix – Annex B – Groundwater WFD assessments; and
  - Water resources assessment – for the CFA(s) of interest[2].
- Any additional ground investigation, survey and monitoring data that has been collated since the publication of the ES/SES;
- Any additional or revised assessments, particularly relating to:
  - Technical Standard – Groundwater Protection;
  - Technical Standard – Land Quality;
  - Technical Standard – Ecology;
  - Technical Standard – Watercourse Diversions;
  - Technical Standard – Water Resources and Flood Risk Consenting ; and
  - Technical Standard – Water Framework Directive Compliance process:
    - WFD surveys, updated assessments and waterbodies with Article 4.7 derogations prepared.
- Design drawings and construction sequence detailing;
- LEMPS; and
- Any additional information that has been made available through advance discussions with the Environment Agency and other stakeholders.

[2] Updated water resources assessments have only been produced for the SES where design changes have occurred within the CFA that impact on the water environment.

3.4 Decision tree phase

3.4.1 Having gathered together the necessary background information, the Decision Trees shall be used to identify whether surface or groundwater monitoring is needed and what type of monitoring (Steps 2 and 3).

3.4.2 Although groundwater and surface water systems can be connected, a distinction can be made between groundwater and surface water monitoring. Consequently, for the purposes of developing Water Resources and Flood Risk Monitoring Plans, two Decision Trees have been developed, one for groundwater (Figure 3:) and one for surface water (Figure 4:).

3.4.3 In using the Decision Trees there are two key sources of information. The route wide WFD risk assessments and the CFA/CA water resource assessments as previously discussed in section 3.3.

WFD assessments

3.4.4 In Step 2, part 1 of each Decision Tree is followed by reviewing the WFD assessments carried out for the HS2 Ltd ES.

3.4.5 Although published in the HS2 Ltd ES, the WFD assessments, in the form of tables, are dynamic documents that are intended to be updated during the Scheme, as and when additional site investigation and monitoring data become available.

3.4.6 The latest version of the WFD assessments shall be obtained from the HS2 Ltd Asset Information Management System (AIMS) and used when drafting Water Resources and Flood Risk Monitoring Plans.

Site-specific water resources assessments

3.4.7 In Step 3, part 2 of each Decision Tree involves the review of the site-specific water resource assessments carried out for the HS2 Ltd ES and any subsequent site-specific assessments that have been completed.

3.4.8 The most up to date site-specific water resource assessments shall be used when drafting Water Resources and Flood Risk Monitoring Plans.

3.4.9 Water monitoring shall be required where the magnitude of impact on a water environment receptor prior to mitigation is flagged as anything other than 'negligible' (ES), 'very low risk' or 'low risk' in any subsequent assessment .

Identifying the right Monitoring Advisory Sheets

3.4.10 Having worked through the Decision Trees the user is referred to one or more Monitoring Advisory Sheets which informs the drafting of Water Resources and Flood Risk Monitoring Plans. Table 5 lists the Decision Trees and associated Advisory Sheets.

Table 5: Monitoring Decision Trees and Advisory Sheets

Monitoring Decision Tree	Monitoring Advisory Sheet (Appendix A)	WFD quality criterion
Groundwater Decision Tree (Figure 3)	Advisory Sheet GW1	Quantitative
	Advisory Sheet GW2	Chemical
	Advisory Sheet GW3	Quantitative and chemical
Surface Water Decision Tree (Figure 4)	Advisory Sheet SW1	Quality (physico-chemical) and Quantity (flow, level)
	Advisory Sheet SW2	Ecology – Macrophytes and Phytobenthos
	Advisory Sheet SW3	Ecology – Macroinvertebrates
	Advisory Sheet SW4	Ecology – Fish
	Advisory Sheet SW5	Hydromorphology

Figure 3: Groundwater Decision Tree

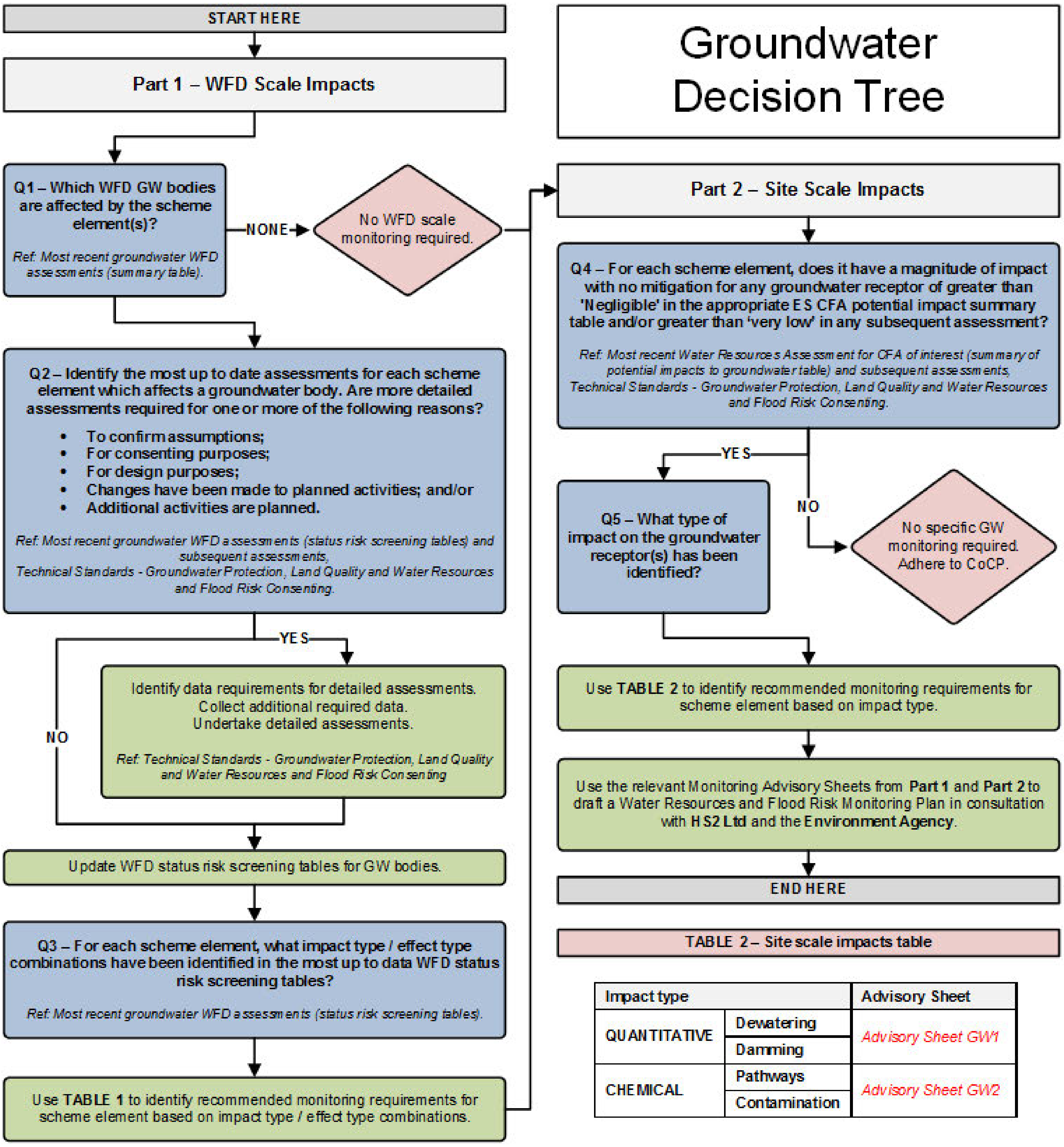


TABLE 2 – Site scale impacts table

Impact type		Advisory Sheet
QUANTITATIVE	Dewatering	Advisory Sheet GW1
	Damming	
CHEMICAL	Pathways	Advisory Sheet GW2
	Contamination	

TABLE 1 – WFD scale impacts table

WFD classification element category	Impact type	Effect type			
		GREEN	YELLOW	AMBER	RED
QUANTITATIVE	Dewatering	No specific WFD GW monitoring required. Adhere to CoCP.	Advisory Sheet GW3	Advisory Sheet GW1	Consult with EA directly
	Damming				
CHEMICAL	Pathways			Advisory Sheet GW2	
	Contamination				

Figure 4: Surface water Decision Tree

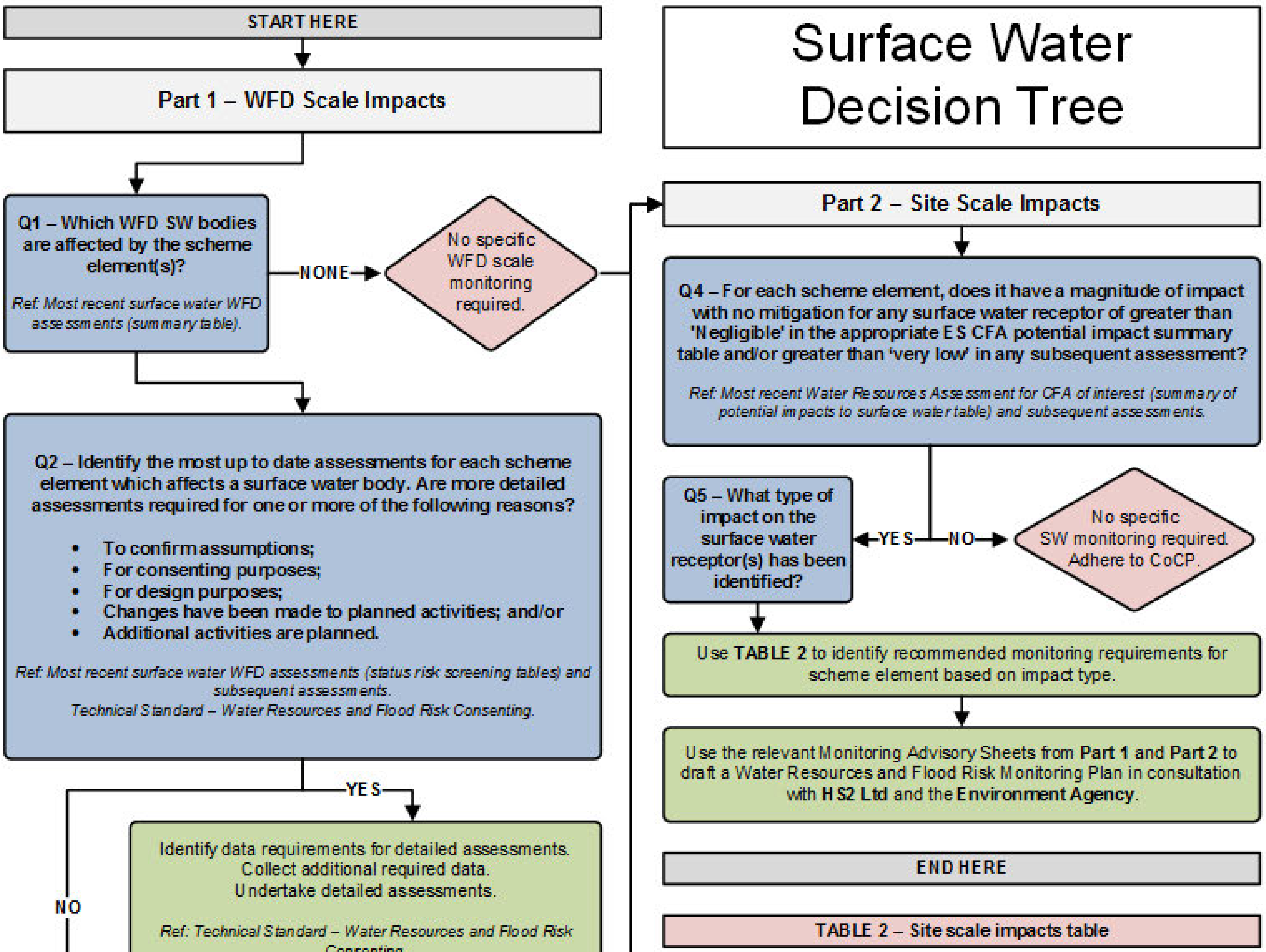


TABLE 2 – Site scale impacts table

Impact type	See advisory sheet: SW1	SW2	SW3	SW4	SW5
Balancing pond	✓	×	×	×	×
Bored tunnel	✓	×	×	×	×
Bridge with footings in water body	✓	✓	✓	✓	✓
Clear span bridge	✓	×	×	×	×
Contamination (from pollution events)	✓	×	✓	×	×
Culvert	✓	✓	✓	✓	✓
Cutting	✓	×	×	×	×
Dewatering	✓	×	×	×	×
Discharge	✓	×	×	×	×
Drainage outfalls to watercourses	✓	×	×	×	✓
Embankments	✓	×	×	×	×
Green tunnel	✓	×	×	×	×
Retaining wall	✓	×	×	×	×
River bank protection	✓	×	×	×	✓
River diversion/realignment	✓	✓	✓	✓	✓
Siphon	✓	×	×	✓	✓
Stations	✓	×	×	×	×
Viaduct	✓	×	×	×	✓

TABLE 1 – WFD scale impacts table

'WFD classification element' category		Effect type: BLUE/LIGHT BLUE (Beneficial)	GREEN	YELLOW	AMBER	RED
Quality (physico-chemical) & Quantity (flow, level)		*Advisory Sheet SW1*	*No specific monitoring unless otherwise identified through Part 2. Adhere to CoCP.*	*Advisory Sheet SW1*		*Consult with EA directly*
Ecological	Macrophytes/Diatoms	*Advisory Sheet SW2*		*Advisory Sheet SW2*		
	Macroinvertebrates	*Advisory Sheet SW3*		*Advisory Sheet SW3*		
	Fish	*Advisory Sheet SW4*		*Advisory Sheet SW4*		
Hydromorphological		*Advisory Sheet SW5*	*No specific monitoring unless otherwise identified through Part 2, or scheme element being considered is a river diversion/realignment (in latter case refer to Advisory Sheet SW5). Adhere to CoCP.*	*Advisory Sheet SW5*		

3.5 Advisory sheet phase

3.5.1 Where monitoring is considered necessary as an outcome from working through the Decision Tree, the user is referred to one or more Monitoring Advisory Sheets covering parameters such as physico-chemical quality, fish and hydromorphology (see Appendix A).

3.5.2 Each Monitoring Advisory Sheet makes water environment monitoring recommendations for each phase (pre-construction, construction and post-construction) of the HS2 Ltd scheme, specifying:

- What should be monitored;
- How should it be monitored;
- Where should it be monitored; and
- When should it be monitored and for how long.

3.5.3 The Advisory Sheets shall be used to help compile the Water Resources and Flood Risk Monitoring Plan for that part of the route (Step 4) and the sheets themselves can be annotated to aid this.

3.5.4 Efficiencies shall be sought between any monitoring requirements of the Water Resources and Flood Risk Monitoring Plan and any other investigations (for example for geotechnical) (Step 5), between scheme elements (Step 6) and between contractors (Step 7), to avoid duplication.

3.5.5 The Water Resources and Flood Risk Monitoring Plans shall be reviewed and updated at the conclusion of any groundwater, surface water or land quality assessment required by the technical standards.

3.5.6 The monitoring recommendations in the Advisory Sheets have been formulated based on a review of published guidance and of monitoring carried out for other large scale infrastructure projects. They inform the development of a draft Water Resources and Flood Risk Monitoring Plan (Step 8) and form the basis for discussion with HS2 Ltd, the Environment Agency and potentially other stakeholders (Step 9).

3.5.7 Finalised monitoring agreed with HS2 Ltd for a particular scheme element may be more or less comprehensive than that specified on the appropriate Advisory Sheet.

3.5.8 The Advisory Sheets are intended to be dynamic documents that can be updated throughout the Scheme.

3.6 Consulting phase

3.6.1 **Step 8** involves the development of a draft Water Resources and Flood Risk Monitoring Plan, which shall include:

- Management structure – detailing roles and responsibilities within the contractor team;
- Summary of the works and risks presented. An outline programme shall also be provided;
- Monitoring schedule – detailing the specifics of the monitoring programme listed below. Much of this information would be captured by on site-specific versions of the appropriate Monitoring Advisory Sheets included in the Water Resources and Flood Risk Monitoring Plan.
  - What – monitoring type;
  - Where – monitoring locations (including maps);
  - When – monitoring frequency and duration; and
  - How – monitoring methodology, including:
    - Procedures for inspecting monitoring locations;
    - Measurement techniques;
    - Sampling techniques (including parameter suites for laboratory analysis);
    - Water sample handling protocol; and
    - QA/QC protocol.
- Assessment criteria[3] (Alert Levels) and compliance criteria (Trigger Levels) for water quality parameters;
- Any Environment Agency consent requirements relevant to the monitoring;
- Data management procedures, including QA/QC protocols;
- Data analysis and review procedures, including comparison with Alert Levels and Trigger Levels;

[3] Assessment criteria are designed to indicate trends in monitoring data that could result in a breach of compliance criteria.

- Reporting procedures;
- Action Plans detailing the response of the contractor to breaches of Alert and Trigger Levels;
- Pollution Incident Response Plans (as required under Section 5.12 of the Code of Construction Practice) detailing the response of the contractor to pollution incidents.

3.6.2 Water Resources and Flood Risk Monitoring plans for water bodies requiring a consent, (as defined in the Water Resources and Flood Risk technical standard eB HS2-HS2-EV-STD-000-000015) shall be discussed with HS2 Ltd and the Environment Agency through the Interdisciplinary Design Reviews (IDRs) and consenting process before being finalised.

3.6.3 Water Resources and Flood Risk Monitoring Plans (Steps 9 and 10) shall be submitted to HS2 Ltd for assurance verification in the Verification Activity Plan (VAP).

3.6.4 Any deviation from the monitoring specified in the Water Resources and Flood Risk Monitoring Plan shall be agreed to with HS2 Ltd and the Environment Agency prior to implementation through the Interdisciplinary Design Reviews (IDRs) and consenting process.

3.7 Review phase

3.7.1 Water Resources and Flood Risk Monitoring plans shall be reviewed at each design stage, following the completion of any revised or updated assessments and during the monitoring period (Step 11).

3.7.2 Revised monitoring plans shall be provided to HS2 Ltd and where a consent is required discussed with HS2 Ltd and the Environment Agency through the Interdisciplinary Design Reviews (IDRs) and consenting process.

3.8 Worked example

3.8.1 A worked example of how the Decision Trees and Monitoring Advisory Sheets can be used to inform the drafting of a Monitoring Plan can be found in Appendix B. This has been based on scheme element Burton Green Tunnel within CFA18 (Stoneleigh, Kenilworth and Burton Green), using the groundwater Decision Tree and Advisory Sheets.

4 General principles for water environmental monitoring

4.1 Introduction

4.1.1 This section outlines the general principles for:

- Monitoring point site selection;
- Monitoring point specification; and
- Monitoring activities.

4.1.2 These principles address both groundwater and surface water monitoring and are supported with more detail in Appendices C to E.

4.1.3 The principles, along with the technical guidance found in Appendices C to E, are intended to underpin implementation and management of the Water Resources and Flood Risk Monitoring Plans as outlined in section 3.

4.2 Groundwater

Monitoring network

Site selection

4.2.1 The site selection process will be informed by:

- The ES and any information contained within (i.e. published geological, hydrological and hydrogeological information);
- The most up to date WFD assessment;
- Available existing information on groundwater conditions held by water companies, regulatory bodies, such as the Environment Agency and Natural England, or other data holders, where relevant;
- The need for consistent, long-term data before, during and after the construction works, and the risk that construction work poses to monitoring equipment; and
- Results of the phased GI programme.

4.2.2 Appendix C provides general and specific guidelines for the selection of sites for groundwater monitoring borehole installation.

Borehole specification and post-drilling development

4.2.3 The borehole specification shall take into account:

- Ground conditions, i.e. geological, hydrogeological and land quality; and
- Monitoring purpose.

4.2.4 All monitoring boreholes shall be dual purpose, suitable for measuring groundwater levels and collecting groundwater samples.

4.2.5 Boreholes used for groundwater monitoring shall not have more than one installation.

4.2.6 Post-drilling development shall be carried out in all monitoring boreholes immediately following installation to ensure good hydraulic continuity between the installation and groundwater, to help remove fine material suspended in groundwater around the installation and to settle the filter pack.

4.2.7 All boreholes within Source Protection Zone 1 (SPZ1) areas shall have high security headworks installed. These security measures must be aligned with those required of the Water Authorities by the Department of Food and Rural Affairs (Defra).

4.2.8 Borehole response zones shall only be present within a singular stratum. They shall not cross different aquifers or link Made Ground with underlying aquifers.

4.2.9 Whereby the borehole is to be purged, for instance prior to sampling, the water level shall be determined immediately prior to purging.

4.2.10 Appendix D provides general and specific guidelines for the specification and post-drilling development of groundwater monitoring boreholes.

Monitoring activities

4.2.11 All monitoring equipment used for measuring water levels and flows and collecting water samples shall be calibrated according to the manufacturer's instructions prior to use.

Checking of borehole condition

4.2.12 The condition of all monitoring boreholes shall be examined during each site visit.

4.2.13 Records shall be kept on borehole performance over time and include: depth of the borehole, rest water level, volume of water purged prior to sampling, response to pumping (if this is the sampling methodology), turbidity and colour of pumped water, time for hydrochemical indicators to stabilise during purging and water quality issues which may have resulted from poor installation and condition of the headworks.

4.2.14 Any problems observed with the borehole performance or condition shall be reported to HS2 Ltd immediately.

4.2.15 Borehole development shall be repeated if performance decreases over time.

4.2.16 Where maintenance or rehabilitative works are required, a working plan shall be devised by the contractor and put in place in a timeframe that ensures continuity of monitoring, following agreement with HS2 Ltd.

