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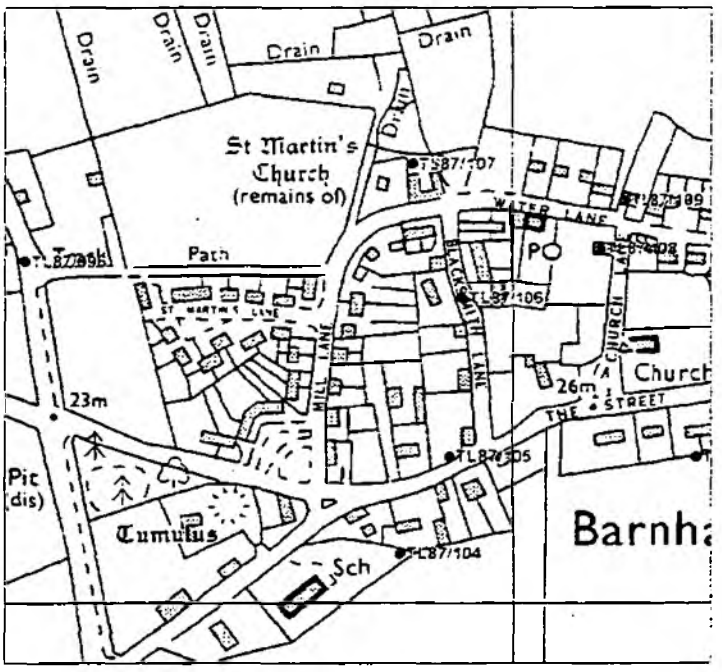
ENVIRONMENT AGENCY

Regional Groundwater Level Monitoring Network Review



Stage 2
Summary Report

March 2002

BINNIE BLACK & VEATCH

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EXECUTIVE SUMMARY

Binnie Black & Veatch was engaged by the Environment Agency to carry out a strategic review of their regional groundwater level monitoring network in the Anglian Region. The review includes:

- an asset survey of the current network covering all the groundwater units in the Region
- the development and application of a network design methodology to identify those boreholes to be included in the primary "core" network that is needed for general resource management
- a Multiple Piezometer Study to identify the requirements for regional long-term monitoring of known or suspected vertical head gradients or head differences
- the production of an Asset Management Plan for the core network.

This report summarises the whole project.

The design methodology is based on ranking each of the boreholes forming the current groundwater monitoring network by a number of attributes to enable them to be assigned to a 3-tier system:

- *Tier 1 National Network:* Consisting of monitoring boreholes with data of the highest quality where monitoring can be carried out to provide the detailed long-term record that is valuable for resource studies. This network will form the basis for the national monitoring network.
- *Tier 2 Regional Network:* This consists of core monitoring sites of regional importance. This network will provide groundwater level monitoring to meet most of the data users' demands for water level information and monitoring of resource variations on a regional basis.
- *Tier 3 Local Network:* These are project orientated monitoring sites, and will typically form an important part of the monitoring network. These should include both long-term regional modelling and investigation projects over wide areas and more local issues such as the monitoring of individual abstraction licences, quality and other environmental impacts, such as the effects of abstractions on wetlands and surface waters.

The design methodology has been applied to both major and minor aquifers and defines criteria for the selection of appropriate monitoring network densities and the most appropriate monitoring frequency for each of the Region's aquifers.

The overall objective is to meet the Agency's needs and obligations to provide groundwater data for the assessment and management of the Region's water resources.

The proposed modifications to the networks in each of the Area catchments should be implemented to improve core network data quality, coverage and reduce operational costs for the Agency.

It is also recommended the Agency implement:

- a periodic review every five years of all Tier 3 boreholes to confirm their continued inclusion in the monitoring network; and,
- the adoption of the proposed minimum monitoring frequency for the core network.

Implementation of the above recommendations will eventually provide the Agency with a core network that meets the requirements for a regional groundwater level monitoring network.

The scope of work for the Multiple Piezometer Study, which was an additional element of Stage 2 of the review, included:

- identification of the requirements for regional long term monitoring of vertical head differences in each aquifer; and
- provision of an outline programme for construction of the proposed piezometers with cost estimates and the integration of this programme into the core network Asset Management Plan.

The objective of the study was to achieve the original objectives as defined in the Terms of Reference for Stage 2 of the Review, in particular:

- the identification of the changes that are needed to improve the efficiency of the regional monitoring network with particular regard to the numbers and locations of the observation boreholes, monitoring frequency and an estimate of the costs of these changes; and,
- to provide data for the Asset Management Plan for the regional core groundwater level monitoring network.

The Multiple Piezometer Study has shown that there is a requirement for additional monitoring boreholes for regional long term monitoring of vertical head differences in each aquifer.

The Asset Management Plan for the whole regional core groundwater level monitoring network includes:

- an evaluation of the borehole age, remaining asset life, current value and replacement cost;
- a review of borehole refurbishment requirements, associated costs and prioritisation for carrying out the works;
- a prioritised programme including refurbishment work, construction of new core monitoring boreholes, decommissioning of redundant boreholes, conversion of multiple monitoring boreholes for the core network and the construction of multiple piezometer study boreholes; and
- a review of current Agency procedures and organisational structure to manage the improved core groundwater network.

The whole currently monitored network comprises 1644 boreholes. Following the application of the network design methodology that was developed and validated during Stage 1 715 of these boreholes have been proposed to make up the core network. The design methodology and multiple piezometer study also recommended the core network include the construction of 221 new boreholes and conversion of 26 multiple monitoring boreholes. Decommissioning of 252 surplus boreholes was also recommended, subject to approval by the area network managers.

An evaluation of the asset surveys carried out for the 715 currently monitored core network boreholes has determined that the average Residual Life of a borehole is 37 years. It has also established that the total estimated Replacement Cost for these boreholes is £7,374,000 and that the total estimated Current Asset Value is £4,493,000.

An assessment of the refurbishment requirements needed to continue the collection of groundwater level data for the current core network has established that £47,000 of remedial works are required over the next 36 months. Of these remedial works £5,000 are considered urgent and should be carried out within the next 3 months.

The total regional cost associated with the implementation of the strategic review capital programme is £3,246,000. This includes construction of new boreholes, decommissioning of surplus boreholes and refurbishment of the core network. This also includes an estimated £67,000 to carry out a datum levelling exercise of the 715 core network boreholes. It is proposed that these works be carried out over the next 8 years at an average cost of £406,000 per year. This work could be carried out under the National Contractors Framework (NCF) or the National Site Investigation Framework (NSIF) agreements. It is estimated that the Agency project management for implementing this programme will require an average 163 staff days/year to administer. The utilisation of NEECA framework consultants may allow the Agency to improve efficiency.

The average annual recurring payments over the next 30 years are £91,000. This includes the replacement cost for loggers, other monitoring equipment and current core network boreholes.

The average annual Agency operating costs for the core network, over the same period, are £138,000. This includes data collection, data processing, archiving, validating, maintenance of loggers, site maintenance provision of information to customers and supervision. Based on implementing the proposed capital works programme the Eastern Area is estimated to have an increase in required staff operating inputs of 47% over the next 7 years. The Central Area is estimated to have an increase of 30% over the next 8 years and the Northern Area is estimated to have an increase of 16% over the next 3 years.

It is recommended that the modifications to the currently monitored network identified in the three Area Stage 2 Design Methodology Reports and the construction of additional boreholes identified in the Multiple Piezometer Report should be made in accordance with the enclosed programme.

A further study should be carried out to extend the requirement for multiple piezometer boreholes (already identified at the new core network locations) to include all those existing core network sites that have a shallow water table present, or any other significant flow horizon in the main aquifer.

It is recommended that datum levelling be carried out for the current core network of 715 boreholes.

The recommended way forward can be summarised as follows:

- The Agency, with consultant support if required, to prepare a strategic plan to implement the recommendations of the review, including construction programmes
- Agency to utilise NEECA framework consultants for design and supervision of construction work
- Agency to utilise National Contractors Framework (NCF) or the National Site Investigation Framework (NSIF) contractors for capital works

1 INTRODUCTION

1.1 BACKGROUND TO THE REVIEW

The Agency has statutory duties to manage and protect water resources in the Anglian Region. To discharge these duties the Agency maintains and collects groundwater level data from a monitoring network of approximately 1600 boreholes throughout the Region, at a current annual cost of approximately £280k.

The monitoring network has grown over several decades on an *ad hoc* basis to meet a variety of needs, but has never been reviewed as a whole, or had any design standards imposed on it. The purposes of the network, and the variety of reasons for collecting groundwater level data, have never been clearly defined and prioritised. Also, the network is known to be inefficient to some degree, in that it has surpluses of borehole numbers in some areas and deficiencies in borehole numbers in other areas.

The need for a full strategic review of the network to address this unsatisfactory situation was identified by the Agency in 1996, and a Strategy Document (Ref. 13) was drawn up to plan the Review.

1.2 THE REGIONAL REVIEW STRATEGY

The overall objectives of the review are:

- Identify the current and future requirements of customers for groundwater level data.
- Carry out a full asset survey on the boreholes within the currently monitored network.
- Review the network by developing a design methodology to classify the boreholes into categories based on the usage of the data that they provide.
- Apply the methodology to identify the primary core network that is needed to provide data for resource management, ensuring that the core network is adequate in terms of coverage, distribution density and frequency of observation.
- Assess the quality of the network (including borehole distribution and construction, data collection and recording, and archive management) and report any changes that are needed to ensure that the network reaches and maintains a satisfactory standard of overall efficiency.

The Strategy Document set out a phased structure for the review programme. Stage 1 was a scoping study, which included three separate projects, namely:

- A trial asset survey of the network in three sample catchments, i.e. the Little Ouse, the Waveney, and the North Lincolnshire Limestone, to provide data for the application of the design methodology and cost estimates for the full asset survey.
- A scoping study to develop a design methodology. The methodology was based on that proposed in a R&D report prepared for the Agency by the British Geological Survey (BGS) in 1994 (Ref. 1). When developed, the methodology was validated by applying it to the data obtained from the asset surveys of the network in the three trial catchments. The methodology is outlined in Section 2.1 and described more fully in Appendix C.
- A customer survey of both internal Agency customers and external customers, which provided information on their requirements and use of the data, and helped the Agency to estimate the value of the data to them.

Stage 2 of the review was originally planned to include (within one project):

- An asset survey of the full regional groundwater level monitoring network, except for the three trial catchments already surveyed.
- The application of the design methodology developed in Stage 1 to classify all the monitoring boreholes in the regional network into three tiers, tiers 1 and 2 comprising the primary core network, and tier 3 including all the remaining boreholes (needed for a variety of purposes). Lists would then be produced of (a) sites where new core boreholes were required and (b) sites where existing monitored boreholes were not needed. These sites would then be reviewed to draw up programmes for constructing new boreholes and decommissioning redundant boreholes.

Binnie Black and Veatch were appointed to carry out Stage 1 and subsequently Stage 2 of the Review, but their brief was later extended to include the following items:

- The preparation of an Asset Management plan for the primary core regional network
- A study to identify the requirements for supplementary piezometers at new core network sites to monitor groundwater levels where vertical head differences existed in main aquifers, or in overlying drift deposits or minor aquifers that were also present.

2 DESIGN METHODOLOGY DEVELOPMENT FOR ANGLIAN REGION

2.1 INTRODUCTION

The methodology developed during Stage 1 of the study was based on that outlined in the British Geological Survey (BGS) Technical Report WD/94/41C "*National Groundwater Level Monitoring Network Review*" (Ref.1), and in particular "Method A" as set out in the report. (A summary of report WD/94/41C is included in Appendix B of this report.)

The design methodology aims to classify all observation boreholes into a 3-tier system:

- *Tier 1 National Network:* Consisting of monitoring boreholes with data of the highest quality where monitoring can be carried out to provide the detailed long-term record that is valuable for resource studies. This network will also form the basis for the national monitoring network.
- *Tier 2 Regional Network:* This consists of core monitoring sites of regional importance. This network will provide groundwater level monitoring to meet most of the data users' demands for water level information and monitoring of resource variations on both regional and national basis. It is assumed that this regional network information will be used primarily at the regional level.
- *Tier 3 Local Network:* These are project orientated monitoring sites. This will typically form an important part of the monitoring network. These should include both long-term regional modelling and investigation projects over wide areas and more local issues such as the monitoring of individual abstraction licences, quality and other environmental impacts, such as the effects of abstractions on wetlands and surface waters.

The design methodology also aims to:

- define criteria for the selection of appropriate monitoring network densities in the Region's aquifers; and
- rank the boreholes by a number of attributes to enable them to be assigned to one of the three tiers.

The overall objective is to meet the Agency's needs and obligations to provide groundwater data for the assessment and management of the Region's water resources. The objectives of a monitoring network are given in Table 1 of the report entitled "Stage 1 – Design Methodology Report", dated October 1999 (Ref.2) and are summarised as follows:

- Spatial distribution (levels, hydraulic behaviour, areas of recharge/discharge)
- Trends (recharge, recession, abstraction impacts)
- Early warning (drought action, flood warning)
- Baseline for future issues (data for modelling, resource investigation, environmental impact)
- Industrial and urban impacts (pollution incidents, rising groundwater)
- Surface water / groundwater interaction (impact of recharge or abstraction on stream flow or wetlands)
- Licensing and operational control (abstraction, recharge)

The methodology is applied to both major and minor aquifers and the review includes recommendations of the most appropriate monitoring frequency for each aquifer.

The adopted methodology is that specified in section 3.2 of the Stage 1 – Design Methodology Report (Ref.2).

The results of the application of the design methodology during Stage 2 are the subject of the following reports:

- Stage 2 Design Methodology Report – Eastern Area May 2001 (Ref.3)
- Stage 2 Design Methodology Report – Central Area May 2001 (Ref.4)
- Stage 2 Design Methodology Report – Northern Area June 2001 (Ref.5)

2.2 APPLICATION

The application of the design methodology is described and summarised in Figure 1 in Appendix C

2.3 DENSITY TARGETS

The density targets used for this study are based on those given in the BGS report (Ref.1). A geographical basis for the coverage of the aquifers is considered the most appropriate to ensure adequate overall density based on aquifer unit or groundwater catchment as well as area. The actual density value used depends on the classification of the network into tiers. Factors considered are:

- The distance over which significant variation can be expected
- Compatibility with current monitoring practices and densities
- Conformity with the densities proposed for groundwater quality monitoring

The values adopted for this review are those shown in Table 1.

Table 1 *Proposed density criteria*

Network Tier	Aquifer units /Catchments	Aquifer density (km^2/borehole)	
		Minor / Major confined	Major Unconfined
1 National	1	200	100
2 Regional		50	25
3 Local		As appropriate	As appropriate

The design methodology invokes aquifer specific target monitoring densities and borehole ranking attribute scores for major and minor aquifers. The methodology was tested in Stage 1 through application to three trial areas – The Waveney, Little Ouse and Northern Lincolnshire Limestone catchments. The target densities were then adopted for the Stage 2 catchments and the results are presented in the reports for the three Regional Areas (Refs. 3, 4 and 5). These target densities have been taken as guidelines only and the actual numbers of monitoring boreholes for each network tier within specific areas and catchments have been adjusted for the local and regional area requirements.

2.4 RESULTS OF APPLICATION

In summary, the proposed modifications to the monitoring network in each of the areas are shown on Table 2. The borehole locations are shown on Figures 1 to 3.

Table 2 *Summary of proposed modifications to monitoring network*

Monitoring network	Eastern Area	Central Area	Northern Area
Tier 1 sites	52	66	45
Tier 2 sites	158	238	156
Tier 3 sites	263	318	96
New core network borehole sites	68	59	21
Surplus sites	33	162	57
Existing Multiple aquifer sites in core network	8	15	3

Recommendations

The proposed modifications to the networks in ~~the~~ each of the Area catchments should be implemented to improve core network data quality, coverage and reduce operational costs for the Agency.

We also recommended the Agency implement:

- a periodic review every five years of all Tier 3 boreholes to confirm their continued inclusion in the monitoring network; and,
- the adoption of the proposed minimum monitoring frequency for the core network.

We consider that implementation of the above recommendations will eventually provide the Agency with a core network that meets the requirements for a regional groundwater level monitoring network.

However as a result of carrying out this review we believe further consideration should be given to the following general points:

- there are a few currently monitored core network sites where the aquifer and construction details are unknown and these details need to be confirmed to improve the quality of data for those sites;
- reviewing all boreholes that go dry annually or are pumped routinely, with the aim of removing or replacing them in the network. Deepening the dry boreholes is an option to be considered;
- replacing multiple aquifer monitoring installations with separate boreholes monitoring the respective aquifers present at that location. These replacements were subsequently considered under the Multiple Piezometer Study to determine vertical head differences between the aquifers at that location;
- considering the installation of new boreholes or modifying existing unlined boreholes to form grouped or nested installations in separate holes alongside each other to monitor regional scale vertical head differences within aquifers to improve resource monitoring. This was subsequently considered under the Multiple Piezometer Study;

- considering the legal requirements to ensure that core network sites can continue to be accessed for monitoring purposes by the Agency in the future. Ideally, all core network sites should have long-term leases or licenses.

Finally, two further points for local consideration are:

- reviewing the opportunity for incorporating some of the new boreholes along the route of the Great Yarmouth gas pipeline into the core network (Eastern area); and
- re-numbering site 7/505 which monitors the Northampton Sand to a number prefixed with 4/*** (the Jurassic Aquifer unit) and sites monitoring the sand and gravel aquifers within N2 and N3 catchments (2/517, 2/519, 2/522, 3/031 & 3/032) to a number prefixed with 8/*** (the Sand and Gravel Aquifer unit) (Northern Area).

2.5 APPRAISAL OF PERFORMANCE AND IMPROVEMENTS FOR FUTURE USE

Unknowns data collection

As noted above in the recommendations, there are core network sites that are lacking aquifer and construction details. Collection of this data would improve the quality of the network.

Ranking, density, classification, updating scoring (5yrs)

There should be a regular reappraisal of the ranking, density distribution and classification of purpose for the network. The scoring for each of the monitoring boreholes could also be carried out on a regular basis to assist in potential transfers between tiers.

3 CORE NETWORK

During the application of the design methodology the Region's aquifers were subdivided into major and minor aquifers. The Agency definition of major and minor aquifer (Taken from Policy and Practice for the Protection of Groundwater EA, 1998) is as follows:

Major Aquifers: These are highly permeable formations usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes.

Minor Aquifers: These can be fractured or potentially fractured rocks, which do not have a high primary permeability, or other formations of variable permeability. Although these aquifers will seldom produce large quantities of water for abstractions, they are important both for local supplies and in supplying base flow for rivers.

The Aquifer Properties Manual published jointly by the Agency and British Geological Survey lists the major and minor aquifers of England and Wales (Refs. 6 and 7).