Groundwater level measurement

4.2.17 Where the use of pressure transducers/data loggers[4] is specified:

- they shall be backed up by manual groundwater measurements at a minimum frequency of every four months or every data download visit[5].
- data shall be downloaded at a minimum frequency of every four months;
- the logger shall have sufficient capacity to store the data for the period of time until the next visit, including a contingency in case the monitoring visit is delayed;
- one barometric logger can be used to correct multiple holes within a range of approximately 5km[6], but shall be set to record at the same intervals (or more frequent) and at the same time as the pressure transducers, so that the readings correlate; and
- corrections shall be applied for differences in elevation between the barometric and pressure transducers.

4.2.18 Where monitoring from pressure transducers and manual dips vary by more than 0.1m then an investigation shall be undertaken, rectified and reported to HS2 Ltd.

4.2.19 Telemetry of groundwater level data should be considered for monitoring highly sensitive receptors, such as SSSIs or public water supply boreholes.

4.2.20 Appendix E details the general and specific guidelines for the measurement of groundwater levels.

[4] A data logger is an electronic device that records data, such as water pressure, over time with a built-in instrument or sensor or via external instruments and sensors.
[5] Except where closed system monitoring is being used (see Appendix D).
[6] If there is a significant height difference between a groundwater level logger and the associated barometric logger, an adjustment for barometric variation with height may be required.

Spring flow measurement

4.2.21 The measurement of spring flow shall be undertaken using surface water flow gauging techniques, where the spring enters/forms a defined flow channel. This could be manual or automatic, depending on the requirements of monitoring.

4.2.22 Telemetry of flow data should be considered, particularly during construction, or where access is constrained.

4.2.23 Appendix E details the general and specific guidelines for spring/surface water flow gauging.

Groundwater quality monitoring

4.2.24 Automated water quality monitoring and telemetry should be considered for monitoring in the vicinity of highly sensitive receptors (such as a SSSIs or public water supplies).

4.2.25 Minimum parameter schedules required for groundwater quality monitoring are contained in the footnotes of the appropriate Advisory Sheets (GW2 and GW3).

4.2.26 Where volatile organic compound contamination is expected, low flow sampling techniques shall be used.

4.2.27 Laboratories used to carry out water sample analysis shall be UKAS and MCERTS accredited.

4.2.28 Appendix E details the general and specific guidelines for sampling of groundwater as well as the handling and preservation of water samples.

4.3 Surface water

Monitoring network

Site selection

4.3.1 The selection of sites for the installation of surface water monitoring points and the selection of reaches for hydromorphological and ecological monitoring should be based on the conceptual model of risk, requirements of monitoring and the sensitivity of nearby receptors. This will inform a conceptualisation of ideal sampling localities.

4.3.2 This selection process should be informed by:

- Published hydrological, hydromorphological and hydrogeological information as detailed in the ES;
- The most up to date WFD assessment;
- Available existing information on surface water conditions held by water

companies, regulatory bodies, such as the Environment Agency and Natural England, or other data holders, where relevant; and

- Site-specific information, including local anecdotal knowledge where necessary.

4.3.3 Appendix C provides general and specific guidelines for siting of surface water monitoring points and reaches.

Monitoring point specification

4.3.4 The monitoring point specification will depend on the type of monitoring activity, the frequency of measurements required, environmental conditions and surface water body characteristics.

4.3.5 Appendix D provides general and specific guidelines for the specification of monitoring locations for surface water level, flow and quality.

Monitoring activities

4.3.6 All monitoring equipment used for measuring water levels and flows, and collecting water samples shall have been calibrated according to the manufacturer's instructions prior to use.

Surface water level measurement

4.3.7 To avoid the need for structures in the channel, which could impact on flood risk and ecology, surface water levels shall be determined using either manual dip measurements (referenced from a fixed datum), gauge plate readings and/or stilling wells[7] with automated transducers.

4.3.8 The data from the pressure transducers shall be downloaded on a regular basis (at a minimum frequency of every four months) with manual dips or gauge plate readings taken during these site visits.

4.3.9 Telemetry of surface water level data should be considered, particularly during construction, or where access is constrained or dangerous.

4.3.10 Appendix E details the general and specific guidelines which should be applied to the measurement of surface water levels.

[7] A stilling well is a structure installed into a river/lake bank with hydraulic connectivity to the water body to house water level instrumentation.

Surface water discharge measurement

4.3.11 To avoid the need for structures in the channel, which could impact on flood risk and ecology, surface water discharge shall be measured using current meter gauging equipment or automatic flow monitoring apparatus (such as ADCP) with data loggers.

4.3.12 The data loggers shall be downloaded on a regular basis (but not less than every 4 months) with manual readings taken during these site visits.

4.3.13 Telemetry of surface water flow data should be considered, particularly during construction, or where access is constrained or dangerous.

4.3.14 Appendix E details the general and specific guidelines which should be applied to the measurement of surface water flows.

Surface water quality monitoring

4.3.15 The use of automated monitoring of water quality via auto-samplers or probes should be considered using a risk-based approach. The key areas in relation to risk would be where there is likely to be significant contamination or risk of pollution from a particular construction activity and where there are particularly sensitive receptors.

4.3.16 Telemetry of surface water quality data should be considered, particularly during construction, or where access is constrained or dangerous.

4.3.17 Minimum parameter schedules required for surface water quality monitoring are contained in the footnotes of the appropriate Advisory Sheet (SW1).

4.3.18 Laboratories used to carry out water sample analysis shall be UKAS and MCERTS accredited.

4.3.19 Appendix E details the general and specific guidelines which should be applied to the sampling of surface water and to the handling and preservation of water samples.

Hydromorphological monitoring

4.3.20 Hydromorphological monitoring where the scheme will affect the morphology of the channel (such as watercourse alteration, watercourse structures or bank protection) comprises of desk-based assessment to inform field based monitoring. Additional, more detailed, hydromorphological monitoring may be required for certain sites where there is hydromorphological risk to an asset or where there is the need to demonstrate habitat creation on a diverted channel (see Appendix E and WFD Technical Standard).

4.3.21 Appendix E details the general and specific guidelines which should be applied when selecting appropriate hydromorphological monitoring.

Aquatic ecological monitoring

4.3.22 The decision to implement aquatic ecological sampling should take account of the nature of the local system affected by the design element. For example, aquatic macrophyte sampling on a heavily shaded system or aquatic macroinvertebrate sampling on an ephemeral system may not be advisable under any circumstances.

4.3.23 Appendix E details the general and specific guidelines which should be applied when selecting appropriate ecological monitoring.

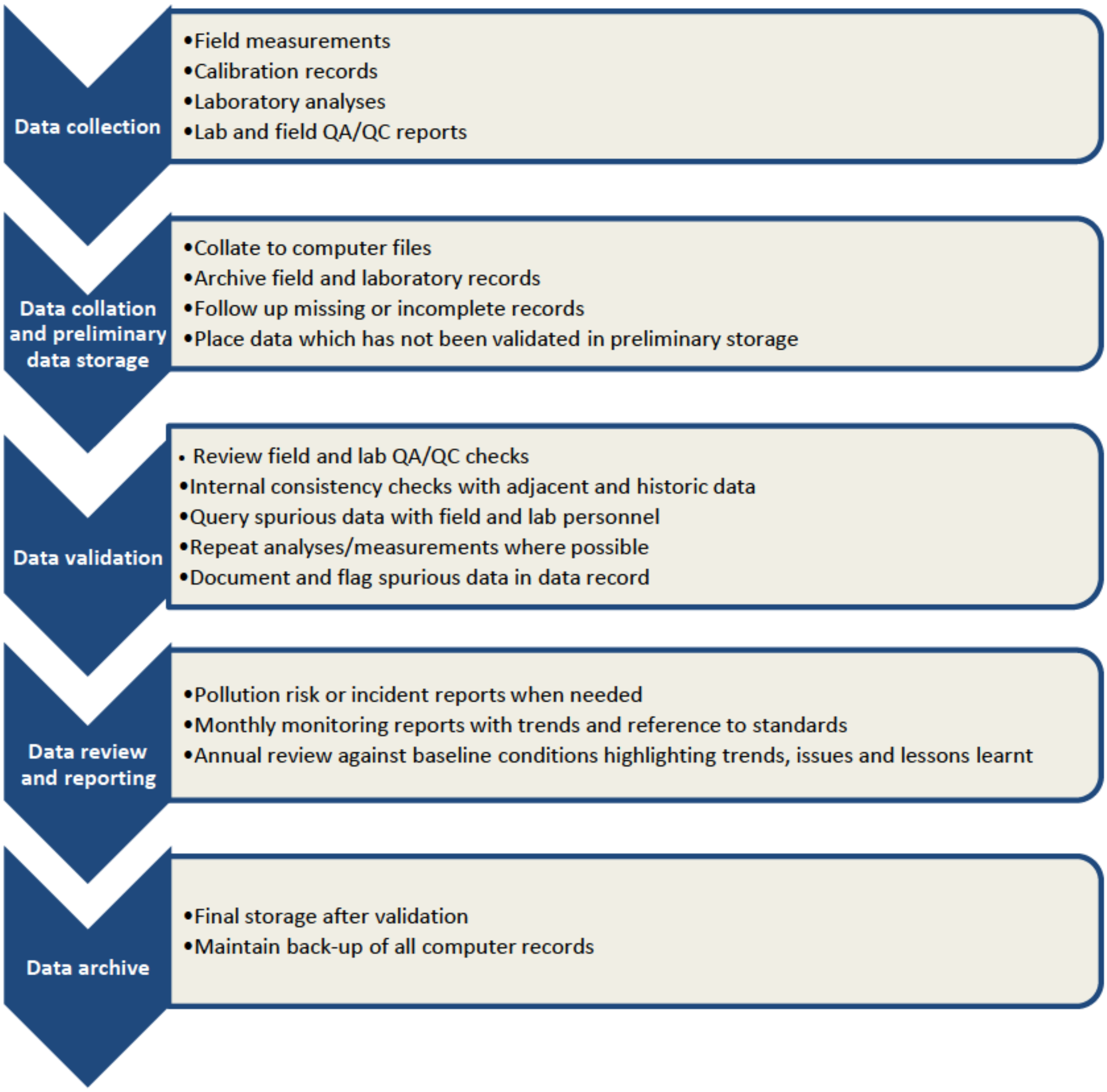
4.4 Managing the monitoring programme

4.4.1 This section of the Water Resources and Flood Risk Monitoring technical standard describes principles for data management and reporting/communications. These are important considerations for all environmental monitoring that will be undertaken as part of the Scheme. HS2 Ltd is currently developing its approach to these areas more broadly across the Scheme.

Data management

4.4.2 The collection of large amounts of monitoring data necessitates the use of a data management system agreed between the key parties. The potential elements of such a system are shown in Figure 5 below.

Figure 5: Elements of data management good practice for a monitoring programme



4.4.3 Data need to be collated and held in a format that allows flexibility for analysis and presentation, while safeguarding the integrity of the data.

4.4.4 Data management shall involve the means to validate and maintain the quality of data. For example, all data stored and manipulated on computers need to be validated carefully and cross-referenced against other records and original source material.

4.4.5 Data management also needs to allow for the identification and reporting of both short term issues and longer term trends.

4.4.6 All data collected for Water Resources and Flood Risk Monitoirng Plans shall be provided to HS2 Ltd in a consistent format as defined in the Water Resources and Flood Risk GIS Specification (eB HS2-HS2-GI-SPE-000-000010).

Reporting and communications

4.4.7 Reporting expectations shall be agreed with HS2 Ltd.

4.4.8 This is anticipated to include:

- Monthly reporting on the routine monitoring data to include trends and reference to standards;
- Details of the contractors response to Alert and Trigger Level breaches and pollution incidents as per the Action Plans defined in the Water Resources and Flood Risk Monitoring Plans; and
- A more detailed annual report summarising the trends, issues and lessons learnt.

Appendix A – Monitoring advisory sheets

Monitoring Advisory Sheet - GW1

To be used for:

Monitoring type:	**Groundwater**	
Impact type:	**Quantitative**[1]	
Effect type:	**Amber**	*As reported in the WFD status risk screening tables*
Impact magnitude:	**Any adverse**	*As reported in the CFA site specific 'potential impact on groundwater receptors' summary table*

RECEPTOR	WHAT?	PHASE	Baseline (pre-construction)			Construction			Operational (post-construction)			AGREED MONITORING WITH EA
		HOW?	WHERE?	WHEN?		WHERE?	WHEN?		WHERE?	WHEN?		
		Method	Locations	Frequency	Duration	Locations	Frequency	Duration	Locations	Frequency	Duration[8]	
Disturbed aquifer(s) (i.e. dewatered, dammed, connected to other aquifers)	**GW level**	*Standard monitoring*										
		Logger measurements *Dips*	*Minimum of 3 x monitoring boreholes in each disturbed aquifer - one up and two down hydraulic gradient of the disturbance, including at least one between disturbed zone and each flagged receptor in the ES*	*Hourly* *Monthly*	*Minimum 12 months*	*As baseline*	*Hourly* *Weekly during any active construction operations*	*Throughout construction phase*	*As baseline*	*Hourly* *Monthly*	*2 years post construction unless agreed otherwise with EA*	
		Additional monitoring if dewatering operations taking place										
		Logger measurements *Dips*	*At least 3 x monitoring boreholes per pumping well where dewatering taking place - one up and two down (background) hydraulic gradient of the pumping well at different radial distances*	*Hourly* *Monthly*	*Minimum 12 months*	*As baseline*	*Hourly* *Weekly during any dewatering operations*	*Throughout construction phase*	*As baseline*	*Hourly* *Monthly*	*2 years post construction unless agreed otherwise with EA*	
	Abstraction rate	*Flow meter*	*Pumping well*	*Hourly*			*Hourly*			*Hourly*		
Choose monitoring specification for other appropriate receptor(s) flagged in the ES												
SW body - watercourse	**SW flow**	*Logger measurements*	*Gauging stations (if already in situ)*[3] *upstream and downstream of the SW body reach down hydraulic GW gradient of disturbance*	*Hourly*	*Minimum 12 months*	*As baseline*	*Hourly*	*Throughout construction phase*	*As baseline*	*Hourly*	*2 years post construction unless agreed otherwise with EA*	
		Current/flow meter	*2 x spot flow locations, upstream and downstream of the SW body reach down hydraulic GW gradient of disturbance*	*Monthly*			*Weekly during any dewatering operations*			*Monthly*		
	SW quality	*Field measurements*		*Monthly (temperature & conductivity)*[4]			*Weekly during any dewatering operations (temperature & conductivity)*[4]			*Monthly (temperature & conductivity)*[4]		
	SW level[2]	*Logger measurements* *Dips*	*2 x stilling well locations, upstream and downstream of the SW body reach down hydraulic GW gradient of disturbance*	*Hourly* *Monthly*			*Hourly* *Weekly during any dewatering operations*			*Hourly* *Monthly*		
SW body - reservoir, lake, pond	**SW level**	*Logger measurements* *Dips*	*1 x stilling well location*	*Hourly* *Monthly*	*Minimum 12 months*	*As baseline*	*Hourly* *Weekly during any dewatering operations*	*Throughout construction phase*	*As baseline*	*Hourly* *Monthly*	*2 years post construction unless agreed otherwise with EA*	
Spring	**Flow**	*Logger measurements* *Various*	*Spring gauging location (if already in situ)*[3] *Spring discharge point*	*Hourly* *Monthly*	*Minimum 12 months*	*As baseline*	*Hourly* *Weekly during any dewatering operations*	*Throughout construction phase*	*As baseline*	*Hourly* *Monthly*	*2 years post construction unless agreed otherwise with EA*	
GW abstraction	**GW level**	*Logger measurements* *Dips*	*Abstraction borehole & any observation borehole in close proximity to abstraction*[5]	*Hourly* *Monthly*	*Minimum 12 months*	*As baseline*	*Hourly* *Weekly during any dewatering operations*	*Throughout construction phase*	*As baseline*	*Hourly* *Monthly*	*2 years post construction unless agreed otherwise with EA*	
	Abstraction rate	*Flow meter*	*Abstraction borehole*	*Hourly*			*Hourly*			*Hourly*		
GWDTE	**GW level**	*Logger measurements*	*Minimum of 1 x monitoring borehole, located in the GWDTE, completed in each affected aquifer*	*Hourly*	*Minimum 12 months*	*As baseline*	*Hourly*	*Throughout construction phase*	*As baseline*	*Hourly*	*2 years post construction unless agreed otherwise with EA*	
		Dips	*Minimum of 1 x monitoring borehole completed in any superficial deposits present in the GWDTE*	*Monthly*			*Weekly during any dewatering operations*			*Monthly*		

Monitoring Advisory Sheet - GW1

Notes

This Monitoring Advisory Sheet is part of the Water Resources and Flood Risk Monitoring Strategy and is intended to be used in conjunction with the Groundwater Decision Tree to inform the development of Water Resources and Flood Risk Monitoring Plans.

[1] Quantitative groundwater impacts assessed in the WFD status risk screening tables are:

Lowering of GW levels and reduction of GW contributions to SW bodies, GWDTE or GW abstractions by temporary dewatering/permenant GW control

Damming of GW flow and reduction in GW contributions

[2] In the absence of a gauging station, SW flows can be obtained from stilling well SW levels if sufficient current meter gaugings are available to define a stage-discharge relationship.

[3] The installation of gauging stations may be required based on discussions with the Environment Agency.

[4] Can be used as baseflow indicators.

[5] If there are no appropriate observation boreholes in-situ, installation of new observation boreholes may be required in some circumstances.

[6] A longer period of operational monitoring maybe necessary to observe any Scheme impacts over a range of conditions (e.g. dry summer, wet winter).

Monitoring Advisory Sheet - GW2

To be used for:

Monitoring type:	**Groundwater**	
Impact type:	**Chemical**[1]	
Effect type:	**Amber**	*As reported in the WFD status risk screening tables*
Impact magnitude:	**Any adverse**	*As reported in the CFA site specific 'potential impact on groundwater receptors' summary table*

RECEPTOR	WHAT?	PHASE	Baseline (pre-construction)			Construction			Operational (post-construction)			AGREED MONITORING WITH EA
		HOW? Method	WHERE? Locations	WHEN? Frequency	Duration	WHERE? Locations	WHEN? Frequency	Duration	WHERE? Locations	WHEN? Frequency	Duration[7]	
Disturbed aquifer(s) (i.e. dewatered, dammed, connected to other aquifers, exposed to potential contaminants)	*Standard monitoring where exposure to potential contaminants during construction*											
	GW level	*Dips*	*Minimum of 3 x monitoring boreholes in each disturbed aquifer - one up and two down hydraulic gradient of the disturbance, including at least one between disturbance and each flagged receptor in the ES*	*Monthly*	*Minimum 12 months*	*As baseline*	*Weekly*	*Throughout construction phase*	*As baseline*	*Monthly*	*2 years post construction unless agreed otherwise with EA*	
	GW quality	*Field measurements*[2]										
		Samples (purged)[3,4]		*Monthly (core suite), quarterly (full suite)*			*Weekly (core suite), monthly (full suite)*			*Monthly (core suite), quarterly (full suite)*		
		Visual (post purge)		*Monthly*			*Weekly*			*Monthly*		
	Additional monitoring if there are known sources of pre-existing poor quality or contaminated groundwater (e.g. landfill site, or elevated nitrate concentrations) in the disturbed aquifer(s)											
	GW level	*Dips*	*At least 1 x monitoring borehole between poor quality / contaminated GW and disturbance* *At least 1 x monitoring borehole between poor quality / contaminated GW and each receptor*	*Monthly*	*Minimum 12 months*	*As baseline*	*Weekly*	*Throughout construction phase*	*As baseline*	*Monthly*	*2 years post construction unless agreed otherwise with EA*	
	GW quality	*Field measurements*[2]										
		Samples (purged)[3,4]		*Monthly (core suite), quarterly (full suite)*			*Weekly (core suite), monthly (full suite)*			*Monthly (core suite), quarterly (full suite)*		
		Visual (post purge)		*Monthly*			*Weekly*			*Monthly*		
Choose monitoring specification for other appropriate receptor(s) flagged in the ES												
SW body - watercourse	**SW flow**	*Current/flow meter*	*2 x monitoring locations, upstream and downstream of the SW body reach down hydraulic GW gradient of disturbance*[5]	*Monthly*	*Minimum 12 months*	*As baseline*	*Monthly*	*Throughout construction phase*	*As baseline*	*Monthly*	*2 years post construction unless agreed otherwise with EA*	
	SW quality	*Field measurements*[2]					*Weekly*					
		Samples[3]		*Monthly (core suite)*			*Weekly (core suite)*			*Monthly (core suite)*		
		Visual		*Monthly*			*Weekly*			*Monthly*		
SW body - lake	**SW level**	*Dips*	*1 x stilling well location*	*Monthly*	*Minimum 12 months*	*As baseline*	*Monthly*	*Throughout construction phase*	*As baseline*	*Monthly*	*2 years post construction unless agreed otherwise with EA*	
	SW quality	*Field measurements*[2]	*1 x sampling location*				*Weekly*					
		Samples[3]		*Monthly (core suite)*			*Weekly (core suite)*			*Monthly (core suite)*		
		Visual		*Monthly*			*Weekly*			*Monthly*		
Spring	**Flow**	*Various*	*Spring discharge point*	*Monthly*	*Minimum 12 months*	*As baseline*	*Monthly*	*Throughout construction phase*	*As baseline*	*Monthly*	*2 years post construction unless agreed otherwise with EA*	
	Quality	*Field measurements*[2]					*Weekly*					
		Samples[3]		*Monthly (core suite)*			*Weekly (core suite)*			*Monthly (core suite)*		
		Visual		*Monthly*			*Weekly*			*Monthly*		
GW abstraction	**GW level**	*Dips*	*Abstraction borehole & any observation borehole in close proximity to abstraction*[6]	*Monthly*	*Minimum 12 months*	*As baseline*	*Weekly*	*Throughout construction phase*	*As baseline*	*Monthly*	*2 years post construction unless agreed otherwise with EA*	
	GW quality	*Field measurements*[2]										
		Samples (purged)[3,4]		*Monthly (core suite)*			*Weekly (core suite)*			*Monthly (core suite)*		
		Visual (post purge)		*Monthly*			*Weekly*			*Monthly*		
GWDTE	**GW level**	*Dips*	*If disturbed aquifer outcrops in the GWDTE - 1 x monitoring borehole located in the GWDTE, completed in the affected aquifer* *If the affected aquifer does not outcrop in the GWDTE - 2 x monitoring boreholes located in the GWDTE, one completed in the disturbed aquifer and the other completed in the superficial deposits*	*Monthly*	*Minimum 12 months*	*As baseline*	*Weekly*	*Throughout construction phase*	*As baseline*	*Monthly*	*2 years post construction unless agreed otherwise with EA*	
	GW quality	*Field measurements*[2]										
		Samples (purged)[3,4]		*Monthly (core suite)*			*Weekly (core suite)*			*Monthly (core suite)*		
		Visual (post purge)		*Monthly*			*Weekly*			*Monthly*		

Monitoring Advisory Sheet - GW2

Notes

This Monitoring Advisory Sheet is part of the Water Resources and Flood Risk Monitoring Strategy and is intended to be used in conjunction with the Groundwater Decision Tree to inform the development of Water Resources and Flood Risk Monitoring Plans.