The major aquifers listed that occur in the Anglian Region are the Chalk, Lower Greensand and Jurassic Limestones (Blisworth Limestone and Lincolnshire Limestone). The minor aquifers listed are the Crag, Lower London Tertiaries, Upper Greensand/Lower Cretaceous/Uppermost Jurassic (Carstone, Roach, Sandringham Sands, Leziate Beds, Spilsby Sandstone) and Jurassic (Corallian, Northampton Sand, Marlstone Rock Bed and Frodingham Ironstone).

The following subdivision of aquifers, based on their regional importance, was used for this study in each of the three Areas.

Eastern Area

The major aquifer in the Eastern Area is the Chalk. The Crag, although normally considered to be a minor aquifer, is included as a major aquifer in the Area due to its hydraulic continuity with the underlying Chalk and its importance for local supply. The minor aquifers for the Area are the Recent gravel, permeable drift and the Basal Sands of the Lower London Tertiary deposits. The gravel and permeable drift provide local supplies and therefore are considered important in a local context.

Central Area

The major aquifers in the Central Area are the Chalk and Lower Greensand. The Crag, although normally considered to be a minor aquifer, is included as a major aquifer in the Area due to its hydraulic continuity with the underlying Chalk and its importance for local supply. The minor aquifers in the region are the Recent gravel, permeable drift, Carstone, Roach, Sandringham Sands, Leziate Beds, Combrash and the Blisworth Limestone. The Blisworth limestone is considered to be a minor aquifer in this area due to its limited thickness and extent. These minor aquifers all provide local supplies and therefore are considered important in a local context.

Northern Area

The major aquifers in the Northern Area are Lincolnshire Limestone, Spilsby Sandstone and the Chalk. The minor aquifer Elsham Sandstone is considered to be both hydraulically and stratigraphically separate from the Spilsby Sandstone. There are a number of minor aquifers in the Jurassic strata (Kellaways Sand, Cornbrash and Blisworth Limestone, Northampton Sand, Marlstone Rock Bed and Frodingham Ironstone) and the Lower Cretaceous strata (Carstone, Roach, Tealby Limestone and Claxby Ironstone). Other minor aquifers in the region are Recent sands and gravel and permeable drift deposits. These all provide local supplies and therefore are considered important in a local context.

3.1 MAJOR AQUIFERS

The application of the design methodology to each of the major aquifers in the region resulted in the core network being developed as shown in Table 3. The borehole locations are shown on Figures 1 to 3.

Table 3 *Core network monitoring of major aquifers*

Aquifer Area	Existing core network	Proposed New core network	Multiple replacement or conversions	Total recommended core network locations	Surplus
Crag					
Eastern	9	17	1	27	-
Central	1	1	-	2	-
Chalk					
Eastern	144	39	8	191	17
Central	209	30	5	244	133
Northern	47	2	-	49	15
Lower Greensand (Woburn Sands)					
Central	26	7	6	39	1
Spilsby sandstone					
Northern	14	5	-	19	3
Lincolnshire Limestone					
Northern	94	6	6	106	37

3.1.1 Crag

There is a marked shortfall in the required numbers for the core network in Eastern Area and the distribution is uneven across the outcrop and where younger deposits overlie the Crag.

In addition to the proposed new core network locations identified under this study the current drilling programme in the Waveney catchment will be installing a further twelve new monitoring boreholes in the Crag.

3.1.2 Chalk

In general the required number of the core network boreholes is adequate and the distribution is even across the outcrop and where younger deposits overlie the Chalk. In detail, the design methodology has identified the requirement for new core network boreholes in the Waveney catchment in Eastern Area and the Ouzel and Ivel catchments in Central Area where there are areas with insufficient Chalk monitoring boreholes.

The current drilling programme in the Waveney catchment will be installing a further eleven new monitoring boreholes in the Chalk.

The design methodology has identified a significant number of boreholes, particularly in Central Area, that are surplus to the proposed core network monitoring requirements for regional water level information and resource monitoring for the Chalk aquifer. These boreholes will be subject to review by Agency Area staff for local and project orientated monitoring such as modelling studies before removal from the monitoring network.

3.1.3 Lower Greensand (Woburn Sands Formation)

The required number of the core network boreholes is generally adequate and the distribution is even across the outcrop. The design methodology has identified the requirement for new core network boreholes where younger deposits overlie the Greensand.

3.1.4 Spilsby Sandstone

There is a shortfall in the number of core network boreholes required and although the distribution is even across the outcrop and over the western part where younger deposits overlie the Spilsby Sandstone there is a lack of coverage further eastwards.

3.1.5 Lincolnshire limestone

There is a shortfall in the number of core network boreholes required and although the distribution is even across the outcrop and over the western part where younger deposits overlie the Lincolnshire Limestone there is a lack of coverage further eastwards.

The design methodology has identified a significant number of boreholes that are surplus to the proposed core network monitoring requirements for regional water level information and resource monitoring for the Lincolnshire limestone aquifer. These boreholes will be subject to review by Agency Area staff for local and project orientated monitoring such as modelling studies before removal from the monitoring network.

3.2 MINOR AQUIFERS

The application of the design methodology to each of the minor aquifers in the region resulted in the core network being developed as shown in Table 4. The borehole locations are shown on Figures 1 to 3.

Table 4 *Core network monitoring of minor aquifers*

Aquifer Area	**Existing core network**	**Proposed New core network**	**Multiple replacement or conversions**	**Total recommended core network locations**	**Surplus**
Recent gravels or permeable drift					
Eastern	21	6	6	33	2
Central	12	15	1	28	8
Northern	26	-	-	26	16

Table 4 *Core network monitoring of minor aquifers*

Aquifer Area	Existing core network	Proposed New core network	Multiple replacement or conversions	Total recommended core network locations	Surplus
Lower London Tertiaries					
Eastern	-	-	1	1	-
Lower Cretaceous /Upper Jurassic					
Central	25	5	8	38	1
Northern	12	-	-	12	-
Other Jurassic /Oolites					
Central	6	-	-	6	-
Northern	4	8	3	15	-

3.2.1 Recent gravels and Permeable drift

There are extensive fluvial sands and gravel deposits and Permeable drift deposits along with later alluvial deposits in river floodplains that are included in the existing core groundwater monitoring network. The coverage in these localised areas is for the most part reasonable both for the sand and gravel aquifers as well as the underlying aquifers.

New boreholes are required in Eastern (6) and Central Area (15) to provide better local coverage. In addition there are 7 multiple sites that have been identified for replacement or conversions to provide better data.

The design methodology has identified a number of boreholes, particularly in Northern Area, that are surplus to the proposed core network monitoring requirements for regional water level information and resource monitoring for these sand and gravel aquifers. These boreholes will be subject to review by Agency Area staff for local and project orientated monitoring such as modelling studies before removal from the monitoring network.

3.2.2 Lower London Tertiaries (Basal Sands)

One existing core network site has been identified for replacement.

3.2.3 Lower Cretaceous/Upper Jurassic

The required number of the core network boreholes is generally adequate and the distribution is even across the outcrop. The design methodology has identified the requirement for new core network boreholes in North Norfolk where younger deposits overlie the Chalk.

Modifications to eight existing core network monitoring boreholes have also been identified where they currently monitor multiple aquifers so that they will monitor single aquifers.

One surplus borehole has been identified. This borehole will be subject to review by Agency Area staff for local and project orientated monitoring such as modelling studies before removal from the monitoring network.

3.2.4 Other Jurassic aquifers and oolites

The required number of the core network boreholes is generally adequate and the distribution is even across the outcrop. The design methodology has however identified the requirement for ~~both~~ some new core network boreholes in Northern Area.

3.3 MONITORING FREQUENCIES

Based on the current monitoring records 82% of the core network boreholes are monitored at monthly intervals. 4% are monitored daily and a further 6% are monitored on a weekly basis. The remaining 8% of boreholes are monitored at time intervals between every three months and twelve months.

The appropriate frequency of monitoring depends on the use to which the data is put and the response of the aquifer to transient events. New boreholes should be fitted with data loggers for the first twelve months to determine the range and response to both seasonal and local effects. The monitoring frequency should be hourly and the results downloaded monthly for the first year. The increased frequency is needed to detect any unexpected daily fluctuations due to e.g. intermittent abstraction nearby from unrecorded private wells, barometric changes in confined aquifers, evapotranspiration from shallow water tables etc. Then after review of the response the frequency may be reduced to relevant Tier 2 frequency for the aquifer type.

The criteria for minimum monitoring frequency given in the Stage 1 report (Ref.2) should be adopted, as set out in Table 5 below, unless at individual sites the results from data logging indicate otherwise.

Table 5 *Proposed minimum monitoring frequency criteria*

Network Tier	Low storage aquifers (e.g. Unconfined Chalk)	High storage aquifers (e.g. Permo Trias)	Minor aquifers, low variation confined or difficult access
1 – National	Daily measurements	Weekly measurements	-
2 – Regional	Monthly measurements	Measurement every two months	Measurement every three months
3 – Local	No criteria	No criteria	No criteria

The Tier 1 sites have been identified as preferred locations for data loggers. These should be downloaded on a monthly basis to reduce the chances of losing data.

The proposed minimum monitoring frequency for the minor aquifers has been increased from every six months as recommended in the BGS report (Ref. 1.) to every three months to ensure that the seasonal variation is better defined.

4 SUMMARY OF MULTIPLE PIEZOMETER STUDY

The scope of work for this additional element of Stage 2 of the review was to:

- identify the requirements for regional long term monitoring of vertical head differences in each aquifer;
- identify approximate 5km grid square locations where such monitoring is required;
- prepare tables for each Area showing where multiple level groundwater monitoring should be implemented;
- provide an outline programme for construction of the proposed piezometers with cost estimates and integrate this programme into the core network Asset Management Plan; and,
- to produce a final report describing the work carried out, presenting the results and recommendations of the study.

The objective of the study was to achieve the original objectives as defined in the Terms of Reference for Stage 2 of the Review, in particular:

- the identification of the changes that are needed to improve the efficiency of the regional monitoring network with particular regard to the numbers and locations of the observation boreholes, monitoring frequency and an estimate of the costs of these changes; and,
- to provide data for the Asset Management Plan for the regional core groundwater level monitoring network.

The results of the study during Stage 2 are given in the Multiple Piezometer Study report, November 2001 (Ref.8)

4.1 VERTICAL HEAD GRADIENTS IN EACH AQUIFER AND BETWEEN ADJACENT AQUIFERS

The following areas have been identified where there is a possibility for vertical head differences to occur within aquifers:

- Areas of recharge;

  This includes those areas of the aquifer that are covered by drift deposits that are able to provide recharge to the underlying aquifer i.e. 'leaky' aquifer conditions.
- Discharge areas including rivers, springs and the sea coast;
- Areas near hydrogeological boundaries such as faults or buried glacial channels;
- Areas where aquifers and overlying aquifers are known or suspected to be in hydraulic continuity; and,
- Areas where model or resource evaluation studies have identified that vertical flow is taking place.

4.2 PROPOSED SITES FOR MULTIPLE PIEZOMETER STUDY

The Multiple Piezometer Study (MPS) has shown that there is a requirement for additional monitoring boreholes for regional long term monitoring of vertical head differences in each aquifer.

The study has identified areas where this monitoring is required and these have been shown in tables and figures of the MPS report (Ref.8). A summary of the results is shown in Table 6 and the borehole locations are shown on Figures 1 to 3.

Where possible existing core monitoring network sites and proposed new core monitoring network borehole sites have been used as potential locations for multiple piezometer installation.

There are also existing monitoring boreholes that monitor multiple aquifers. The network review recommended that new replacement boreholes be constructed next to the existing borehole to monitor a single aquifer. Both of these were to be monitored for at least five years to develop a correlation of water level response. Under the MPS the existing borehole can either be converted, if technically feasible, or an additional new borehole be constructed. One advantage of the second option is that the borehole can be constructed immediately rather than having to wait five years for the correlation between the existing and new replacement core network borehole.

The distribution of the grouped multiple piezometer holes in Eastern Area are such that they will provide data throughout the area.

The distribution of the grouped multiple piezometer holes in the Central and Northern Areas are such that they will allow a representative section with more comprehensive monitoring to be drawn through the aquifers present. Adjacent sections will provide valuable additional information for extrapolation.

Table 6 *Multiple piezometer monitoring of the aquifers in the region*

Aquifer	Eastern Area				Central area				Northern Area			
	Existing grouped Tiers 1-3	New core net-work	New MPS	MPS conver-sion	Existing grouped Tiers 1-3	New core net-work	New MPS	MPS conver-sion	Existing grouped Tiers 1-3	New core net-work	New MPS	MPS conver-sion
Crag	10		11 +12*	1		1						
Chalk	77	4	16 +11*		110	10	9	6	11	2	2	
Lower Greensand (Woburn Sands)					3	6	3	4				
Spilsby sandstone									5	2		
Lincolnshire Limestone									19	2		
Recent gravels and Permeable drift	72	2	7 +3*	6	64	7	5	1	33			
Lower London Tertiaries	1			1								
Lower Cretaceous /Upper Jurassic					7	5	3	4	5		3	3
Other Jurassic /Oolites					5				3	8		

* Currently being drilled in the Waveney catchment

4.2.1 Existing core network sites

There are a number of locations that have groups of monitoring boreholes already installed. These broadly fall into the following categories:

- Environmentally sensitive areas such as SSSI wetlands
- River abstraction or flow augmentation schemes, and
- Modelling areas

The wetland grouped boreholes have many shallow boreholes but not many deep ones. These groups of boreholes have been shown as single points for diagrammatic clarity on Figures 1, 2 and 3.

In general the other groups comprise monitoring installations in the major aquifer and the overlying superficial deposits at the site. The numbers of installation in each of the aquifers of the area are shown on Table 6 and their locations shown on Figures 1 to 3.

4.2.2 Proposed new MPS boreholes

Additional new boreholes for the MPS were required as follows:

- Thirty-four in Eastern Area;
- Twenty in Central Area; and,
- Five in Northern Area.

The sites that have been selected are to provide information that will allow a typical or representative section to be drawn through the aquifers present. These sections would ideally be targeted at areas of proposed model studies or areas of over abstraction or stress within the aquifer.

The intention is, where possible, to utilise existing groups or core network single sites and the proposed new monitoring sites for the core monitoring network.

4.2.3 New core network boreholes

As part of the review of the core monitoring network the requirement for new monitoring boreholes was identified. In a number of cases the requirement for more than one installation was also identified. Lists of these locations are in Tables 1, 5 and 8 of the MPS report (Ref.8).

4.2.4 Conversion of existing boreholes monitoring multiple aquifers

The number of conversions identified were:

- Eight in Eastern Area;
- Fifteen in Central Area; and,
- Three in Northern Area.

For this multiple piezometer study, consideration has been given to whether the original observation boreholes could be converted at these sites to monitor water levels in the underlying Northampton Sand aquifer. If conversion of the original borehole were technically not feasible then a second new observation borehole would have to be drilled.

These sites with grouped or nested installations in separate holes alongside each other would allow the measurement of vertical head differences as well as any recharge or discharge response differences in the various aquifers at the location.

5 ASSET SURVEY RECOMMENDATIONS

5.1 REVIEW AND COMMENTS – DATA COLLECTION, DATABASE DEVELOPMENT AND POPULATION, REVIEW OF INFORMATION, SITE INSPECTION

The results of the asset survey are given in the Area reports (Refs. 9, 10 and 11).

Eastern Area

The quality of the available data, data collection and archiving systems was reviewed and found to be lacking; digital data were incomplete and often conflicted with paper records.

The existing asset data have been found to be incomplete and often inefficient to access. These issues should be resolved for both reasons of efficiency and clarity of approach to meet statutory groundwater monitoring and general environmental responsibilities. The large amount of missing data are understood to be mainly due to lack of hydrometric staff resources in the past to enable data to be properly collected and archived.

Central Area

The quality of the available data, data collection and archiving systems was reviewed and found to be fairly substantial; digital data were complete except for a few fields.

The existing asset data have been found to be complete although there are often insufficient or poor photographs to aid in locating the sites.

Northern Area

The quality of the available data, data collection and archiving systems was reviewed and found to be fairly satisfactory; digital data were substantially incomplete

The existing asset data have been found to be complete although there are often insufficient or poor photographs to aid in locating the sites.

5.2 DATABASE TRANSFER

All the spreadsheets used to analyse the data, carry out the data comparison and rank the boreholes were exported back into the project Access database. This database contains all data used for the study in the most corrected and up-to-date form.

The Project Data CD-ROM also contains all the Geographical Information System (GIS) data used to produce the various report drawings. This information includes the:

- digitised hydrogeological boundaries;
- groundwater catchment boundaries;
- coast, river and other water features;
- major town names;
- 50,000km and 10,000km grid lines;
- wetland sites;
- current borehole network plotted by aquifer colour and proposed tier symbol; and,
- all proposed new boreholes plotted by aquifer colour.

It should be noted that all hydrogeological data has been digitised and is stored under licence from the British Geological Survey (Licence No. 2000/118). All Ordnance Survey

data is stored under licence from the Ordnance Survey (Licence No. GD03177G). Use of such data should be in accordance with the respective licence agreement

The digital site photos, location sketches and headwork sketches have been stored on a separate CD-ROM for each Area.

5.3 GENERAL LESSONS LEARNT

To obtain full benefit from the data in future the Agency will need to ensure that adequate staff resources are available to regularly update and control the quality of the site information and groundwater level data contained within the database. It is also recommended that the database be set up to show when details were last updated.

A procedure needs to be implemented so that comments by the field staff during their regular monitoring visits are routinely recorded on the Borehole Record sheets and Station Manager database.

For the data to remain reliable the database should be repopulated with time dependent asset survey data (e.g. condition fields) at suitable intervals.

6 SUMMARY OF FINDINGS OF AMP RELATED TO CORE NETWORK

The AMP for the whole regional core groundwater level monitoring network includes:

- an evaluation of the borehole age, remaining asset life, current value and replacement cost;
- a review of borehole refurbishment requirements, associated costs and prioritisation for carrying out the works;
- a prioritised programme including refurbishment work, construction of new core monitoring boreholes, decommissioning of redundant boreholes, conversion of multiple monitoring boreholes for the core network and the construction of multiple piezometer study boreholes; and
- a review of current Agency procedures and organisational structure to manage the improved core groundwater network.

The results of the study during Stage 2 are given in the Asset Management Plan for the core network, February 2002 (Ref. 12).

6.1 ASSET EVALUATION

For 341 of the 715 core network boreholes there is a record of the construction date of the borehole and hence the age is known. Where the construction date is unknown then the length of the hydrograph data is taken as the Actual Age.

The Effective Age is based on the current condition of the asset. Although an asset comprises the borehole, associated headworks, monitoring equipment and any access ancillaries, it has been assumed that only the condition of the borehole itself has an impact on the Effective Age of the asset.

The condition of the borehole has been quantified by assessing any reduction in depth of the borehole compared with the original construction depth and has been assumed to deteriorate uniformly over its Economic Life (see below). For example a borehole that is constructed 100m deep and has subsequently deteriorated to 50m depth is assumed to have an Effective Age of half its Economic Life. There are many factors that contribute to the life of a borehole and there are man variations in the type of borehole in the monitoring network. The use of borehole depth to determine the age is a simplification of all these factors due to the variability of the amount and quality of data available for each borehole.

Although a lined borehole should have a longer life than one without lining we consider that it would be impossible to quantify the difference in life expectancy. This is because of the multitude of combinations of lining type and condition that there are. For this reason it has been assumed that the given Economic Life of 60 years is based on an average borehole

The Economic Life for an observation borehole is assumed to be 60 years. The Residual Life has been calculated as the Economic Life less the greater of the Actual Age or Effective Age of the asset.

A borehole with an Actual or Effective Age greater than the Economic Life of 60 years is considered to have no Residual Life.

6.2 COSTINGS OF CORE NETWORK

Replacement costs and Current Asset Value

The Replacement Cost of an asset has been estimated based on contracts for similar work carried out over the past year or planned for this year.

The Current Value of an asset is the cost of an asset of equivalent productive capacity to satisfy the remaining service potential of the asset, less accumulated current cost depreciation. In other words

$$\text{Current Value} = (\text{Residual Life} / \text{Economic Life}) \times \text{Replacement Cost}$$

Appendix D of the AMP report (Ref. 12) lists the borehole Age (the greater of the Actual Age or Effective Age), Residual Life, Replacement Borehole Cost and Current Asset Value. These have been sorted by ascending Residual Life to highlight the estimated required borehole replacement order.

The results show that the average Residual Life of a core network borehole is 37 years. The total Replacement Cost is £7,374,000 and the total Current Asset Value is £4,493,000.

Refurbishment costs

The cost of refurbishment of a borehole comprises two parts:

a) Fixed Cost - Travel to and from the average site location (inc. vehicle, labour and fuel); and

b) Component Unit Cost - Sum of the refurbishment of the individual components (inc. materials, labour and plant).

Of the 715 core network boreholes only 259 require refurbishment. Tables in Appendix C of the AMP report (Ref. 12) detail the results of the refurbishment prioritisation along with components requiring refurbishment and the associated cost. The results are grouped by Area and are sorted in descending order of priority.

Table 7 below summarises these results.

Table 7: *Summary of Refurbishment Requirements*

BAND	REFURBISH-MENT PERIOD	Eastern		Central		Northern		TOTAL	
		No.	Cost	No.	Cost	No.	Cost	**No.**	**Cost**
A	0-3 mths	8	£2,774	3	£1,122	2	£639	**13**	**£4,535**
B	3-12 mths	45	£9,654	24	£3,524	30	£6,450	**99**	**£19,628**
C	12-24 mths	67	£11,781	31	£4,144	35	£4,897	**133**	**£20,822**
D	24-36 mths	2	£247	4	£569	8	£1,075	**14**	**£1,891**
TOTAL		**122**	**£24,456**	**62**	**£9,359**	**75**	**£13,061**	**259**	**£46,876**

6.3 PROGRAMME OF EXPENDITURE

This section details costs associated with the capital works proposed in the design methodology and multiple piezometer study reports (see Refs. 3-5 & 8), recurring payments associated with replacing Agency equipment and Agency operating costs associated with the proposed core network.

Appendix E of the AMP report (Ref.12) contains tables detailing the proposed Area capital works programme and associated costs. These costs are summarised in Table 8.

Table 8: *Summary of Capital Works and associated costs*

Borehole	Number	Capital costs (£)	Associated legal costs (£)	Consultants costs (£)	Agency costs (£)
New core network	136	916,000	220,000	367,000	218,000
Decommissioning	252	182,000	-	126,000	63,000
New Multiple Piezometer Study	59	298,000	8,000	29,500	15,000
Current Multiple Piezometer – new replacement	26	199,000	41,000	55,000	42,000
Current Multiple Piezometer – Conversion	26	103,000	-	13,000	6,500
Total Costs		1,698,000	269,000	590,500	344,500

6.3.1 New Boreholes

A total number of 136 new boreholes (Eastern 57, Central 58, and Northern 21) are proposed to be added to the current core network as a result of the application of the network design methodology (see Refs. 3-5). The total estimated capital costs for the construction includes an estimated £200 per site for general items for offices and stores for the Contractor. Associated legal costs of £220,000 are estimated to be incurred based on costs of £2,000 per site that include Agency staff costs, legal fees, land agent fees as well as the landowner's fees (including land agent and solicitor's) and any compensation monies agreed. It has been assumed that multiple boreholes at one site incur a total legal cost of £2,000.

The consultant's costs associated with the design and site supervision are based on costs BB&V have provided the Thames Region of the Agency, under the National Engineering and Environmental Consultancy Agreement (NEECA), for the design and site supervision of 30 new boreholes for a groundwater monitoring network and is equivalent to £2,700 per borehole.

Agency costs associated with the installation of a groundwater monitoring borehole are estimated at £1600 per borehole and are based on the Agency costs associated with 28 new boreholes at 12 sites in the Waveney catchment. These include PID preparation, site access acquisition, liaison with other Agency staff and management of consultant/site queries.

6.3.2 Decommissioning of Surplus Boreholes

A total number of 252 boreholes (Eastern 33, Central 162, and Northern 57) have been identified as surplus to the requirements of Tier 2 and 3 as a result of the application of the network design methodology (see Refs. 3-5), subject to review by Agency Area Staff. Decommissioning of surplus boreholes will also be subject to the owner's agreement.

In accordance with the Agency's guidelines, decommissioning of redundant boreholes and wells will consist of backfilling the entire hole with low permeability material (bentonite grout) and capping.

The total estimated capital cost includes an estimated £50 per site for general items for offices and stores for the Contractor. It has been assumed that there will be no legal costs associated with decommissioning.

The total consultant's costs associated with the design and site supervision are an equivalent rate of £500 per borehole.

Agency costs associated with the decommissioning of a groundwater monitoring borehole are estimated as £150 per borehole.

6.3.3 New Multiple Piezometer Study Boreholes

A total number of 59 new sites (Eastern 34, Central 20, and Northern 5) have been proposed for new multiple piezometer monitoring boreholes as a result of the multiple piezometer study (see Ref. 8). These sites have been selected to provide information that will allow a typical or representative section to be drawn through the aquifers present. The total estimated capital costs include an estimated £200 per site for general items for offices and stores for the Contractor. There are assumed to be no legal costs associated with those boreholes that are located at core network sites. There are six sites in Central Area and two sites in Northern Area, which are not associated with current core network boreholes that will incur legal costs of £8,000.

The total consultant's costs associated with the design and site supervision are an equivalent rate of £500 per borehole. It has been assumed that the construction will follow on from the construction of the new core network borehole at the site.

Agency costs associated with the installation of a groundwater monitoring borehole are estimated as £150 per borehole.

6.3.4 Current Multiple Monitoring Borehole – New Replacement

A total number of 26 boreholes (Eastern 8, Central 15, and Northern 3) have been identified as monitoring multiple aquifers (see Refs. 3-5). It is proposed that they are to be replaced with a new borehole that will monitor a single aquifer and that they be added to the current core network. The total estimated capital costs include an estimated £200 per site for general items for offices and stores for the Contractor. Agency legal fees of £41,000 are estimated to be incurred based on staff costs of £1,000 per site located on public land and £2,500 per site located on private land.

The total consultant's costs associated with the design and site supervision are an equivalent rate of £2,100 per borehole.

Agency costs associated with the installation of a groundwater monitoring borehole are estimated as £900 per borehole.

6.3.5 Current Multiple Monitoring Borehole – Conversions

As stated above a total number of 26 boreholes (Eastern 8, Central 15, and Northern 3) have been identified as monitoring multiple aquifers (see Refs. 3-5). As a result of the multiple piezometer study (see Ref. 8) these sites have been selected to provide information that will allow a typical or representative section to be drawn through the aquifers present. To achieve this the borehole must be replaced or modified to monitor a single aquifer. The options are either to convert the existing multiple installation, or the construction of an additional new borehole. Conversion depends on the existing construction details and technical feasibility. For this study it is proposed that they be replaced with an additional borehole that will monitor a single aquifer but will not form part of the core network, as this can be monitored immediately. There is no sum included for offices and stores for the

Contractor as it is anticipated that these boreholes will be installed at the same time as the core network new replacements. Likewise there are no associated legal costs.

The total consultant's costs associated with the design and site supervision are equivalent to £500 per borehole. It has been assumed that the construction will follow on from the construction of the new replacement core network borehole at the site.

Agency costs associated with the installation of a groundwater monitoring borehole are estimated as £150 per borehole.

6.3.6 Existing Tier 1 Borehole Legal Costs

It is recommended that all core network boreholes and future borehole installations should have a legal agreement to allow continuing access for monitoring.

A total number of 81 core network boreholes (Eastern 14, Central 30, and Northern 37) have been identified as being located on public land and have no legal agreement to allow access for monitoring (see Refs. 3-5). Agency legal fees of £81,000 are estimated to be incurred based on staff costs of £1,000 per site located on public land that include Agency staff costs, legal fees, land agent fees as well as landowner's fees (including land agent and solicitor's) and any compensation monies agreed.

A total number of 62 core network boreholes (Eastern 27, Central 30, and Northern 5) have been identified as being located on private land and have no legal agreement to allow access for monitoring (see Refs. 3-5). Agency legal fees of £155,000 are estimated to be incurred based on staff costs of £2,500 per site located on private land that include Agency staff costs, legal fees, land agent fees as well as landowner's fees (including land agent and solicitor's) and any compensation monies agreed.

6.3.7 Core Network Refurbishment

As part of this AMP the refurbishment requirements of the core network have been reviewed. The costs associated with this refurbishment are detailed in section 6.2. Table 7 summarises the Area refurbishment costs and the recommended refurbishment period. Tables in Appendix D detail the results of the refurbishment prioritisation programme along with components requiring refurbishment and the associated cost.

6.3.8 Datum Levelling

It is recommended that datum levelling be carried out for the current core network of 715 boreholes using one of several newly available Global Positioning Systems (GPS) developed by various surveying equipment suppliers. Details are given in the AMP Report (Ref.12).

It is anticipated that this system would provide savings compared with levelling of datums using traditional levelling methods.

It is estimated that 9 sites could be levelled per day. Based on current NEECA framework on site rates it is estimated that this would cost £67,000 including hire of equipment.

6.3.9 Replacement of Agency Equipment

The Agency Area Hydrometry Staff have provided details of the various equipment types. The associated unit replacement cost has been split uniformly over the lifespan of the unit.

6.3.10 Replacement of Current Core Network Boreholes

As part of this AMP the Residual Asset Life and Replacement Cost of the current core network boreholes has been determined.

The total Replacement Capital Cost of the 715 current core network is £4,014,000 over a 60-year period. This includes an estimated £200 per site for general items for offices and stores for the Contractor. Agency legal fees of £715,000 are estimated to be incurred based on staff costs of £1,000 per site. It has been assumed that replacement sites will be located on public land.

It is estimated that the total consultant's costs associated with the design and site supervision will be £1,502,000. This is an equivalent cost of £2,100 per borehole and is based on costs BB&V have provided the Thames Region of the Agency under the NEECA framework for the design and site supervision for a groundwater monitoring network.

Agency costs associated with the installation of a groundwater monitoring borehole are estimated as £1600 per borehole. The total Agency cost is £1,144,000.

The total annual recurring expenditure over the next 30 years is estimated to range from £34,000 to £301,000 with an average annual total of £91,000.

6.3.11 Programme Summary

The programme of capital works, as shown in the tables in Appendix E, has been developed based on the following priorities:

1st Priority: Uniform total capital expenditure over a 7-year period.

2nd Priority: Core network new boreholes.

3rd Priority: New MPS Boreholes where associated with core network location.

4th Priority: Multiple Aquifer Borehole -New Replacements and MPS Conversions

In practice it might be cost effective to carry out the construction on an area by area basis depending on the distribution of the various installation types.

The total capital strategic review costs over the next 8 years are £3,242,000. The average annual total recurring payment costs over the next 30 years are £91,000. The average annual Agency operating costs for the core network, over the same period, are £138,000.

6.4 AGENCY STAFFING REQUIREMENTS

6.4.1 Agency Operating Staff Inputs

The Agency Area Hydrometry Staff have provided details of the Agency operating staff inputs associated with the current groundwater level monitoring network. These have been used to estimate the Area staffing input for each task (data collection, data processing, provision of information, maintenance of loggers and supervision). An average of these values has been taken to give the Regional average staffing input for each task per borehole. These values are listed in Table 9 below.

The table in Appendix F details the current staff operating requirements for the current core network in each area based on the overall Regional average staff inputs per borehole listed in table 9 below. This table also shows the effect of the proposed capital works programme (as detailed in section 6.3) on the required staff operating requirements.

Table 9: *Regional Agency Operating Staff Inputs*

Task	Grade of staff	Current Staff Inputs (Staff days/unit per annum)	Current Staff Inputs * (total Staff days/year)	Longterm Staff Inputs * (total Staff days/year)
Data collection (per borehole)	2	0.49	348	468
Data processing, archiving & validation (per borehole)	2/3	0.18	127	170
Provision of information (per borehole)	3	0.09	65	87
Maintenance of loggers (per logger)	3/4	0.47	95	95
Supervision (per borehole)	4/5	0.03	24	32

Key: * These values are for monitoring the current core groundwater level monitoring network only.

Based on implementing the proposed capital works programme the Eastern Area is estimated to have an increase in required staff operating inputs of 47% over the next 7 years. The Central Area is estimated to have an increase of 30% over the next 8 years and the Northern Area is estimated to have an increase of 16% over the next 3 years. This assumes that the current Agency operating staff required for groundwater level monitoring are fully utilised.

6.4.2 Agency Capital Works Staff Inputs

To implement the proposed capital works programme there will be a requirement for Agency staff to carry out the following tasks: PID preparation; site access acquisition, liaison with other Agency staff, management of consultant and handling site queries. Agency staff inputs have been estimated based on the Agency inputs associated with the new Waveney boreholes. These inputs are detailed in Table 10 below.

The table in Appendix F details the effect of the proposed capital works programme (as detailed in Chapter 5.2) on the required staff project management inputs.

Based on previous experience, there is likely to be a requirement for average staff inputs of 163 staff days/year over the next 8 years for the proposed capital works programme. The Agency has recently set up a framework agreement that may allow opportunities for efficiency savings.

Table 10: *Capital Works Staff Inputs*

Task	Grade	Input	Unit (per year)
Capital Works supervision for decommissioning, new MPS boreholes and MPS conversions (@ £250 per borehole)	4/5	1	Staff days/borehole
Capital Works supervision for new core network boreholes and multiple aquifer replacements (@ £1600 per borehole)	4/5	6	Staff days/borehole

7 ASSET MANAGEMENT PLAN

7.1 CONCLUSIONS

The whole currently monitored network comprises 1644 boreholes. Following the application of the network design methodology that was developed and validated during Stage 1 715 of these boreholes have been proposed to make up the core network. The design methodology and multiple piezometer study also recommended the core network include the construction of 221 new boreholes and conversion of 26 multiple monitoring boreholes. Decommissioning of 252 surplus boreholes was also recommended, subject to approval by the area network managers.

An evaluation of the asset surveys carried out for the 715 currently monitored core network boreholes has determined that the average Residual Life of a borehole is 37 years. It has also established that the total estimated Replacement Cost for these boreholes is £7,374,000 and that the total estimated Current Asset Value is £4,493,000.

An assessment of the refurbishment requirements required to continue the collection of groundwater level data for the current core network has established that £47,000 of remedial works are required over the next 36 months. Of these remedial works £5,000 are considered urgent and should be carried out within the next 3 months.

The total regional cost associated with the implementation of the strategic review capital programme is £3,246,000. This includes construction of new boreholes, decommissioning of surplus boreholes and refurbishment of the core network. This also includes an estimated £67,000 to carry out a datum levelling exercise of the 715 core network boreholes. It is proposed that these works be carried out over the next 8 years at an average cost of £406,000 per year. This work could be carried out under the National Contractors Framework (NCF) or the National Site Investigation Framework (NSIF) agreements. It is estimated that the Agency project management for implementing this programme will require an average 163 staff days/year to administer. The utilisation of NEECA framework consultants may allow the Agency to improve efficiency.

The average annual recurring payments over the next 30 years are £91,000. This includes the replacement cost for loggers, other monitoring equipment and current core network boreholes.

The average annual Agency operating costs for the core network, over the same period, are £138,000. This includes data collection, data processing, archiving, validating, maintenance of loggers, site maintenance provision of information to customers and supervision. Based on implementing the proposed capital works programme the Eastern Area is estimated to have an increase in required staff operating inputs of 47% over the next 7 years. The Central Area is estimated to have an increase of 30% over the next 8 years and the Northern Area is estimated to have an increase of 16% over the next 3 years.

7.2 RECOMMENDATIONS

It is recommended that the modifications to the currently monitored network identified in the three Area Stage 2 Design Methodology Reports and the construction of additional boreholes identified in the Multiple Piezometer Report should be made in accordance with the enclosed programme.

A further study should be carried out to extend the requirement for multiple piezometer boreholes (already identified at the new core network locations) to include all those existing core network sites that have a shallow water table present, or any other significant flow horizon in the main aquifer.

It is recommended that datum levelling be carried out for the current core network of 715 boreholes.

The recommended way forward can be summarised as follows:

- The Agency, with consultant support if required, to prepare a strategic plan to implement the recommendations of the review, including construction programmes
- Agency to utilise NEECA framework consultants for design and supervision of construction work
- Agency to utilise National Contractors Framework (NCF) or the National Site Investigation Framework (NSIF) contractors for capital works

8 REFERENCES

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Appendix A - Terms of Reference

REVIEW OF REGIONAL GROUNDWATER LEVEL MONITORING NETWORK: STAGE 2

TERMS OF REFERENCE

1. Introduction

The Environment Agency project to review the Anglian region groundwater level monitoring network is planned to be carried out in two stages. Stage 1, which is essentially a scoping study, has now been completed. Stage 2, which was originally planned to include an asset survey of the network and a review of the network (based on the application of a design methodology developed in Stage 1), has now been extended to include the preparation of an asset management plan for the primary core network (tiers 1 and 2).

The purpose of this brief is to set out the revised Terms of Reference for Stage 2 of the review, which replaces section 4.4 in the original Terms of Reference for the project. Note that the subsequent sections of the original Terms of Reference (sections 5 to 11) are still in force for Stage 2 of the project, except where modified as below.