[1] Chemical groundwater impacts assessed in the WFD status risk screening tables are:

Creating or altering of pathways along which existing poor quality GW can migrate;

Disturbing or mobilising existing poor quality GW by temporary dewatering or depressurisation and permanent GW control.

In addition the CFA site specific 'potential impact on groundwater receptors' summary tables highlight the impact caused by the introduction of contaminants during construction activities.

[2] Field measurements shall include T, pH, EC, DO and redox potential. For GW sampling these parameters shall be monitored throughout purging where appropriate to ensure stabilisation of water chemistry before sample is taken.

[3] Core suite shall include T, pH, EC, DO, nitrate, ammonium and a suite of major and trace ions and any other parameters agreed with EA to reflect local conditions.

During the construction phase, this suite shall be supplemented by TPH (total petroleum hydrocarbons) and other likely contaminants from construction materials.

Full suite shall be supplemented with determinands appropriate to detect impacts from known areas of pre-existing poor quality or contaminated groundwater and any contaminants related to construction activities, including speciated TPH.

[4] Low flow sampling methodology shall be used where non-aqueous phase liquid (NAPL), VOC/ SVOCs or significant contamination is suspected, or to reduce the volume of waste water with the agreement of the Environment Agency.

[5] A discharge monitoring point would also be required if dewatering effluent is being returned to the watercourse.

[6] If there are no appropriate observation boreholes in-situ, installation of new observation boreholes may be required in some circumstances.

[7] A longer period of operational monitoring maybe necessary to observe any Scheme impacts over a range of conditions (e.g. dry summer, wet winter).

Monitoring Advisory Sheet - GW3

To be used for:
Monitoring type: **Groundwater**
Impact type: **Quantitative[1] and chemical[2]**
Effect type: **Yellow** *As reported in the WFD status risk screening tables*

RECEPTOR	WHAT?	PHASE	Baseline (pre-construction)			Construction			Operational (post-construction)			AGREED MONITORING WITH EA
		HOW? Method	WHERE? Locations	WHEN? Frequency	Duration	WHERE? Locations	WHEN? Frequency	Duration	WHERE? Locations	WHEN? Frequency	Duration[5]	
Disturbed aquifer(s) (i.e. dewatered, dammed, connected to other aquifers, exposed to potential contaminants)	**GW level**	*Logger measurements*	*Minimum of 1 x monitoring borehole up hydraulic GW gradient and 1 x monitoring borehole down hydraulic GW gradient per 500 m of route, within aquifers potentially affected by the scheme*	*na*	*Minimum 12 months*	*As baseline*	*na*	*Throughout construction phase*	*As baseline*	*na*	*2 years post construction unless agreed otherwise with EA*	
		Dips		*Monthly*			*Fortnightly*			*Monthly*		
	GW quality	*Field measurements[3]*		*Monthly (core suite)*			*Fortnightly (core suite)*			*Monthly (core suite)*		
		Samples (purged)[4]										
		Visual (post purge)										

Notes

This Monitoring Advisory Sheet is part of the Water Resources and Flood Risk Monitoring Strategy and is intended to be used in conjunction with the Groundwater Decision Tree to inform the development of Water Resources and Flood Risk Monitoring Plans.

[1] Quantitative groundwater impacts assessed in the WFD status risk screening tables are:
Lowering of GW levels and reduction of GW contributions to SW bodies, GWDTE or GW abstractions by temporary dewatering/permenant GW control
Damming of GW flow and reduction in GW contributions
[2] Chemical groundwater impacts assessed in the WFD status risk screening tables are:
Creating or altering of pathways along which existing poor quality GW can migrate;
Disturbing or mobilising existing poor quality GW by temporary dewatering or depressurisation and permanent GW control.
In addition the CFA site specific 'potential impact on groundwater receptors' summary tables highlight the impact caused by the introduction of contaminants during construction activities.
[3] Field measurements shall include T, pH, EC, DO and redox potential - monitored throughout purging where appropriate to ensure stabilisation of water chemistry before sample is taken.
[4] Core suite shall include T, pH, EC, DO, nitrate, ammonium and a suite of major and trace ions and any other parameters agreed with EA to reflect local conditions.
During the construction phase, this suite shall be supplemented by TPH (total petroleum hydrocarbons) and other likely contaminants from construction materials.
Low flow sampling methodology shall be used where non-aqueous phase liquid (NAPL), VOC/ SVOCs or significant contamination is suspected, or to reduce the volume of waste water with the agreement of the Environment Agency.
[5] A longer period of operational monitoring maybe necessary to observe any Scheme impacts over a range of conditions (e.g. dry summer, wet winter).

Monitoring Advisory Sheet - SW1

To be used for:
Monitoring type: **Surface water**
Impact type: **Quality (physico-chemical) & Quantity**
Effect type: **Amber** / **Yellow** / **Blue** — *As reported in the WFD status risk screening tables*
Impact magnitude: **Any adverse** — *As reported in the CFA site specific 'potential impact on surface water receptors' summary table*

RECEPTOR	WHAT?	PHASE	Baseline (pre-construction)			Construction			Operation (post-construction)			AGREED MONITORING WITH THE EA
		HOW? Method	WHERE? Locations[4]	WHEN? Frequency	Duration	WHERE? Locations	WHEN? Frequency	Duration	WHERE? Locations	WHEN? Frequency	Duration	
SW body - watercourse	**Quality**	*Spot sampling[2]*	*Upstream and downstream control sites typically within 50m of the construction zone*	*Monthly (core suite), quarterly (full suite)*	*Minimum 12 months*	*As baseline[5]*	*Weekly (core suite), monthly (full suite)*	*Throughout construction phase*	*As baseline*	*Monthly (core suite), quarterly (full suite)*	*2 years post construction unless agreed otherwise with EA*	
		Visual inspection		*Monthly*		*Additional construction monitoring sites*	*Daily*			*Monthly*		
		Field measurements[3]					*Weekly*					
		Meteorology	*na*	*na*		*Construction site office*	*Daily summary*		*na*	*na*		
	Flow	*Logger measurements*	*Upstream and downstream gauging stations in proximity to the construction zone (if already in-situ)[6]*	*Hourly*		*As baseline[5]*	*Hourly*		*As baseline*	*Hourly*		
		Current/flow meter	*Upstream and downstream control sites typically within 50m of the construction zone*	*Monthly*			*Monthly*			*Monthly*		
	Level[1]	*Logger measurements*	*Upstream and downstream stilling well control sites typically within 50m of the construction zone*	*Hourly*		*As baseline*	*Hourly*			*Hourly*		
		Dips		*Monthly*			*Monthly*			*Monthly*		
SW body - reservoir, lake, pond	**Quality**	*Spot sampling[2]*	*1 x sampling location*	*Monthly (core suite), quarterly (full suite)*	*Minimum 12 months*	*As baseline*	*Weekly (core suite), monthly (full suite)*	*Throughout construction phase*	*As baseline*	*Monthly (core suite), quarterly (full suite)*	*2 years post construction unless agreed otherwise with EA*	
		Visual inspection		*Monthly*		*Additional construction monitoring sites*	*Daily*			*Monthly*		
		Field measurements[3]					*Weekly*					
		Meteorology	*na*	*na*		*Construction site office*	*Daily summary*		*na*	*na*		
	Level	*Logger measurements*	*1 x stilling well location*	*Hourly*		*As baseline*	*Hourly*		*As baseline*	*Hourly*		
		Dips		*Monthly*			*Monthly*			*Monthly*		

Notes

This Monitoring Advisory Sheet is part of the Water Resources and Flood Risk Monitoring Strategy and is intended to be used in conjunction with the Surface Water Decision Tree to inform the development of Water Resources and Flood Risk Monitoring Plans.

[1] In the absence of a gauging station, SW flows can be obtained from stilling well SW levels if sufficient current meter gaugings are available to define a stage-discharge relationship.

[2] The use of automatic water quality sampling equipment rather than spot sampling may be appropriate at some locations based on discussions with the EA - for example, those highlighted as amber risk for water quality.

Core suite shall include T, pH, EC, DO, BOD, COD, suspended solids, nitrate, ammonium, chlorophyll a, hardness, copper, zinc and a suite of major and trace ions and any other parameters agreed with the EA to reflect local conditions.

During the construction phase, this suite shall be supplemented by TPH (total petroleum hydrocarbons) and other likely contaminants from construction materials during the construction phase.

Full suite shall be supplemented with a wide range of possible contaminants, particularly those related to construction activities, including speciated TPH.

[3] Field measurements shall include T, pH, EC, DO and redox potential.

[4] Information on existing monitoring sites (e.g. EA routine monitoring sites), discharge consents, abstractions, control structures etc. shall be collated in order to best determine monitoring site locations. See Appendix C.

[5] A discharge monitoring point would also be required if dewatering effluent is being returned to the watercourse.

[6] The installation of gauging stations may be required based on discussions with the Environment Agency.

Monitoring Advisory Sheet - SW2

To be used for:		
Monitoring type:	**Surface water**	
Impact type:	**Aquatic Ecology - Aquatic Macrophytes and Phytobenthos**	
Effect type:	**Amber**	*As reported in the WFD status risk screening tables*
	Yellow	
	Blue	
Impact magnitude:	**Any adverse**	*As reported in the CFA site specific 'potential impact on surface water receptors' summary table*

RECEPTOR	WHAT?	PHASE	Baseline (pre-construction)			Construction			Operation (post-construction)			AGREED MONITORING WITH THE EA
		HOW?	WHERE?	WHEN?		WHERE?	WHEN?		WHERE?	WHEN?		
		Method	Locations	Season	Duration	Locations	Season	Duration	Locations	Season	Duration	
SW body	**Aquatic macrophyte community abundance, species richness and distribution.**	*Standard LEAFPACS2 aquatic macrophyte survey method (see Appendix E for further details).*	*The location of monitoring will be dependant on the nature of the design element.*			*No surveys required during construction*			*The location of monitoring will be dependant on the nature of the design element.*			
			Where habitat loss/severance occurs (e g. culvert/bridge/viaduct placement), monitoring shall be undertaken at 2 sites; one upstream and one downstream within, as far as practically possible, 50m of the design element.	*Summer (June-August)*	*Single Survey*				*Where habitat loss/severance occurs (e.g. culvert/bridge/viaduct placement), monitoring shall be undertaken at 2 sites; one upstream and one downstream within, as far as practically possible, 50m of the design element.*	*Summer (June-August)*	*Single Surveys (one year post-construction and five-year post construction)*	
			Where habitat severance does not occur (e.g. river diversions/enhancements) monitoring shall be undertaken within the existing channel that will be affected by the design element. This shall be undertaken at a minimum of one location, or at a rate of one location per km of channel affected, whichever is the highest.	*Summer (June-August)*	*Single Survey*				*Where habitat severance does not occur (e.g. river diversions/enhancements) monitoring shall be undertaken within the existing or newly created channel associated with the design element.*	*Summer (June-August)*	*Single Surveys (one year post-construction and five-year post construction)*	
	Aquatic phytobent-hos community abundance and species richness.	*Standard DARLEQ2 aquatic phytobenthos survey method (see Appendix E for further details).*	*The location of monitoring will be dependant on the nature of the design element.*			*No surveys required during construction*			*The location of monitoring will be dependant on the nature of the design element.*			
			Where habitat loss/severance occurs (e g. culvert/bridge/viaduct placement), monitoring shall be undertaken at 2 sites; one upstream and one downstream within, as far as practically possible, 50m of the design element.	*Spring (March-May)* *OR* *Autumn (September-November)*	*Single Survey*				*Where habitat loss/severance occurs (e.g. culvert/bridge/viaduct placement), monitoring shall be undertaken at 2 sites; one upstream and one downstream within, as far as practically possible, 50m of the design element.*	*To be consistent with Baseline survey i.e. either:* *Spring (March-May)* *OR* *Autumn (September-November)*	*Single Surveys (one year post-construction and three-year post construction)*	
			Where habitat severance does not occur (e.g. river diversions/enhancements) monitoring shall be undertaken within the existing channel that will be affected by the design element. This shall be undertaken at a minimum of one location, or at a rate of one location per km of channel affected, whichever is the highest.	*Spring (March-May)* *OR* *Autumn (September-November)*	*Single Survey*				*Where habitat severance does not occur (e.g. river diversions/enhancements) monitoring shall be undertaken within the existing or newly created channel associated with the design element.*	*To be consistent with Baseline survey i.e. either:* *Spring (March-May)* *OR* *Autumn (September-November)*	*Single Surveys (one year post-construction and three-year post construction)*	

Notes

This Monitoring Advisory Sheet is part of the Water Resources and Flood Risk Monitoring Strategy and is intended to be used in conjunction with the Surface Water Decision Tree to inform the development of Water Resources and Flood Risk Monitoring Plans.

Aquatic macrophytes are good biological indicators of medium to long term functional changes in river w ater quality and habitat provision (through, for example, changes in chemical composition, flow and sediment dynamics). Where monitoring is required, pre-construction baseline and post-construc ion monitoring can help ensure that design elements have met heir ecological and WFD objectives in respect to he riverine environment.

Aquatic phytobenthos are good biological indicators of short to medium term func ional changes in river w ater quality and habitat provision (hrough, for example, changes in chemical composi ion, flow and sediment dynamics). Where monitoring is required, pre-construction baseline and post-construc ion monitoring can help ensure that design elements have met heir ecological and WFD objectives in respect to he riverine environment.

This advisory sheet provides overarching principles of how , w here and w hen aqua ic macrophyte or phytoben hos sampling is advisable. How ever, the decision to implement aquatic macrophyte or phytobenthos sampling shall take account of the nature of the local system affected by the design

For phytobenthos w here possible do not collect spring samples before mid spring (before mid-April).

For fur her details of the methods described for aquatic macrophyte and phytobenthos surveying, please refer to Appendix E Monitoring Ac ivity requirements.

Data held by HS2 and the Environment Agency shall be review ed spa ially and temporally to determine if existing information provides an appropriate proxy that negates the need for baseline monitoring.

Monitoring Advisory Sheet - SW3

To be used for:

Monitoring type: **Surface water**
Impact type: **Aquatic Ecology - Aquatic Macroinvertebrates**
Effect type: **Amber** / **Yellow** / **Blue** — *As reported in the WFD status risk screening tables*
Impact magnitude: **Any adverse** — *As reported in the CFA site specific 'potential impact on surface water receptors' summary table*

RECEPTOR	WHAT?	PHASE	Baseline (pre-construction)			Construction			Operation (post-construction)			AGREED MONITORING WITH THE EA
		HOW? Method	WHERE? Locations	WHEN? Season	Duration	WHERE? Locations	WHEN? Season	Duration	WHERE? Locations	WHEN? Season	Duration	
SW body	**Aquatic macroinvert-ebrate community abundance and species richness.**	*Standard RIVPACS aquatic macroinvertebrate survey (see Appendix E for further details).*	*The location of monitoring will be dependant on the nature of the design element.*			*Construction monitoring will only be required in response to a specific contamination event of the surface water body, with reference to the ongoing water quality monitoring.*			*The location of monitoring will be dependant on the nature of the design element.*			
			Where habitat loss/severance occurs (e.g. culvert/bridge/viaduct placement), monitoring shall be undertaken at 2 sites; one upstream and one downstream within, as far as practically possible, 50m of the design element.	*Spring (March-May) OR Autumn (September-November)*	*Single Survey*	*Monitoring shall be undertaken at one site upstream and at a minimum of one site downstream of the contamination source (assuming point source contamination event). Additional downstream sites may be required depending on the propogation of the event.*	*Non-seasonal. Sample to be collected as soon after the specific pollution event as practically possible.*	*Dependant on the severity of the event. Advice shall be sought from the regulator.*	*Where habitat loss/severance occurs (e.g. culvert/bridge/viaduct placement), monitoring shall be undertaken at 2 sites; one upstream and one downstream within, as far as practically possible, 50m of the design element.*	*To be consistent with Baseline survey i.e. either: Spring (March-May) OR Autumn (September-November)*	*Single Surveys (one year post-construction and three-year post construction)*	
			Where habitat severance does not occur (e.g. river diversions/enhancements) monitoring shall be undertaken within the existing channel that will be affected by the design element. This shall be undertaken at a minimum of one location, or at a rate of one location per km of channel affected, whichever is the highest.	*Spring (March-May) OR Autumn (September-November)*	*Single Survey*				*Where habitat severance does not occur (e.g. river diversions/enhancements) monitoring shall be undertaken within the existing or newly created channel associated with the design element.*	*To be consistent with Baseline survey i.e. either: Spring (March-May) OR Autumn (September-November)*	*Single Surveys (one year post-construction and three-year post construction)*	

Notes

This Monitoring Advisory Sheet is part of the Water Resources and Flood Risk Monitoring Strategy and is intended to be used in conjunction with the Surface Water Decision Tree to inform the development of Water Resources and Flood Risk Monitoring Plans.

Aquatic macroinvertebrates are excellent biological indicators of short to long term functional changes in river water quality and habitat provision (through, for example, changes in chemical composition, flow and sediment dynamics). Where monitoring is required, pre-construction baseline and post-construction monitoring can help ensure that design elements have met their ecological and WFD objectives in respect to the riverine environment.

This advisory sheet provides overarching principles of how, where and when aquatic macroinvertebrate sampling is advisable. However, the decision to implement aquatic macroinvertebrate sampling shall take account of the nature of the local system affected by the design element. For example, aquatic macroinvertebrate sampling on ephemeral ditches may not be advisable regardless of the nature of the modification.

For further details of the methods described for each of the techniques, please refer to Appendix E Monitoring Activity requirements.

Data held by HS2 and the Environment Agency shall be reviewed spatially and temporally to determine if existing information provides an approriate proxy that negates the need for baseline monitoring.

Monitoring Advisory Sheet - SW4

To be used for:		
Monitoring type:	**Surface water**	
Impact type:	**Aquatic Ecology - Fish**	
Effect type:	Amber	*As reported in the WFD status risk screening tables*
	Yellow	
	Blue	
Impact magnitude:	**Any adverse**	*As reported in the CFA site specific 'potential impact on surface water receptors' summary table*

RECEPTOR	WHAT?	PHASE	Baseline (pre-construction)			Construction			Operation (post-construction)			AGREED MONITORING WITH THE EA
		HOW?	WHERE?	WHEN?		WHERE?	WHEN?		WHERE?	WHEN?		
		Method	Locations	Season	Duration	Locations	Season	Duration	Locations	Season	Duration	
SW body	**Fish community species richness, density and standing crop (weight per unit area).**	*Electric fishing survey (see Appendix E for further details).*	*The location of monitoring will be dependant on the nature of the design element.*			*Construction monitoring will only be required in response to a specific contamination event of the surface water body, with reference to the ongoing water quality monitoring.*			*The location of monitoring will be dependant on the nature of the design element.*			
			Where habitat loss/severance occurs (e.g. culvert/bridge/viaduct placement), monitoring shall be undertaken at 2 sites; one upstream and one downstream within, as far as practically possible, 50m of the design element.	*March to October. Optimal period within this range will be partly informed by the structure of the fish assemblage and will need to be agreed with the regulator as part of licensing requirements.*	*Single Survey*	*Following a pollution event there may be a requirement to implement an ecological watching brief to target signs of fish stress. This watching brief may trigger the need for a fish rescue, depending on the severity of the event.*	*Non-seasonal.*	*Watching brief to be instated as soon as the specific pollution event has occured. Dependant on the severity of the event. Advice shall be sought from the regulator.*	*Where habitat loss/severance occurs (e.g. culvert/bridge/viaduct placement), monitoring shall be undertaken at 2 sites; one upstream and one downstream within, as far as practically possible, 50m of the design element.*	*March to October. Optimal period within this range will be partly informed by the structure of the fish assemblage and will need to be agreed with the regulator as part of licensing requirements.*	*Single Surveys (one year post-construction and three-year post construction)*	
			Where habitat severance does not occur (e.g. river diversions/enhancements) monitoring shall be undertaken within the existing channel that will be affected by the design element. This shall be undertaken at a minimum of one location, or at a rate of one location per km of channel affected, whichever is the highest.	*March to October. Optimal period within this range will be partly informed by the structure of the fish assemblage and will need to be agreed with the regulator as part of licensing requirements.*	*Single Survey*				*Where habitat severance does not occur (e.g. river diversions/enhancements) monitoring shall be undertaken within the existing or newly created channel associated with the design element.*	*March to October. Optimal period within this range will be partly informed by the structure of the fish assemblage and will need to be agreed with the regulator as part of licensing requirements.*	*Single Surveys (one year post-construction and three-year post construction)*	

Notes

This Monitoring Advisory Sheet is part of the Water Resources and Flood Risk Monitoring Strategy and is intended to be used in conjunction with the Surface Water Decision Tree to inform the development of Water Resources and Flood Risk Monitoring Plans.

Fish are good biological indicators of short to long term changes in river water quality and habitat provision (through, for example, changes in chemical composition, flow and sediment dynamics). Fish kills, observational signs of fish stress, and population displacement are all indicators of localised deterioration in water quality. Where monitoring is required, pre-construction baseline and post-construction monitoring can help ensure that design elements have met their ecological and WFD objectives in respect to the riverine environment.

This advisory sheet provides an overarching guide to the principles of how, where and when fish sampling is advisable. However, the decision to implement fish sampling shall take account of the nature of the local system affected by the design element. It shall also take account of the functional ecology of the populations present (i.e. if the assemblage dominated by fish with a low tolerance to environmental disturbance it will be a better indicator of local change).

For further details of the methods described for each of the techniques, please refer to Appendix C Monitoring Activity requirements.

Data held by HS2 and the Environment Agency shall be reviewed spatially and temporally to determine if existing information provides an approriate proxy that negates the need for baseline monitoring.

This advisory sheet does not include requirements for any fish captures or translocations that may be required as part of a specific design element, e.g. coffer damming or river channel realignment work. It is assumed these will be covered in the workpackages produced for individual design element

Monitoring Advisory Sheet - SW5

To be used for:		
Monitoring type:	**Surface water**	
Impact type:	**Hydromorphology**	
Effect type:	**Amber**	*As reported in the WFD status risk screening tables*
	Yellow	
	Blue	
Impact magnitude:	**Any adverse**	*As reported in the CFA site specific 'potential impact on surface water receptors' summary table*

RECEPTOR	WHAT?	PHASE HOW? Method	Baseline (pre-construction) WHERE? Locations	WHEN? Season	Duration	Construction WHERE? Locations	WHEN? Season	Duration	Operation (post-construction) WHERE? Locations	WHEN? Season	Duration	AGREED MONITORING WITH THE EA
Watercourse reach or SW body catchment depending on use of hydromorphological data	**Hydromorphology** Required monitoring for the following (large impact) scheme elements: River diversion/realignment, Culvert	*Reconnaissance (walkover) survey* *It would involve a fairly detailed assessment of the changes in geomorphological form and function using geo-referenced photos and mobile mappers at 1-2m resolution. The principal objective is to monitor channel change and monitor changes to habitat form as it evolves.*	*Scheme impact location plus upstream and downstream up to approximately 100m within site boundary. This could be extended up to 500m for sites that are impacted over a longer distance.*	*Not season specific but preferably at the same time as ecological surveys are carried out.*	*Single survey*	*Point photography is recommended during construction*			*Repeat survey approximately 3 months, 1, 3 and 5 years post construction.*	*Not season specific but preferably at the same time as ecological surveys are carried out.*	*Single survey*	
		Fixed point photography *Photographs taken at a set of identical locations before, during, just after and several years after the works.*	*Scheme impact location where changes will occur e.g. river diversions/realignments. It shall be carried out in conjunction with the reconnaissance survey.*	*Not season specific but preferably at the same time as ecological surveys are carried out.*	*Single survey*				*Repeat of survey approximately 3 months, 1, 3 and 5 years post construction.*	*Not season specific but preferably at the same time as ecological surveys are carried out.*	*Single survey*	
	Hydromorphology Required monitoring for the following scheme elements: Viaduct/Bridge with footing in the water body, Siphon, Drainage outfalls to watercourses, River bank protection	*Reconnaissance (walkover) survey* *It would involve an assessment of the changes in geomorphological form and function using geo-referenced photos and mobile mappers at 1-2m resolution. The resolution of monitoring could be less detailed than for large elements such as a river diversion/realignment and the length of the reach monitored could be less i.e. only at the scheme impact location and not up and downstream.*	*Scheme impact location*	*Not season specific but preferably at the same time as ecological surveys are carried out.*	*Single survey*				*Repeat survey approximately 3 months after construction. Further surveys unlikely to be required, unless perhaps a large hydrological event leads to concerns about channel stability.*	*NA*	*Single survey at 3 months and then Isolated surveys as required*	
		Fixed point photography *Photographs taken at a set of identical locations before, during, just after and several years after the works.*	*Scheme impact location where changes will occur e.g. where drainage outfalls are to be sited. It shall be carried out in conjunction with the reconnaissance survey.*	*Not season specific but preferably at the same time as ecological surveys are carried out.*	*Single survey*				*Repeat survey approximately 3 months after construction. Further surveys unlikely to be required, unless perhaps a large hydrological event leads to concerns about channel stability.*	*NA*	*Single survey at 3 months and then isolated surveys as required*	
	Detailed River datasets Additional monitoring may also be required for the following scheme elements especially where there are hydromorphological risks that could affect an asset: River diversion/realignment, Culvert, Siphon	*Topographic Surveys*	*Scheme location incorporating channel and surrounding floodplain.*	*NA*	*Single survey*				*Unlikely to need to be repeated post construction unless perhaps a large hydrological event leads to concerns about channel stability.*	*NA*	*Isolated surveys as required*	
		Repeat Cross sections	*Scheme location. The number of cross sections required will be dependent on length of river reach affected and how active the channel is at that point.*	*NA*	*Single survey*				*May be required where there are hydromorphological concerns. Frequency and locations of surveys will depend on site specific details.*	*Not season specific but preferably at the same time as ecological surveys are carried out.*	*Isolated surveys as required*	
	Habitats Additional monitoring may also be required for the following scheme elements: River diversion/realignment	*Habitat Mapping (RCS)* *Mapping vegetation structures along a watercourse and includes a map of physical habitat and a botanical survey.*	*Scheme impact location plus upstream and downstream up to approximately 250m within site boundary. This could be extended over 500m reaches for sites that are impacted over a longer distance.*	*Not season specific but preferably at the same time as hydromorphology reconnaissance surveys are carried out.*	*Single survey*				*Repeat survey approximately 3 months, 1, 3 and 5 years post construction.*	*Not season specific but preferably at the same time as hydromorphology reconnaissance surveys are carried out.*	*Single survey*	
		River habitats survey (RHS)			*Single survey*							
	Sediment Additional monitoring may also be required for the following scheme elements: Culvert Drainage outfalls to watercourses	*Sediment analysis could include: bed substrate analysis*	*Scheme impact location*	*Not season specific but preferably at the same time as other surveys are carried out.*	*Single survey*				*Repeat survey approximately 3 months after construction. Further surveys unlikely to be required, unless perhaps a large hydrological event leads to concerns about channel stability.*	*NA*	*Single survey at 3 months and then Isolated surveys as required*	
	Extended Reach studies Additional monitoring may also be required for the following scheme elements: Several river diversions/realignments (or other scheme elements) occurring within close proximity and affect the same river reach/water bodies.	*Larger reconnaissance survey*	*Extended reach including all scheme impact locations plus upstream and downstream to appropriate reach boundaries.*	*Not season specific but preferably at the same time as ecological surveys are carried out.*	*Single survey*				*Repeat survey approximately 3 months after construction. Further surveys unlikely to be required, unless perhaps a large hydrological event leads to concerns about channel stability.*	*NA*	*Single survey at 3 months and then Isolated surveys as required*	

Monitoring Advisory Sheet - SW5

Notes

This Monitoring Advisory Sheet is part of the Water Resources and Flood Risk Monitoring Strategy and is intended to be used in conjunction with the Surface Water Decision Tree to inform the development of Water Resources and Flood Risk Monitoring Plans.

Hydromorphological monitoring is required to assess, manage and mitigate any hydromorphological risks associated with the scheme, as well as being useful to monitor scheme channel diversions to ensure appropriate habitat recovery, and also to check for WFD compliance.

Each hydromorphological study per Scheme location will need to be bespoke taking into account site specific objectives, targets, local hydromorphological parameters (such as given the location, the geology, gradient, planform, sediment, scale, land use) and risks and uncertainties associated with the scheme. Below is a generic guide to inform the type of monitoring that is likely to be required per scheme element type:
For all scheme elements hydromorphological monitoring will require a form of reconnaissance survey combined with fixed point photography; however the resolution and frequency of survey can be tailored to the likely impact and site specific data.
For some scheme elements additional hydromorphological monitoring may also be useful, especially in terms of assessing ongoing risks during the operational phase.
For river diversions habitat data could be collected at the same time as reconnaissance surveys to support analysis of whether appropriate hydroecological targets have been met.

For further details on method descriptions for each of the techniques please refer to Appendix C Monitoring Activity requirements where references can be found. Additional surveys may be required post significant channel forming events.

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Appendix B – Case study: using the water resources and flood risk monitoring strategy decision trees and monitoring advisory sheets

1 Introduction

1.1 Case study notes

1.1.1 To help with the implementation of the Water Resources and Flood Risk Monitoring Strategy Decision Trees and Monitoring Advisory Sheets, this appendix provides a worked example based on Scheme element Burton Green Tunnel (CFA18 – Stoneleigh, Kenilworth and Burton Green).

1.1.2 This appendix contains versions of the following Water Resources and Flood Risk Monitoring Strategy tools, completed with information regarding Burton Green Tunnel in purple text:

- Groundwater Decision Tree; and
- Groundwater Monitoring Advisory Sheets GW1, GW2 and GW3.

1.1.3 This worked example covers steps 1 to 4 of the 'step by step' guide shown in Figure 2 of the Water Resources and Flood Risk Monitoring Strategy. Steps 5 and 6, which involve looking for monitoring efficiencies between scheme elements and between surface water and groundwater, have not been illustrated in this Appendix.

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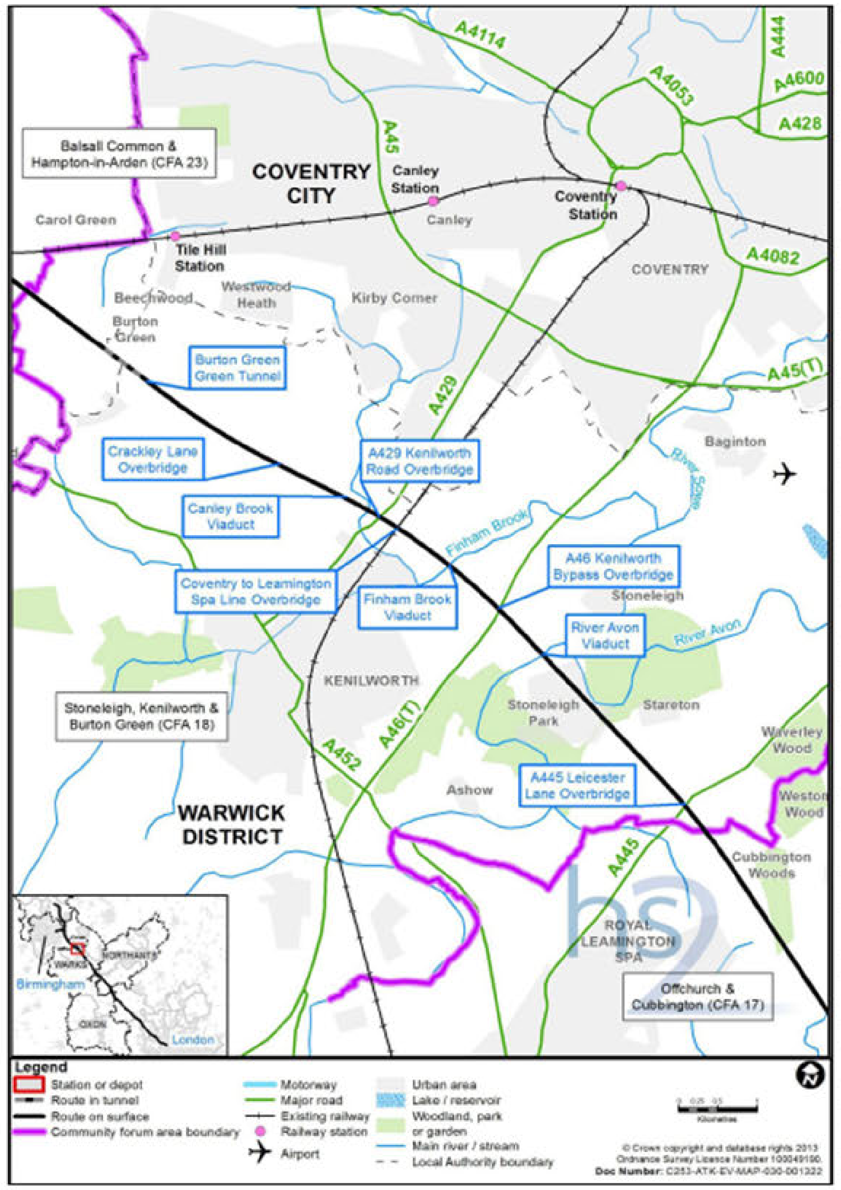
Groundwater Monitoring Decision Tree – Part 1

CFA Report – Stoneleigh, Kenilworth and Burton Green/No 18 | Overview of the area and description of the Proposed Scheme

Figure 2: Area context map



Illustrated for **Burton Green Tunnel**

START **WFD scale impacts**

PART 1

Q1 Which WFD GW bodies are affected by the scheme element(s)?

Ref: ES groundwater WFD assessments (summary table)

GB40902G302200 (Principal) - Warwickshire Avon - Coal Measures Coventry

Go to Q2

Q2 Identify the most up to date assessments for each scheme element which affects a groundwater body. Are more detailed assessments required for one or more of the following reasons?

- To confirm assumptions;
- For consenting purposes;
- For design purposes;
- Changes have been made to planned activities; and
- Additional activities are planned.

Ref: ES groundwater WFD assessments (status risk screening tables) and subsequent assessments

Technical Standards - Groundwater Protection, Land Quality and Water Resources and Flood Risk Consenting Strategy

YES GB40902G302200, "reassess once site investigation and monitoring data available"

- Identify data requirements for detailed assessments
- Collect additional required data
- Undertake detailed assessments
- Update WFD status risk screening tables for GW bodies

Ref: Technical Standards - Groundwater Protection, Land Quality and Water Resources and Flood Risk Consenting Strategy

Go to Q3

Q3 For each scheme element, what impact type/effect type combinations have been identified in the most up to date WFD status risk screening tables?

Ref: ES groundwater WFD assessments (status risk screening tables)

Use the table to identify recommended monitoring requirements for scheme element based on impact type / effect type combinations?

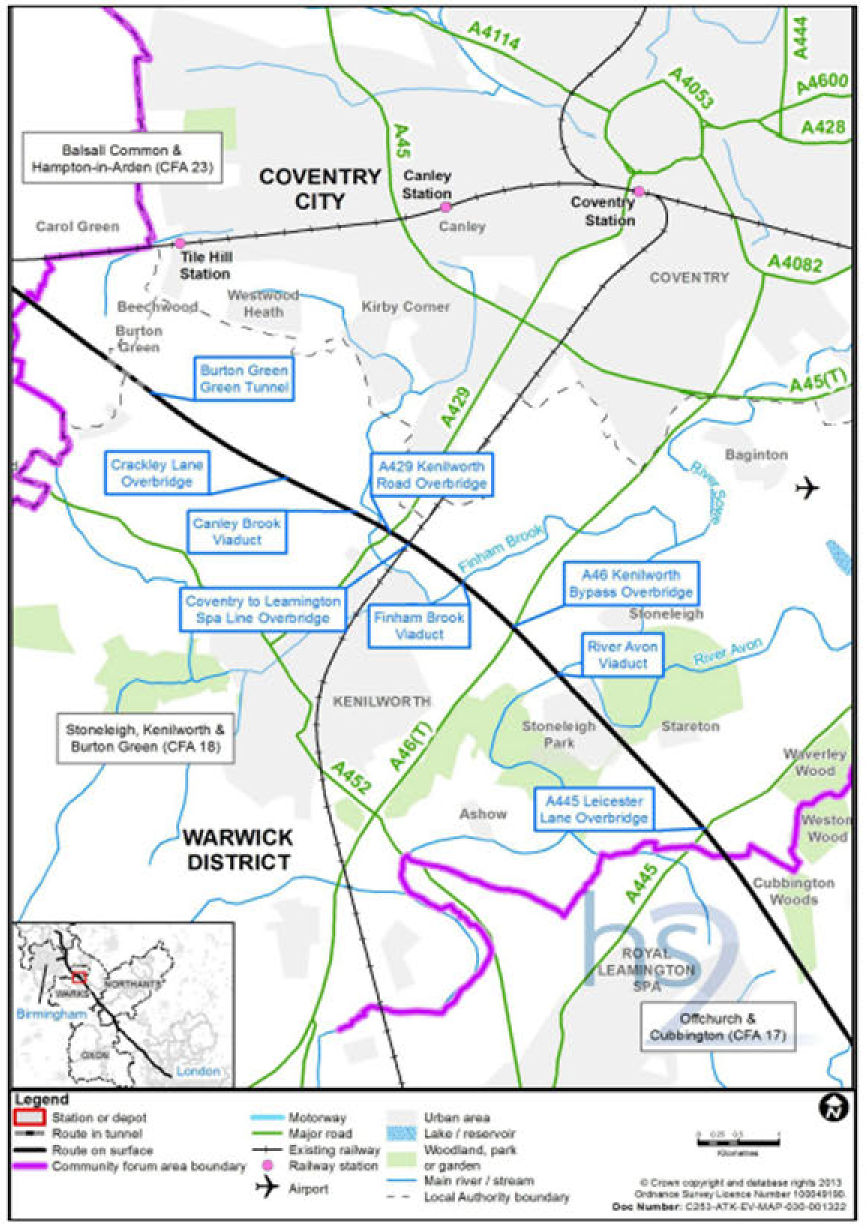
		Effect type			
WFD classification element category	**Impact type**	**Green**	**Yellow**	**Amber**	**Red**
QUANTITATIVE	**Dewatering**	*No specific WFD GW monitoring required - adhere to CoCP and PPGs*	*Advisory sheet - GW3*	*Advisory sheet - GW1*	*Consult directly with EA*
	Damming				
CHEMICAL	**Pathways**			*Advisory sheet - GW2*	
	Contamination				

Scheme element	**Receptor**	**Impact type**	**Effect type**	**Advisory Sheet**
Burton Green Tunnel	GB40902G302200	QUANTITATIVE	Amber	**GW1**
Burton Green Tunnel	GB40902G302200	CHEMICAL	Yellow	**GW3**

Go to Part 2

Groundwater Monitoring Decision Tree – Part 2

CFA Report – Stoneleigh, Kenilworth and Burton Green/No 18 | Overview of the area and description of the Proposed Scheme
Figure 2: Area context map



Illustrated for **Burton Green Tunnel**

Site scale impacts

PART 2

Q4 For each scheme element, does it have a magnitude of impact with no mitigation for any groundwater receptor of greater than 'Negligible' in the appropriate ES CFA potential impact summary table and/or greater than 'very low' in any subsequent assessment?

Ref: ES Water Resources Assessment for CFA of interest (summary of potential impacts to groundwater table) and subsequent assessments
Technical Standards - Groundwater Protection, Land Quality and Water Resources and Flood Risk Consenting Strategy

YES

Go to Q5

Q5 What type of impact on the groundwater receptor(s) has been identified?