2. Objectives

The objectives of Stage 2 of the review are:

2.1 Complete a full asset survey of the existing groundwater level monitoring network in all of the groundwater units in the region that were not surveyed in Stage 1 of the project.

2.2 Apply the design methodology that was established in Stage 1 of the review to the asset survey data obtained in Stage 2, and hence classify the boreholes surveyed in Stage 2 into the 3 monitoring categories i.e. tiers 1, 2 and 3.

2.3 Identify the changes that are needed to improve the efficiency of the network in the groundwater units surveyed in Stage 2, with particular regard to the numbers and locations of observation boreholes, and estimate the cost of these changes.

2.4 Prepare an asset management plan for the whole regional primary core groundwater level monitoring network, i.e. BGS category tiers 1 and 2, (including primary core boreholes identified during Stage 1 of the project).

3. Scope of Work

The Consultant shall be required to complete the following tasks: -

3.1. Complete a full asset survey of the existing groundwater level monitoring network in all those groundwater units in the region that were not surveyed in Stage 1 of the project. In particular, for each borehole in the network:

3.1.1 Collect and collate all the available data that is currently recorded on the Agency databases Hydrolog 2 and Hydrolog 3, and any data held on paper records, and copy the data into the customised project database developed by the Consultant in Stage 1 of the project. [The Consultant shall not be required to digitise water level charts].

3.1.2 Review the data. The data review will examine the quality of both the station archive information and the water level hydrographs. Any anomalies or apparent errors shall be reported and listed, but corrections shall not be made until they have been approved by the Agency, in accordance with the database population protocol established during Stage 1 of the project. Extra items not currently recorded will need to be entered into the database. Note that the appropriate code for "Monitoring Purpose" should initially be entered as the *current* purpose, as confirmed by the Agency's appropriate Area Hydrogeologist; following the application of the design methodology the codes for some boreholes will need to be changed to represent the new classification.

3.1.3 At the end of Stage 2 of the review, the Consultant shall transfer the data from the customised project database into the Agency's current database. The Consultant shall be required to liaise fully with the Agency to ensure that the data fields and data formats of the project database and the Agency's database are fully compatible, to ensure a smooth transition. Any data contained within fields of the project database that are not available in the Agency's database will be entered into Excel spreadsheets, which will be supplied to the Agency at the time of data transfer.

3.1.4 Site Inspections. The Consultant shall carry out a brief site inspection of each borehole (and staff gauge/gaugeboard) and complete the information requirements of the project proforma (the form of which was agreed with the Agency at the start of Stage 1 of the project). Note that the National Grid Reference of the site is to be defined to 8 figures and the borehole depth and water level are to be measured and recorded (unless artesian conditions make this impracticable, which may be the case e.g. for a number of boreholes in Northern Area). The equipment needed to carry out these tasks is to be provided by the Consultant. The inspection should include an assessment of the site access, the physical condition of the borehole and its headworks (including needs for repair/remaining asset life), and a full Health and Safety risk assessment of the monitoring operation at the site to enable a safe method of work for monitoring the borehole to be produced. The Consultant shall compare the information obtained from the site inspection with the information already recorded for the borehole, confirm any required corrections with the Agency's appropriate Area Hydrogeologist, and enter the accurate information into the project database, as required by the established protocol.

3.1.5 Following the review of the data collected for each borehole, the Consultant shall advise the Agency of any requirements for particular boreholes to be geophysically logged or surveyed with CCTV to determine any missing information, or to resolve any anomalies between the information obtained from the site inspection and that recorded on the original data list. The Consultant shall draw up a list of boreholes and a proposed programme to carry out this work, with cost estimates, and submit the proposal to the Agency's Project Manager for approval. Subject to the agreement of the Agency's Project Manager, the Consultant shall then carry out the logging programme, interpret the results, and modify the data entered on the database as appropriate.

3.1.6 Produce a report that describes the work carried out in the Stage 2 asset survey, and summarises the results.

3.2 Apply the design methodology that was established in Stage 1 of the review to the asset survey data obtained in Stage 2, and hence classify the boreholes in the network into the 3 monitoring categories i.e. tiers 1, 2 and 3. In particular:

3.2.1 The methodology to be implemented by the Consultant during Stage 2 of the review will be that specified in section 3.2 of the report produced by Binnie Black and Veatch entitled "Stage 1 - Design Methodology Report", dated October 1999, subject to any minor amendments that may be required by the Agency (such amendments to be confirmed by the Agency at the initial project meeting).

3.2.2 The Consultant shall apply the methodology to all those current monitoring boreholes within the network that were not included in the Stage 1 review, for both major and minor aquifers, and hence classify the boreholes in the network into the 3 monitoring categories i.e. tiers 1, 2 and 3.

In applying the methodology the Consultant shall also review and recommend the most appropriate monitoring frequency for each particular aquifer, making allowance for the hydrogeological regime within the aquifer (e.g. confined/unconfined/leaky).

3.2.3 Identify the changes that are needed to improve the capacity of the network to record and provide information on groundwater levels within the groundwater units surveyed in Stage 2, with particular regard to; -

- the numbers and locations of observation boreholes
- the recommended frequency of monitoring

Prepare lists of the sites where new monitoring boreholes are required to meet the criteria for minimum network density of the combined tier1/tier 2 network for each of the groundwater units. Also prepare lists of boreholes in the groundwater units that could potentially be removed from the monitoring network as there is no longer any perceived need for the data that they provide. Provide an outline programme for carrying out the work of constructing new boreholes and decommissioning surplus boreholes, with cost estimates.

3.2.4 Also, the Consultant shall, for each aquifer (including those reviewed in Stage 1 of the project), identify the requirements for regional long-term monitoring of differences in head at different depths, both within the aquifer and in superficial deposits overlying "leaky" aquifers. Particular consideration should be given to recharge and discharge areas within unconfined and leaky aquifers.

The Consultant shall then prepare tables of monitoring sites where multiple-depth groundwater level monitoring is required, giving details of appropriate intake zones for the proposed piezometers. Both new borehole sites (i.e. those filling gaps in the network) and suitable existing borehole sites should be considered. (An existing site could potentially be converted into nested piezometers, or alternatively be converted to a "short intake zone" observation borehole with one or more piezometers installed next to it). The Consultant

should also provide an outline programme for constructing the proposed piezometers, with cost estimates.

3.2.5 Produce a final report describing the survey work carried out, and the results and recommendations of the review.

3.3 Prepare an asset management plan for the primary core regional groundwater level monitoring network. In order to produce the plan the Consultant will be required to carry out the following tasks:

For each of the monitoring borehole sites included within tiers 1 and 2 of the regional network: -

3.3.1 Collect and collate the information listed in Table 1, and enter the information into the Agency's new National Water Resources Asset Inventory, which is in the form of an Excel spreadsheet. (A copy of the spreadsheet will be provided by the Agency). Much of the information will have already been obtained and entered into the project database during the asset survey (see sections 3.1.1 & 3.1.3 above), but the consultant will have to obtain the extra information that is required to determine the asset life span and current value of the borehole.

The National Water Resources Asset Inventory was produced by a national working group and copied to all the Agency's regions, for data population with whatever asset information was available at the time, and Anglian region data was entered as of 30 September 1999. As the list of monitoring boreholes that was entered was downloaded from Hydrolog Station Master at that time there are numerous gaps and inaccuracies in the information provided, and a quality audit will be carried out on the Inventory by the Agency during the next 12 months. In the longer term, the Agency intends to develop a Water Resources Asset Management System (WRAMS) by the year 2004.

For Stage 2, the Consultant will be required to define and agree a protocol for data population of the Asset Inventory with the Agency, similar to that already defined for the Asset Survey, before supplying the validated Asset Register spreadsheet to the Agency at the end of the project.

3.3.2 Estimate the age of the borehole and evaluate its remaining asset life, its current value, and its replacement cost. A nominal value of 60 years should be assumed as a typical life span for an observation borehole, but the consultant will need to estimate the present age of the borehole, and deduct this from 60 years to determine the remaining asset life. Due allowance for the present physical condition of the borehole should be made when estimating its remaining asset life span; if the present physical condition of the borehole is poor, the estimated "remaining asset life" may need to be reduced accordingly.

3.3.3 Using the information obtained during the site inspections and the asset survey, identify the refurbishment requirements for the site, estimate the cost of the work, and assign a priority ranking for the work. The basic information for assessing refurbishment requirements will be provided by: -

- The visual inspections of the headworks and the visible upper part of the inner lining of the borehole carried out during the asset survey (see 3.1.4 above).

- Plumbing the boreholes and comparing the plumbed depth with previous depth measurements to identify possible blockages or sediment infilling (see 3.1.4 above).

- If required, CCTV inspection, possibly supplemented by other geophysical probes. (This will also help establish the integrity of both screened and unscreened (i.e. plain casing) sections of the inner lining of the borehole).

Priority rankings for the refurbishment work should take into consideration the following: -

- Defects posing an immediate safety hazard 5
- Defects identified as a potential hazard, but not requiring immediate attention 2
- Structural or other defects that prevent or impair data collection 4
- Defects that could result in deterioration of the structure 3
- Defects that could result in potential security risks at the site – *eg. vandalism, theft of equipment* 1

3.3.4 Prepare a prioritised programme to carry out the refurbishment work, including the construction of new monitoring boreholes and decommissioning of redundant boreholes, and tabulate the projected cost estimates. The programme should reflect the urgency to carry out the necessary work at each site by assigning the work to a particular category band based on the priority rankings e.g. as follows: -

Band A – Emergency works
Band B – Urgent works - *e.g. within 12 months*
Band C – Short term remedial works - *e.g. within 30 months*
Band D – Long term maintenance works - *e.g. within 48 months*

Also, in addition to the capital works programme, the Consultant should provide recommendations and a programme (with cost estimates) for routine maintenance of the boreholes (e.g such items as checking and replacing padlocks, greasing bolts, strimming surrounding overgrown vegetation, etc).

The programme should consider refurbishment and maintenance requirements (both "capital" and "routine") over the next 10 years, and should include a programme to re-level the measurement datum at each site (with cost estimates).

3.3.5 Produce a report presenting the asset management plan and summarising the work involved in its preparation.

5. Consultation

The Consultant shall throughout the project report to the Agency's Project Manager, David Clarke, who is based at the Agency's Peterborough office.

Within the Agency, the Consultant shall also need to consult the respective Area Hydrogeologists and Area Hydrologists (Hydrometry), as during the previous Stage 1 of the project.

During Stage 2 of the project the Consultant will also need to liaise with the staff of Entec UK, who are currently engaged as the Agency's term consultant for the regional groundwater modelling and investigation contract. During the course of their investigations they will need to use groundwater level data and other hydrogeological information contained in Hydrolog, and will also need to be aware of the updated information contained within the Stage 2 review project database. Initial contact with Entec will be arranged by the Agency's project manager.

8. The Proposal

8.1 Technical proposal

The Consultant shall submit a detailed proposal for the completion of the tasks described in the Terms of Reference for Stage 2 of the project.

8.2 Financial Proposal

To be drafted. [In view of the extensive information obtained by the Consultant during the execution of Stage1 of the review, the Agency expects that a substantial proportion of the work for Stage 2 will be carried out on a fixed fee basis].

9. Programme

The programme for Stage 2 of the project will be as described in the Agency report (prepared by Binnie Black & Veatch) entitled "Regional Groundwater Level Monitoring Network Review Stage2 Project Initiation Report" (October 1999).

10. Administration and Reporting

10.1 The Agreement between the Agency and the Consultant shall comprise the Association of Consulting Engineers Conditions of Engagement 1981, Agreement 1 (reprinted 1993/94) amended and extended to include the Agency's standard revisions, and Memorandum of Agreement, the Terms of Reference and Supporting Documentation.

10.2 Progress meetings will be held as set out in the programme for Stage 2 of the review. These meetings will take place at the Agency's Peterborough office or at another agreed location. Written progress reports summarising work completed and projected, consultancy fees and expenses incurred, outstanding contractual matters, etc, shall be submitted to the Agency's Project Manager every month, together with monthly invoices. Progress reports shall be submitted to the Project Manager at least one week before each progress meeting. The Consultant shall be required to minute all meetings involving the Agency. All minutes shall be submitted for approval within two weeks of each meeting and shall be confirmed at the following progress meeting.

10.3 Three copies of each of the Final Reports on the Asset Survey and Design Methodology studies for Central, Eastern and Northern Areas (i.e. 6 separate reports, 3 copies of each report) are to be submitted to the Agency on the dates specified in the project programme. Two draft copies of each of the 6 reports are to be provided by

the Consultant for the Agency's approval at least two weeks in advance of the final reports to allow adequate time for comments and corrections to be made.

10.4 During Stage 2 of the project the Consultant's contacts with the Agency will be: -

David Clarke	(Project Manager)
Chris Taylor	(Central Area Hydrogeologist)
David Seccombe	(Eastern Area Hydrogeologist)
Peter McConvey	(Northern Area Hydrogeologist)

TABLE 1. Data Requirements for the National Water Resources Asset Inventory

The following items of information are required for inclusion in the Environment Agency's National Water Resources Asset Inventory: -

Water Resources Asset Reference Code – *same as Site Reference Number e.g. TL76/55*
Area – *e.g. Central*
Asset Name – *same as Station Name e.g. Lea Farm , Lakenheath*
National Grid Reference
Aquifer – *e.g. Chalk*
Asset Category – *e.g. Observation borehole*
Station Type (IOH) – *Not applicable, applies to streamflow gauging stations*
Status – *e.g. Active*
Ownership: Site - *e.g. Agency or Landowner*
Ownership: Equipment – *e.g. water level data logger (Agency)*

NB: The above items will be available from the project database or Hydrolog 3 upon completion of the Asset Survey. The information items listed below will need to be separately collected or determined by the consultant during the preparation of the asset management plan.

Date commissioned – *available from Agency records*
Date of last major refurbishment
Date of last survey
Urgency of works
Date of next survey
Asset Life Span
Estimate of Current Value
Estimate of Value after Refurbishment

Proposed Breakdown of Fixed Fee and Target Fee Items* for Stage 2 of the Network Review

*[i.e. Target Fee together with staff time rates]

Fixed Fee Items

Asset Survey:

Data collection (item 3.1.1)

Database development and population (item 3.1.1)

Review of information (item 3.1.2)

Site Inspections (item 3.1.4)

Preparation of Asset Survey Report (item 3.1.6)

Design Methodology:

All items as in 3.2, except for item 3.2.4

[NB: Production of final report copies would be a Fixed Fee item.]

Target Fee and Tendered Staff Rates

Asset Survey:

Transfer of data to Agency (item 3.1.3)

Site revisits

Geophysical surveys (item 3.1.5)

Asset management plan (item 3.3)

Design Methodology:

Multiple depth measurement recommendations (item 3.2.4)

TERMS OF REFERENCE

1. Introduction

The Anglian Region of the Environment Agency (hereafter referred to as "the Agency") proposes to engage a consultant to carry out a strategic review of the existing regional groundwater level monitoring network (see Map 1). For the purposes of this review "the network" is taken to comprise the observation installations of all types (including boreholes, wells, piezometers, and a small number of staff gauges on groundwater-fed surface water features), together with the water level observations collected, the data collection system (including recording instrumentation), and the databases.

The review will include an asset survey of the current network, a design methodology study and a project appraisal study to determine the business case for collecting the data. The ultimate aim of the review will be to identify any changes to the network which are necessary to ensure that both the long term and short term monitoring needs of the region are fully met.

The review will be implemented in two stages.

Stage 1 will be a Pilot Study to determine the business case for operating, maintaining and improving the regional network, and will include a survey of three representative groundwater units within the Region to provide the information needed. Stage 2 will be the Main Asset Survey of the whole Regional network. Stage 1 will provide the business case for carrying out Stage 2, and will define the costs and time scale for the Stage 2 programme.

Stage 1 will comprise the following tasks: -

a) An asset survey of the current groundwater level monitoring network in three of the region's groundwater resource units. These units are: -

the Little Ouse Chalk unit	(area 970 km^2;	~~200~~ 270 boreholes)
the Waveney Chalk/Crag unit	(area 740 km^2;	~~35~~ 45 boreholes)
the Northern Lincs. Limestone unit	(area 490 km^2;	35 boreholes)

These units are shown on the attached Groundwater Units map (Map 2). Data are available at the Agency's Area offices at Brampton, Ipswich and Lincoln (see attached Anglian Region map, Map 3).

NB: - In this document the term "borehole" is taken to apply to all types of observation borehole, including small diameter piezometers. The groundwater level monitoring network also includes a small number of staff gauge/gaugeboard sites, installed in open water bodies and occasionally running water, as well as boreholes. These are mostly located on wetland conservation sites, often in association with shallow piezometers. Data from the levelled boards is included in the groundwater level database.

The asset survey will collect and collate all the available information on the geology, construction and ownership of each monitoring installation (ie borehole, piezometer, and staff gauge) in each groundwater unit, assess the present condition and the asset life of the installation, evaluate the quality of the data records, input all the information onto a common database, and assess the cost of completing a full asset survey for the rest of the region. The survey will include brief site inspections of the boreholes and staff gauges in the Little Ouse Chalk unit (approximately ~~200~~ 30 boreholes and up to ~~20~~ staff gauges), and a number of boreholes in all three units may also require further visits for geophysical logging, to fill data gaps.

b) A design methodology study

The British Geological Survey (BGS) has carried out an R&D study for the Agency to review the national groundwater level monitoring network (September 1994). Their report suggests overall network densities for particular classes of aquifers and recommends a three tier classification scheme, but the methodology proposed to determine which monitoring sites are to be included in each tier requires some further development to create a precise and practical methodology. The aim of the proposed study is to establish a design methodology which will address the BGS recommendations and will also make appropriate allowances for the specific requirements of the Anglian Region network. This new regional methodology will be evaluated by applying it to the data from the three asset survey trial groundwater units, and making any necessary modifications to the methodology. Recommendations will be made of any changes to the monitoring network that would improve its efficiency in the three trial units.

c) An economic appraisal (cost-benefit study)

This will define the business case for maintaining and developing the network. The study will include a customer requirements survey, to establish the needs for the whole Region of our customers (both within the Agency and externally) for groundwater level data, and to help estimate the value of the data.

Stage 2 will be the main phase of the strategic review, and will comprise an asset survey of the monitoring network in all the other groundwater units within the Anglian Region, and the application of the design methodology established in Stage 1 to identify the changes in the network that are needed to improve its efficiency.

Stage 2 will only proceed if the results of Stage 1 satisfactorily establish the business case to justify carrying out the full review.

The Consultant shall be retained to undertake the full Stage 2 review of the network provided that the following conditions are all met:

- **The outcome of the Stage 1 trial and the performance of the Consultant in Stage**

1 are satisfactory.