Use the table to identify recommended monitoring requirements for scheme element based on impact type

Impact type		
QUANTITATIVE	Dewatering	*Advisory sheet - GW1*
	Damming	
CHEMICAL	Pathways	*Advisory sheet - GW2*
	Contamination	

Scheme element	Receptor	Impact type	Impact magnitude	Advisory Sheet
Burton Green Tunnel	Principal bedrock aquifer: Bromsgrove Sandstone Formation, Kenilworth Sandstone Group, Ashow Formation and the Tile Hill Mudstone Formation	Quant & Chem	Moderate adverse	GW1 and 2
Burton Green Tunnel	Black Waste Wood	Quant	Moderate adverse	GW1
Burton Green Tunnel	Big Poors and Little Poors Wood	Quant	Minor adverse	GW1
Burton Green Tunnel	Issues and watercourse near Black Waste Wood	Quant	Moderate adverse	GW1
Burton Green Tunnel	Ponds x 2 - removed during construction	Quant	Major adverse	GW1

END

Groundwater Monitoring Advisory Sheets

Monitoring Advisory Sheet - GW1
Example based on Burton Green Tunnel (CFA18)
To be used for:

Monitoring type:	**Groundwater**	
Impact type:	**Quantitative**	
Effect type:	**Amber**	**WFD status risk screening table text for Burton Green Tunnel** Crosses Big Poors & Little Poors Wood LWS and near to Black Waste Wood AW, both potential GWDTEs. Cutting crosses Kenilworth to Balsall Railway Embankment LWS and is near to Beanit Farm Hedge LWS; neither considered GWDTE. Loss of habitat beneath scheme element footprint not assessed. Embedded mitigation to reintroduce water to ground via SuDS to the SE downstream of tunnel. Localised impacts possible.
Impact magnitude:	**Adverse**	**Site scale impacts - receptors adversely impacted by Burton Tunnel** Principal bedrock aquifer: Bromsgrove Sandstone Formation, Kenilworth Sandstone Group, Ashow Formation and the Tile Hill Mudstone Formation Black Waste Wood Big Poors and Little Poors Wood Issues and watercourse near Black Waste Wood

RECEPTOR	WHAT?	PHASE	Baseline (pre-construction)			Construction			Operational (post-construction)			AGREED MONITORING WITH EA
		HOW?	WHERE?	WHEN?		WHERE?	WHEN?		WHERE?	WHEN?		
		Method	Locations	Frequency	Duration	Locations	Frequency	Duration	Locations	Frequency	Duration[8]	
Disturbed aquifer(s) (i.e. dewatered, dammed, connected to other aquifers)	**GW level**	*Standard monitoring*										
		Logger measurements *Dips*	*Minimum of 3 x monitoring boreholes in each disturbed aquifer - one up and two down hydraulic gradient of the disturbance, including at least one between disturbed zone and each flagged receptor in the ES*	*Hourly* *Monthly*	*Minimum 12 months*	*As baseline*	*Hourly* *Weekly during any active construction operations*	*Throughout construction phase*	*As baseline*	*Hourly* *Monthly*	*2 years post construction unless agreed otherwise with EA*	**Monitoring boreholes in disturbed aquifer (Tile Hill Mudstone) to meet the following criteria:** **- 1 x borehole up hydraulic gradient and 2 x down gradient of Burton Green Tunnel** **- 1 x borehole between Burton Green Tunnel and Black Waste Wood (and associated watercourse/ issues)** **- 1 x borehole between Burton Green Tunnel and Little Poors Wood** **- 3 x boreholes per pumping well used for dewatering** **NB - monitoring borehole may be used to meet more than one of the listed criteria**
		Additional monitoring if dewatering operations taking place										
		Logger measurements *Dips*	*At least 3 x monitoring boreholes per pumping well where dewatering taking place - one up and two down (background) hydraulic gradient of the pumping well at different radial distances*	*Hourly* *Monthly*	*Minimum 12 months*	*As baseline*	*Hourly* *Weekly during any dewatering operations*	*Throughout construction phase*	*As baseline*	*Hourly* *Monthly*	*2 years post construction unless agreed otherwise with EA*	
	Abstraction rate	*Flow meter*	*Pumping well*	*Hourly*			*Hourly*			*Hourly*		
Choose monitoring specification for other appropriate receptor(s) flagged in the ES												
SW body - watercourse	**SW flow**	*Logger measurements*	*Gauging stations (if already in situ) upstream and downstream of the SW body reach down hydraulic GW gradient of disturbance*	*Hourly*	*Minimum 12 months*	*As baseline*	*Hourly*	*Throughout construction phase*	*As baseline*	*Hourly*	*2 years post construction unless agreed otherwise with EA*	**na**
		Current/flow meter	*2 x spot flow locations, upstream and downstream of the SW body reach down hydraulic GW gradient of disturbance*	*Monthly*			*Weekly during any dewatering operations*			*Monthly*		**2 x spot flow locations on the watercourse near Black Waste Wood, upstream and downstream of Burton Green Tunnel**
	SW quality	*Field measurements*		*Monthly (temperature & conductivity)*			*Weekly during any dewatering operations (temperature & conductivity)*			*Monthly (temperature & conductivity)*		
	SW level[2]	*Logger measurements* *Dips*	*2 x stilling well locations, upstream and downstream of the SW body reach down hydraulic GW gradient of disturbance*	*Hourly* *Monthly*			*Hourly* *Weekly during any dewatering operations*			*Hourly* *Monthly*		**na**
Spring	**Flow**	*Logger measurements*	*Spring gauging location (if already in situ)*	*Hourly*	*Minimum 12 months*	*As baseline*	*Hourly*	*Throughout construction phase*	*As baseline*	*Hourly*	*2 years post construction unless agreed otherwise with EA*	**na**
		Various	*Spring discharge point*	*Monthly*			*Weekly during any dewatering operations*			*Monthly*		**Issues discharge location near Black Waste Wood (if feasible)**
GWDTE	**GW level**	*Logger measurements*	*Minimum of 1 x monitoring borehole, located in the GWDTE, completed in each affected aquifer*	*Hourly*	*Minimum 12 months*	*As baseline*	*Hourly*	*Throughout construction phase*	*As baseline*	*Hourly*	*2 years post construction unless agreed otherwise with EA*	**Monitoring boreholes in the superficial deposits and disturbed aquifer (Tile Hill Mudstone Formation) at Black Waste Wood and Little Poors Wood** **NB - Little Poors Wood is located between Burton Green Tunnel and Big Poors Wood, therefore monitoring at Big Poors is likely to be unnecessary)**
		Dips	*Minimum of 1 x monitoring borehole completed in any superficial deposits present in the GWDTE*	*Monthly*			*Weekly during any dewatering operations*			*Monthly*		

Monitoring Advisory Sheet - GW2

Example based on Burton Green Tunnel (CFA18)

To be used for:

Monitoring type:	Groundwater	
Impact type:	Chemical	
Effect type:	Amber	WFD status risk screening table text for Burton Green Tunnel None
Impact magnitude:	Adverse	Site scale impacts - receptors adversely impacted by Burton Tunnel Principal bedrock aquifer: Bromsgrove Sandstone Formation, Kenilworth Sandstone Group, Ashow Formation and the Tile Hill Mudstone Formation (potential introduction of contaminants during construction)

RECEPTOR	WHAT?	PHASE	Baseline (pre-construction)			Construction			Operational (post-construction)			
		HOW? Method	WHERE? Locations	WHEN? Frequency	Duration	WHERE? Locations	WHEN? Frequency	Duration	WHERE? Locations	WHEN? Frequency	Duration	AGREED MONITORING WITH EA
Disturbed aquifer(s) (i.e. dewatered, dammed, connected to other aquifers, exposed to potential contaminants)	*Standard monitoring where exposure to potential contaminants during construction*											
	GW level	*Dips*	*Minimum of 3 x monitoring boreholes in each disturbed aquifer - one up and two down hydraulic gradient of the disturbance, including at least one between disturbance and each flagged receptor in the ES*	*Monthly*	*Minimum 12 months*	*As baseline*	*Weekly*	*Throughout construction phase*	*As baseline*	*Monthly*	*2 years post construction unless agreed otherwise with EA*	Monitoring boreholes in disturbed aquifer (Tile Hill Mudstone) to meet the following criteria: - 1 x borehole up hydraulic gradient and 2 x down gradient of Burton Green Tunnel
	GW quality	*Field measurements*										
		Samples (purged)		*Monthly (core suite), quarterly (full suite)*			*Weekly (core suite), monthly (full suite)*			*Monthly (core suite), quarterly (full suite)*		
		Visual (post purge)		*Monthly*			*Weekly*			*Monthly*		

Monitoring Advisory Sheet - GW3

Example based on Burton Green Tunnel (CFA18)

To be used for:

Monitoring type:	Groundwater	
Impact type:	Quantitative and chemical	
Effect type:	Yellow	WFD status risk screening table for Burton Green Tunnel

RECEPTOR	WHAT?	PHASE	Baseline (pre-construction)			Construction			Operational (post-construction)			
		HOW? Method	WHERE? Locations	WHEN? Frequency	Duration	WHERE? Locations	WHEN? Frequency	Duration	WHERE? Locations	WHEN? Frequency	Duration	AGREED MONITORING WITH EA
Disturbed aquifer(s) (i.e. dewatered, dammed, connected to other aquifers, exposed to potential contaminants)	GW level	*Logger measurements*	*Minimum of 1 x monitoring borehole up hydraulic GW gradient and 1 x monitoring borehole down hydraulic GW gradient per 500 m of route, within aquifers potentially affected by the scheme*	*na*	*Minimum 12 months*	*As baseline*	*na*	*Throughout construction phase*	*As baseline*	*na*	*2 years post construction unless agreed otherwise with EA*	Minimum of 1 x monitoring borehole up hydraulic GW gradient and 1 x monitoring borehole down hydraulic GW gradient per 500 m of route within disturbed aquifer (Tile Hill Mudstone) NB - in practice it is likely that this monitoring requirement will have already been met by the monitoring specified by GW1 and GW2
		Dips		*Monthly*			*Fortnightly*			*Monthly*		
	GW quality	*Field measurements* [3]		*Monthly (core suite)*			*Fortnightly (core suite)*			*Monthly (core suite)*		
		Samples (purged) [4]										
		Visual (post purge)										

Appendix C – Site selection for monitoring locations

1 Introduction

1.1.4 The purpose of this appendix is to provide general guidelines for the selection of sites for groundwater monitoring borehole installation, surface water monitoring point installation and hydromorphological/ecological surveys across the Scheme. These guidelines are not exhaustive and should routinely be reviewed and updated as new information or guidance becomes available.

2 Groundwater

2.1 General principles

2.1.1 The following general guidelines should apply to the siting of groundwater monitoring boreholes:

- Monitoring boreholes should generally be located within 500m of the Scheme in areas where consents will not be required, with the exception of where monitoring is required in or close to a sensitive receptor which is at a greater distance;
- Monitoring boreholes should be located in an area where they are less likely to be affected by construction works (i.e. not within a cutting footprint), but remain close enough to the Scheme to detect potential impacts. This is to ensure that these boreholes form part of a long-term monitoring network and remain accessible throughout the entire construction and operation period;
- Monitoring boreholes should be easily accessible, both in terms of physical setting and in terms of landowner permission;
- The number and array of monitoring boreholes should be selected using a risk-based approach and should be based on the potential impacts of the scheme elements identified through the ES/SES;
- Should existing monitoring or observation boreholes be available and suitably sited for this purpose, permission should be sought to include these within the

monitoring network for a specified duration[8]; and

- Where possible, groundwater monitoring boreholes should be combined with boreholes for other purposes, such as geotechnical investigation or gas monitoring, provided all monitoring requirements are met by the borehole specification.

2.2 Where excavation is required

2.2.1 The following general guidelines should apply to the siting of groundwater monitoring boreholes where excavation is required:

- A ground investigation monitoring borehole should be installed in each aquifer (defined by observed hydraulic response and/or expert hydrogeological review) penetrated by an excavation to determine if groundwater is likely to be encountered during construction;
- If groundwater is encountered, the number and array of monitoring boreholes installed, where excavation is required and sensitive receptors are present, should be sufficient to determine the local horizontal and vertical direction of groundwater flow within each aquifer or hydrogeological unit and each groundwater body. Typically this will consist of three monitoring boreholes installed within each aquifer and arranged in a triangular pattern;
- Where receptors (surface water bodies, GWDTE's or groundwater abstractions) have been identified as being at-risk, monitoring boreholes should be located between the Scheme and the receptor within each aquifer potentially affected by the scheme. This is for the purpose of providing an early warning system of unacceptable changes in water quality or levels at the receptor; and
- Where GWDTE's have been identified as being at-risk (following pre-baseline assessment) and are to be investigated, at least one monitoring borehole per aquifer potentially affected by the Scheme (including any superficial deposits), subject to Environment Agency and Natural England approval in discussion with HS2. This is to determine the vertical hydraulic gradients and to confirm the GWDTE status. Particular care should be taken during installation to ensure that the borehole does not alter existing flow conditions within the site.

[8] Assuming sufficient geological and construction detail is available to ensure the boreholes meet the criteria included in Appendix D and monitoring data is usable.

2.3 Where dewatering[9] may be required

2.3.1 In addition to the principles outlined in section 2.1 and section 2.2, the following general guidelines should apply to the siting of groundwater monitoring boreholes where groundwater dewatering/control may be required:

- A ground investigation monitoring borehole should be installed in each aquifer (defined by observed hydraulic response and/or expert hydrogeological review) penetrated by an excavation to determine if groundwater is likely to be encountered during construction;
- If groundwater is likely to be encountered, the number and array of monitoring boreholes should be sufficient to monitor the effects of aquifer testing (i.e. pumping tests), groundwater dewatering/control or the discharge of pumped water;
- To that end, at least three monitoring boreholes for each pumping well should be installed where groundwater dewatering/control is likely to be required (i.e. cutting) and per aquifer potentially affected by the Scheme;
- The monitoring boreholes should ideally be arranged radially at different distances from the pumping well, to identify boundary conditions and any anisotropy. The spacing of the monitoring boreholes from the pumping well should be based on lithology, on an indication of aquifer transmissivity (BS, 2003b) and on available space;
- Monitoring locations should take into account the site-specific conceptual model of risk and the estimated radius of influence (RoI) of groundwater dewatering/control, as defined through the ES/SES and following ground investigation works; and
- Should dewatering not be required, the ground investigation boreholes should not be decommissioned but used to identify any changes in groundwater levels over time.

[9] The term dewatering is used to cover both dewatering by pumping and lowering of groundwater levels and depressurisation by lowering of hydraulic pressures within a confined or low permeability aquifer.

2.4 Where contamination is anticipated to be encountered

2.4.1 The following general guidelines should apply to the siting of groundwater monitoring boreholes where a "significant area of contamination"[10], as identified within the ES/SES, is anticipated to be encountered:

- A ground investigation monitoring borehole should be installed in each aquifer (defined by observed hydraulic response and/or expert hydrogeological review) potentially affected by construction as close as possible to the source to confirm the presence of contamination in groundwater;
- Should contamination be encountered, the number and array of monitoring boreholes installed should be selected using a risk-based approach. At least three monitoring boreholes should be installed in each aquifer to determine the local horizontal and vertical direction of groundwater flow: at least one located between the identified source and the Scheme. In addition one borehole should be located between the source and each sensitive receptor;
- Should no contamination be encountered, ground investigation boreholes should not be decommissioned but used to identify any changes in groundwater quality over time.

3 Surface water: quality and quantity

3.1 General principles

3.1.1 The following general principles should apply to the siting of surface water monitoring points and be taken into account to reduce subjectivity and to ensure accurate data is obtained consistently and safely:

- Routine surface water monitoring locations should be located upstream and downstream of the main construction works and should form part of a long-term monitoring network, accessible throughout the entire baseline, construction and operational phases; during the construction phase, additional surface water monitoring locations should be located as close to the point of impact on a specific watercourse as possible (with the exception where monitoring is required in a sensitive receptor which is at a greater distance

[10] A risk-based approach will be taken in accordance with the Environment Agency and DEFRA guidance in order to investigate "significant areas of contamination". Prior to investigation, these are considered to be where past uses of land indicate a high risk of previous significant contamination and potential risk to receptors. These are urban areas, in particular London and Birmingham, localised industries, old and existing landfill sites, old sewage farms and other issues that need to be assessed with respect to contaminative effects (see Volume 5 Technical Appendices – Scope and Methodology Report (HS2, 2013b) and Scope and Methodology Report Appendum (HS2, 2013c)).

from the point of impact);

- Surface waterbodies should be considered as both a receptor and a pathway, therefore requiring a site-specific approach to selecting surface water monitoring points. This approach should be based on:
  - Direct impacts from a Scheme element, whereby the surface water monitoring locations should be situated as close to the point of impact as possible, and
  - Indirect impacts from a Scheme element, whereby the surface water monitoring locations may need to be situated some distance from the point of impact, where a surface waterbody may be acting as a pathway to a different surface waterbody or sensitive receptor.
- A network of flow monitoring locations should be situated along linear, flowing surface water bodies (i.e. main rivers, canals, ordinary watercourses) affected by the Scheme to determine the hydrometric scheme and flow regime, with a minimum of two monitoring locations being considered, one upstream and one downstream of the scheme element;
- A single water level monitoring location should be sufficient to record water level in static or impounded surface water bodies (i.e. lakes, wetlands, reservoirs), depending on size/complexity;
- Where the Scheme crosses or intersects a static or impounded surface water body, there should be a minimum of two water level monitoring locations, situated either side of the Scheme crossing/intersection;
- The distance between surface water monitoring locations in a flowing watercourse should be determined on a site-specific basis, with reference to the hydraulic and hydrological characteristics of the watercourse and any associated tributaries/distributaries;
- Should existing flow/level monitoring structures (e.g. gauging stations, weirs, flumes, stilling wells) be available and suitably sited for this purpose, permission should be sought to include these within the monitoring network for a specified duration. Further detail should be provided within specific LEMPs; and
- Flow and/or level monitoring locations should take into account existing permanent flow/level monitoring structures to transpose/extrapolate recorded flows and/or levels at Scheme monitoring locations across a broader range of flows and/or levels collected over a greater time period.

3.2 Where dewatering may be required

3.2.1 In addition to those listed under general principles, the following guidelines should apply to the siting of surface water monitoring locations where dewatering or depressurisation is likely to be required:

- For the purposes of observing the effects on flowing surface water bodies from dewatering (during testing or construction) and groundwater control (during operation), at least two surface water monitoring locations should be setup within each risk area. These monitoring locations should be situated upstream, and immediately downstream of the predicted RoI of dewatering and both upstream of where the dewatering discharge is returned to the watercourse;
- Additional surface water monitoring locations should be considered where there is likely to be more than one direct impact on an individual surface water body (i.e. where the surface water body itself is considered to be the receptor), and situated as close to the point of impact as practically possible;
- Additional surface water monitoring locations should also be considered where there is likely to be indirect impacts on a surface water body or receptor at distance from the immediate area of direct impact e.g. changes in surface water flows may lead to reduced flow affecting a surface water abstraction downstream of the risk area; and
- A monitoring point for the specific purpose of monitoring the effect of dewatering discharge quality should be included.

3.3 Where drainage works are required

3.3.1 In addition to those listed under the General Principles of this appendix, the following guidelines should apply to the siting of surface water monitoring locations where drainage works (e.g. drainage ditches, culverts and diversions/realignments) are likely to be required:

- For the purposes of observing the effects on all surface water bodies from drainage works during construction and operation, at least 2 two surface water monitoring locations should be setup within each risk area. These monitoring locations should be situated upstream and downstream of the Scheme, ensuring all outfalls fall within the risk area;
- Additional surface water monitoring locations should be considered where there is likely to be more than one direct impact on an individual surface water body and situated as close to the point of impact as practically possible;
- Where multiple impacts are likely to occur on one surface water body (i.e.

multiple individual culverts within the same catchment), the number and array of surface water monitoring locations installed should be selected using a risk-based approach; and

- Additional surface water monitoring locations should also be considered where there is likely to be indirect impacts on a surface water body or receptor at distance from the immediate area of direct impact (e.g. changes in surface water flows may lead to reduced flow affecting a surface water abstraction downstream of the risk area).

3.4 Where contamination is anticipated to be encountered

3.4.1 In addition to those listed under general principles, the following guidelines should apply to the siting of surface water monitoring locations where a "significant area of contamination" is anticipated to be encountered:

- Where a "preview" monitoring borehole has confirmed the presence of contamination in groundwater, surface water quality monitoring locations should be situated as close to the potential point of impact as practically possible, to provide an early warning system of potential changes in surface water quality for the Scheme;
- The number of surface water monitoring locations should be increased where required using a risk-based approach in relation to any identified sensitive receptors (such as water-dependent SSSI); and
- The array of surface water monitoring locations should be determined by the function of the water body acting as a receptor and/or pathway to other receptors downstream, in order to provide an early warning system of potential changes in surface water quality as a result of or the Scheme.

4 Surface water: hydromorphology

4.1 General principles

4.1.1 The following general principles should apply to developing hydromorphological studies (with specific reference to choosing monitoring locations) and be taken into account to reduce subjectivity and to ensure accurate data is obtained consistently and safely:

- A hydromorphological study is required wherever the Scheme will affect the morphology of the channel (such as watercourse alteration, watercourse structures or bed or bank protection, drainage entering the channel or hydromorphological enhancements linked to the scheme);

- A hydromorphological study would normally comprise an initial desk-based assessment of existing reports, analyses and aerial photography followed by field based surveys at the Scheme impact locations;
- Typically field based surveys should focus on the area immediately adjacent to the scheme (typically 100m up and downstream of the scheme element) within the scheme boundary;
- Field based survey development should be informed by the desk-based assessment (for example areas where the Scheme could lead to geomorphological instability or where a channel is to be realigned, specific types of field monitoring would be required);
- Hydromorphological monitoring (such as fixed-point photography, cross-sections, topographic surveys or bed substrate sampling) would take place within the Scheme impact area. The number and frequency of data collection points for each type of survey would be dependent on the potential magnitude and scale of hydromorphological change and the risks/opportunities that this may create;
- Where the Scheme poses a risk of cumulative impacts along a river reach, or there is a sensitive receptor (such as protected species or an internationally designated site) a larger reach scale assessment may be required to provide a greater level of detail about sediment dynamics within a larger reach or catchment based context; and
- Each hydromorphological study per Scheme location will need to be bespoke taking into account site-specific objectives, targets, local hydromorphological parameters (such as given the location, the geology, gradient, planform, sediment, scale, land use) and risks and uncertainties associated with the scheme.

5 Surface water: aquatic ecology

5.1 General principles

5.1.1 Ecological monitoring of some description is likely to be required wherever the Scheme will affect the water quality, hydrology or morphology of the riverine environment (such as channel diversions/realignments, watercourse structures or enhancements linked to the scheme).

5.1.2 Appendix A provides overarching principles of how, where and when aquatic ecological sampling is advisable. However, the decision to implement aquatic ecological sampling should take account of the nature of the local system affected by the design element.

For example, aquatic macrophyte sampling on a heavily shaded system or aquatic macroinvertebrate sampling on an ephemeral system may not be advisable, regardless of the Scheme element.

5.1.3 The location of monitoring sites will be dependent on the nature of the design element, and it is therefore critical that an aquatic ecologist is involved in the survey design process. However, the following broad principles will generally apply:

- Where habitat loss/severance occurs (e.g. culvert/bridge/viaduct placement), baseline and post-construction monitoring should be undertaken at 2 sites; one upstream and one downstream within, as far as practically possible, 50m of the design element;
- Where habitat severance does not occur (e.g. river diversions/realignments/enhancements), baseline monitoring should be undertaken within the existing channel that will be affected by the design element. This should be undertaken at a minimum of one location, or at a rate of one location per km of channel affected, whichever is the highest;
- Where habitat severance does not occur (e.g. river diversions/realignments/enhancements) post-construction monitoring should be undertaken within the existing or newly created channel associated with the design element.

5.1.4 Further details on the timing and duration of ecological sampling are provided in Appendix A.

Appendix D – Monitoring location specification

1 Introduction

1.1.1 The purpose of this appendix is to provide general guidelines for the design and installation of groundwater and surface water monitoring points for the Scheme. These guidelines are not exhaustive and should routinely be reviewed and updated as new information or guidance becomes available.

2 Groundwater

2.1 Guidance

2.1.1 Groundwater monitoring point design and installation should take into account the relevant British Standards, industry guidance and best practice, such as:

- British Standard ISO 5667-22: 2010 Guidance on the design and installation of groundwater monitoring points;
- British Standard EN ISO 22475-1: 2006 Geotechnical investigation and testing — Sampling methods and groundwater measurements — Part 1: Technical principles for execution;
- British Standard ISO 5667-11: 2009 Water quality – Sampling – Part 11: Guidance on sampling of groundwater;
- Environment Agency (2006), Guidance on the design and installation of groundwater quality monitoring points, Science Report SC020093;
- British Standard EN ISO 22282-4:2012, Geotechnical investigation and testing - Geohydraulic testing – Pumping tests;
- British Standard ISO 14686: 2003, Hydrometric determinations – Pumping tests for water wells – Considerations and guidelines for design, performance and use; and
- Sterrett, R.J. (2007) Groundwater and wells, 3rd edition. Johnson Screens, New Brighton, MN, USA.

2.2 Open or closed monitoring systems

2.2.1 In general, open systems should be used for measuring groundwater levels in medium to high permeable soils and rock (i.e. not clays or fine silts). An open system consists of a filter pack and slotted piezometer pipe which permits equilibrium with atmospheric pressure (BSI, 2006a).

2.2.2 Consideration should be given to using a closed system in soils and rock with very low permeability or in artesian conditions. It is suitable for measuring rapid changes in pore pressure in low permeable soils and rock or for measuring artesian conditions (BSI, 2006a).

2.3 Monitoring borehole specification

2.3.1 Where more than one aquifer or hydrogeological horizon is present, multiple boreholes at different depths should be installed. Nested piezometers[11] should not be used.

2.3.2 All monitoring boreholes should have a minimum drilling diameter of approximately 150mm (6"), have a minimum installation internal diameter of 50mm (2") and a minimum annulus of 50mm (HS2, 2014a) either side of the installation for the filter pack.

2.3.3 The standpipe or piezometer casing should consist of a material that does not significantly interact with or otherwise modify (through sorption, leaching or other chemical reaction) the composition of the groundwater or contaminants in the ground (BSI, 2010). In general, the tubing should consist of un-plasticised polyvinylchloride (uPVC) or high-density polyethylene (HDPE) unless otherwise specified.

2.3.4 The response zone should be created by installing a suitably sized filter pack (see paragraph 2.3.7 and Figure 6) in the annulus around one or more lengths of slotted casing. The borehole should be installed such that at least part of the response zone remains within the saturated zone during the period of monitoring, given the likely seasonal fluctuation of the water table (EA, 2006a). Table 6 provides an indication of the anticipated seasonal variation in water levels in different aquifer formations.

[11] For the purposes of this report, the term "piezometer" is defined as a standpipe (casing with a perforated section at the base) or as a standpipe piezometer (casing with a porous or perforated tip) with which groundwater level or pore water pressure is measured.

Table 6: Potential fluctuation of water table in different aquifers

Lithology	Formation	Maximum anticipated seasonal variation in water levels	Reference
Limestone	Chalk	30m	BGS, 1997
	Inferior Oolite	10m	
	Lower Magnesian	4m	
	Jurassic Limestones	20m	BGS, 2000
Sandstones	Permo-Triassic	3m	
Siltstones	Lower Cretaceous/Upper Jurassic of the Weald	2m	
Mudstones	Triassic Mudstones	5m	
Unconsolidated gravels	River Terrace Deposits	5m	Gandy, 2004

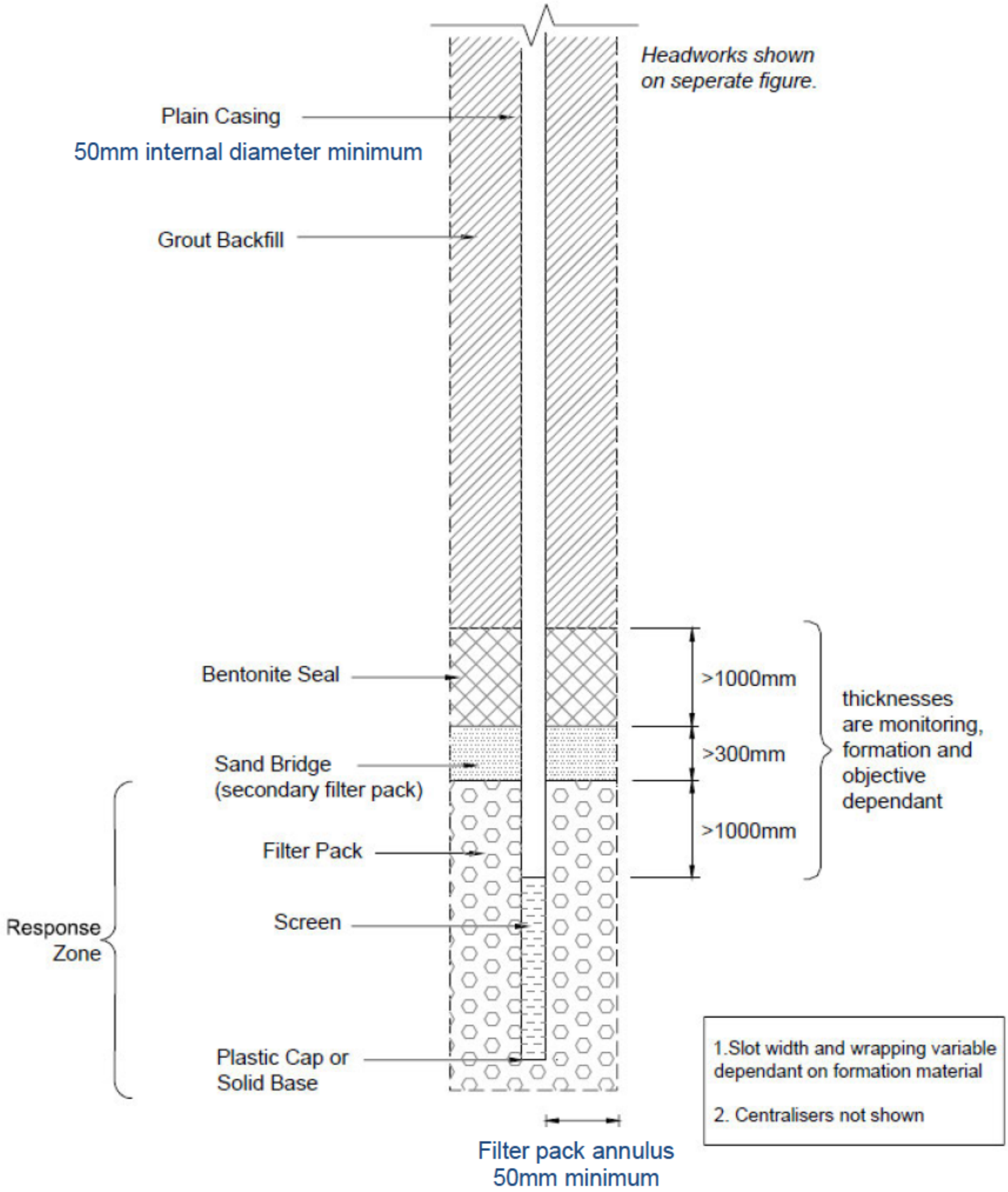
2.3.5 Borehole response zones should be installed in one aquifer or hydrogeological unit only (BSI, 2010) to ensure that readings accurately represent conditions within one aquifer only.

2.3.6 In general, the response zone should be kept to a maximum of 3m in length to avoid inducing vertical flow and disturbing natural flow patterns and geochemistry, unless otherwise specified (BSI, 2010), such as in pumping wells or where there is a very large seasonal variation in water levels (see Table 6).

2.3.7 The response zone slot size, type and open area should be selected to ensure protection from fouling through silting and biological activity and to allow sufficient ingress of water for sampling (BSI, 2010). However, it is likely that 1mm slots and 3 to 6mm clean, inert, well-graded and well-rounded granular fill with 90 to 95% quartz grains will be suitable in the majority of situations (HS2, 2014a). The filter pack should be a minimum thickness of 50mm (2”) and be appropriately sized to account for the grain size of the aquifer and the size of the screen openings.

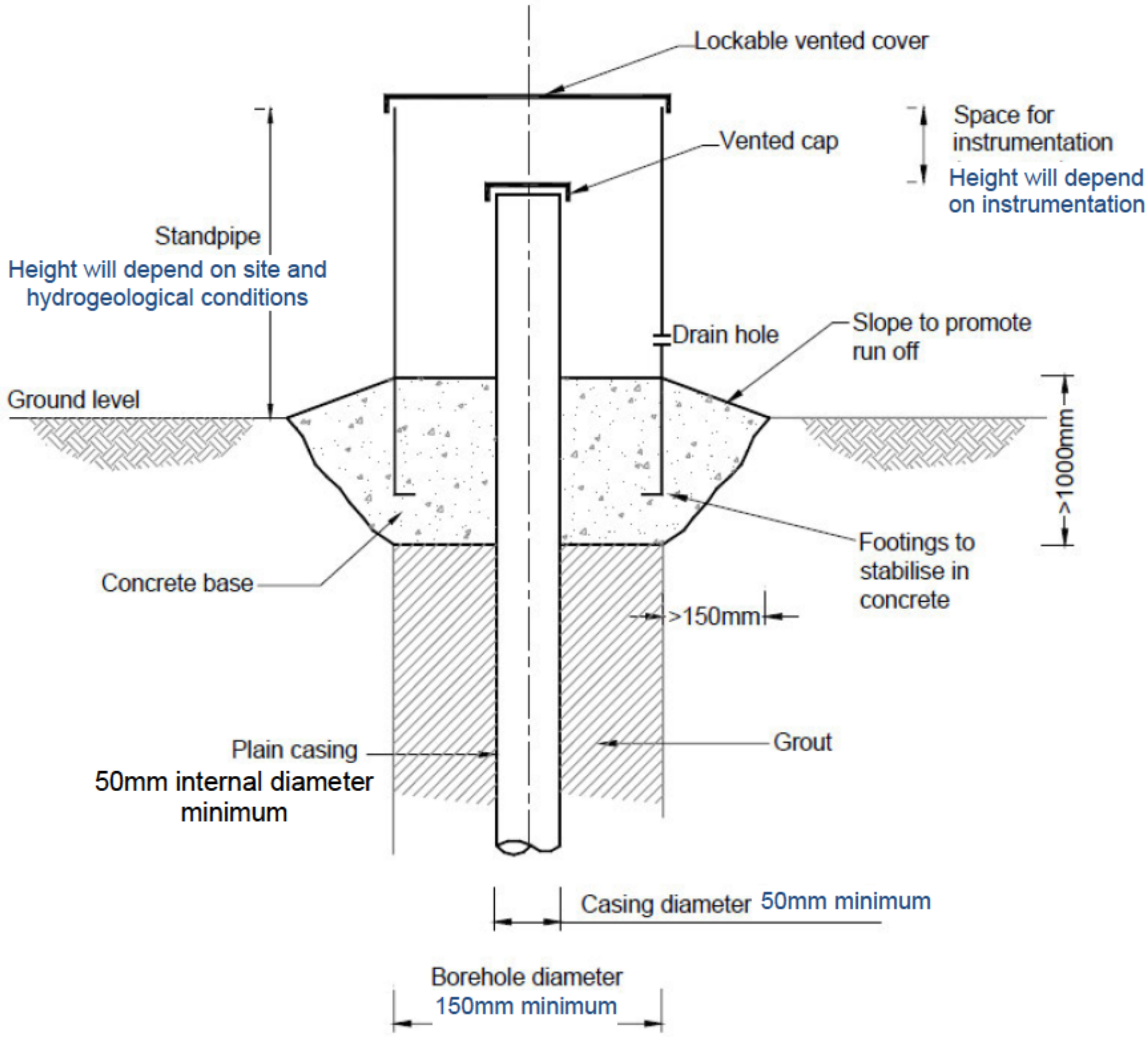
2.3.8 Figure 6 provides an overview of general groundwater monitoring point installation (EA, 2006a).

Figure 6: Groundwater monitoring point installation (Adapted from EA, 2006a)



2.3.9 The casing should be fitted with a removable cap to prevent ingress of surface water and a lockable cover to avoid vandalism or interference and with sufficient room to house telemetric data logger equipment, if required (for example, see Figure 7– EA, 2006a).

Figure 7: Standpipe headworks (Adapted from EA, 2006a)



2.3.10 Where artesian[12] conditions are anticipated or encountered, the monitoring borehole should be constructed to prevent groundwater from persistently flowing from it and being lost from the aquifer but also to allow groundwater level measurements to be taken. The non-slotted top section of casing should protrude above ground level and be

[12] Artesian refers to where the groundwater level rises above the top of a fully saturated aquifer, with the potential to overflow at the ground surface if the groundwater level exceeds ground level.

fitted with a blank flange, complete with a threaded dipping plug (National Groundwater and Contaminated Land Centre, 2003) – see Figure 7.

2.3.11 Following installation, monitoring boreholes should be checked to ensure the proper function of the groundwater measuring system (BSI, 2006a).

2.4 Where excavation is required

2.4.1 Monitoring boreholes to be installed where excavation is required should extend to at least the depth of excavation plus the maximum anticipated seasonal fluctuation in groundwater levels (see Table 6).

2.5 Where dewatering[13] is likely to be required

2.5.1 Monitoring boreholes to be installed where dewatering or depressurisation is likely to be required should penetrate below the depth of the excavation plus the maximum anticipated seasonal fluctuation in groundwater levels in the aquifer or hydrogeological unit of interest. These boreholes should be installed to the same depth as the pumping well in highly stratified aquifers to ensure that the equivalent response zone is monitored during testing and allowing the full range of drawdown to be captured (HS2, 2014a). In some circumstances monitoring boreholes will also be required in aquifers above or below the formation being pumped.

2.6 Where contamination is anticipated to be encountered

2.6.1 In addition to the general principles listed above, the following guidelines should apply to the design of monitoring boreholes where a "significant area of contamination"[14] , as identified within the ES/SES, is anticipated to be encountered:

- Where light non-aqueous phase liquid (LNAPL) contamination is anticipated or encountered, the screened section should span the anticipated depth range of the water table so that LNAPLs can be more easily detected and the thickness of the liquid determined (BSI, 2010);
- Where dense non-aqueous phase liquid (DNAPL) contamination is anticipated

[13] The term dewatering is used to cover both dewatering by pumping and lowering of groundwater levels and depressurisation by lowering of hydraulic pressures within a confined or low permeability aquifer.

[14] A risk-based approach will be taken in accordance with the Environment Agency and DEFRA guidance in order to investigate "significant areas of contamination". Prior to investigation, these are considered to be where past uses of land indicate a high risk of previous significant contamination and potential risk to receptors. These are urban areas, in particular London and Birmingham, localised industries, old and existing landfill sites, old sewage farms and other issues that need to be assessed with respect to contaminative effects (see Volume 5 Technical Appendices – Scope and Methodology Report (HS2, 2013b) and Scope and Methodology Report Appendum (HS2, 2013c)).

or encountered, the screen section should extend to the base of the aquifer or at points where low permeability material is present to allow for the detection of DNAPLs (BSI, 2010);

- At least one of the sampling boreholes within an area of contamination should be screened near to the surface of the saturated zone, this being the most sensitive part of the aquifer to pollution (BSI, 2009).

2.7 Post-drilling development

2.7.1 All post-drilling development activities should be in accordance with relevant British Standards, industry guidance and best practice, such as:

- British Standard ISO 5667-22: 2010 Guidance on the design and installation of groundwater monitoring points;
- Environment Agency (2006), Guidance on the design and installation of groundwater quality monitoring points, Science Report SC020093; and
- Sterrett, , R.J. (2007) Groundwater and wells, 3rd edition.

2.7.2 Ideally, borehole development should be undertaken immediately after installation and should involve the removal of any fluids[15] added to the formation during drilling and of any fine material from the borehole and surroundings (EA, 2006a).

2.7.3 The removal of water from the borehole should continue until the purged water is clean, i.e. reasonably free of suspended solids, and of a constant quality. To that end, chemical parameters, such as electrical conductivity, pH, temperature, redox potential, dissolved oxygen and turbidity, should be measured during pumping to ensure stability is achieved (BSI, 2010).

2.7.4 Borehole development could comprise of one of the following methods (Table 7 summarises the suitability of each method to the different lithologies likely to be encountered during construction of the Scheme):

- Over-pumping, consisting of pumping the well or borehole at the highest rate attainable until the water runs clear:
  - This method is not suitable where installation diameters are less than 50mm (2”) as it is difficult to pump at a rate high enough to permit effective development (Gass,

[15] Borehole development in a contaminated environment needs to be undertaken with care. Careful consideration needs to be given to the most appropriate development method and the disposal of borehole water.

unknown);

- This method is less suitable in unconsolidated formations, particularly poorly sorted ones, and is best coupled with another method in these circumstances, such as mechanical surging (Aliewi, unknown); and
- This method is suitable in consolidated, relatively non-stratified sandstone formations (Sterrett, 2007).

- Mechanical surging, consisting of forcing water to flow into and out of the screen by operating a surge block or plunger up and down in the casing (Sterrett, 2007):
  - This method can be an effective means of developing small-diameter (50mm) monitoring boreholes (Gass, unknown); and
  - This method is suitable to cable tool drilling but not suitable for very deep boreholes (over 60m) (Aliewi, unknown).
- Air-lifting, consisting of injecting air into the well to lift the water to the surface, thereby blowing the sediment out of the well (Sterrett, 2007):
  - This method is the most commonly used to develop small-diameter (50mm) monitoring boreholes (Gass, unknown); and
  - This method is less suitable in stratified, coarse sand and gravel deposits separated by thin, impermeable clay layers (Sterrett, 2007).
- Jetting, consisting of shooting high velocity streams of water out through the screen openings (Sterrett, 2007):
  - Where small-diameter (50mm) jetting tools are available, this method can be an effective means of developing small-diameter (50mm) monitoring boreholes (Gass, unknown);
  - This method is suitable in highly stratified, unconsolidated formations (Sterrett, 2007); and
  - This method is particularly successful in unconsolidated sands and gravels and in consolidated fractured lithologies, when combined with air-lift pumping (Sterrett, 2007).

Table 7: Borehole development techniques for different lithologies

Lithology	Aquifer	Over-pumping	Mechanical surging	Air-lifting	Jetting
Limestone	Chalk	√	√	√	√
	Jurassic Limestones (including Great Oolite and Inferior Oolite)	√	√	√	√
Sandstones	Permo-Triassic	√	√	√	√
	Lower Cretaceous	√	√	√	√
Unconsolidated gravels	River Terrace Deposits	X (√ if coupled with mechanical surging)	X	X	√
Mudstones	Triassic Mudstones	√	√	√	√
	Carboniferous mudstones & sandstones	√	√	√	√

2.7.5 The disposal of pumped water will be subject to agreement between HS2 Ltd and the Environment Agency and should take account of anticipated or suspected water quality issues.

2.7.6 A variable head test (using a slug and pressure transducer) should be undertaken following the completion of development to assess the permeability of the screened interval and the performance of the borehole.

2.8 Further testing

2.8.1 During construction and following installation and development, further testing can be carried out on the monitoring borehole to help characterise and understand the monitoring point. These include core sampling, hydraulic parameter testing and down-hole geophysics.

2.8.2 Detailed guidance on these testing activities is beyond the scope of this appendix. If further information is required, the relevant British Standard, industry guidance and best practice listed below should be consulted:

- Core sampling:

- Ulusay, R. & Hudson, J.A. (2007), The Complete ISRM Suggested Methods for Rock Characterisation Testing and Monitoring: 1974-2006;
- British Standard 1377-3: 1990, Soils for civil engineering purposes – Part 3: Chemical and electro-chemical tests; and
- British Standard 1377-3: 1990, Soils for civil engineering purposes – Part 9: In situ tests.

- Hydraulic testing:
  - British Standard ISO 14686:2003, Hydrometric determinations — Pumping tests for water wells — Considerations and guidelines for design, performance and use;
  - British Standard EN ISO 22282-1:2012, Geotechnical investigation and testing - Geohydraulic testing - General rules;
  - Sterrett, R.J. (2007) Groundwater and wells, 3rd edition; and
  - British Standard 5930:1999 + A2:2010, Code of practice for site investigations.
- Down-hole geophysics:
  - Sterrett, R.J. (2007) Groundwater and wells, 3rd edition; and
  - British Standard 5930:1999 + A2: 2010, Code of practice for site investigations.

3 Surface water: quality and quantity

3.1 General principles

3.1.1 The choice of individual monitoring locations must endeavour to minimise the amount of effort and time involved, while at the same time minimising measurement uncertainties.

3.1.2 The monitoring point specification will depend on the type of monitoring activity selected, the frequency of measurements required, access limitations, waterbody morphology, environmental conditions and surface water body characteristics. These monitoring activities and types of monitoring points are further detailed in the following section.

3.1.3 Monitoring requirements will vary between sites, with each site falling within one of the following parameter requirements:

- Water level monitoring only;

- Water quality monitoring only;
- Water level and quality monitoring;
- Flow and water level monitoring; or
- Flow, water level and water quality monitoring.

3.1.4 As a general guideline, surface water level should be measured from a fixed datum at all flow monitoring locations before and after the period of recording, using either manual dip measurements, gauge plate readings and/or stilling wells, to verify and quality control flow readings and automatic level readings.

3.1.5 All surface water monitoring points should be installed and gauged in accordance with relevant British Standards, industry guidance and best practice.

3.1.6 In choosing the monitoring location, it must first be established that the level, flow and/or water quality at the site represents the data required for the purpose.