- The price agreement for the Stage 2 work is acceptable to both the Consultant and the Agency.

- The business case is approved by the Agency.

The Consultant shall be required to provide and undertake such services in accordance with the Association of Consulting Engineers Conditions of Engagement 1981 (reprinted 1993 & 1994) Agreement 1, but amended and extended to include the Agency's standard revisions.

2. Background

The Anglian Region stretches from the Humber Estuary in the north to the Thames Estuary in the south and covers an area of 27,000 km^2 of Eastern England with a population of 5 million. In order to discharge its statutory responsibility to manage and protect water resources, the Agency maintains and collects groundwater level data from a monitoring network of approximately 1900 boreholes in the region. (The groundwater level monitoring network also includes a small number of staff gauge/gaugeboard sites, installed in open water bodies and occasionally running water, as well as boreholes; these are mostly located on wetland conservation sites, often in association with shallow piezometers, and data from the levelled boards are included in the groundwater level database). All the major aquifers and some of the more important minor aquifers in the region (a total area of approximately 20,000 km^2) are covered by networks of varying density, as shown on Map 1.

For administrative purposes, Anglian Region is divided into three Areas, Northern, Central and Eastern Areas, managed from offices at Lincoln, Brampton and Ipswich respectively (see Map 3). Each Area office has a Water Resources section which manages the collection, recording and archiving of hydrometric data within its own Area boundary; the groundwater level network is quality controlled by the respective Area Hydrogeologists. Each Area is divided into a number of Groundwater management units: these are based on natural hydrogeological boundaries (which do not always coincide with surface catchment boundaries).

In each Area most of the groundwater level data are stored in digital form. Borehole details are generally stored on a Hydrodat database, originally developed by Hydrogeological Services International Ltd (HSI). This database also holds the water level data obtained from monthly manual observations on boreholes and a small number of staff gauges. Shorter periods of more frequently recorded data obtained from data loggers (eg from pumping tests or abstraction licence monitoring) are stored on a Hydrolog database (developed by Hydro-Logic Ltd). Some continuous chart records are also stored; in Central Area monthly values have been interpolated from the charts and entered onto the Hydrodat database, but the charts have not been digitised.

The regional groundwater level monitoring network has evolved over several decades

principally in response to Parliamentary legislation and specific resource management projects and investigations, such as the Great Ouse Groundwater Scheme. Prior to 1963 only 50 sites were monitored, but thereafter the number of boreholes monitored increased rapidly to 500 by 1970, 1000 by 1977, and over 1300 by 1985. Recently an extensive programme to install observation boreholes at 50 wetland conservation sites in the Region has added a futher 200 boreholes to the network. The total number of boreholes in the network is now estimated to be approximately 1900. The bulk of the water level data dates from 1970 onwards, but the long term records are of particular value.

There have been a limited number of previous reviews of the monitoring network but these have been conducted primarily on an individual catchment or groundwater unit basis. Where wider reviews have been conducted they have generally been concerned largely with establishing a broad density relationship for particular major aquifers, but have not given detailed consideration to such factors as the classification of boreholes by their intended data usage, or how well they represent the local aquifer conditions.

There is now a clearly identified need to carry out a thorough strategic review of the monitoring network.

3. Objectives

The overall objective of the project is to ensure that the business needs of the Agency in Anglian Region are fully met with regard to the data quality, collection, archiving and supply of groundwater level data to its customers in an efficient and economic manner.

The specific objectives of the project are as follows: -

Stage 1:

3.1 Complete a full asset survey of the existing groundwater level monitoring network in the following regional groundwater units: -

the Little Ouse Chalk groundwater unit
the Waveney Chalk/Crag groundwater unit
the Northern Lincs. Limestone groundwater unit

The asset survey will establish the condition of the current assets and their remaining asset life. It will include a survey and assessment of the physical condition of the installations, a review of the quality of the data, data collection and archiving systems, together with an assessment of the costs and timescales required to complete a full asset survey for the rest of the regional monitoring network.

3.2 Develop a design methodology that is based on that described as Method "A" in the BGS R&D Technical Report WD/94/41C "National Groundwater Levels Monitoring Network Review" (ref. 1), a copy of which is enclosed with this document.

The Consultant should note that the BGS Report document is provided solely to provide information for this project and is to be treated as Strictly Confidential.

3.2.1 The methodology should be capable of: -

- classifying all of the observation boreholes in the existing Anglian Region groundwater level monitoring network into a 3 tier system, ie "Reference", "National" and "Local" networks;

- defining criteria for the selection of appropriate monitoring network densities in the regional aquifers for the regional "Reference" and "National" networks;

- ranking the boreholes by a number of attributes (ie the BGS Method "A") to enable them to be assigned to one of the 3 tiers;

3.2.2 Evaluate the methodology by applying it to the data obtained from the asset survey of the 3 trial groundwater units, making any necessary modifications.

3.2.3 Identify the changes that are needed to improve the efficiency of the network in the 3 trial groundwater units, with particular regard to the numbers and locations of observation boreholes, and estimate the costs of these changes.

3.3 Complete an economic appraisal (cost - benefit analysis) of the regional groundwater monitoring network, that will: -

3.3.1 establish the current uses of the data and the future needs of the Agency's customers (both internal and external) in Anglian Region for groundwater level data, and determine the value of the data to the Agency and its customers;

3.3.2 evaluate the current costs of collecting, processing and supplying the data to the customers;

3.3.3 examine and cost the options (including the "Do Nothing" option) for completing Stage 2 of the review, considering the benefits (including intangible benefits) and risks, and make appropriate recommendations.

Stage 2:

3.4 **Provided that the Agency confirms that Stage 1 of the project has satisfactorily established that proceeding with Stage 2 of the review is the preferred business option:**

3.4.1 complete a full asset survey of the existing groundwater level monitoring network in all the groundwater units in the region that were not surveyed in

Stage 1 of the project;

3.4.2 Apply the design methodology that was established in Stage 1 to the asset survey data obtained in Stage 2 to classify the boreholes into the 3 categories.

3.4.2 identify the changes that are needed to improve the efficiency of the network in the groundwater units surveyed in Stage 2, with particular regard to the numbers and locations of observation boreholes, and estimate the cost of these changes.

4. Scope of Work

The Consultant shall be required to complete the following tasks: -

Stage 1

4.1 Asset Survey

Complete a full asset survey of the existing groundwater level monitoring network in the following regional groundwater units: -

the Little Ouse Chalk groundwater unit
the Waveney Chalk/Crag groundwater unit
the Northern Lincs. Limestone groundwater unit

In particular: -

For each groundwater level monitoring borehole in the network in the above catchments: -

4.1.1 Collect and collate all the available data currently recorded for the borehole on the Agency databases Hydrodat and Hydrolog, and any data held on paper records, and copy the data into a stand-alone customised project database (to be provided by the Consultant). The Consultant shall not be required to digitise water level charts.

The project database must be fully compatible with the Agency's new national groundwater database, "Hydrolog Station Manager", which will operate within the Agency's Windows 95 harmonised platform and will utilise MS Access. ("Hydrolog Station Manager" is currently being developed by Hydro-Logic Ltd, and should become available for data entry in Anglian region in January 1999, provided that the Agency approves it as the Best Interim Solution (BIS) for the Agency's convergence, harmonisation and Year 2000 programmes). Note that the Consultant will probably need to be based at each of the Area offices for a period of time (at least several days) to collect, collate and

transfer data.

The Consultant shall be required to provide the software of the standalone database, together with any necessary PC's or laptop computers that the Consultant may need to carry out the project.

NB: The groundwater level monitoring network also includes a small number of staff gauge/gaugeboard sites, installed in open water bodies and occasionally running water, as well as boreholes. These are mostly located on wetland conservation sites, often in association with shallow piezometers. Data from the staff gauges is included in the groundwater level database, and is to be included in the review. The total number of staff gauges included in the groundwater level monitoring network is small (less than 10% of all monitoring installations, including boreholes).

4.1.2 Review the data. A provisional list of the data requirements for inclusion in the asset survey is given in Table 1 for guidance; the final list will be agreed with the Agency at the start of the project. The data review will examine the quality of both the station archive information and the water level hydrographs; any anomalies or apparent errors will be reported and listed, but corrections should not be made unless approved by the Agency. Extra items not currently recorded, such as "Legal Status" (site monitoring rights) and "Monitoring Purpose" categories, will need to be entered on the database. Information on legal status of the monitoring rights at each site is available from the Regional Estates Manager at the Agency's Peterborough office. The appropriate code(s) for Monitoring Purpose to be entered on the project database should initially reflect the current purpose, as confirmed by the Agency's Area Hydrogeologist; following the application of the design methodology the codes for some boreholes will need to be changed to represent the new classification

4.1.3 When Hydrolog Station Manager becomes available in January 1999, the Consultant shall transfer the data from the stand-alone project database into the Agency's Hydrolog Station Manager database. The Consultant should note that during this period Hydro -Logic will also be transferring all the Agency's monitoring network data from the old Hydrolog/Hydrodat databases into the new database. The Consultant shall be required to liaise fully with both the Agency and Hydro-Logic to ensure that the data fields and data formats of the project database and Hydrolog Station Manager are fully compatible, to ensure a smooth transition.

4.1.4 In the Little Ouse Chalk groundwater unit and the Wavenev Chalk/Grag groundwater unit, carry out a brief site inspection of each borehole (and staff gauge/gaugeboard) and complete the information requirements of the Agency's proforma, a provisional form of which is included here as Appendix A,

together with draft guidance notes for the site inspection procedure. The final version of the proforma will be agreed with the Agency at the start of the project. Note that the National Grid Reference of the site is to be defined to 8 figures, and for some remote sites (eg wetlands) may need to be checked with a Global Positioning System. Also, the borehole depth and water level are to be measured. The equipment needed to carry out these tasks is to be provided by the Consultant. The inspection should include an assessment of the site access, the physical condition of the borehole and its headworks (including needs for repair/remaining asset life), and a full risk assessment of the monitoring operation at the site to enable a safe method of work for monitoring the borehole to be produced.

Compare the information obtained from the site inspection with the information already recorded for the borehole, confirm any required corrections with the Agency's Area Hydrogeologist, and enter the accurate information into the project database.

NB: The site inspections of the boreholes in the monitoring networks in the Northern Lincs. Limestone groundwater unit will be carried out by Agency staff, using the same proforma (Appendix A), but the Consultant shall be required to compare the information obtained by the Agency staff with that already recorded, make corrections as necessary with the agreement of the Area Hydrogeologist, and enter the correct information on to the database.

4.1.5 Following the review of the data collected for each borehole, the Consultant shall advise the Agency of any requirements for particular boreholes to be geophysically logged or surveyed with CCTV to determine any missing information, or to resolve any anomalies between the information obtained from the site inspection and that recorded on the original data list. The Consultant shall draw up a list of boreholes and a proposed programme to carry out this work, with cost estimates, and submit the proposal to the Agency's Project Manager for approval. Subject to the agreement of the Agency's Project Manager, the Consultant shall then carry out the logging programme, interpret the results, and modify the data entered on the database as appropriate.

4.1.6 Prepare a project plan for completing the asset survey on the remaining catchments/groundwater units in the Anglian region (Stage 2), with budget cost estimates and a detailed programme.

4.1.7 Produce a report describing the work carried out in the asset survey of the 3 groundwater units, summarising the results, and presenting the recommendations for further work to be carried out in Stage 2 of the project.

4.2 Design Methodology

Carry out a design methodology study. In particular: -

4.2.1 Review the methodology described as "Method A" in the British Geological Survey Technical Report WD/94/41C "National Groundwater Levels Monitoring Network Review", September 1994, a copy of which is enclosed with this document. Particular reference should be made to sections 4 and 5 of the report.

4.2.2 Develop a methodology that will implement the "Method A" approach. The methodology must be capable of classifying the monitoring boreholes in the network into the 3 categories recommended in the BGS Technical Report, p25, ie: -

Reference Network (high quality data, long continuous hydrographs, unaffected by abstractions)

National/Regional Network (core monitoring sites, providing data for resource management purposes)

Local Network (project orientated monitoring sites eg modelling studies, wetland monitoring, abstraction impacts, GPZ delineation, etc)

The methodology should be developed by adapting the procedures set out in section 5 of the BGS report for Method A to be more representative of the particular aquifer conditions and network management requirements of the Anglian region. This will necessarily involve close liaison with Agency staff. (Method B, based on a statistical approach, has been judged to be inappropriate for this review).

In particular, the Consultant should develop a ranking scheme similar in structure to that proposed by the BGS (see Figure 5.1.1, p40, Table 5.1.2, p41, and Figure 5.1.2, p42, in the BGS report), but specific to the Anglian region network demands, aquifer conditions and data availability. The number of boreholes to give the required network density in each aquifer unit will then be selected by choosing high ranked boreholes. Boreholes not included in the Reference or National networks will be assigned to the Local Network.

Note that the Consultant shall need to agree with the Agency the network density criteria to be adopted for each aquifer unit in the Anglian region. The criteria for the selection of monitoring network density will be broadly those recommended in the BGS Technical Report, Table 4.2.1, p27, but for the purposes of this review the criteria assigned to Major Aquifers will also be assigned to all Minor aquifers which are used for public water supply, eg the Norwich Crag, Sandringham Sands.

4.2.3 Prepare an interim report that fully describes the methodology that has been developed, and outlines how it will be applied to classify the boreholes in the regional monitoring network into the 3 categories described in section 4.2.2. Four copies of the draft report are to be submitted to the Agency for review and comment.

The Consultant shall be required to attend a meeting at the Agency's Peterborough office to present the methodology to the Agency and resolve any concerns that the Agency may have on the suitability and application of the methodology. Following this meeting the Consultant shall produce and submit a final draft of the interim report to the Agency for agreement by the Project Manager.

4.2.4 Following Agency approval of the interim report, the Consultant shall evaluate the methodology by applying it to the asset survey data for the boreholes in the monitoring networks in the 3 trial groundwater units listed in section 4.1. The Consultant shall identify any modifications to the methodology that will improve its effectiveness in classifying the boreholes into the 3 categories, agree these changes with the Agency, and incorporate them into the methodology.

4.2.5 Identify the changes that are needed to improve the efficiency of the network in the 3 trial groundwater units surveyed in Stage 1. Particular regard should be given to the overall numbers and locations of observation boreholes, bearing in mind the need for adequate coverage in recharge (interfluve) areas and discharge areas (ie rivers, springs and wetlands) and the need to obtain adequate data on hydrogeological depth profiles in drift covered and layered aquifers (eg by installing "nested" piezometers); attention should also be given to advantageous changes in monitoring frequencies.

Prepare lists of the sites where new monitoring boreholes are required to meet the criteria for minimum network density of the combined Reference/National network for each of the 3 trial groundwater units. Also prepare lists of boreholes in the 3 trial groundwater units that could potentially be removed from the monitoring network as there is no longer a perceived need for the data that they provide. Provide a programme for carrying out this work, with cost estimates.

4.2.6 Produce a final report describing the methodology developed, and the results and recommendations of the study.

4.3 Economic Appraisal

Carry out an economic appraisal (cost - benefit analysis) of the regional groundwater monitoring network, that will establish the needs of the Agency's customers (both internal and external) in Anglian region for groundwater level data, and determine the

value of the data to the Agency and its customers. The appraisal should evaluate the current costs of collecting and supplying the data, identify several options for completing Stage 2 of the review, examine and cost the options and make appropriate recommendations for the preferred option. The Consultant shall carry out the economic appraisal in a manner conforming to the Agency's guidelines for the preparation of Project Initiation Documents and economic appraisals (reference 2, "Project Management in the Agency", Appendices F and K; a copy of this reference is included in the Terms of Reference for information purposes, as Appendix B).

In particular, the Consultant shall: -

4.3.1 Carry out a Customer Requirements Survey of both Internal (Agency) Customers and External Customers to establish their needs for groundwater level data. Following an initial briefing meeting with the Agency, the Consultant shall prepare a questionnaire and submit it to the Agency for approval. The questionnaire should include questions designed to enable some estimate to be made of the monetary value of the data to the customer. When the questionnaire has been approved by the Agency the Consultant shall draw up a list of the Agency's known customers and circulate the questionnaire among them. The list of customers will be compiled by the Consultant following discussions with the Agency, and agreed with the Agency's Project Manager before circulation, but for guidance a list of potential categories of customers is presented in Table 2. (For planning purposes the Consultant may assume that up to 10 external customers per category, ie up to 110 in total, could be issued with a questionnaire, together with up to 30 internal Agency customers). The Consultant shall collate and review the replies to the questionnaire, and prepare and submit to the Agency a report on the findings of the survey.

4.3.2 Carry out an economic analysis to estimate the value of the groundwater level data collected by the Agency in Anglian Region to its customers (both internal and external).

4.3.3 Establish the costs to the Agency in Anglian Region of collecting and supplying groundwater level data to its customers (both internal and external).

4.3.4 Carry out a full cost - benefit analysis to examine the justification for continuing to monitor groundwater levels in the Anglian region, and to carry out Stage 2 of the project by completing a full asset survey and review of the regional groundwater level monitoring network. All feasible options for completing the review (including the "Do Nothing" option of continuing with the current network), should be considered, the most favourable 3 or 4 options selected for detailed evaluation, and the preferred option recommended; intangible benefits and risks should also be included in the analysis.

4.3.5 Produce a report on the economic appraisal which presents the full results of the appraisal, together with the conclusions of the study and recommendations for further actions.

Stage 2

4.4 **Provided that the Agency confirms that Stage 1 of the project has satisfactorily established that proceeding with Stage 2 of the review is the preferred business option:**

4.4.1 Complete a full asset survey of the existing groundwater level monitoring network in all the groundwater units within the region that were not included in Stage 1 of the project. The detailed requirements of the Stage 2 survey will be specified when Stage 1 has been completed and the results evaluated, but the general requirements will be similar to those described in section 4.1 for the Stage 1 asset survey.

4.4.2 Apply the design methodology that was established in Stage 1 to the asset survey data obtained in Stage 2 (section 4.4.1) to classify the boreholes into the 3 categories described in section 4.2.2.

4.4.3 Identify the changes that are needed to improve the capacity of the network to record and provide information on changes in water level within the groundwater units surveyed in Stage 2, with particular regard to the numbers and locations of observation boreholes. Prepare lists of the sites where new monitoring boreholes are required to meet the criteria for minimum network density of the combined Reference/National network for each of the groundwater units. Also prepare lists of boreholes in the groundwater units that could potentially be removed from the monitoring network as there is no longer a perceived need for the data that they provide. Provide a programme for carrying out this work, with cost estimates.

4.4.4 Produce a final report describing the survey work carried out, and the results and recommendations of the review.

5. Consultation

The Consultant shall throughout the project report to the Agency's Project Manager, Mr David Clarke, who is based at the Agency's Peterborough office.