3.1.7 The channel upstream and downstream of the flow monitoring location should be long, straight and as uniform as possible to ensure parallel and non-turbulent flow. Locations displaying vortices, reverse flow or standing dead water should be avoided.

3.1.8 The channel should have well defined banks and a solid, regular and relatively smooth bed, free from vegetation, obstructions and debris.

3.1.9 The monitoring location should be remote from artificial obstructions, natural obstructions, river control and water release structures (e.g. locks).

3.1.10 Particular care must be taken about the proximity of any tributary or distributary, discharge or abstraction to the monitoring location.

3.1.11 When considering the use of an electromagnetic current meter, care must also be taken during the site selection process to ensure the monitoring location is remote from overhead or underground power cables, or other structure which may generate an electrical magnetic field which can interfere with the electromagnetic current meter.

3.1.12 Consideration should be given to the possibility of flow loss due to bed leakage or accretion of flow from groundwater when selecting a monitoring location.

3.1.13 Velocities at the monitoring location should be as regular and consistent as possible, and should be greater than the minimum response speed of the chosen current meter but should not exceed the maximum calibration speed.

3.1.14 There should be sufficient depth of flow across the whole cross section of the monitoring location, and consideration made as to the likely ranges of depths experienced throughout the seasons.

3.1.15 The monitoring location must be safe and accessible when measurements are required.

4 Surface water: hydromorphology

4.1 General principles

4.1.1 Routine hydromorphological monitoring involves a reconnaissance survey which is carried out over an appropriate reach length (dependent on the Scheme Impact) upstream and downstream of the Scheme impact location.

4.1.2 A reconnaissance survey is normally accompanied by fixed point photography; which is geo-referenced. The number of points where photographs are to be taken will vary dependent on type and scale of the Scheme impact, and the scale of channel adjustment.

4.1.3 Other types of additional hydromorphology monitoring may be required for a few Scheme elements at specific sites. Some of these involve monitoring at a reach scale while others are point specific.

5 Surface water: aquatic ecology

5.1 General principles

5.1.1 Routine ecological monitoring involves a survey over a reach scale (fisheries and aquatic macrophytes) or over habitats in proportion to their occurrence at a site scale (aquatic macroinvertebrates and phytobenthos), rather than monitoring points *per se*.

5.1.2 Further details on monitoring site selection are provided in Appendix C.

Appendix E – Monitoring activity requirements

1 Introduction

1.1.1 The purpose of this appendix is to provide general guidelines for monitoring activities for the Scheme. These guidelines are not exhaustive and should routinely be reviewed and updated as new information or guidance becomes available.

2 Groundwater

2.1 Groundwater level measurement

2.1.1 All groundwater level monitoring activities should be in accordance with relevant British Standards, industry guidance and best practice, such as:

- National Groundwater and Contaminated Land Centre (2003), A guide to monitoring water levels and flows at wetland sites; and
- Onset (2007), Data logger series, Choosing a Water Level Logger, 5 Things You Should Know.

2.1.2 Manual dip measurements should be taken using a calibrated borehole dip-meter or "dipper". The measurement should be taken from a defined, surveyed and recorded datum point consistent for all monitoring boreholes, to ensure consistency between site visits. The accuracy of measurement should be to within about 1cm (National Groundwater and Contaminated Land Centre, 2003).

2.1.3 Where artesian[16] conditions are anticipated or encountered, manual dip measurements should be taken by removing the plug (see Appendix D) and fitting a transparent tube or calibrated pressure gauge. If a tube is used, it should be held vertically and the vertical distance between a fixed point on the flange and the water surface measured. If a pressure gauge is used, the pressure can be easily read and interpreted as 1 bar of pressure at ground level will rise to approximately 10m above ground level (National Groundwater and Contaminated Land Centre, 2003).

[16] Artesian refers to where the groundwater level rises above the top of a fully saturated aquifer, with the potential to overflow at the ground surface if the groundwater level exceeds ground level..

2.1.4 In as far as practically possible, pressure transducers used within the same aquifer or within a specific region of the monitoring network should have the same sensitivity ranges and should be approved by HS2 prior to purchase. In addition, they should be synchronised and initiated simultaneously so that groundwater levels are recorded at the same times and at the same intervals.

2.1.5 A non-vented, rather than a vented, logger system, should be used, provided there is good QA/QC management in place to reduce post-processing errors. This would include a barometric logger to allow correction of the logger dataset for variations in atmospheric pressure.

2.1.6 The selection of pressure transducers should take into account the maximum pressure likely to be exerted by the overlying column of water and of the manufacturer's intended sensitivity range.

2.1.7 If a pressure transducer reading is consistently different to manual dips, by in the order of 100mm, then an investigation should be launched to determine the cause.

2.1.8 The raw and corrected logger data should be provided to HS2 in original and Excel-compatible formats within 7 days of each download.

2.1.9 In general, telemetry of groundwater level monitoring data is not considered necessary; however it may be appropriate at monitoring boreholes adjacent to water company abstractions and to sensitive GWDTE's.

2.1.10 Where free-phase hydrocarbon product is anticipated or encountered, groundwater level measurements should be taken using an interface dipper. This can accurately measure the thickness of any floating or sinking hydrocarbon. The dipper should be cleaned thoroughly between measurements.

2.1.11 If the groundwater has an elevated salinity then the pressure transducer needs to incorporate a water density monitoring capability.

2.2 Groundwater quality sampling

2.2.1 All groundwater quality sampling activities should be in accordance with relevant British Standards, industry guidance and best practice, such as:

- British Standard ISO 5667-11: 2009 Water quality – Sampling – Part 11: Guidance on sampling of groundwater;
- Environment Agency (2013), Groundwater protection: Principles and practice (GP3); and

- British Standard ISO 5667-3: 2012 Water quality – Sampling – Part 3: Preservation and handling of water samples.

General conditions

2.2.2 Prior to sampling, the monitoring borehole should be pumped or purged in order to obtain a representative sample. The purge volume will be dependent on the design of the monitoring point (BSI, 2009) and is generally a minimum of three borehole volumes or until physico-chemical parameters have stabilised.

2.2.3 Field parameters, such as electrical conductivity, temperature, redox potential, pH and dissolved oxygen, should be monitored throughout purging to ensure stabilisation of water chemistry before taking a sample. This should be conducted using a multi-parameter meter and a flow-through cell, where possible, to avoid contact between groundwater and the atmosphere (BSI, 2009). The meter should be calibrated before each use against known standards.

2.2.4 Pumped samples, rather than depth-specific samples, should be collected, as a composite vertical sample of approximately average composition is all that it is required for potable supply purposes (BSI, 2009).

2.2.5 If a depth sample is required, a pneumatic bladder, electric submersible pump or peristaltic pump (BSI, 2009) should be used, whichever is appropriate to groundwater conditions encountered during borehole installation. The pump should be used to "micro-purge" and to sample the monitoring boreholes, without removal to reduce the chance of mixing within the borehole (BSI, 2009).

2.2.6 The pump intake should be lowered down the borehole to the middle or slightly above the middle of the screened section. Ideally the intake should be at least 500mm under water to prevent mixing of water and air (BSI, 2009). The pump rate should be set to a level that will not induce drawdown.

Where contamination is anticipated to be encountered

2.2.7 Consideration should be given to using a low flow sampling methodology, to "micro-purge" the monitoring boreholes where non-aqueous phase liquid (NAPL), volatile organic compounds (VOCs) or significant contamination is suspected. The principle behind this method is to extract formation water through the screened section of the borehole at approximately the same rate as it flows out of the formation, without disturbing the stagnant water column above. This is achieved by pumping at a rate which results in minimal drawdown of the water level in the borehole. The advantages of this method are as follows:

- It improves sample quality through reduced disturbance to the aquifer and to the borehole (for example not dispersing NAPL and incorporating within samples);
- It minimises the entrainment of sediment within the water that is to be sampled;
- It reduces the volume of water to be pumped and disposed of;
- It can reduce the time required for purging and sampling, and therefore can reduce field labour costs;
- It increases borehole life through reduced pumping stress; and
- The required equipment is more portable than pumps required for more traditional purging methods.

2.2.8 All sampling equipment should be decontaminated after the purging and sampling of each borehole.

3 Surface water: quality and quantity

3.1 Surface water level measurement

3.1.1 All surface water level monitoring activities and installations should be in accordance with relevant British Standards, industry guidance and best practice, such as:

- Environment Agency (2011), Hydrometric manual; and
- British Standard ISO 4373: 2008 Hydrometry – Water Level measuring devices.

3.1.2 The selection of a manual or automatic measurement technique is dependent on:

- the physical characteristics of the surface waterbody/monitoring location;
- the Scheme element;
- the frequency of measurements required;
- the purpose of the measurement and the application of the data;
- the rate of change and range of water level variations expected;
- the period over which monitoring is required;
- the required accuracy and resolution of measurements; and

- the cost of manual methods compared with the cost of automatic recorders.

3.1.3 The criteria to follow when selecting a suitable surface water monitoring location are provided in Appendix C.

3.1.4 Manual dip measurements should be taken using a calibrated dip-meter or "dipper". The measurement should be taken from a defined, surveyed and reference datum point consistent for all monitoring locations, to ensure consistency between site visits. The accuracy of measurement should be to within approximately 1cm.

3.1.5 A visible marker (such as a small mark of paint) on publicly accessible features, such as a bridges, culverts or footpaths which cross a surface waterbody, can be used as a reference datum point from which a manual dip measurement can be taken consistently.

3.1.6 Consideration should be given to the installation of a gauge plate which offers an alternative method of manual measurement. A gauge plate should be surveyed and levelled to a local datum and securely attached to a vertical surface on the bank at right angles to the water surface.

3.1.7 Where possible, the gauge plate should be attached to a well-established permanent feature within the waterbody (i.e. a bridge pillar, parapet, piled bank). Where this is not possible, a gauge post made of metal, concrete or timber should be installed, to which the gauge plate can be attached.

3.1.8 Automatic water level measurements should be taken using a calibrated pressure transducer or shaft encoder installed into an appropriately positioned and sized stilling well. Stilling wells installed into a river bank should ensure hydraulic connectivity to the waterbody through multiple narrow diameter inlet holes. Stilling pipes can be attached to bridge parapets or vertical walls.

3.1.9 Any associated data logger, telemetry equipment or external power supply required should be located nearby in secure housing; however, consideration should be given to the potential flood depths of the waterbody being monitored.

3.1.10 Consideration should be given to recalibrating the data logger upon download should the logger reading be ± 5cm different to the manual dip or gauge plate reading.

3.1.11 The raw and corrected logger data should be provided to HS2 Ltd in original and Excel-compatible formats within seven days of each download.

3.1.12 Telemetry of surface water level monitoring data should be considered, to reduce the number of site visits required and to provide an early warning system to water company abstractions and to sensitive ecological sites.

3.1.13 Consideration should be given to the application of both a manual and automatic method for water level measurement to verify, quality control and calibrate automatic level readings.

3.1.14 Locations for manual and automatic methods for water level measurement should generally avoid areas which experience turbulence, drawdown, siltation, debris accumulation, but which are easy and safe to access for reading and, if necessary, cleaning.

3.2 Surface water discharge measurement

3.2.1 All surface water discharge monitoring activities and installations should be in accordance with relevant British Standards, industry guidance and best practice, such as:

- Environment Agency (2011), Hydrometric manual;
- British Standard ISO 748: 2007 Hydrometry – Measurement of liquid flow in open channels using current-meters or floats;
- British Standard ISO 15769: 2010 Hydrometry – Guidelines for the application of acoustic velocity meters using the Doppler and echo correlation methods; and
- British Standard EN ISO6416: 2005 Hydrometry – Measurement of discharge by the ultrasonic (acoustic) method.

3.2.2 The selection of a manual or automatic measurement technique is dependent on:

- the physical characteristics of the surface waterbody/monitoring location;
- the Scheme element;
- the frequency of measurements required;
- the purpose of the measurement and the application of the data;
- the rate of change and range of water level variations expected;
- the period over which monitoring is required;
- any land access restrictions;

- the required accuracy and resolution of measurements, and
- the cost of manual methods compared with the cost of automatic recorders.

3.2.3 The criteria to follow when selecting a suitable surface water monitoring location are provided in Appendix C.

Manual flow measurement

3.2.4 Manual flow gauging measurements should be taken using the most appropriate technique, such as a calibrated rotating element (REM) or electromagnetic current meter for wade gauging or, where flow monitoring locations are greater than 0.5m deep, flow gauging should be undertaken using an Acoustic Doppler Current Profiler (ADCP).

3.2.5 Electromagnetic current meters should be considered where monitoring locations experience very low velocities (<0.1m/s), shallow depths, high silt loads and/or vegetated conditions.

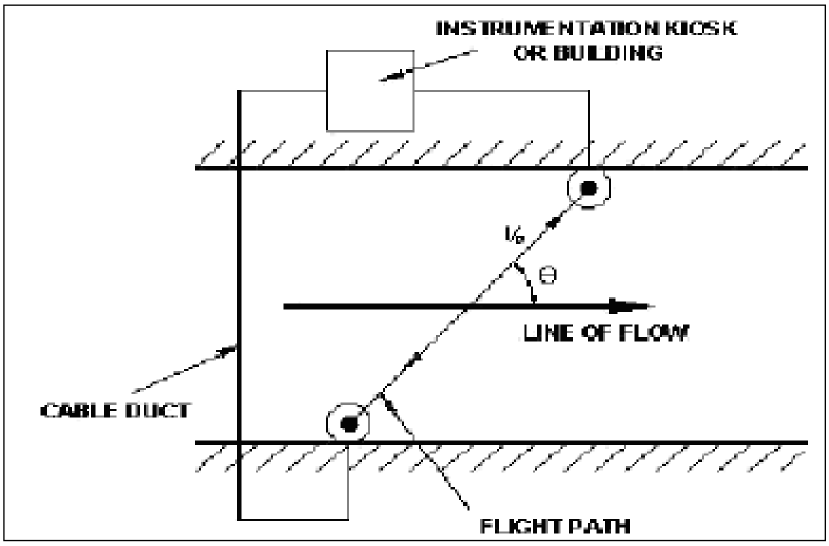
3.2.6 When considering the use of an electromagnetic current meter, care must also be taken during the site selection process to ensure the monitoring location is remote from overhead or underground power cables, or other structures which may generate an electromagnetic field which can interfere with the electromagnetic current meter.

3.2.7 ADCP's should be considered where monitoring locations are greater than 0.5 metres at the deepest point of the cross section. The ADCP should be deployed either by raft, boat, cableway or rope and should be operated by a suitably qualified or experienced hydrologist.

Automatic flow measurement

3.2.8 Transit time ultrasonic flow measurement (see Figure 8) requires the installation of ultrasonic transducers into the river banks, and can consist of either single path, multi-path, crossed path or reflected path systems depending on physical and hydraulic conditions. The depth of installation is dependent on the transducer frequency and path length.

Figure 8: A basic ultrasonic (time of flight) flow gauge set up (EA, 2011c)



3.2.9 Acoustic (Echo) correlation velocity profilers (see Figure 9) and ultrasonic Doppler systems (see Figure 10) should be bed mounted onto a levelled concreted slab. They can be used as portable and permanent flow monitoring installations, and are most suitable for small artificial and natural channels where conventional flow measurement structures are not feasible.

Figure 9: A bed mounted acoustic (echo) correlation velocity profiler (EA, 2011c)

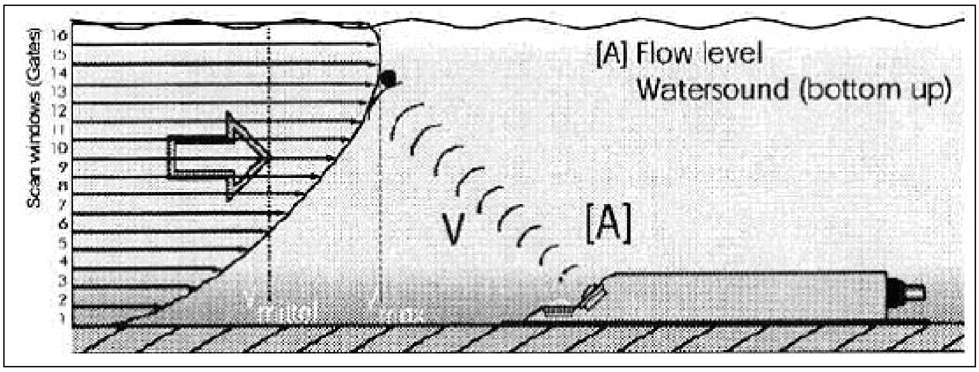
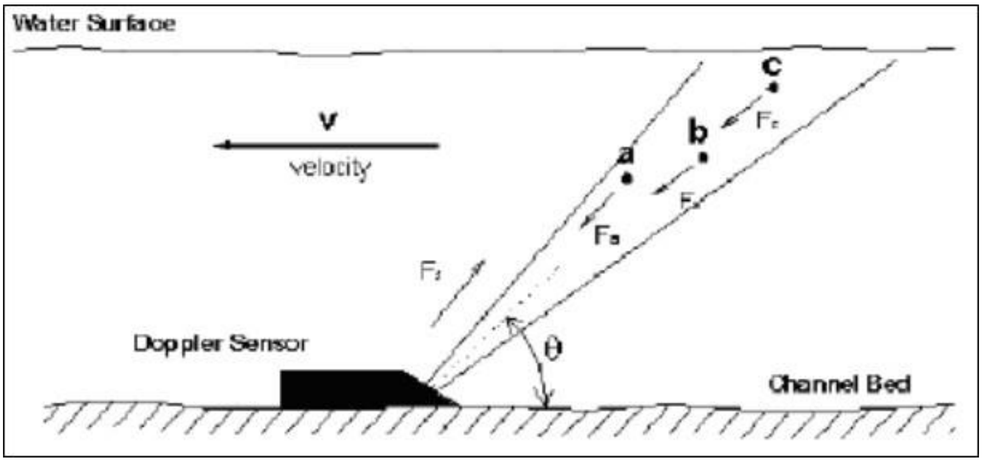
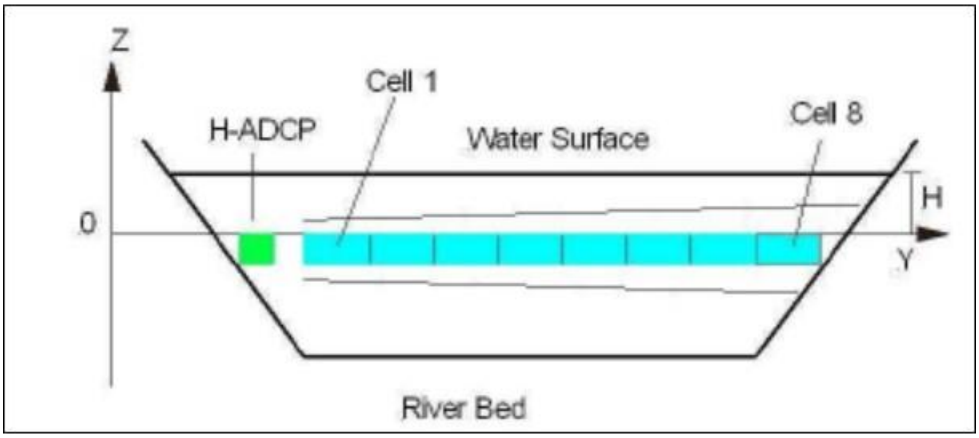


Figure 10: A bed mounted acoustic (echo) correlation velocity profiler (EA, 2011c)



3.2.10 Horizontal/side looking ADCPs (see Figure 11) should be installed securely on a mounting bracket to the side of a channel and look across measuring velocities in one horizontal layer the full width of the monitoring location cross-section. Care should be taken to ensure that the Horizontal ADCP is set to a depth where it will remain fully submerged.

Figure 11: A horizontal acoustic Doppler current profiler (EA, 2011c)



3.2.11 It should be noted that fixed acoustic devices require an index velocity rating to be developed in order to derive the true mean velocity in a channel. This process can be time consuming as a range of calibration measurements need to be taken, therefore when using these fixed acoustic devices, the instrumentation should be installed in advance of any accurate data being required.

3.2.12 Any associated data logger, telemetry equipment and external power supply should be located nearby in secure housing; however, consideration should be given to the potential flood depths of the waterbody being monitored.

3.2.13 The raw and corrected logger data should be provided to HS2 Ltd in original and Excel-compatible formats within seven days of each download.

3.2.14 Telemetry of surface water discharge monitoring data should be considered, to reduce the number of site visits required and to provide an early warning system to water company abstractions and to sensitive ecological sites.

3.2.15 Consideration should be given to the application of both a manual and automatic method for water level measurement to verify, quality control and calibrate automatic level readings.

3.2.16 Table 8 below provides a summary of when different methods are more suitable in relation to variable site conditions, alongside the likely level of cost and maintenance associated with each surface water flow monitoring method and technique.

Table 8: Site conditions, cost and maintenance considerations

Method	Channel Width (m)	Depth (m)	Average Velocity (m/s)	Silt Load	Cost	Maintenance
Rotating element current meter	< 50	0.1 – 0.5	0.3 – 1.0	Low	Low	Low
Electromagnetic current meter	< 50	0.05 – 0.5	-1.0 – 1.0	High	Low	Low
ADCP	5 – 100	> 0.5	-10 – 10	Low	High	Low
Transit time ultrasonic	0.5 – 100	>0.1	-10 – 10	Low	Moderate/High	Moderate

Acoustic (Echo) Correlation and Ultrasonic Doppler	0.3 – 3.0	0.075 – 2.0	0.1 – 5.0	Low	Low/Moderate	Moderate
Horizontal ADCP	1.0 - 100	>0.3	0.1 – 6.0	Low	Low/Moderate	Moderate

3.3 Surface water quality sampling

3.3.1 All surface water quality sampling activities should be in accordance with relevant British Standards, industry guidance and best practice, such as:

- British Standard 1427:2009 Guide to on-site test methods for the analysis of waters;
- British Standard EN ISO 5667-1: 2006 Water quality – Sampling – Part 1: Guidance on the design of sampling programmes and sampling techniques;
- British Standard ISO 5667-3: 2012 Water quality – Sampling – Part 3: Preservation and handling of water samples;
- British Standard ISO 5667-6: 2005 Water quality – Sampling – Part 6: Guidance on sampling of rivers and streams; and
- Environment Agency (2011), Hydrometric manual.