Within the Agency, the Consultant shall also need to consult the respective Area Hydrogeologists and Area Hydrologists (Hydrometry). Initial contacts with Area staff will be arranged by the project manager.

The Consultant shall also need to liaise closely with Hydro-Logic Ltd, with regard to database specification and data transfer into the Hydrolog Station Manager

Appendix B - Review of BGS Technical Report WD/94/41C taken from Stage 1 report

2 REVIEW OF BGS TECHNICAL REPORT WD/94/41C

2.1 INTRODUCTION

The BGS report (Ref. 1) states that the review had three stages:

1. Collection of information from the various regions of the National Rivers Authority (the predecessor to the Environment Agency).
2. Collation and review of information: identification of best practice in network design, monitoring frequency and production of recommendations with regard to national design and operational criteria for application to regional networks.
3. Production of recommendations for changes to the existing regional networks to meet the design and operational criteria identified in Stage 2 above.

The scope of the report included:

- The principal objectives of monitoring;
- Evaluation of the present approaches nationally to monitoring;
- Identification of deficiencies in networks and aspects of best practice;
- Provision of a framework for unifying criteria for groundwater level monitoring network design and operation;
- And finally, provision of recommendations for development and changes in regional practice.

The following limitations to the scope of the BGS report (Ref.1) were noted by the authors:

- The review was concerned with the primary long-term groundwater level monitoring network and boreholes used for long term operational monitoring. The review was not concerned with boreholes monitored only for short term investigations, such as pump testing or commissioning of abstraction or recharge schemes.
- The report considered current and proposed Environment Agency practice in the operation of groundwater monitoring networks.
- Consideration of the data management aspects of groundwater level measurement was not included.

Consideration of the local hydrogeological regime was to be included at an area level.

2.2 PRINCIPAL OBJECTIVES OF MONITORING

The objectives for a national network are set out in Table 2.4.1 of the BGS report (Ref.1), which is reproduced overleaf as Table 1. This list is considered to be applicable to the Anglian Region. However, information output to be used for mine water incidents is unlikely to arise. Information for use in the monitoring of groundwater associated with wetland areas would, however, be an identifiable output (now specifically required to meet the needs to implement the EC Habitats Directive).

Monitoring boreholes are usually multi-purpose and provide information to meet many of the objectives listed in the table. The overall philosophy should be that the monitoring sites should provide data for as large a number of objectives as possible for proper understanding of the hydrogeological conditions and the management of groundwater resources.

Table 1 *Groundwater monitoring network objectives*

Objective	Information Output
Spatial distribution	Maps of groundwater level. Quantitative data on the hydraulic behaviour of aquifers. Identification of areas of recharge/discharge.
Trends	Monitoring of recharge, recession and natural groundwater level fluctuations. Monitoring impact of local and regional groundwater abstraction.
Early warning	Information to allow assessments of resources during periods of groundwater stress. Data for drought action monitoring. Flood warning.
Baseline for future issues	Provision of data to support groundwater modelling. Provision of data for water resources investigation and environmental impacts.
Industrial and urban impacts	Mine water and pollution incidents. Monitoring areas of rising groundwater levels.
Surface water / groundwater Interaction	Data to assess the impact of recharge or abstraction on stream flow or wetlands.
Licensing and operational control	Data to control the monitoring and licensing of groundwater abstraction on a regional and local scale. Data for the operational control of abstraction/recharge works.
Support water quality studies	Aquifer protection associated with major developments. Water quality monitoring and control.

2.3 MONITORING BEST PRACTICE IDENTIFIED FROM THE 1994 SURVEY

The following best practice is identified in the BGS report (Ref. 1) based on the responses to a questionnaire sent to the Regions in April 1994.

- A network should comprise primary and secondary sub-networks of monitoring boreholes. The primary network should provide representative coverage of each aquifer for monitoring long term changes in groundwater levels and hence storage due to both natural and man-made influences. Boreholes in this network should be owned by the Agency or have a long lease and should preferably have a continuous autographic or digitally logged record extending over several decades.
- The secondary network provides infill data between the primary boreholes and, although more flexible regarding the addition and removal of boreholes, it provides the key tool for managing the aquifer as it gives a more comprehensive view of groundwater level changes. Water levels are measured at intervals sufficient to determine seasonal fluctuations, which will vary with aquifer properties.
- Comprehensive reviews of monitoring networks should be undertaken every 3 to 5 years. These reviews need to be documented and the criteria for inclusion or exclusion

of boreholes need to be itemised. The addition or removal of sites is controlled by the status of the existing network.

- Groundwater levels should be monitored automatically at a core network of sites. These readings should be supplemented with a numerically larger network of manually read sites monitored at intervals required to define the ground water fluctuations accurately enough to meet the use that is to be made of the data.
- Key boreholes that are monitored continuously using a datalogger or chart recorder should be downloaded at monthly intervals, longer if the equipment is reliable and the data are not required immediately. This will ensure that annual maxima and minima are captured.

2.4 FRAMEWORK FOR GROUNDWATER LEVEL MONITORING

The BGS report (Ref. 1) identifies a set of criteria that may be used for assessing a groundwater level monitoring network.

2.4.1 Classification

The main conclusion of the BGS report (Ref. 1) is that there is a need to classify monitoring boreholes. They propose a simple hierarchical classification which mirrors that proposed for the national groundwater quality monitoring network.

The proposed scheme has three tiers:

- *National Network*: Consisting of monitoring boreholes with data of the highest quality where monitoring can be carried out to provide the detailed long term record that is valuable for resource studies. This network will also form the basis for the national monitoring.
- *Regional Network*: Core monitoring sites on a regional basis. This network will provide groundwater level monitoring to meet most of the data users' demands for water level information and monitoring of resource variations on both a local and national basis. It is assumed that this regional network information will be used primarily at the regional level.
- *Local Network*: Project orientated monitoring sites. This will typically form an important part of the monitoring network. These should include both long term regional projects over wide areas and more local issues such as the monitoring of individual abstraction licences.

The need for a degree of flexibility in these categories is recognised and it is expected that boreholes may be reclassified periodically subject to review of data utility and demand.

In addition, individual boreholes would be assigned one or more functional classifications from the list given in Table 4.1.2 of the BGS report (Ref. 1). The table is included in Appendix B of this report.

2.4.2 Network density

The recommendations for network density are based on the premise that the overall resources committed by the Agency, at the time of the report, were broadly appropriate to the task of satisfying the user's data requirements. Also, that the densities selected to produce a network were compatible with current practice.

Two approaches were considered, namely:

- A geographical basis for coverage of the aquifers, coupled with a consideration of the importance of an aquifer based on abstraction rates, to ensure adequate overall density (referred to as "Method A").
- Detailed statistical examination of aquifer characteristics, requiring a considerable volume of existing data and therefore limited to those aquifers that have the necessary data (referred to as "Method B").

The geographical selection of network density is based on three criteria. The first is spatially based on aquifer units or alternatively surface water catchments. The second is based on aquifer area and the third is the volume of water abstracted. The BGS report (Ref. 1) proposed minimum density should be the highest of these three criteria.

The actual ranges of criteria used depend on the classification of the network. Factors considered are:

- The distance over which significant variation can be expected.
- Compatibility with current monitoring practices and densities.
- Conformity with the densities proposed for groundwater quality monitoring.

The values are given in Table 4.2.1 of the BGS report and are reproduced below.

Table 2 *BGS proposed monitoring density criteria*

Network Tier	Aquifer units /Catchments	Aquifer density (km^2/borehole)		Aquifer exploitation (Ml/day/borehole)
		Minor / Major confined	Major Unconfined	
1 - National	1	200	100	
2 - Regional		50	25	0.6
3 – Local		As appropriate	As appropriate	

For the Tier 2 network, the BGS report (ref. 1) suggests a density of 25km^2/borehole should also be applied to minor aquifers that are exploited for public supply.

The BGS report (Ref. 1) states that in 1994 the Anglian Region monitored the following aquifers: Chalk (904 sites), Jurassic Limestones (250 sites), Superficial deposits (93 sites) and others (92 sites) i.e a total of 1339 sites. The overall density for the Anglian Region is given as 1 borehole per 15.6 km^2. In the Northern area the density was reported as Unconfined 1 per 25 km^2, Confined 1 per 50 km^2. In the Eastern area the density was reported as West of Crag (unconfined) 1 per 25 km^2, Crag (confined) 1 per 50 km^2. In the Central area the mean network density in the Chalk aquifer in 1985 was 1 per 7km^2.

Borehole numbers have risen since 1994 and now stand at approximately 1600. Monitoring densities are now significantly higher than the densities proposed in Table 2.

The statistical approach for density ("Method B") was summarised as the selection of an optimal monitoring network based on observed aquifer behaviour, using statistical correlation between levels across an aquifer.

While application of this technique may be desirable for designing an optimal network, it was considered by the Environment Agency that it was not technically suitable for the Anglian aquifers and that even if the necessary data were available, the costs of applying such a rigorous analysis would probably outweigh the benefits that would result. Quantifying the cost/benefit of such a study would require significant investment. The Environment Agency

has therefore opted to utilise "Method A" for the Anglian Region. This conclusion is endorsed.

2.4.3 Inclusion and Categorisation

While there are objective criteria that may be applied to the selection of observation boreholes, the complex nature of hydrogeological data requires that a subjective assessment should also be made of the utility of a particular monitoring borehole.

It has been shown that a dual approach is the most effective method of appraising methods in several hydrometric reviews.

Subjective criteria

Subjective criteria are classified as those factors which are either not easily quantifiable, or if quantifiable, need careful interpretation to establish their significance.

The criteria applied, when the regional monitoring networks were reviewed by Monkhouse and Murti in 1981 (Ref.2), were reported as follows:

"As far as possible, the regional sites are selected on the basis of showing only natural fluctuations, which means in areas where little or no groundwater is abstracted. Where that is not possible, sites are selected where groundwater abstraction is essentially at a constant rate, and the natural fluctuations are not masked by pumping effects.

The second requirement is a reasonable and clearly discernible range of fluctuations. Some sites show a long lag-time between rainfall and water level rise. Such sites often have value when considering long term effects but it is not unusual for minor responses to be blurred, and they have limited value for rapid and immediate assessments. The responses of boreholes in confined aquifers often show similar limited information.

For operative observation boreholes, the period of record is important. Sites with less than 10 years of record have only limited value"

The decision to include a borehole in the monitoring network should take account of local hydrogeological conditions and knowledge.

2.4.4 Removal of a borehole from the monitoring network

There will inevitably be an element of natural wastage in a large network, where monitoring boreholes are lost through changes in land use or through deterioration of the physical installation.

Decisions to remove boreholes from the monitoring network should be based on four principal factors:

- Hydrogeological value
- Borehole condition and ownership
- Current costs of monitoring
- Health and Safety reasons

The current Anglian Region procedure is for the relevant parties to be consulted prior to removal from the network. Factors that may lead to removal include: the reason for the installation has ceased, borehole collapse, and access problems.

In addition to the above, there may be reasons beyond the control of the Environment Agency that lead to removal of a borehole from the monitoring network, such as withdrawal of permission to enter by the Owner.

2.4.5 Monitoring frequency

Monitoring frequency depends on an assessment of the use to which data from an individual borehole will be put, and on the speed of response of the aquifer to the transient events such as recharge or abstraction.

For boreholes to form functional components of a groundwater level monitoring network the BGS report (Ref. 1) states that it is necessary to take a minimum of two observations per year. These should ideally be timed to coincide with annual peaks and troughs of level.

Table 4.5 of the BGS report (Ref. 1), which is included in Appendix B, showed the suggested minimum measurement intervals classified by aquifer storage. The current frequency of reading is mainly monthly or more frequently, with only some 15 to 20% read bi-monthly or at longer intervals.

It is recommended in the BGS report (Ref. 1) that boreholes that form part of the national network should be equipped with continuous chart recorders or with data-loggers capable of recording daily levels. Where the aquifer behaviour of the aquifer is predictable manual monitoring may be adequate.

It is recommended that the regional network should be monitored at least six times a year. The monitoring frequency will need to be higher in those boreholes that show pronounced fluctuations.

Continuous recordings of water levels in new observation boreholes over a full hydrometric year or longer was reported as good practice. This allows the characteristic behaviour of a borehole to be established before making a decision on long term measuring frequency.

Local monitoring borehole measuring frequency will depend on the use to which the data will be put.

In 1994 the Anglian Region had 98 core network sites with continuous records (that were downloaded monthly) and a total of 1240 sites measured manually. 51 sites were visited more frequently than monthly, 1070 were visited monthly and 218 sites were visited less frequently where long-term records demonstrated this to be satisfactory.

2.4.6 Inclusion of sites from other monitoring programs

The utility of groundwater data archives will be enhanced by the systematic inclusion of water level measurements made as part of other programmes, or by observers outside the Agency. It will be necessary to characterise the accuracy and reliability of these measurements.

2.5 ESTABLISHMENT OF THE NATIONAL MONITORING NETWORK

The BGS report (Ref. 1) makes a number of recommendations for the implementation of the national groundwater level monitoring network.

2.5.1 Classification of existing monitoring boreholes

Existing monitoring boreholes should be classified using the 3 level classification scheme. The detailed classification comprised several steps as outlined in Figure 5.1.1 of the BGS report (included in Appendix B):

- Prepare target figures for monitoring network density.
- Rank existing boreholes by suitability to be considered as National and Regional sites. The method chosen would be to assign scores to boreholes based on a number of attributes. This is "Method A" in the BGS report and the proposed scoring system is

shown in Table 5.1.2 and summarised in Figure 5.1.2 of the BGS report (copies of both of these are found in Appendix B).

- Select the required number of boreholes to achieve target network density, by choosing the highest ranking boreholes.
- Boreholes not included in the National or Regional networks are assigned to the local network.

As "Method B" is not being used, the comparison of the rankings from the two methods and the return loop to re-ranking shown in Figure 5.1.1 of the BGS report are not carried out.

2.5.2 Assessment of monitoring effectiveness

Spatial coverage

The actual monitoring network should be compared with the proposed criteria for National and Regional sites:

- Areas of insufficient monitoring density. Additional sites to be promoted from the Regional and Local tiers. If no existing boreholes are found then plan for new sites which would start at the Local level.
- Adequate density of National and Regional sites. No Local sites.
- Adequate density of National and Regional sites. Some Local sites. Business case required for continued monitoring by the Environment Agency of the local sites.

Monitoring frequency

The monitoring frequency should then be examined:

- Boreholes monitored at insufficient frequency - increase when resources permit.
- Adequate monitoring frequency.
- Boreholes monitored too frequently - reduce frequency or make business case to justify continuation.

2.5.3 Good practice

A checklist of points is given in Table 5.4.1 of the BGS report (a copy is found in Appendix B):

- Classification of monitoring sites
- Periodic network review
- Annual summaries of network
- Co-operation with other networks
- Review policy on data loggers' telemetry
- Archiving data from other providers
- Digitisation of data.
- Centralised data holdings

Appendix C - Application of Design Methodolgy

Appendix C

APPLICATION OF DESIGN METHODOLOGY

C1 METHODOLOGY

Stage 1 differed from Stage 2 in that it identified the standard threshold scores to be applied to the entire Region during Stage 2 based on data from the three trial catchments (i.e. steps 3, 4 and 5 below apply only to Stage 1). The methodology is described below with reference to application to a particular groundwater catchment.

1. **Set monitoring density targets** This was described in Section 2.4.2 of the Stage 1 report (Ref.2).
2. **Score and rank** individual sites according to water level data, hydrogeological context and site characteristics. This was described in Section 3.2.1 of the Stage 1 report (Ref.2).
3. **Set the minimum score thresholds** (*Stage 1 only*).
4. **Compare existing and target monitoring densities** (*Stage 1 only*).
5. **Finalise threshold scores** (*Stage 1 only*).
6. **Apply the standard threshold scores** and review the numbers in each preliminary tier to achieve the target density.
7. **Finalise Tier 1 and 2 numbers** so that the target density is achieved. The selection of sites is based on a review of preliminary tier, current monitoring purpose, legal status and spatial distribution requirements.
8. **Identify Tier 2 new borehole requirements** when there are no sites available from preliminary tiers 1 and 3 that will improve the Tier 2 coverage.
9. **Assign remaining boreholes to Tier 3 (Local).** Sites not included in Tiers 1 and 2 that have an identified local importance are assigned to Tier 3. The sites must have special monitoring purposes (e.g. licence requirements) and will be subject to review by the Agency Area staff for continued inclusion in line with the following factors:
    - Hydrogeological value
    - Borehole condition
    - Access or ownership
    - Current costs of monitoring/budget
    - Health and safety standards
10. **Identify potential surplus sites.** These are sites that are considered to be surplus to the regional monitoring needs (Tiers 1 and 2) and appear to have no special local requirement for monitoring (Tier 3) and could therefore be excluded from the monitoring network. These sites have been identified to be taken out of the network subject to review by the Agency Area staff taking into account factors including the regional modelling project data requirements.

C2 PRELIMINARY TIERING

The scoring system used for borehole ranking is that set out in section 3.3 of the Stage 1 report (Ref. 2) and is shown on Table 3 overleaf. The system is broadly based on that given in the BGS report (Ref.1).

The attributes that are to be scored have been placed into three categories:

Category 1 Groundwater level data

Category 2 Hydrogeological context

Category 3 Site characteristics

There were a number of attributes that were considered appropriate to add to the list given in the BGS report.

Addition to Category 1 - Existing Level Data

- The average monitoring frequency over the period of record

Additions to Category 2 - Hydrogeological Context

- The response zone being monitored,
- Range of fluctuations from the general trace,
- Abstraction influence function,
- The hole diameter

The extent of alteration from the natural regime is scored by identifying the range of fluctuation or scatter from the normal response trace. The abstraction influence function is based on a summation of licensed abstractions in the same aquifer divided by radial distance within a 10km radius.

Additions to Category 3 - Site Characteristics

- Access restrictions
- Risk assessment

Table C1 *Attribute scores*

Maximum Score	Attribute
80	• Length of record (years)
20	• Average monitoring frequency over period of record (yr.)
15	• Response zone • Range of annual variation (metres) aquifer specific (seasonal) • Legal Status
10	• Continuity of record (% length of record on yearly basis) • Current monitoring frequency (per year) • Range of fluctuation (metres) aquifer specific (spatial) • Abstraction influence function • Borehole construction/Lithological data • Is hole pumped?
5	• Current method of measurement • Borehole diameter • Does borehole go dry? • Access restrictions • Headworks condition • Risk assessment

Initial scoring runs were carried out during Stage 1 using actual data collected. This exercise highlighted the need to ensure that a site with a long record of say 2 to 10 years, but with less than 90% continuity scored more highly than a site with a short record of < 2 years with 100% continuity. The longer record is considered more useful for resource

management than the continuity over a short period. The maximum score for the length of record was raised to 80 marks and the continuity maximum score was reduced to 10 for more than 90% continuity to reflect this.