3.3.2 The selection of sampling technique, manual or automatic, will be based on:

- the physical characteristics of the surface waterbody/monitoring location;
- the Scheme element and predicted significance of effect;
- the frequency of measurements required;
- the purpose of the measurement and the application of the data;
- the rate of change and range of water level variations expected;
- the period over which monitoring is required;
- the required accuracy and resolution of measurements; and
- the cost of manual methods compared with the cost of automatic recorders.

3.3.3 Spot sampling undertaken in-situ should be the preferred method of water quality sampling for as many determinands as possible, reducing the potential for contamination or degradation of the sample.

3.3.4 Temperature, pH, conductivity and dissolved oxygen are some of the parameters which should be recorded in-situ. The appropriate field kit for undertaking in-situ spot sampling should be acquired, and the manufacturer's instructions followed carefully.

3.3.5 Efforts should be made to avoid disturbing the bottom of the waterbody as far as possible when taking a sample, as this will cause particles to become suspended.

3.3.6 The use of automatic water quality monitoring equipment should be considered in order to develop more accurate, high resolution, time-series data for certain determinands, enabling a much greater understanding of how surface water quality is affected. Where possible, automatic monitoring equipment should be appropriately submerged within the middle of the channel but away from the bed sediment, which could interfere with readings. Equipment should be cleaned and calibrated to the manufacturers specifications in order to maintain an accurate data record (approximately once per month during winter months and more frequently when algal growth is strong during the spring and summer).

3.3.7 Telemetry of automatic surface water monitoring data should also be considered, to reduce the number of site visits required and to provide an early warning system to water company abstractions and to sensitive ecological sites.

3.3.8 Any associated separate data logger, telemetry equipment and external power supply should be located nearby in secure housing; however, consideration should be given to the potential flood depths of the waterbody being monitored.

3.3.9 Meteorological data should be collected from the nearest local weather station (where possible) alongside the surface water quality monitoring. Where there is no reliable station available, consideration should be given to the installation of a purpose-built weather station (to include minimum and maximum air temperatures, wind speed and direction, and rainfall volume) to cover the monitoring site area.

3.3.10 All supporting information should be recorded (visual inspection) before leaving the monitoring location. Such conditions as the ambient air temperature, the weather, the presence of dead fish floating in the water or of oil slicks, growth of algae, or any unusual sights or smells should be noted.

3.4 Water sample storage & transportation

3.4.1 With regards to water sample handling, as far as is practical, the testing of as many determinands as possible should be carried out onsite or as soon as possible after sample collection (BSI, 2009).

3.4.2 Sample bottles should be placed in a box for transport to an Environment Agency and UKAS accredited laboratory. Sturdy, insulated wooden or plastic boxes will protect samples from sunlight, prevent the breakage of sample bottles, and use of cool packs should allow a temperature of 4 °C to be maintained during transport.

A chain of custody process should be established, within which a unique sample identifier and additional sample details should be available to the chosen laboratory, so that responsibility for the samples can be passed to the laboratory on arrival and that the maximum storage period for each determinand, as listed in BS ISO 5667-3: 2012, is not exceeded.

4 Surface water: hydromorphology

4.1 Design of hydromorphological study

4.1.1 A hydromorphological study is required where ever the Scheme will affect the morphology of the channel (such as watercourse alteration, watercourse structures or bed or bank protection, drainage entering the channel or river or wetland enhancements linked to the scheme).

4.1.2 A hydromorphological study would normally comprise an initial desk-based assessment (see section 4.2) followed by field based surveys (see section 4.3) at the Scheme impact locations.

4.1.3 Field based survey development should be informed by the desk-based assessment (for example areas where the Scheme could lead to geomorphological instability or where a channel is to be realigned, additional types of field monitoring would be required, for further details see section 4.3).

4.1.4 Where the Scheme poses a risk of cumulative impacts along a river reach, or there is a sensitive receptor (such as protected species or an internationally designated site) a larger scale reach based assessment may be required to provide a greater level of detail about sediment dynamics within an extended reach context, for further details see section 4.3).

4.1.5 Each hydromorphological study per Scheme location will need to be bespoke taking into account site-specific objectives, targets, local hydromorphological parameters (such as given the location, the geology, gradient, planform, sediment, scale, land use) and risks, uncertainties and opportunities associated with the scheme.

4.2 Desk-based assessment(s)

4.2.1 A desk-based assessment of existing reports, analyses, and aerial photography (if available) should be undertaken by a hydromorphologist to extract appropriate information that should be used to inform the scale and frequency of hydromorphological monitoring required. A review of aerial maps over time could also be used as part of this assessment to help determine future hydromorphological risk.

4.2.2 A method description for a desk-based review of existing report/analyses can be found within Appendix E Level 1 Assessment methods of the following report: Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme-WFD Expert Assessment of Flood Management Impacts (2009).

4.3 Field-based monitoring

4.3.1 Field-based survey development should be informed by the desk-based assessment to define the type of monitoring required over what spatial and temporal scale.

4.3.2 There are a variety of field survey techniques available and selection will be dependent on the Scheme impact type, Scheme impact size, sensitivity of the location, cumulative effects of other impacts up and downstream, risks and opportunities.

4.3.3 For Scheme impacts, that are considered to have an impact on hydromorphology[17], a combination of a reconnaissance survey (site walkover survey of the impact location and up and downstream within the scheme boundary) and fixed point photography (photographs taken at a set of identical locations before, during, just after for a period of time after construction has been completed) would generally be adequate to record adjustment over time.

4.3.4 These surveys would usually be undertaken pre-construction (to develop a baseline), immediately after construction at about 3 months, and for several years post construction, for example for a large Scheme impact such as a channel

[17] Scheme impacts considered to have an impact on hydromorphology are likely to be viaducts with footings in the waterbody, bridges with footings in the waterbody, culverts, siphons, river diversions/realignments, drainage outfalls to watercourses, and river bank protection. This list has been derived from Table 1 with additional expert opinion. It should not be viewed as an exhaustive list and should be used to guide monitoring decisions.

diversion/realignment post construction monitoring at 1 year,3 years and 5 years would be appropriate.

4.3.5 The scale of the reconnaissance/fixed photo survey required is very much dependent on scale of the Scheme impact and sensitivity of the site. It is considered that Scheme impacts such as river diversions/realignments and culverts might require surveys over larger reaches and have a greater number of repeat surveys in subsequent years than for Scheme impacts that have more localised impacts such as river bank protection or drainage outfalls to watercourses.

4.3.6 A method description for these reconnaissance/fixed photo field survey techniques (should more information be required) can be found within Appendix 2 'Monitoring techniques' of the following report: Environment Agency (2007), Geomorphological Monitoring Guidelines for River Restoration Schemes, Final Report B0435600.

4.3.7 Where there are particular areas of hydromorphological concern (such as bank stability issues requiring channel cross-sectional analysis or river diversions/realignments requiring habitat mapping to demonstrate hydromorphological and ecological improvement etc.) there are many other additional techniques (see Table 9) that may need to be used.

4.3.8 Within Table 9 an indication of when it might be appropriate to use these techniques is provided as well as a suggestion of which type of Scheme impact may require each technique.

4.3.9 For more details of these techniques please refer to the appropriate reference where a method description will be found.

4.3.10 The additional field survey techniques listed within Table 9 may, or may not, be required for each Scheme element listed against them. This table is a guide and not a prescriptive monitoring plan.

Table 9: Toolbox of additional hydromorphological field survey techniques that may need to be used on a case by case basis

Additional field survey technique name *Reference*	**Additional field survey technique description**	**Suggestion of when to use?**	**Type of Scheme element which may require the survey technique**
Habitat mapping (RCS) *(RRC, 2011)*	Mapping vegetation structures along a watercourse and includes a map of physical habitat and a botanical survey	When data is required to demonstrate channel diversions/realignments have recovered to an appropriate level	River diversions/realignments

River Habitat Survey (RHS) *(EA, 2007; RRC, 2011)*	A river habitat survey	When data is required to demonstrate channel diversions/realignments have recovered to an appropriate level	River diversions/realignments
Topographic surveys *(EA, 2007; SEPA, 2005; RRC, 2011)*	Provides information about river plan and longitudinal changes through time	When data is required to inform large channel diversion/realignment design or a channel that is in a sensitive location	Channel modifications , River crossings, Instream structures, Impoundments
Repeat cross sections *(EA, 2007; SEPA, 2005; RRC, 2011)*	Provides information about a specific section of a river and floodplain and may be related to hydrology and habitat information	When there are concerns about lateral or vertical channel adjustment.	Channel modifications, River crossings, Instream structures, Impoundments, Bank modifications
Sediment monitoring (e.g. Bed substrate analysis) *(EA, 2007; SEPA, 2005)*	Provides more detailed information on sediment dynamics	When there are expected to be large scale impacts to sediment movement	When there are expected to be large scale impacts to sediment movement

5 Surface water: aquatic ecology

5.1 Design of ecological study

5.1.1 Appendix A provides overarching principles of how, where and when aquatic ecological sampling is advisable. However, the decision to implement aquatic ecological sampling should take account of the nature of the local system affected by the design element. For example, aquatic macrophyte sampling on a heavily shaded system or aquatic macroinvertebrate sampling on an ephemeral system may not be advisable under any circumstances. It is therefore critical that an aquatic ecologist is consulted on the design of ecological monitoring.

5.1.2 Ecological monitoring of some description is likely to be required wherever the Scheme will affect the water quality, hydrology or the morphology of the riverine environment (such as channel diversions/realignments, watercourse structures or enhancements linked to the scheme).

5.1.3 The location of monitoring sites will be dependent on the nature of the design element, and it is therefore critical that an aquatic ecologist is involved in the survey design process. However, the following broad principles will generally apply:

- Where habitat loss/severance occurs (e.g. culvert/bridge/viaduct placement), baseline and post-construction monitoring should be undertaken at two sites; one upstream and one downstream within, as far as practically possible, 50m of the design element;
- Where habitat severance does not occur (e.g. river diversions/realignments/enhancements), baseline monitoring should be undertaken within the existing channel that will be affected by the design element. This should be undertaken at a minimum of one location, or at a rate of one location per km of channel affected, whichever is the highest; and
- Where habitat severance does not occur (e.g. river diversions/realignments/enhancements) post-construction monitoring should be undertaken within the existing or newly created channel associated with the design element.

5.1.4 Further details on the timing and duration of ecological sampling are provided in Appendix A.

5.2 Desk-based assessment

5.2.1 Where the Decision Tree identifies the need for ecological monitoring, existing reports and data (e.g. HS2 Ltd; EA biological monitoring data) should be reviewed spatially and temporally to determine whether existing information provides an appropriate proxy that negates the need for baseline monitoring. This should be undertaken by an aquatic ecologist.

5.3 Field based monitoring

5.3.1 Where required, and upon identification of suitable monitoring sites with reference to Appendix A and Appendix C, all field monitoring for aquatic ecology should be undertaken with reference to specific guidance as follows:

Aquatic Macrophytes

- River LEAFPACS 2: WFD-UKTAG, 2014. UKTAG River Assessment Method Macrophytes and Phytobenthos. Macrophytes (River LEAFPACS2). A report by the Water Framework Directive – United Kingdom Technical Advisory Group: http://www.wfduk.org/sites/default/files/Media/Characterisation%20of%20the%20water%20environment/Biological%20Method%20Statements/River%20Macrophytes%20UKTAG%20Method%20Statement.pdf; and
- British Standard BS EN ISO 14184_2003_Guidance standard for the surveying

of aquatic macrophytes in running waters.

Aquatic Phytobenthos

- River DARLEQ2: WFD-UKTAG, 2014. UKTAG River Assessment Method Macrophytes and Phytobenthos. Phytobenthos – Diatoms for Assessing River and Lake Ecological Quality (River DARLEQ2). A report by the Water Framework Directive – United Kingdom Technical Advisory Group: http://www.wfduk.org/sites/default/files/Media/Characterisation%20of%20the%20water%20environment/Biological%20Method%20Statements/River%20Phytobenthos%20UKTAG%20Method%20Statement%20Dec2014.pdf; and
- British Standard BS EN 15708_2009 Guidance standard for the surveying, sampling and laboratory analysis of phytobenthos in shallow running water.

Aquatic Macroinvertebrates

- UK Aquatic Macroinvertebrate RIVPACS Sampling Method: http://www.eu-star.at/pdf/RivpacsMacroinvertebrateSamplingProtocol.pdf; and
- British Standard EN ISO 10870_2012_Guidance for the selection of sampling methods and devices for macroinvertebrates in fresh waters.

Fish

- Guidelines for Electric Fishing Best Practice. R&D Technical Report W2-054/TR: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/290344/sw2-054-tr-e-e.pdf; and
- British Standard EN ISO 14011_2003_Sampling fish with electricity.

5.4 Ecological data analysis

5.4.1 Following field survey, summary ecological data and a number of standard ecological metrics should be calculated. These will be used to determine the nature and extent of ecological impacts as a result of the design element or activity, and whether ecological and WFD objectives in respect to the riverine environment have been met.

5.4.2 Fish survey data should be used to calculate species richness, density and standing crop estimates, based on catch-depletion methods (Carle and Strubb, 1978). With reference to species tolerance to environmental disturbance within the Fisheries Classification Scheme 2 (FCS2) (WFD-UKTAG, 2008), changes in the composition, density and standing crop of the assemblage can be used to assess the impact of the design element or activity.

5.4.3 For aquatic macroinvertebrates, a range of biological metrics should be calculated include the following:

- Number of taxa (N-TAXA);
- Whalley, Hawkes, Paisley and Trigg (WHPT) (2014);
- Average Score per Taxon (ASPT);
- Community Conservation Index (CCI) (Chadd & Extence, 2004);
- Lotic-invertebrate Index for Flow Evaluation (LIFE) (Extence et al, 1999); and
- Proportion of Sediment-Sensitive Invertebrates (PSI) (Extence et al 2013).

5.4.4 The number of taxa (N-TAXA) is a simple diversity index. It is a non-specific index of environmental pressure and is useful when pressure-specific indices such as ASPT and LIFE show no response. Habitat-rich rivers, such as lowland Chalk streams will often have N-Taxa scores exceeding 30. Upland systems with restricted habitats tend to have lower values. Stretches of river with impoverished habitat quality, siltation issues or reduced water quality will often have reduced N-TAXA scores from similar unimpacted stretches of river.

5.4.5 The Biological Monitoring Working Party score (BMWP) is primarily used to monitor the impact of organic water quality, but will also show responses to toxic pollution, siltation, habitat reduction and reduced flows. High BMWP scores are associated with good water quality and high habitat quality. BMWP scores cannot be directly compared across river types. A high BMWP score in an upland stream might be 70, where as a high score in a Chalk stream could be upwards of 250. This has since been replaced by the WHPT metric.

5.4.6 The Whalley, Hawkes, Paisley and Trigg (WHPT) replaces the BMWP indicies and forms the basis of WFD status classification from 2015. WHPT responds to the same range of pressures as ASPT. WHPT is based on more familes than BMWP with a separate value for each abundance category of each taxon. It is more sensitive than BMWP using more data. It offers better comparability with LIFE, PSI and other abundance-weighted indices.

5.4.7 Average score per taxon (ASPT) is derived from the BMWP index and is the average BMWP sensitivity score of all the taxa occurring in the sample. It is primarily used as an indicator of organic pollution. This index is directly comparable between samples collected from different river types and in different seasons. ASPT scores above 5, are considered to represent invertebrate communities living in good water quality. Lower scores are indicative of invertebrate communities suffering from stress due to reduced water quality.

5.4.8 The Community Conservation Index (CCI) incorporates both rarity and taxon richness. Individual species are assigned a Conservation Score (CS) based on their known conservation status in the UK, both locally and nationally. CCIs can range from 0 to >40; a guide to the interpretation of scores is included in the paper text.

5.4.9 The Lotic-invertebrate Index for Flow Evaluation (LIFE) was developed as a means of assessing flow as a stressor of the macroinvertebrate community of flowing watercourses. Individual species and family groups are assigned to a flow group depending on their documented flow preferences (current velocity) ranging from I (Rapid) to VI (Drought Resistant). Species LIFE (S) provides a more precise measure than Family LIFE (F) as a number of aquatic invertebrate families contain species with wide-ranging flow requirements. A full list of assigned family/species flow groups is included in paper text.

5.4.10 The Proportion of Sediment-Sensitive Invertebrates (PSI) is a biotic index designed to describe an invertebrate community's sensitivity to sedimentation. It is based on the known ecological responses of different macroinvertebrate species or family groups to the accumulation of sediment on riverine substrata. The index declines as the pressure of fine sediments cover the river bed.

5.4.11 Those taxa that are known to benefit from, or that are largely unaffected by, sedimentation, are given a high score, known as a 'Sediment Sensitivity Rating (SSR)'. Those taxa that are known to suffer from the accumulation of sediment are given a low SSR. The metric also depends on the relative abundance of different taxa and so is not just dependent on 'presence-absence', but also on the numbers of different taxa recorded. The PSI score describes the percentage of sediment-sensitive taxa present in a sample with high values indicating a greater proportion (percentage) of silt intolerant invertebrate species present within the macroinvertebrate community sampled i.e. the less a site is affected by silt the greater the PSI score. A full guide to the interpretation of scores is included in the paper text.

5.4.12 For aquatic macrophytes, a range of biological metrics should be calculated include the following:

- River Macrophyte Nutrient Index (RMNI);
- River Macrophyte Hydraulic Index (RMHI);
- Number of macrophyte taxa (NTAXA);

- Number of Functional Groups (NFG); and
- Cover of green filamentous algae (ALG).

5.4.13 The above all form part of the LEAFPACS2 suite of indices used for WFD classification.

5.4.14 River Macrophyte Nutrient Index (RMNI) is designed to categorise a macrophyte communities preferences to nutrient levels. Scores range from 1 to 10 with scores of 1 representing plant communities with preference for very low levels of nutrients and 10 representing communities with a preference for very enriched conditions.

5.4.15 The River Macrophyte Hydraulic Index (RMHI) describes a plant community's preference for flow conditions on a scale of 1 to 10. Scores of 1 indicate a plant community that has a preference for very slow flows or no-flow, while scores of 10 are found in plant communities with a preference for very fast, powerful flows.

5.4.16 The number of macrophyte taxa (NTAXA). This is a community richness index and simply describes the number of truly aquatic taxa present. Higher values represent a more diverse and rich aquatic plant community.

5.4.17 The Number of Functional Groups (NFG) is another richness or diversity index and describes the number of functional macrophyte groups existing within a surveyed plant community. Twenty-three different functional groups have been defined. The higher the NFG value, the more diverse and rich the plant community is considered to be.

5.4.18 Both the NFG and NTAXA indices are very useful indicators of habitat quality. High quality habitats with good flow regime, habitat heterogeneity, upstream connectivity and low sedimentation pressures will have higher values for both these indices. In areas where channel modifications exist both these indices will often be reduced.

5.4.19 The Cover of green filamentous algae (ALG) provides a measure of how much of the survey reach is covered in filamentous algae. High cover can often occur in situations where there has been a sudden increase in nutrient levels or high background nutrient levels. The index is a good indicator of acute nutrient releases rather than long-term eutrophication as well as sudden physical disturbances that can result in sudden nutrient pulses. This is because algae respond much quickly than higher plants to nutrient increase. Only algal species such as *Cladophora* agg. and *Enteromorpha* that respond to nutrient enrichment are included in this index.

5.4.20 For phytobenthos (diatoms), collected using the standard benthic diatom sampling techniques can be used to calculate the following biotic indices:

- Trophic Diatom Index (TDI);

- Percentage Motile Taxa (% Motile);
- Percentage Planktonic Taxa (% Planktonic); and
- Diatom Acidity Metric (DAM).

5.4.21 All of the above can be used in the DARLEQ2 tool to help interpret and classifiy diatom data and biotic indices.

5.4.22 The Trophic Diatom Index (TDI) describes the nutrient preferences of a diatom community. It ranges from 1 (preference for extremely low nutrient levels) to 100 (preference for extremely high high nutrient levels). Where there are several versions of the TDI, use the most up to date version of the TDI.

5.4.23 The Percentage Motile Taxa (% Motile) provides the proportion of taxa identified as motile. Higher values represent diatom communities with high proportions of motile taxa. This normally occurs where light is a limiting factor to the benthic diatom community, for example where siltation levels are high or growth of filamentous algae is becoming dominant. In these situations motile taxa can move to the surface to get to the light.

5.4.24 Percentage Planktonic Taxa (% planktonic). This index simply describes the proportion of taxa identified as being planktonic. Higher values mean more of the diatom community are made up of planktonic taxa. In situations where rivers have been impounded or flows reduced, the proportion of planktonic taxa can increase. The proportion of planktonic taxa can also increase in areas immediately downstream of lake or reservoir discharges.

5.4.25 Diatom Acidity Metric (DAM). This is a relatively recent index and describes the acidity of the environment within which the diatom community exists. As with other environmental factors diatoms have a specific pH range within which they thrive. The DAM index describes what pH conditions the diatom community have been experiencing. The index ranges from 1 (low pH conditions) to 100 (high pH conditions). In conditions experiencing 'acidification', scores will be lower than those expected in non-acidified locations of a similar nature.

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