A protocol for determining the scores for each of the attributes is included in Appendix C of the Area reports (Refs. 3, 4 and 5).

The ranking of the sites was undertaken within the project database for each of the groundwater catchments in each of the Region's Areas. The results of the scoring for all the catchments are shown in Appendix D of the relevant Area reports (Refs. 3, 4 and 5).

Table C2 *Design Methodology Borehole Scoring Scheme*

Attributes	Score ranges					
Category 1 – Groundwater Level Data	**Maximum Total 125 points**					
Length of record	Years	<2	2-9	10-19	20-30	>30
	Score	5	25	50	70	80
Continuity of record (% length of record on yearly basis)	%	<50%	50-74%	>74%		
	Score	2	5	10		
Average monitoring frequency over period of record (year)	Period	6 monthly	Quarterly	Monthly	Weekly	Daily
	Score	2	5	10	15	20
Current monitoring frequency (per year)	Period	6 monthly	Quarterly	Monthly	Weekly	Daily
	Score	1	3	6	8	10
Current method of measurement	Method	Manual	Chart recorder		Data logger	
	Score	0	3		5	
Category 2 – Hydrogeological Context	**Maximum Total 80 points**					
Response zone	Type	Multiple aquifer		Single aquifer		
	Score	1		15		
Range of annual variation (metres) **aquifer specific** (seasonal)	m	<1	1-3	3-5	>5	
	Score	1	5	10	15	
Range of fluctuation (metres) **aquifer specific** (spatial)	m	>0.5	0.5-0.3	0.3-0.1	<0.1	
	Score	1	3	6	10	
Abstraction influence function	Unit	>50	50-10	10-5	<5	
	Score	0	3	5	10	
Borehole construction/Lithological data	Type	No data	Drillers log only	Geologist log	Geologist log + Geophysics/ CCTV	
	Score	0	5	8	10	
Borehole diameter	mm	>500mm	250-500mm	50-250mm	<50mm	
	Score	1	2	3	5	
Is borehole pumped?	Frequency	Routinely	Infrequently (quarterly)	Never		
	Score	1	5	10		
Does borehole go dry?	Frequency	Annually	Occasionally	Never		
	Score	0	2	5		
Category 3 – Site Characteristics	**Maximum Total 30 points**					
Legal status for access	Type	No agremnt. (Private land)	No agremnt. (Public land)	Licence to monitor	Leasehold	Freehold
	Score	0	5	7	10	15
Access restrictions	Type	Seasonal	Advance notice	None		
	Score	1	3	5		
Headworks condition	Grade	Poor				Good
	Score	0	1	2	3	4	5
Risk assessment	Grade	High				Low
	Score	0	1	2	3	4	5

NOTE: The attributes marked **aquifer specific** above refer to the following aquifers: Chalk, and Spilsby Sandstone, Lincolnshire Limestone, Permeable drift and Recent sands and gravel.

The range of annual fluctuation is the difference between maximum and minimum level taken over a calendar year. The range of fluctuation is the average scatter about the record trace over the entire period of record.

The Stage 1 trial showed that there was a variation in tier threshold scores for each of the trial areas if the target densities were used as control (Ref. 2, Table 5). The preliminary tier threshold scores are different for each of the areas. The tier 1 preliminary threshold score varied from 150 to 175. If there are more sites than required for the target density then the options to consider are either raising the threshold score and/or moving sites down a tier. Alternatively, if there are too few then the threshold scores could be lowered and/or sites moved up a tier.

The adopted tier threshold scores are those identified in section 4.5 of the Stage 1 report (Ref.2) and should be the same across the Region. The scores therefore, have been set as follows:

- Threshold score between Tiers 1 and 2 set at 175
- Threshold score between Tiers 2 and 3 set at 150

If the resultant number of sites in each preliminary tier results in a density more or less than the target density then the numbers should be adjusted by promotion or demotion of suitable sites from other tiers accordingly. If there are still not enough sites then provision should be made for the construction of new sites to achieve the target densities.

C3 FINALISE TIER 1 AND TIER 2

The results of the application of the scoring and preliminary tiering based on the above thresholds was then reported for observation boreholes monitoring the major aquifers in each catchment. Density criteria for the superficial deposit minor aquifers (such as permeable drift, recent sands and gravel, peat) in the major aquifer catchments are considered to be of little value due to their limited area and linear nature of the aquifers.

The selection of the sites to be promoted or demoted should take into account a number of factors including:

- Hydrogeological value, single aquifer monitoring sites preferred, especially with shorter open/screened lengths giving better response zones.
- Spatial distribution, close proximity to recharge and discharge areas preferred.
- Current monitoring purpose, multipurpose sites being preferred.
- Legal status for access, freehold, leasehold and licence to be monitored are preferred.
- Comparison of ranking attributes of candidates where two or more potential sites have been identified based on spatial distribution requirements.

The current monitoring purposes have been identified as National Network – water level (N), Regional Network (R), Special Resource Investigation (S), Environmental Protection – river and wetland (E), Abstraction – protection and EI for GPZ (A), Contamination (C) and Quality Network (Q).

The application of the design methodology to the catchment areas has shown that borehole numbers in preliminary tiers 1 and 2 (National and Regional) often have to be modified to meet target densities.

The Tier 1 (National) network will be made up from sites:

- that do not go dry or have uncontrolled artesian flow at any time;
- ranked in preliminary tier 1; or

- promoted from preliminary tier 2.

The Tier 2 (Regional) network will be made up from sites:

- demoted from preliminary tier 1;
- ranked in preliminary tier 2; or
- promoted from preliminary tier 3.

The Tier 3 network will contain all those sites that are not required for the Tier 1 and 2 networks but are considered necessary to fulfil the local catchment area monitoring requirements. These sites should be subject to periodic review by Agency Area staff for continuing inclusion in Tier 3

In some catchments there are areas that do not have any suitable monitoring sites and therefore if the target density is to be achieved new boreholes will be required.

Sites that are deemed surplus to requirements of Tier 2 and 3 are flagged to be taken 'out' of the network. These sites are subject to review by Agency Area staff for removal from the monitoring round and potentially decommissioned, subject to the owner's agreement.

Decisions to remove boreholes from the monitoring network should be based on five principal factors:

- little or no hydrogeological value;
- poor borehole condition;
- problems with access or ownership;
- current costs of monitoring/budget; and
- failing Health and Safety standards.

The current Anglian Region procedure is for relevant parties to be consulted prior to removal of any borehole from the network. Factors that may lead to removal include: the borehole is regularly dry; has become blocked and cannot economically be reinstated; the reason for the installation has ceased; and, there are access problems.

In addition to the above, there may be reasons beyond the control of the Agency that lead to removal of a borehole from the monitoring network. These include withdrawal of permission to enter by the owner or that the site has been redeveloped and the installation has either been covered over, or filled in.

During the review there was a process of consultation with the Area Hydrogeologists in order to agree the classification of the existing monitoring boreholes and their purpose. The Tier 1 sites were selected primarily on their score and provided that their distribution was even across the catchment the number was modified to meet the target density based on the promotion/demotion criteria set out above. The remaining sites were then classified as Tier 2 and the classification process repeated for the regional core network.

These sites have been identified and are shown on the tables in Appendix E of the relevant Area reports (Refs. 3, 4 and 5).

C4 IDENTIFY NEW BOREHOLE REQUIREMENTS FOR TIER 1 AND TIER 2

There are a number of areas in each catchment where the coverage is currently inadequate to meet the proposed density targets for major aquifers or the monitoring of minor aquifers. New monitoring boreholes are to be constructed to meet these requirements. These sites would start in Tier 2 and be promoted eventually to Tier 1, if required, as and when the data was up to the specific Tier standard.

During the review there was a process of consultation with the Area Hydrogeologists in order to agree the location of the proposed new monitoring boreholes and their purpose.

The locations of all new boreholes shown on the figures in the reports are indicative of their general intended area. The actual locations will depend on suitable local sites being found. An example of adjustments of locations that can be made are the new Waveney boreholes in Eastern Area.

C5 ASSIGN REMAINING TO TIER 3

During the review process and consultation with the Area Hydrogeologists sites have been identified to remain in Tier 3 of the network and are shown on the tables in Appendix E of the relevant Area reports (Refs. 3, 4 and 5).

C6 SURPLUS IDENTIFIED (TIERS 1 OR 2 AND 3)

There are areas where the number of boreholes is greater than required for the proposed Regional aquifer density criteria and where the sites have no special local requirement for monitoring. These sites are considered to be surplus to the network requirements for regional water level information, resource monitoring requirements, local and project-orientated monitoring such as modelling studies and, therefore, should be excluded from the monitoring network.

These sites have been identified to be taken 'out' of the network and are shown on the tables in Appendix E of the relevant Area reports (Refs. 3, 4 and 5)

The boreholes will be subject to review by Agency Area staff for removal from the network in line with the factors given in section C3 above and if removal is confirmed they should be infilled, subject to the owner's agreement.

C7 REPLACEMENT BOREHOLES

There are sites within the proposed core network that have been identified as monitoring multiple aquifers, based on the construction details, water levels and lithological data. This situation occurs when a borehole is constructed so that two or more aquifers can contribute to the water level that is monitored.

At these sites a new observation borehole should be constructed next to the existing borehole to monitor the selected aquifer alone, and both boreholes should be monitored. When sufficient data has been collected to establish a correlation in water level response between the two boreholes (e.g. over a 5-year period) then consideration should be given to whether the original observation boreholes could be converted at these sites to monitor the water levels in the other aquifer. These sites with grouped or nested installations in separate holes alongside each other would allow the measurements of vertical head differences as well as any recharge or discharge response differences in the various aquifers at the location.

Table D1 - Remedial Works Summary - Eastern Area : Approximate cost per priority band (results sorted in descending order of priority)

Site ID	Priority Band				Travel Time Cost	TOTAL COST	Overall Priority Band	Work Required
	A	B	C	D				
TG22/801	£126.00	£126.00	£135.50	£0.00	£80	£468	A	Black painted steel tube, Well lining - brickworks, Manhole cover, Manhole frame, Protective safety screen,
TG22/801A	£126.00	£126.00	£73.00	£0.00	£80	£405	A	Well lining - brickworks, Manhole cover, Manhole frame, Protective safety screen,
TF92/290	£126.00	£126.00	£0.00	£0.00	£80	£332	A	Manhole cover, Manhole frame, Protective safety screen,
TG11/619	£126.00	£126.00	£0.00	£0.00	£80	£332	A	Manhole cover, Manhole frame, Protective safety screen,
TM02/633	£126.00	£126.00	£0.00	£0.00	£80	£332	A	Manhole cover, Manhole frame, Protective safety screen,
TG13/765A	£126.00	£73.00	£46.50	£0.00	£80	£326	A	Manhole frame, Protective safety screen, Overhead trees,
TG03/644A	£126.00	£0.00	£0.00	£0.00	£80	£206	A	Protective safety screen,
TM14/510	£106.00	£0.00	£188.00	£0.00	£80	£374	A	Black painted steel tube, Black painted steel cap, Manhole cover, Overhead trees,
TM47/070	£0.00	£252.00	£17.00	£0.00	£80	£349	B	Borehole paintwork, Manhole cover, Manhole frame,
TF93/362	£0.00	£145.00	£96.00	£0.00	£80	£321	B	Flange type steel tube, Flange bolts, Metal ground plate, Manhole frame,
TM46/481	£0.00	£139.50	£30.00	£0.00	£80	£250	B	Padlock and key, Datum reference, Protective safety screen,
TF91/622	£0.00	£126.00	£141.50	£0.00	£80	£348	B	Concete Slab, Black painted steel tube, Manhole cover, Manhole frame,
TF91/886	£0.00	£126.00	£86.50	£0.00	£80	£293	B	Flange type steel tube, Manhole cover, Manhole frame, Surrounding overgrowth,
TG32/760A	£0.00	£126.00	£79.00	£0.00	£80	£285	B	Concete Slab, Manhole cover, Manhole frame,
TF91/886A	£0.00	£126.00	£63.00	£0.00	£80	£269	B	Flange type steel tube, Manhole cover, Manhole frame,
TM05/493	£0.00	£126.00	£63.00	£0.00	£80	£269	B	Flange type steel tube, Manhole cover, Manhole frame,
TF91/774	£0.00	£126.00	£62.50	£0.00	£80	£269	B	Black painted steel tube, Manhole cover, Manhole frame,
TG32/760	£0.00	£126.00	£62.50	£0.00	£80	£269	B	Black painted steel tube, Manhole cover, Manhole frame,
TF83/323	£0.00	£126.00	£0.00	£0.00	£80	£206	B	Manhole cover, Manhole frame,
TL84/450	£0.00	£125.00	£62.50	£73.50	£80	£341	B	Black painted steel tube, Paint site ID number , Wooden monitoring equipment box, Overhead trees,
TL63/410	£0.00	£122.50	£79.50	£0.00	£80	£282	B	Black painted steel tube, Padlock and key, Borehole paintwork, Wooden monitoring equipment box,
TG03/358	£0.00	£107.00	£220.50	£0.00	£80	£408	B	Concete Slab, Black painted steel tube, Black painted steel cap, Dipping hole bolt, Manhole frame,
TL72/360	£0.00	£106.00	£0.00	£0.00	£80	£186	B	Manhole cover,
TQ79/160	£0.00	£73.00	£0.00	£0.00	£80	£153	B	Stopcock chamber,
TM03/970	£0.00	£70.00	£136.00	£0.00	£80	£286	B	Flange type steel tube, Dipping hole bolt, Manhole cover, Manhole frame,
TL84/410	£0.00	£63.00	£23.50	£0.00	£80	£167	B	Protective safety screen, Surrounding overgrowth,
TM26/702	£0.00	£53.00	£0.00	£0.00	£80	£133	B	Manhole cover,
TG13/389	£0.00	£34.00	£129.00	£0.00	£80	£243	B	Flange type steel tube, Flange bolts, Dipping hole bolt,
TL74/480	£0.00	£27.00	£79.50	£0.00	£80	£187	B	Borehole paintwork, Datum reference, Wooden monitoring equipment box,
ERUST4A	£0.00	£27.00	£73.50	£0.00	£80	£181	B	Borehole paintwork, Flange bolts, Paint site ID number , Surrounding overgrowth,
ERUST4B	£0.00	£27.00	£73.50	£0.00	£80	£181	B	Borehole paintwork, Flange bolts, Paint site ID number , Surrounding overgrowth,
TG03/934C	£0.00	£27.00	£70.00	£0.00	£80	£177	B	Paint site ID number , Surrounding overgrowth, Overhead trees,
TG03/934D	£0.00	£27.00	£70.00	£0.00	£80	£177	B	Paint site ID number , Surrounding overgrowth, Overhead trees,
TL62/602	£0.00	£27.00	£63.00	£0.00	£80	£170	B	Flange type steel tube, Datum reference,
TF74/745	£0.00	£27.00	£62.50	£0.00	£80	£170	B	Black painted steel tube, Datum reference,
TG12/577	£0.00	£27.00	£40.50	£0.00	£80	£148	B	Borehole paintwork, Datum reference, Surrounding overgrowth,
TM26/704	£0.00	£27.00	£19.50	£0.00	£80	£127	B	Locking bar, Paint site ID number ,
TL72/950	£0.00	£27.00	£17.00	£27.00	£80	£151	B	Borehole paintwork, Paint site ID number , Datum reference,
TL65/450	£0.00	£27.00	£0.00	£0.00	£80	£107	B	Datum reference,
TG02/776	£0.00	£17.00	£96.00	£0.00	£80	£193	B	Flange type steel tube, Flange bolts, Dipping hole bolt,
TL75/850	£0.00	£17.00	£67.00	£0.00	£80	£164	B	Borehole paintwork, Flange bolts, Dipping hole bolt,
TL65/730	£0.00	£17.00	£56.50	£0.00	£80	£154	B	Flange bolts, Dipping hole bolt, Surrounding overgrowth,
TG13/151	£0.00	£17.00	£34.00	£0.00	£80	£131	B	Borehole paintwork, Dipping hole bolt,
TM16/7462	£0.00	£13.50	£324.00	£0.00	£80	£418	B	Black painted steel tube, Borehole paintwork, Flange type steel tube, Flange bolts, Datum reference, Wooden monitoring equipment box, Surrounding overgrowth,
TL52/770	£0.00	£13.50	£106.00	£0.00	£80	£200	B	Manhole cover, Datum reference,
TL75/450	£0.00	£13.50	£79.50	£27.00	£80	£200	B	Borehole paintwork, Paint site ID number , Datum reference, Wooden monitoring equipment box,
TL63/810	£0.00	£13.50	£70.00	£0.00	£80	£164	B	Datum reference, Surrounding overgrowth, Overhead trees,
TL73/200	£0.00	£13.50	£66.00	£0.00	£80	£160	B	Flange bolts, Datum reference,
TM14/5824	£0.00	£13.50	£63.00	£0.00	£80	£157	B	Flange type steel tube, Datum reference,

Table D1 - Remedial Works Summary - Eastern Area : Approximate cost per priority band (results sorted in descending order of priority)

Site ID	Priority Band				Travel Time Cost	TOTAL COST	Overall Priority Band	Work Required
	A	B	C	D				
TM14/5282	£0.00	£13.50	£62.50	£0.00	£80	£156	B	Black painted steel tube, Datum reference,
TG20/557	£0.00	£13.50	£23.50	£93.00	£80	£210	B	Datum reference, Surrounding overgrowth, Overhead trees,
TM26/703L	£0.00	£13.50	£19.50	£46.50	£80	£160	B	Locking bar, Paint site ID number , Overhead trees,
TM26/710	£0.00	£13.50	£0.00	£0.00	£80	£94	B	Paint site ID number ,
TL74/740	£0.00	£0.00	£255.00	£0.00	£80	£335	C	Borehole paintwork, Flange type steel tube, Flange bolts, Wooden monitoring equipment box,
TM24/5455	£0.00	£0.00	£252.00	£0.00	£80	£332	C	Manhole cover, Manhole frame,
TM22/000	£0.00	£0.00	£229.50	£0.00	£80	£310	C	Flange type steel tube, Flange bolts, Dipping hole bolt, Surrounding overgrowth, Overhead trees,
TM37/2119	£0.00	£0.00	£212.00	£0.00	£80	£292	C	Black painted steel tube, Manhole cover, Manhole frame, Surrounding overgrowth,
TG12/172	£0.00	£0.00	£211.50	£0.00	£80	£292	C	Black painted steel tube, Black painted steel cap, Surrounding overgrowth, Overhead trees,
TG03/934A	£0.00	£0.00	£166.00	£0.00	£80	£246	C	Flange type steel tube, Flange bolts, Surrounding overgrowth, Overhead trees,
TM23/7950	£0.00	£0.00	£163.00	£0.00	£80	£243	C	Borehole paintwork, Flange type steel tube, Flange bolts,
TM12/390	£0.00	£0.00	£151.00	£0.00	£80	£231	C	Concete Slab, Metal ground plate,
TQ78/780	£0.00	£0.00	£149.00	£0.00	£80	£229	C	Concete Slab, Surrounding overgrowth, Overhead trees,
TG14/410A	£0.00	£0.00	£143.00	£0.00	£80	£223	C	Borehole paintwork, Manhole cover, Manhole frame,
TG14/410	£0.00	£0.00	£142.50	£0.00	£80	£223	C	Flange type steel tube, Flange bolts, Overhead trees,
TG10/621	£0.00	£0.00	£142.00	£62.50	£80	£285	C	Concete Slab, Flange type steel tube, Boreholes enclosure,
TG01/136	£0.00	£0.00	£141.50	£0.00	£80	£222	C	Concete Slab, Black painted steel tube,
TM19/683	£0.00	£0.00	£140.00	£0.00	£80	£220	C	Surrounding overgrowth, Overhead trees,
TM58/2823	£0.00	£0.00	£136.00	£0.00	£80	£216	C	Black painted steel tube, Black painted steel cap, Borehole paintwork,
TM26/3236	£0.00	£0.00	£130.00	£0.00	£80	£210	C	Borehole paintwork, Flange type steel tube, Flange bolts,
TG00/460	£0.00	£0.00	£126.00	£0.00	£80	£206	C	Manhole cover, Manhole frame,
TG22/060	£0.00	£0.00	£125.50	£0.00	£80	£206	C	Concete Slab, Overhead trees,
TL73/250	£0.00	£0.00	£116.00	£46.50	£80	£243	C	Flange type steel tube, Manhole cover, Overhead trees,
TM45/599	£0.00	£0.00	£113.00	£0.00	£80	£193	C	Concete Slab, Borehole paintwork,
TQ67/093	£0.00	£0.00	£105.50	£0.00	£80	£186	C	Black painted steel cap, Locking bar, Overhead trees,
TG13/320	£0.00	£0.00	£103.50	£0.00	£80	£184	C	Borehole paintwork, Flange type steel tube, Surrounding overgrowth,
TL63/811	£0.00	£0.00	£100.00	£0.00	£80	£180	C	Borehole paintwork, Flange bolts,
TF90/879	£0.00	£0.00	£96.00	£0.00	£80	£176	C	Flange type steel tube, Flange bolts,
TL64/840	£0.00	£0.00	£96.00	£0.00	£80	£176	C	Concete Slab, Borehole paintwork,
TL93/260	£0.00	£0.00	£93.50	£0.00	£80	£174	C	Surrounding overgrowth, Overhead trees,
TM14/6449	£0.00	£0.00	£93.00	£0.00	£80	£173	C	Overhead trees,
NTG3224P1	£0.00	£0.00	£86.00	£0.00	£80	£166	C	Wooden monitoring equipment box, Surrounding overgrowth,
NTG3224P2	£0.00	£0.00	£86.00	£0.00	£80	£166	C	Wooden monitoring equipment box, Surrounding overgrowth,
TM24/3313	£0.00	£0.00	£80.50	£23.50	£80	£184	C	Borehole paintwork, Surrounding overgrowth, Overhead trees,
TF82/382	£0.00	£0.00	£80.00	£0.00	£80	£160	C	Borehole paintwork, Flange type steel tube,
TL92/650	£0.00	£0.00	£79.50	£0.00	£80	£160	C	Borehole paintwork, Wooden monitoring equipment box,
TL72/361	£0.00	£0.00	£79.00	£70.00	£80	£229	C	Concete Slab, Surrounding overgrowth, Overhead trees,
TM06/0288	£0.00	£0.00	£79.00	£46.50	£80	£206	C	Concete Slab, Overhead trees,
TL64/880	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
TL94/660	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
WAVOBS04	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
WAVOBS09	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
TG32/914	£0.00	£0.00	£73.00	£0.00	£80	£153	C	Manhole frame,
TL63/454	£0.00	£0.00	£73.00	£0.00	£80	£153	C	Manhole frame,
TL63/455	£0.00	£0.00	£73.00	£0.00	£80	£153	C	Manhole frame,
TL74/300	£0.00	£0.00	£73.00	£0.00	£80	£153	C	Manhole frame,
TG42/334	£0.00	£0.00	£72.00	£0.00	£80	£152	C	Metal ground plate,
TL95/000	£0.00	£0.00	£72.00	£0.00	£80	£152	C	Metal ground plate,
TG03/934B	£0.00	£0.00	£70.00	£0.00	£80	£150	C	Surrounding overgrowth, Overhead trees,

Table D2 - Remedial Works Summary - Central Area : Approximate cost per priority band (results sorted in descending order of priority)

Site ID	Priority Band				Travel Time Cost	TOTAL COST	Overall Priority Band	Work Required
	A	B	C	D				
TL25/010	£495.00	£0.00	£0.00	£0.00	£80	£575	A	Concete Slab, Protective safety screen, Surrounding overgrowth, Protective fencing,
TL43/002	£126.00	£82.00	£0.00	£0.00	£80	£288	A	Protective safety screen, Protective fencing,
TL53/006	£126.00	£53.00	£0.00	£0.00	£80	£259	A	Manhole cover, Protective safety screen,
TL25/004	£0.00	£126.00	£0.00	£0.00	£80	£206	B	Manhole cover, Manhole frame,
TF72/004	£0.00	£106.00	£0.00	£0.00	£80	£186	B	Manhole cover,
TF71/084	£0.00	£102.00	£0.00	£0.00	£80	£182	B	Black painted steel tube, Black painted steel cap,
TL56/007	£0.00	£102.00	£0.00	£0.00	£80	£182	B	Black painted steel tube, Black painted steel cap,
TL76/002	£0.00	£82.00	£46.50	£0.00	£80	£209	B	Overhead trees, Protective fencing,
TL03/003	£0.00	£70.00	£0.00	£0.00	£80	£150	B	Dipping hole bolt, Manhole cover,
TF62/004	£0.00	£60.00	£0.00	£73.00	£80	£213	B	Padlock and key, Well lining - brickworks,
TL23/041L	£0.00	£60.00	£0.00	£0.00	£80	£140	B	Padlock and key,
TL44/239	£0.00	£59.00	£0.00	£0.00	£80	£139	B	Well lining - plastic inner lining,
TF81/116	£0.00	£36.50	£0.00	£13.50	£80	£130	B	Wooden marker post, Overflow control valve,
SP93/136	£0.00	£34.00	£136.00	£0.00	£80	£250	B	Black painted steel tube, Black painted steel cap, Borehole paintwork, Dipping hole bolt,
TL65/064	£0.00	£33.00	£90.00	£0.00	£80	£203	B	Borehole paintwork, Flange bolts, Manhole frame,
TF80/218L	£0.00	£33.00	£0.00	£0.00	£80	£113	B	Flange bolts,
TL75/009	£0.00	£17.00	£99.00	£0.00	£80	£196	B	Black painted steel tube, Dipping hole bolt, Stopcock chamber,
TF73/007	£0.00	£17.00	£0.00	£0.00	£80	£97	B	Dipping hole bolt,
TL05/085	£0.00	£17.00	£0.00	£0.00	£80	£97	B	Dipping hole bolt,
TL66/007	£0.00	£17.00	£0.00	£0.00	£80	£97	B	Dipping hole bolt,
TL65/004	£0.00	£13.50	£63.00	£0.00	£80	£157	B	Flange type steel tube, Paint site ID number ,
TL33/048	£0.00	£13.50	£17.00	£0.00	£80	£111	B	Borehole paintwork, Wooden marker post,
TF60/002	£0.00	£13.50	£0.00	£0.00	£80	£94	B	Paint site ID number ,
TL24/100	£0.00	£13.50	£0.00	£0.00	£80	£94	B	Paint site ID number ,
TL35/011	£0.00	£13.50	£0.00	£0.00	£80	£94	B	Paint site ID number ,
TL89/018	£0.00	£13.50	£0.00	£0.00	£80	£94	B	Paint site ID number ,
TM08/011	£0.00	£13.50	£0.00	£0.00	£80	£94	B	Paint site ID number ,
TL85/001	£0.00	£0.00	£93.00	£0.00	£80	£173	C	Overhead trees,
TL44/427	£0.00	£0.00	£80.50	£0.00	£80	£161	C	Borehole paintwork, Overhead trees,
TL13/123	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
TL23/006	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
TL33/043	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
TL46/005	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
TL67/117	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
TL76/110	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
TL56/127	£0.00	£0.00	£70.00	£0.00	£80	£150	C	Surrounding overgrowth, Overhead trees,
TL78/004	£0.00	£0.00	£63.00	£46.50	£80	£190	C	Flange type steel tube, Overhead trees,
TL23/015L	£0.00	£0.00	£63.00	£0.00	£80	£143	C	Flange type steel tube,
TL24/002	£0.00	£0.00	£62.50	£0.00	£80	£143	C	Black painted steel tube,
TL75/001	£0.00	£0.00	£47.00	£0.00	£80	£127	C	Surrounding overgrowth,
SP92/017	£0.00	£0.00	£46.50	£0.00	£80	£127	C	Overhead trees,
TL12/107	£0.00	£0.00	£46.50	£0.00	£80	£127	C	Overhead trees,
TL35/004	£0.00	£0.00	£46.50	£0.00	£80	£127	C	Overhead trees,
TL43/054	£0.00	£0.00	£46.50	£0.00	£80	£127	C	Overhead trees,
TL54/014	£0.00	£0.00	£46.50	£0.00	£80	£127	C	Overhead trees,
TL57/003	£0.00	£0.00	£46.50	£0.00	£80	£127	C	Overhead trees,
TL66/055	£0.00	£0.00	£46.50	£0.00	£80	£127	C	Overhead trees,
TL66/087	£0.00	£0.00	£46.50	£0.00	£80	£127	C	Overhead trees,
TL34/011	£0.00	£0.00	£40.50	£0.00	£80	£121	C	Borehole paintwork, Surrounding overgrowth,

Table D2 - Remedial Works Summary - Central Area : Approximate cost per priority band (results sorted in descending order of priority)

Site ID	Priority Band				Travel Time Cost	TOTAL COST	Overall Priority Band	Work Required
	A	B	C	D				
TL66/004	£0.00	£0.00	£36.50	£0.00	£80	£117	C	Stopcock chamber,
TL24/001	£0.00	£0.00	£23.50	£46.50	£80	£150	C	Surrounding overgrowth, Overhead trees,
TF70/025	£0.00	£0.00	£23.50	£0.00	£80	£104	C	Surrounding overgrowth,
TF70/034	£0.00	£0.00	£23.50	£0.00	£80	£104	C	Surrounding overgrowth,
TL14/125L	£0.00	£0.00	£23.50	£0.00	£80	£104	C	Surrounding overgrowth,
TL66/089L	£0.00	£0.00	£23.50	£0.00	£80	£104	C	Surrounding overgrowth,
TL45/010	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
TL79/002	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
TL89/003	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
TL53/021	£0.00	£0.00	£0.00	£93.00	£80	£173	D	Overhead trees,
TF72/093B	£0.00	£0.00	£0.00	£63.00	£80	£143	D	Flange type steel tube,
SP92/009	£0.00	£0.00	£0.00	£46.50	£80	£127	D	Overhead trees,
TL98/036	£0.00	£0.00	£0.00	£46.50	£80	£127	D	Overhead trees,

Table D3 - Remedial Works Summary - Northern Area : Approximate cost per priority band (results sorted in descending order of priority)

Site ID	Priority Band				Travel Time Cost	TOTAL COST	Overall Priority Band	Work Required
	A	B	C	D				
7/127	£304.00	£0.00	£17.00	£0.00	£80	£401	A	Concete Slab, Borehole paintwork, Manhole frame,
7/126	£158.00	£0.00	£0.00	£0.00	£80	£238	A	Concete Slab,
3/702	£0.00	£228.00	£0.00	£0.00	£80	£308	B	Concete Slab, Flange type steel tube, Flange bolts, Manhole cover,
1/601	£0.00	£205.00	£17.00	£0.00	£80	£302	B	Concete Slab, Borehole paintwork, Manhole cover, Manhole frame,
2/535	£0.00	£164.00	£0.00	£0.00	£80	£244	B	Protective fencing,
5/002	£0.00	£158.00	£163.00	£0.00	£80	£401	B	Concete Slab, Borehole paintwork, Manhole frame,
3/510	£0.00	£149.00	£175.00	£0.00	£80	£404	B	Concete Slab, Borehole paintwork, Flange type steel tube, Flange bolts, Manhole cover,
6/069	£0.00	£146.00	£0.00	£0.00	£80	£226	B	Manhole frame,
8/567	£0.00	£126.00	£0.00	£0.00	£80	£206	B	Manhole cover, Manhole frame,
3/711	£0.00	£106.00	£304.00	£0.00	£80	£490	B	Concete Slab, Manhole cover, Manhole frame,
2/508	£0.00	£106.00	£17.00	£0.00	£80	£203	B	Borehole paintwork, Manhole cover,
3/507	£0.00	£106.00	£0.00	£0.00	£80	£186	B	Manhole cover,
3/704	£0.00	£106.00	£0.00	£0.00	£80	£186	B	Manhole cover,
2/613	£0.00	£102.00	£0.00	£0.00	£80	£182	B	Black painted steel tube, Black painted steel cap,
8/926	£0.00	£99.00	£0.00	£0.00	£80	£179	B	Locking bar, Padlock and key,
2/529	£0.00	£79.00	£258.00	£0.00	£80	£417	B	Concete Slab, Manhole frame, Manhole chamber,
5/040	£0.00	£79.00	£163.00	£0.00	£80	£322	B	Concete Slab, Borehole paintwork, Manhole frame,
1/633	£0.00	£79.00	£17.00	£0.00	£80	£176	B	Concete Slab, Borehole paintwork,
3/107	£0.00	£73.00	£0.00	£0.00	£80	£153	B	Overflow control valve,
7/128	£0.00	£73.00	£0.00	£0.00	£80	£153	B	Manhole frame,
2/617	£0.00	£66.00	£0.00	£0.00	£80	£146	B	Flange bolts,
3/629	£0.00	£53.00	£129.00	£0.00	£80	£262	B	Flange type steel tube, Flange bolts, Manhole cover,
5/039	£0.00	£53.00	£17.00	£0.00	£80	£150	B	Borehole paintwork, Manhole cover,
7/077	£0.00	£53.00	£17.00	£0.00	£80	£150	B	Borehole paintwork, Manhole cover,
1/588	£0.00	£53.00	£0.00	£0.00	£80	£133	B	Manhole cover,
2/536	£0.00	£53.00	£0.00	£0.00	£80	£133	B	Manhole cover,
2/541	£0.00	£53.00	£0.00	£0.00	£80	£133	B	Manhole cover,
3/022	£0.00	£53.00	£0.00	£0.00	£80	£133	B	Manhole cover,
3/638	£0.00	£53.00	£0.00	£0.00	£80	£133	B	Manhole cover,
2/510	£0.00	£33.00	£0.00	£0.00	£80	£113	B	Flange bolts,
2/514	£0.00	£33.00	£0.00	£0.00	£80	£113	B	Flange bolts,
2/611	£0.00	£33.00	£0.00	£0.00	£80	£113	B	Flange bolts,
2/639	£0.00	£0.00	£304.00	£0.00	£80	£384	C	Concete Slab, Manhole frame,
6/096	£0.00	£0.00	£243.50	£0.00	£80	£324	C	Shingle infill, Manhole chamber,
2/540	£0.00	£0.00	£158.00	£0.00	£80	£238	C	Concete Slab,
6/074	£0.00	£0.00	£146.00	£0.00	£80	£226	C	Manhole frame,
2/879	£0.00	£0.00	£96.00	£0.00	£80	£176	C	Flange type steel tube, Flange bolts,
3/020	£0.00	£0.00	£93.00	£63.00	£80	£236	C	Protective safety screen, Overhead trees,
6/090	£0.00	£0.00	£90.00	£0.00	£80	£170	C	Borehole paintwork, Manhole frame,
3/621	£0.00	£0.00	£79.50	£0.00	£80	£160	C	Borehole paintwork, Wooden monitoring equipment box,
3/316	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
3/504	£0.00	£0.00	£79.00	£0.00	£80	£159	C	Concete Slab,
7/094	£0.00	£0.00	£73.00	£0.00	£80	£153	C	Manhole frame,
1/606	£0.00	£0.00	£53.00	£0.00	£80	£133	C	Manhole cover,
2/509	£0.00	£0.00	£53.00	£0.00	£80	£133	C	Manhole cover,
6/044	£0.00	£0.00	£53.00	£0.00	£80	£133	C	Manhole cover,
6/078	£0.00	£0.00	£53.00	£0.00	£80	£133	C	Manhole cover,
7/081	£0.00	£0.00	£53.00	£0.00	£80	£133	C	Manhole cover,
8/636	£0.00	£0.00	£19.50	£0.00	£80	£100	C	Shingle infill,

Table D3 - Remedial Works Summary - Northern Area : Approximate cost per priority band (results sorted in descending order of priority)

Site ID	Priority Band				Travel Time Cost	TOTAL COST	Overall Priority Band	Work Required
	A	B	C	D				
8/637	£0.00	£0.00	£19.50	£0.00	£80	£100	C	Shingle infill,
1/598	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
1/599	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
2/547	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
2/548	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
3/018	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
3/019	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
5/003	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
5/037	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
5/041	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
5/117	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
6/047	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
7/006	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
7/017	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
7/042	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
7/125	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
8/026	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
8/812	£0.00	£0.00	£17.00	£0.00	£80	£97	C	Borehole paintwork,
5/910	£0.00	£0.00	£0.00	£82.00	£80	£162	D	Protective fencing,
8/922	£0.00	£0.00	£0.00	£82.00	£80	£162	D	Protective fencing,
8/923	£0.00	£0.00	£0.00	£82.00	£80	£162	D	Protective fencing,
3/308	£0.00	£0.00	£0.00	£72.00	£80	£152	D	Metal ground plate,
7/001	£0.00	£0.00	£0.00	£46.50	£80	£127	D	Overhead trees,
3/310	£0.00	£0.00	£0.00	£23.50	£80	£104	D	Surrounding overgrowth,
3/516	£0.00	£0.00	£0.00	£23.50	£80	£104	D	Surrounding overgrowth,
5/108	£0.00	£0.00	£0.00	£23.50	£80	£104	D	Surrounding overgrowth,

Appendix E - Programme of Expenditure

Appendix F - Current Staffing Requirements